United States Department of Agriculture
Forest Service

Pacific Southwest
Research Station

General Technical Report
PSW-GTR-244

March 2014

Cascades Frog Conservation Assessment

Karen Pope, Catherine Brown, Marc Hayes,
Gregory Green, and Diane Macfarlane

Technical Coordinators

Karen Pope is a research wildlife biologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521; **Catherine Brown** is a wildlife biologist, U.S. Department of Agriculture, Forest Service, Stanislaus National Forest, currently located at the Pacific Southwest Research Station, 800 Buchanan Street, Albany, CA 94710; **Mark Hayes** is a senior research scientist, Washington Department of Fish and Wildlife, 600 Capitol Way North, Olympia, WA 98501; **Gregory Green** is a wildlife ecologist, Tetra Tech EC, 19803 North Creek Parkway, Bothell, WA 98011, currently located at Owl Ridge Natural Resource Consultants, Inc., 22116 45th Ave SE, Bothell, WA 98021; **Diane Macfarlane** is a wildlife biologist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, 1323 Club Drive, Vallejo, CA 94592.

Cover photograph by Karen Pope.

Abstract

Pope, Karen; Brown, Catherine; Hayes, Marc; Green, Gregory; Macfarlane, Diane, tech. coords. 2014. Cascades frog conservation assessment. Gen. Tech. Rep. PSW-GTR-244. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 116 p.

The Cascades frog (*Rana cascadae*) is a montane, lentic-breeding amphibian that has become rare in the southern Cascade Range and remains relatively widespread in the Klamath Mountains of northern California. In the southern Cascades, remaining populations occur primarily in meadow habitats where the fungal disease, chytridiomycosis, and habitat desiccation pose threats to persistance. Major risk factors in the Klamath Mountains include introduced fish and chytridiomycosis. Conservation actions are needed for the Cascades frog in California and especially in the southern Cascades. Conservation options include restoration of breeding pools in the southern Cascades, fish removals in the Klamath Mountains, and adaptive methods to help alleviate the effects of chytridiomycosis rangewide.

Keywords: *Rana cascadae*, southern Cascades, Klamath Mountains, risk factors, chytridiomycosis.

Summary

The Cascades frog (*Rana cascadae*) was once abundant in the aquatic habitats of the southern Cascade Range and Klamath Mountains of California. Currently, the species remains fairly widespread in the Klamath Mountains but has become extremely rare in the southern Cascades. Declines and extirpations were first recognized during the early 1980s and have continued to the present. The realization that these patterns might place the species at risk of further declines led to a USDA Forest Service-initiated multiagency effort to develop a conservation assessment focused on attenuating the risk factors responsible. This conservation assessment consists of three parts: (1) a synopsis of Cascades frog ecology, (2) a review of Cascades frog distribution and abundance over its historical geographic range in California, and (3) an evaluation of risk factors to identify those that may affect the Cascades frog and its habitat currently and in the future.

Cascades frogs in California, Oregon, and Washington are currently recognized as one taxonomic unit, but genetic evidence suggests that the California populations may be genetically distinct. In California, Cascades frogs occupy a range of aquatic habitats including lakes, wet meadows, ponds, and adjacent streams. They breed in still or very slow-flowing water, and their larvae metamorphose in the same season they develop from eggs.

Most of the historical range in California is on federal land, including three national forests (Lassen, Klamath, and Shasta-Trinity), and Lassen Volcanic National Park (LVNP); the remainder of the range is on private and state-owned lands. In the southern Cascades, only 11 known populations remain and the species appears to be extirpated in LVNP. The species remains more common in the Klamath Mountains from the east side of the Trinity Alps Wilderness to Castle Crags Wilderness.

Researchers are making major strides in understanding the primary reasons for declines of the Cascades frog in California. In the Klamath Mountains, introduced fishes are common and have been shown to have negative impacts on Cascades frog populations. In addition, recent studies have found the fungal pathogen *Batrachochytrium dendrobatidis* (*Bd*), which causes the amphibian disease chytridiomycosis, to be widespread across the range in California. Some Cascades frog populations seem relatively unaffected by the disease, while others seem to be experiencing decreased survival, especially juvenile frogs. In the southern Cascades, remaining populations of Cascades frogs seem to have extremely low recruitment of juvenile frogs into the adult population. Researchers recently concluded that the primary reasons for low recruitment were insufficient duration of standing water in breeding pools, and low survival of juvenile frogs owing to chytridiomycosis. Now that

populations are so few and abundances so small, any disturbance that reduces survival may pose a high risk to population persistence. Other risk factors that may affect population persistence include airborne contaminants, climate change, vegetation and fuels management activities, recreational activities, and livestock grazing.

Conservation actions are needed for the Cascades frog in the southern Cascades. In 2009 and 2010, the Lassen National Forest initiated habitat restoration measures in three meadows to improve breeding habitat conditions. They expanded and deepened breeding pools and dug several additional pools. If determined successful, restoration measures could be expanded to other remaining populations. In addition, research into ways to help alleviate the effects of *Bd* on the remaining populations is needed. Other conservation options include additional protection of remaining populations on private lands, more site-by-site assessments of appropriate restoration options, investigation of captive breeding and translocation options, and ongoing monitoring of the remaining populations. For the Klamath Mountains, conservation options include increasing the amount of fishless habitat, research into ways to help alleviate the effects of *Bd*, and monitoring of rangewide population status.

Contents

1 **Introduction**
1 Purpose
2 Geographic Scope
2 Document Organization
4 **Ecology**
4 Systematics and Taxonomy
5 Habitat Requirements
8 Life History
10 Population Dynamics
11 Movement
11 Feeding
12 Mortality
13 **Status**
13 Southern Cascades
15 Klamath Mountains
16 Conclusions About Status
16 **Risk Factors Affecting the Status of the Species**
18 Airborne Contaminants
24 Climate Change
25 Disease
27 Fire Suppression
29 Introduced (Nonnative) Fish and Other Predators
31 Livestock Grazing
33 Recreational Activities
35 **Relative Importance of Risk Factors**
35 Southern Cascades
35 Klamath Mountains
36 Rangewide
36 **Existing Management and Research**
36 **Conservation Options**
37 Within California in General
37 Southern Cascades

38 **Acknowledgments**
38 **English Equivalents**
39 **References**
64 **Appendix 1: Agency Direction**
64 USDA Forest Service
65 National Park Service
67 California Department of Fish and Wildlife
68 U.S. Fish and Wildlife Service
69 **References**
71 **Appendix 2: Museum Standard Symbolic Codes**
72 **Appendix 3: Status—Administrative Units**
72 Lassen National Forest
77 Lassen Volcanic National Park
79 Shasta-Trinity National Forest
81 Klamath National Forest
83 **References**
87 **Appendix 4: Surveys in the Southern Cascade Range Since 1980**
89 **References**
91 **Appendix 5: Other Risk Factors**
91 Habitat Loss
91 Locally Applied Pesticides
94 Mining
95 Research Activity
97 Restoration Activities
98 Roads
100 UV-B Radiation
103 Vegetation and Fuels Management
104 Water Development and Diversion
105 **References**
113 **Appendix 6: Cascades Frog Working Group**

Introduction

Purpose

Since about 1970, Cascades frog numbers and populations have undergone precipitous declines in California (Fellers and Drost 1993, Fellers et al. 2008, Jennings 1996, Jennings and Hayes 1994). Estimates indicate disappearance from over 95 percent of historical localities in the Lassen region centered around Lassen Peak (Fellers and Drost 1993, Jennings and Hayes 1994), and continued surveys suggest that Cascades frogs are still declining in this region (Fellers et al. 2008, Pope et al. 2011). Many factors, individually and likely in combination, have contributed to the species' decline. Nonnative fishes and pathogens (especially *Batrachochytrium dendrobatidis* [*Bd*]) have been found to have widespread impacts, and several other factors including pesticides, livestock grazing, recreational activities, increased occurrences of drought, and ultraviolet radiation have been identified as potential contributing factors affecting this species and its habitats.

The Sierra Nevada Forest Plan Amendment (SNFPA) Record of Decision (ROD) commits the USDA Forest Service to complete a conservation assessment for the Cascades frog in cooperation with other federal agencies, state agencies, universities, and research scientists (USDA Forest Service 2001b). The conservation assessment is envisioned to be the first of a three-phase process that also includes a conservation strategy and a conservation agreement. The conservation assessment synthesizes available conservation- or management-pertinent information on life history, habitat associations, distribution and abundance, and risk factors providing the informational foundation for the conservation strategy. The conservation strategy delineates specific conservation actions, and leads to an agreement among various agencies and partners to implement the conservation strategy. Following approval of the SNFPA ROD, a working group of biologists from the Pacific Southwest Region of the USDA Forest Service, National Park Service (NPS), U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Wildlife (CDFW), and academic and independent research scientists was established to develop this assessment. Each agency has specific directives and guidelines that direct its actions in relation to management and protection of native at-risk species. These directives and guides for each participating agency are explained in appendix 1.

Geographic Scope

Populations of Cascades frogs occur in the southern Cascade Range and Klamath Mountains in northern California (fig. 1), and in Oregon and Washington. The initial direction for this effort was to address the range of the species within the planning area described by the Sierra Nevada Forest Plan Amendment (USDA FS 2001a), which, for this species, was limited to California's southern Cascades region. Because populations are believed to be near extirpation in this area, the geographic scope of the assessment was expanded to the species' entire range within California (see fig. 1). Thus, the assessment was extended to include the Klamath Mountains in addition to the southern Cascades. Two national forests (Klamath and Shasta-Trinity), including four wilderness areas (Trinity Alps, Marble Mountains, Russian, and Castle Crags) encompass this added segment of the Cascades frog range in California. California populations face similar risks and occur primarily on federal lands with similar management directives. However, populations at the southern extent of the species' range in the southern Cascades have become so reduced relative to the Klamath Mountains that geographically targeted conservation measures are appropriate. Cascades frog populations in the latter region may provide important information about habitat requirements, population structure, and conservation options that may be critical for maintaining populations throughout the historical range.

Document Organization

The three main sections of this document address the ecology and status of the Cascades frog and an assessment of the factors that might present a risk to the Cascades frog's continued survival in California. The ecology section details the species' ecological requirements, an understanding of which is necessary to develop a successful strategy to recover this species. The status section provides information on distribution and abundance within the species' California range, plus discussion on how these populations have changed pre- and post-1980. Appendix 3 provides more geographical detail on the changes pre- and post-1980 by subdividing the discussion for each of the national forests and Lassen Volcanic National Park (LVNP). The risk factor section identifies, describes, and evaluates the relative importance of key risk factors for the species. Risk factors include management activities (e.g., fish introduction, pesticide use, fire suppression) and large-scale factors (e.g., disease, climate change) that may have played a role in current Cascades frog trends in California, and are important considerations in future population recovery. These sections provide the conceptual and scientific foundation for the subsequent conservation strategy.

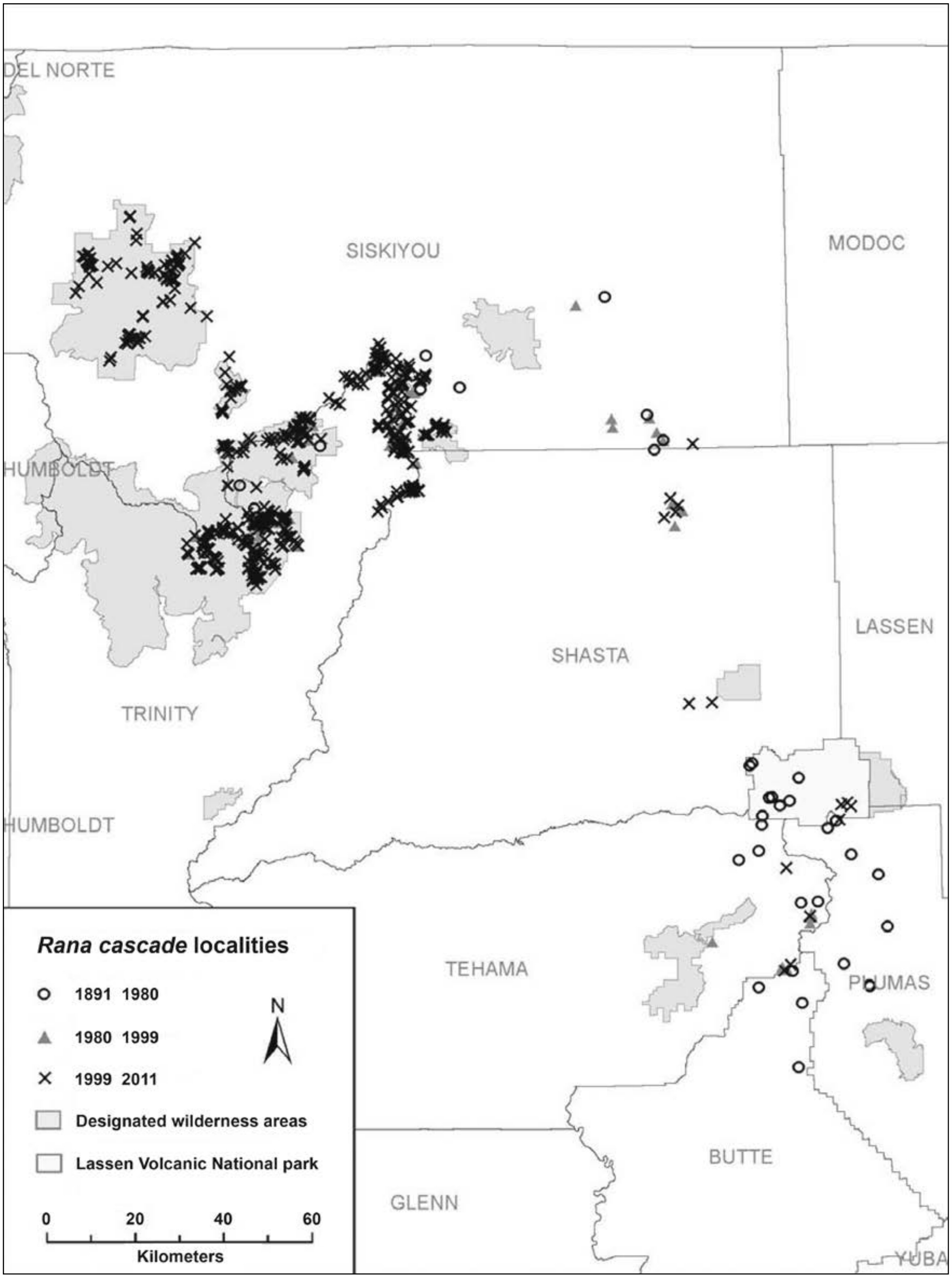

Figure 1—Recent and historical distribution of the Cascades frog (*Rana cascadae*) in California. This map contains known localities up to 2011. The sites in Trinity and Siskiyou Counties are in the Klamath Mountains and the sites in Shasta, Tehama, Butte, and Plumas Counties are in the southern Cascade Range. The southernmost grouping of points around Lassen Volcanic National Park is considered the Lassen region.

Ecology

Systematics and Taxonomy

The Cascades frog is a member of the true frog family, Ranidae, and is a morphologically (Dunlap 1955, Slater 1939) and genetically (Case 1976, 1978; Green 1986a, 1986b) distinct species. Published data on genetic variation within *R. cascadae* (Case 1976, 1978; Monsen and Blouin 2003, 2004) indicate some potentially significant within-species variation. Recent genetic analysis of the Cascades frog using both mitochondrial and nuclear DNA suggests that California populations differ significantly from populations in Oregon and Washington (Monsen and Blouin 2003). The California populations differ from the Oregon/Washington populations by 3.2 percent at the mtDNA loci studied by Monsen and Blouin (2003), which they concluded represents two distinct population segments. As currently recognized, however, the Cascades frog is distributed along the length of the Cascades Mountain axis from northern California to northern Washington with a disjunct population on the Olympic Peninsula in Washington (Blaustein et al. 1995, Jennings and Hayes 1994, Pearl and Adams 2005, Stebbins 2003). In California, the frog occurs in mountainous areas from the Klamath-Trinity region (fig. 2) and the Cascades Mountain axis in the vicinity of Mount Shasta southward to the headwater tributaries of the Feather River (fig. 3), and has a known altitudinal range from 230 to approximately 2500 m (Jennings and Hayes 1994).

Karen Pope

Figure 2—Diamond Lake in the Trinity Alps Wilderness, Klamath Mountains.

Figure 3—Juniper Lake in Lassen Volcanic National Park.

Habitat Requirements

Cascades frogs can be found in a range of aquatic habitats, including large lakes, ponds, wet meadows, and flowing streams, but occurrence in these habitats varies by life stage and season (fig. 4). Reproduction occurs in shallow still-water habitats that are the first to become exposed by snowmelt early in the spring and retain water long enough for egg and tadpole development (about 3 to 4 months depending on water temperature). These habitats include shallow alcoves of lakes, ponds, potholes, flooded areas in meadows, and occasionally slow-moving streams or stream backwaters. In the Klamath Mountains, Cascades frogs breed primarily in lakes, ponds, and wet meadows that hold water throughout the summer, are free of fish, and contain a high percentage of silt in the near-shore habitat (Welsh et al. 2006). In the southern Cascades, eight of the known remaining breeding sites are located in stream-associated wet meadow habitats and the other two are in ponds with adjacent stream habitats (Pope et al. 2011). Historical reports show that Cascades frogs used to breed in lake, pond, and meadow habitats in LVNP (Grinnell et al. 1930, Stebbins 1951a). Many of the historical records from the Lassen National Forest coincide with fens, which are wetlands characterized by neutral to alkaline water chemistry and high mineral but low nutrient content.

Carla Mingione

Jon Stead

Figure 4—Habitat types used by Cascades frogs: (A) recently metamorphosed Cascades frogs in a shallow pond in the Trinity Alps Wilderness, (B) adult male Cascades frog and an egg mass in a meadow pool on the Lassen National Forest, and (C) adult Cascades frog along a stream on the Shasta-Trinity National Forest.

Figure 4—Continued.

Nonbreeding active-season habitat is more variable than breeding habitat (Garwood 2009, Pope et al. 2011). Adults and subadults use a wide array of aquatic habitats during the nonbreeding season; these include ponds, meadows, lakes, and streams (Brown 1997, Bury and Major 1997, 2000, Garwood 2009, Pope et al. 2011). Adults often use sites with open, sunny areas, often along the shorelines, which may be favorable because they provide basking and foraging opportunities (Fellers and Drost 1993). They also use floating logs or emerged rocks that provide basking and foraging opportunities while also providing an aquatic escape from predators. Juveniles are often found in similar habitats as adults (Pope et al. 2011). Stream use increases dramatically during summer months; in Deep Creek Basin in the Trinity Alps Wilderness, Garwood (2009) found adult females in streams about 40 percent of the time and males about 20 percent of the time. Pope et al. (2011) found similar habitat use in the southern Cascades with larger frogs moving to flowing water habitats in the summer. Larger frogs can negotiate stream currents better than smaller frogs and likely gain abundant food resources and refuge sites.

Based on the frog's movement patterns and distribution in early spring and late fall, overwintering habitat is almost as restrictive as breeding habitat (Garwood 2009). In late fall, Garwood (2009) found frogs congregated at spring-fed ponds and lakes, and perennially flowing streams (although the frogs may have been using the streams as movement corridors to lentic overwintering habitats). The frogs are suspected of overwintering in aquatic sites that do not freeze solid (e.g., springs and deep lakes), similar to the mountain yellow-legged frog (*Rana muscosa* and *R. sierrae*) in the Sierra Nevada (Bradford 1983). Briggs (1987) found Cascades frogs overwintering in deep, loose silt at the bottom of a pond and in surrounding spring-water saturated ground at Bear Spring Pond in Oregon.

Life History

Cascades frogs breed shortly after spring snowmelt (Briggs 1987, Garwood and Welsh 2007, Nussbaum et al. 1983, Olson 1988). Males appear first and form chorusing groups when melting ice and snow creates open water along the edges of water bodies (Briggs 1987, Garwood and Welsh 2007). Males do not defend territories, but male-male interactions may produce a regular spacing pattern in the breeding habitat (Olson 1988). Females are highly cryptic during breeding, swimming primarily underwater to breeding sites and leaving the site as soon as breeding is complete (Olson 1992).

Oviposition occurs between April and July, depending on seasonal conditions and elevation. Egg masses are often laid communally in pond and lake habitats (Garwood 2009, Garwood et al. 2007, Pope and Larson 2010). In the southern Cascades, more than 90 percent of the egg masses found in pond habitats were clumped, whereas more than 80 percent of the egg masses found in meadow pools were singletons (Pope and Larson 2010). A small percentage of egg masses in the southern portion of the southern Cascades have been found in small, low-gradient channels with slow flow (Pope 2008b). Egg masses are usually found at the surface in shallow water with emergent vegetation, but have been found in deep water (2 m) and free-floating in lakes (Garwood et al. 2007, Pope and Larson 2010). They can also be attached to emergent vegetation, wood, boulders, or the shoreline (Pope and Larson 2010).

Length of embryonic development appears highly temperature-dependent as shown by both laboratory and field studies (Blouin and Brown 2000, Olson 1988, Sype 1975), but generally takes about 3 weeks in both the Klamath Mountains and southern Cascades (Garwood and Larson, n.d.). Consistently cold water conditions (2 to 10 °C), such as found in some springs, may delay hatching by a few days but eggs generally are laid in shallow open-water locations where the sun quickly warms the water surrounding the egg mass to temperatures above 13 °C that are more optimal for development. In the high-elevation habitats in California, larvae usually hatch in early to mid-July and metamorphose into frogs in September. However, some larvae do not successfully complete metamorphosis prior to the onset of winter (Garwood and Welsh 2007). No larvae have been observed to survive the winter (Garwood 2009). In the southern Cascades, larvae usually hatch in June and metamorphose in late August (Pope and Larson 2010).

Tadpoles can tolerate a wide range of water temperatures. They tend to aggregate in the warmest areas of ponds and lakes during the day (Brattstrom 1963; Pope, n.d.; Wollmuth et al. 1987); this generally consists of wind-protected, gently sloping, shallow near-shore areas (O'Hara 1981, Olson 1992, Welsh et al. 2006) where temperatures can warm to more than 20 °C on a sunny afternoon but drop to near freezing at night. In shallow meadow breeding pools in the southern Cascades, daytime water temperatures have been measured at 38 °C. This seems to be above their temperature tolerance as the tadpoles appeared highly stressed; they moved between cooler temperatures in the silt substrate and the surface where they gulped air (Pope and Larson, n.d.).

Tadpoles and metamorphs are known to discriminate between kin and nonkin (kin recognition) and preferentially associate with kin in laboratory and field experiments (Blaustein and O'Hara 1982a, 1982b, 1987; Blaustein et al. 1984; O'Hara and Blaustein 1981, 1985). Kin association can influence growth, predator avoidance, and other factors (Hokit and Blaustein 1994, 1995, 1997). Tadpoles are sensitive to visual and physical disturbances of the water and have an explosive escape response when startled (Hews and Blaustein 1985). Tadpoles occasionally become stranded at sites with short hydroperiods and desiccate as the water evaporates (Garwood 2009, O'Hara 1981, Pope et al. 2011, Sype 1975). Newly metamorphosed frogs tend to stay near their natal ponds (Garwood 2009).

Cascades frogs are relatively long-lived and late maturing. A skeletochronology study conducted in the Klamath Mountains found that frogs can live more than 10 years (Garwood, n.d.). Ages at maturity are between 3 and 4 years for males and 4 to 5 years for females based on mark-recapture studies in the Klamath Mountains and southern Cascades (Garwood and Larson, n.d.). Adult Cascades frogs display a high degree of site fidelity (Blaustein and Olson 1992, Briggs and Storm 1970, Garwood 2009, Olson 1992). At Deep Creek Basin in the Trinity Alps Wilderness, Garwood (2009) found that adults commonly move among unique breeding, feeding, and overwintering habitats following a consistent annual pattern (see "Movement" section). At other sites where breeding, feeding, and overwintering habitat occur at the same site, frogs may remain at the same water body throughout the year (Pope 2008a).

Population Dynamics

Populations of Cascades frogs can reach high densities because the species is not territorial and there seems to be ample algal and detrital food for larvae and terrestrially and aquatically derived insects for adults (Briggs and Storm 1970, Joseph et al. 2011, Larson 2012). As is true for many long-lived species, annual survival rates of adult Cascades frogs is fairly high. In a 16-lake population dynamics study conducted in the Trinity Alps Wilderness, annual survival of adult frogs ranged from 68 to 93 percent with significantly higher survival rates when introduced fish were removed from the system (Pope 2008a). Annual survival estimates calculated for four sites in the southern Cascades varied strongly by life stage and site. Adult survival ranged from >70 percent at Carter Meadow and Nelson Creek to only 44 percent at Old Cow Creek (Pope et al. 2011). Survival of metamorphs and young-of-previous-year (YOPY) was low at all sites (<1 and <20 percent, respectively). These survival values are likely being affected by the amphibian disease, chytridiomycosis, which has been found to be widespread in both the Klamath Mountains (Piovia-Scott et al. 2011) and southern Cascades (Pope et al. 2011). New evidence suggests that the effects of the disease can differ by site and year depending on its prevalence and density at a site (Pope et al. 2011) and its virulence (Piovia-Scott et al. 2013).

Montane amphibians probably exhibit metapopulation structure (Bradford 1991, Brown 1997, Olson 1992). Individual local populations may go extinct because of a variety of chance events (e.g., severe winters, prolonged drought), but they are eventually recolonized by animals from other nearby populations (Hanski and Gilpin 1991, Levins 1970). In the Klamath region, Welsh et al. (2006) found a positive association between site occupancy and the proximity of additional suitable habitats. Isolated sites were less likely to support populations of frogs. In a study examining recolonization patterns after the eruption of Mount St. Helens in Washington, frogs quickly recolonized a barren posteruption lake 2.5 km from the nearest extant population (C. Crisafulli, pers. comm., in Brown 1997). In contrast, one extirpated *R. cascadae* site in Oregon was reported to have taken 12 years to be recolonized despite the presence of a *R. cascadae* population within 2 km (Blaustein et al. 1994). In a detailed movement study, Garwood (2009) found 19 of his study animals (1 percent) dispersed outside of the study basin, travelling distances over 1 km and across ridgelines. These results suggest that gene flow is sufficient to maintain genetic diversity among subsets of larger metapopulations (Garwood 2009, Mills and Allendorf 1996). Although metapopulation structure may be maintained among neighboring basins, genetic data suggest that local populations of Cascades frog have high degrees of isolation at relatively small geographic scales (Monsen and Blouin 2004). Specifically, the authors determined that the genetic “neighborhood,” the distance over which the exchange of individuals between "populations" drops sharply, is roughly 10 km. These data generally agree with movement information for the Cascades frog and other ranid frogs, which suggest maximum movement scales of a few kilometers (Garwood 2009, Smith and Green 2005, see "Movement" below). In many regions of California (southern Cascades, Russian Wilderness, and Castle Crags), populations of Cascades frogs seem to be small isolated remnants (see "Status" section), so are more vulnerable to chance events that could result in extirpation, with low likelihood of later recolonization.

Movement

Movement ecology was studied in detail and at multiple scales from 2003 to 2008 in a large, complex basin in the Trinity Alps Wilderness of California (Garwood 2009). Garwood found that movement patterns varied strongly by life stage. Newly metamorphosed animals stayed close to natal rearing habitats while juvenile frogs moved frequently among habitat patches without evidence of site fidelity (Garwood 2009). In contrast, adult frogs often migrate seasonally among habitat patches for breeding, feeding, and overwintering, and express annual site fidelity to specific patches (Garwood and Welsh 2007). Pope and Larson (2010) found similar results in the southern Cascades with many adult frogs returning to the breeding, feeding, and overwintering habitats year after year, whereas seasonal distribution patterns of juveniles were much less predictable.

Distances traveled between habitat patches can range from very short to over 1 km from wintering sites to breeding ponds. Garwood and Welsh (2007) found that 71 of 1,669 frogs moved over 1 km. Intrabasin dispersal movements were documented 19 times with minimum distances traveled averaging 1.2 km (Garwood 2009). These dispersals were primarily made by juvenile frogs prior to their first breeding season (Garwood 2009). Potential gene flow from these dispersers via "leapfrogging" spanned an air distance of 4 km, which included four neighboring basins. The maximum vertical gain from a dispersal event was 308 m (Garwood 2009).

Feeding

Postmetamorphic Cascades frogs are generalist predators, primarily of aquatically and terrestrially derived insects and spiders (Joseph et al. 2011, Larson 2012). At Deep Creek Basin in the Trinity Alps Wilderness, Larson (2012) identified insects from 102 different families in the stomach contents of frogs. Only rarely were larval aquatic insects found in stomach contents, suggesting that most foraging is terrestrial or on the surface of the water (Larson 2012). Joseph et al. (2011) found that the diet of Cascades frogs varied in lakes with fish versus those without; in lakes with fish, the frogs ate more terrestrial insects such as grasshoppers, and in lakes without fish they ate more adult aquatic insects such as caddisflies. The authors concluded that introduced trout may influence native amphibians indirectly through competition for food resources. Although their diet primarily consists of invertebrates, Cascades frogs occasionally prey upon larvae and recently metamorphosed Pacific chorus frogs and conspecifics.

Mortality

Cascades frogs are susceptible to a variety of stochastic environmental events. Breeding occurs soon after thaw, so eggs are vulnerable to late freezes (Pope and Larson 2010). In some ephemeral habitats that dry out during the summer, larvae may desiccate before metamorphosis (Pope et al. 2011). Survival of all life stages may also be affected by unusually long winters with heavy snowfall if the frogs do not have enough energy stored to last until the thaw. In a study conducted in the central Oregon Cascades, Briggs and Storm (1970) estimated a relatively high mortality rate for adults (about 45 percent) and suggested that most adult mortality occurred during overwintering.

During the summer active season, Cascades frogs face a wide range of predators including nonnative fish (Simons 1998, Welsh et al. 2006), garter snakes (Garwood and Welsh 2007, Pope et al. 2008); birds such as American dippers (Garwood and Welsh 2007), American robins (Briggs and Storm 1970) and Clark's nutcrackers (Garwood 2006); mammals such as river otters (ARRIS 2013); other amphibians including rough-skinned newts (Peterson and Blaustein 1991); aquatic insects including diving beetles, giant water bugs, and dragonfly naiads (Garwood and Wheeler 2007, Nauman and Dettlaff 1999, Peterson and Blaustein 1991); and predatory leeches (Stead and Pope 2010).

In the southern Cascades, predatory leeches have been proposed as a potential predator of eggs and larvae of Cascades frogs (Stead and Pope 2010). The authors observed the predatory leech *Haemopis marmorata* probing or tearing at eggs on several occasions in two meadows, and found that leeches were observed 10 times more frequently in plots centered on egg masses than in similar plots without egg masses. Six species of leeches were identified from the region, five of which may be predators of amphibian eggs and hatchlings (Stead and Pope 2010).

Frogs are also susceptible to diseases. *Batrachochytrium dendrobatidis* (*Bd*) is now widely distributed throughout the range of Cascades frogs in California (Piovia-Scott et al. 2011, Pope et al. 2011) (see "Disease Risk Factor" section). *Batrachochytrium dendrobatidis* is a fungal pathogen that has been implicated in die-offs and extinctions of amphibians worldwide (Skerratt et al. 2007). From more than 100 sites sampled throughout the Klamath Mountains, *Bd* was detected at 64 percent of them and was commonly found associated with Cascades frogs (Piovia-Scott et al. 2011).

Mass mortality of developing Cascades frog eggs in Oregon has been documented and linked to the pathogenic water mold, *Saprolegnia ferax* (Blaustein et al. 1994). The communal pattern of oviposition makes Cascades frogs more susceptible to mortality from this fungus (Kiesecker and Blaustein 1997). In California, no major mortality events have been observed resulting from *Saprolegnia ferax* despite numerous egg mass surveys (Pope n.d.).

Status

Comparisons between recent (1980 to 2011) and historical (prior to 1980) distributions and abundances of Cascades frogs are provided in the following sections. Documentation from museum collections is listed according to the standard symbolic codes for each institution (app. 2) and the pertinent specimen number(s). Appendix 3 provides distribution and abundance information for individual national forests and national parks.

In California, Cascades frogs were historically distributed from the Shasta-Trinity region to the Modoc Plateau and extended southward through the Lassen National Forest (NF) to the upper Feather River (Jennings and Hayes 1994) (fig. 1). Traditionally, the geographic range in California has been considered two disjunct regions, the southern Cascades and the Klamath Mountains, although the degree of separation is unclear. Regardless, because the regions differ physiographically (Norris and Webb 1990) and have different levels of decline of Cascades frogs, the species' distribution and abundance are discussed separately for each region. The southern Cascades represent roughly 40 percent of the species' California range and the Klamath Mountains represent about 60 percent of that range.

Southern Cascades

Pre-1980—

No systematic surveys were conducted prior to 1980, but Cascades frogs appear to have been fairly widespread. They were present in and around LVNP and in the northwestern and southern portions of Lassen NF; an area that encompasses portions of the Pit River and most of the headwater tributaries of Hat, Deer, Mill, Battle, and Butte creeks, and upper North Fork and West Branch Feather River (see app. 3 for more details).

Prior to 1980, more than 250 animals from at least 39 localities were collected in Lassen NF or its vicinity and more than 130 Cascades frogs were collected from at least 16 different localities in LVNP (app. 3). Records extend back to the 1920s in this region, when survey parties associated with the Museum of Vertebrate Zoology began collecting data across an elevational transect at the latitude of the recently established LVNP (Grinnell et al. 1930). Although data are limited, no evidence of declines was observed until the 1970s.

Few data exist on the historical abundance of Cascades frogs in the southern Cascades, but scattered data from LVNP and Lassen NF suggest that the species was historically abundant, at least in some areas (Fellers and Drost 1993; see app. 3). In their 1925 visit to Emerald Lake, Grinnell et al. (1930) implied that the species was abundant, recording "one frog for nearly every meter around the lake." Borrel (1924) also described Cascades frogs as abundant at Lake Helen.

Post-1980—

Declines in the southern Cascades were first observed in the 1990s when surveys of historical sites in LVNP found few or no frogs (Fellers and Drost 1993, Jennings and Hayes 1994). Based on data accumulated over the interval 1988–1992, Jennings and Hayes (1994) estimated that the species had disappeared from about 99 percent of its historical range in the Lassen region (LVNP and south) of the southern Cascades (see also Jennings 1996). Davidson et al. (2002) reevaluated these data, and found that only 1 of 32 historical Cascades frog sites (defined as pre-1990) was still occupied in the early 1990s.

Since that time, extensive surveys have been conducted for Cascades frogs (app. 4) and, as declines became increasingly apparent, an increased effort was made to detect individuals across the historical range (Fellers et al. 2008). Cascades frogs have been recorded from 12 sites since 1993, all with low counts of frogs. A 4-year (2008–2011) repeated capture-mark-recapture study conducted on five populations found that estimated population sizes ranged from five frogs at Colby Creek (the southern-most known extant population) to 150 frogs at Carter Meadow, Lassen NF (Pope et al. 2011). Although population sizes at some sites were larger than previously thought (Fellers et al. 2008), they were found to be slowly declining over the course of the study. The most current data on the status of the remaining populations indicate that about half are near extirpation and the rest are at risk of continued declines. No remaining populations have been found in LVNP since 2008 despite multiple resurveys of the most recent known locations and additional extensive surveys of appropriate meadow habitat (Pope and Larson, n.d.). However, three populations have been discovered since 2010 on private lands south of the park adjacent to Lassen NF lands (Pope and Larson, n.d.). In addition, three populations have been found north of the park since 2006 (Pope and Larson, n.d.).

Klamath Mountains

Pre-1980—

Records for the Klamath Mountains extend back to the 1890s, when Rutter and Chamberlain collected two Cascades frogs from the Shasta-Trinity NF. By the close of the 1970s, the species had been recorded from at least 25 different localities from the vicinity of this forest (see app. 2). On the Klamath NF, only four verifiable historical records exist. Available data provide no evidence for or against the decline of Cascades frogs on the Shasta-Trinity NF through the 1970s. Data on population abundances are unavailable prior to 1980.

Post-1980—

Up to the mid-1990s, Cascades frogs seemed common in appropriate habitat in the Klamath Mountains (Jennings and Hayes 1994). Davidson et al. (2002) estimated that 20 (77 percent) of 26 historical Cascades frog sites (defined as pre-1990) associated with the Shasta-Trinity NF were still occupied in the early 1990s. From 1999 to 2002, systematic surveys in wilderness areas in the Klamath Mountains were conducted. Abundance data as well as occupancy data were collected for all mapped lakes, ponds, and wet meadows in the Trinity Alps Wilderness, Russian Wilderness, Marble Mountains Wilderness, Siskiyou Wilderness, Red Buttes Wilderness, Castle Crags Wilderness, and parts of the Shasta-Trinity and Klamath NFs outside of wilderness areas (Welsh and Pope 2004, Welsh et al. 2006). Of 380 water bodies surveyed in the Trinity Alps Wilderness, 58.7 percent (n = 223) were found to support at least one individual of any life stage of Cascades frogs (Welsh and Pope 2004). Evidence of reproduction (egg masses or larvae) was recorded at 30.5 percent (n = 116) of the sites. Approximately 250 water bodies were searched in the Marble Mountains and 54 water bodies were searched in the Russian Wilderness. Cascades frogs were recorded from 32 percent of the water bodies in the Marble Mountains (n = 80) and at 31 percent of water bodies in the Russian Wilderness (n = 17). However, evidence of reproduction (egg masses or tadpoles) was found at even fewer sites: only 11 percent of sites in the Marble Mountains (n = 28) and at only 5.5 percent of sites in the Russian Wilderness (n = 3). Cascades frogs were also detected at three of 16 water bodies in Castle Crags Wilderness, three sites on the Klamath NF outside of a wilderness area and 15 sites on the Shasta-Trinity NF outside of a wilderness area (Welsh and Pope 2004). No Cascades frogs were found in the Siskiyou or Red Buttes wilderness areas (Welsh and Pope 2004).

In 2008, 112 sites where Cascades frogs were found to be present in the 1999–2002 surveys were resurveyed and 79 percent were found to still support frog populations (Piovia-Scott et al. 2011). No major declines in frog numbers were observed. However, at the majority of sites surveyed since 1999, abundances of

Cascades frogs appeared low (Welsh et al. 2006). Of 695 water bodies searched from 1999 to 2001 in the Trinity Alps, Marble Mountains, and Russian Wildernesses, the maximum number of adults seen at a water body was 32 and the mean number of adults encountered at sites with Cascades frogs was four (Welsh and Pope 2004). Since then, eight populations in the Trinity Alps Wilderness have been studied for 9 years using mark-recapture techniques (Garwood, n.d.; Pope 2008a). While adult numbers were less than 25 in five of these populations, three populations appeared fairly robust. Two headwater lakes were estimated to support more than 500 adult frogs in 2010 (Pope and Piovia-Scott, 2010). Only one other site in the Trinity Alps is thought to have comparable numbers.

Conclusions About Status

The Cascades frog has declined in the southern Cascades. Based on recent survey data, there are 11 remaining populations in this region. Population viability at these sites is of concern because numbers of individuals are low and population growth trajectories appear to be stable or declining (Pope et al. 2011). Without active management, some of the remaining populations may disappear within 10 years and the rest will be at risk of extirpation.

Cascades frogs are still widespread and fairly abundant in the Klamath Mountains. However, a prevalence of small populations and some recent extirpations suggest the need for caution and continued monitoring. Populations in the eastern portion of the region in the Castle Crags Wilderness and the Klamath NF may be particularly at risk owing to low population numbers and more sites where frogs have recently disappeared (Pope and Piovia-Scott 2010).

Risk Factors Affecting the Status of the Species

Risk factors include environmental conditions and human activities that may negatively affect individuals, populations, or their habitat. The following are the risk factors (listed in alphabetical order) identified and evaluated for the Cascades frog.

- Airborne contaminants (including pesticides)
- Climate change
- Disease
- Fire suppression
- Habitat removal
- Introduced fish and other predators
- Livestock grazing
- Locally applied pesticides
- Mining

- Recreational activities (including packstock)
- Research activities
- Restoration activities
- Roads
- UV-B radiation
- Vegetation and fuels management
- Water development and diversion

Weighing the relative importance of each risk factor provides the rationale for the conservation actions to be developed in the conservation strategy. The following evaluation criteria were used to assess the importance of each risk factor relative to other risk factors:

- Spatial extent—Does the risk have the potential to affect a large proportion of the frog's range?
- Duration and persistence—Is the risk ongoing and expected to continue in the short or long term?
- Intensity—What proportion of frogs or their habitats are affected and how severely?
- Ecological permanence—Does the effect on the species persist or can the frog recover from or adapt to the risk?
- Potential for management to reduce or reverse impacts—Can the risk be reduced or eliminated by management?
- Weight of the evidence—Is the risk well researched with minimal uncertainty?

Based on an assessment of the risk factors, 7 of the 16 were deemed to be of highest current or future concern for the persistence of the species in one or both of the geographic regions in California and are discussed here in alphabetical order. The other nine risk factors are discussed in appendix 5. The seven major risk factors for the Cascades frog are:

- Airborne contaminants
- Climate change
- Disease
- Fire suppression
- Introduced fish and other predators
- Livestock grazing
- Recreational activities

The following section describes each risk factor in alphabetical order and includes its potential impacts (summarized in table 1) and relative importance.

Airborne Contaminants

The transport and deposition of pesticides from the Central Valley to the Sierra Nevada is well documented (Aston and Seiber 1997, Bradford et al. 2010, Datta et al. 1998, Hageman et al. 2006, Lenoir et al. 1999, McConnell et al. 1998) and residues of some of the pesticides have been found in the bodies of frogs in the Sierra Nevada (Cory et al. 1970, Fellers et al. 2004). Pesticides used in the Central Valley can be carried on wind currents or as part of eastbound storm systems into the Sierra Nevada (Aston and Seiber 1997, Cahill et al. 1996, Seiber et al. 1998, Zabik and Seiber 1993) and southern Cascades (Davidson 2004, Davidson et al. 2002). In the Central Valley, between 48 to 69 million kg (106 to 152 million lbs.) of pesticides were recorded as having been used annually from 1990 to 2002; use generally increased through 1998, declining somewhat thereafter (CDPR 1989–2003).

Davidson et al. (2002) proposed that airborne pesticides could be responsible for the greater declines of Cascades frogs in the Lassen region of the southern Cascades compared to the Klamath Mountains. They found about four times as much agricultural land use upwind of sites where Cascades frogs had almost disappeared, compared to sites where the species was still present. However, in a followup study comparing pesticide residuals in water, sediment, and anuran tissue in the Klamath Mountains and southern Cascades, no significant pattern between pesticide concentrations and Cascades frog distribution patterns were found (Davidson et al. 2012). None of the 73 chemicals assessed showed a pattern of greater concentrations in the southern Cascades compared to the Klamath Mountains, and residual concentrations of pesticides in frog tissue and sediment were no different at sites where Cascades frogs have declined or remain relatively abundant (Davidson et al. 2012). In another recent study in the Sierra Nevada that compared concentrations of historically and currently used pesticides with the population statuses of southern mountain yellow-legged frogs and Sierra Nevada yellow-legged frogs (*Rana muscosa* and *R. sierra*, respectively) over a wide area of the southern Sierra Nevada, the authors also found no association between either species' population status and measured pesticide concentrations (Bradford et al. 2011). In addition, pesticide concentrations in water and amphibian tissue were consistently below concentrations found to be toxic to amphibians (Bradford et al. 2011). The authors conclude that chytridiomycosis is more likely responsible for the decimation of these yellow-legged frog populations in a generally west-to-east pattern across the Sierra Nevada (Bradford et al. 2011).

Table 1—Summary of the evaluations of risk factors for the Cascades frog

Risk factor	Spatial extent of the risk	Duration and persistence	Intensity of the threat	Ecological permanence	Potential for management[a]	Weight of evidence	Jurisdiction of participating agencies
Airborne contaminants	Regional; variable owing to composition and regional loading.	Persistence depends on chemical use patterns and chemical type. DDT is still found in sediment and amphibian tissue, despite being banned for use in the United States in 1972.	Likely low owing to low concentrations found in amphibian and soil samples; may be interactive effects.	Depending on chemical, non-permanent. But airborne contamination from the Central Valley is not likely to cease.	Requires broad coordination among multiple regulatory agencies; may be able to reduce use of particularly harmful chemicals, if identified.	One published study measured residual contaminant levels in amphibians and habitats in the Klamath Mountains and Lassen region of the southern Cascades. Another study in the Sierra Nevada found similar results.	None, although agencies can guide the development of management and science.
Climate change	Global with regional effects documented.	Long term and persistent; changes regional hydrology.	Unknown; may reduce the quality of breeding sites and increase chances of severe weather events.	Essentially permanent given time scales addressed by management.	Requires broad coordination among multiple regulatory agencies. Local and regional mitigations to improve habitat resilience can be implemented; effectiveness unknown.	Climate change is well documented, but impacts are unknown. Only correlative studies link climate change to Cascades frog declines.	Some, over the development and management of habitat resiliency projects.

Table 1—Summary of the evaluations of risk factors for the Cascades frog (continued)

Risk factor	Spatial extent of the risk	Duration and persistence	Intensity of the threat	Ecological permanence	Potential for management[a]	Weight of evidence	Jurisdiction of participating agencies
Disease	Large scale. Amphibian chytrid has been found throughout the frog's range.	Unknown, but likely persistent.	For chytrid, high. New research shows low survival of infected juvenile frogs in both the Klamath Mountains and southern Cascades.	Unknown; some frog populations seem to persist with the disease while others are declining.	Promising. Studies are ongoing on the effectiveness of tools to improve chances of survival of frogs with *Batrachochytrium dendrobatidis* (*Bd*).	Chytrid detected throughout range. Cascades frogs are known to be susceptible to the disease. Studies are ongoing.	Some, toward the prevention of spread and implementation of new techniques to reduce the virulence of *Bd*.
Fire suppression	Widespread in Lassen NF and areas outside LVNP and wilderness areas.	Variable. Short term for water removal; potentially long term for habitat alteration.	Variable, potentially severe; may reduce risk of severe fires.	Impacts reversible, but recovery is likely to vary with local conditions.	Yes; effectiveness depends on implementation approach.	Unstudied relative to this species but studies exist on fire management and its effects on riparian and aquatic habitats.	Yes, within the jurisdiction of participating agencies.

Table 1—Summary of the evaluations of risk factors for the Cascades frog (continued)

Risk factor	Spatial extent of the risk	Duration and persistence	Intensity of the threat	Ecological permanence	Potential for management[a]	Weight of evidence	Jurisdiction of participating agencies
Introduced fish and other predators	Widespread in lake and stream habitats throughout the range.	Long term and persistent in many habitats; persistence depends on continued stocking in some habitats.	For fish, high with direct and indirect effects; less intense threats from other introduced predators (leeches, bullfrogs) but may increase in the future.	In some lakes, fish populations are self-sustaining unless actively removed.	Yes, fish removals are effective in lentic habitats.	Strong correlative and direct experimental evidence showing negative effects of introduced fish. Recovery of frog populations following fish removals also has been demonstrated.	Yes. Some fish stocking has been stopped in habitats containing Cascades frogs and fish removals are planned.
Livestock grazing	Widespread except in LVNP, remote wilderness basins and, more recently, known breeding sites on the Lassen NF. Heavy grazing occurred historically throughout the range.	Potential for long-term persistence depends on management decisions.	Variable dependent on grazing management practices, intensity and implementation of best management practices; can be severe under heavy grazing.	Level of habitat damage affects recovery timeline. Severe alterations to hydrology due to historical grazing practices are long term.	Can reduce impacts by removing cattle, creating pools for breeding, repairing incised channels and raising water tables to reduce long-term impacts.	Grazing effects on habitats are relatively well studied. Lowered water tables can result in reduced egg and larval survival, especially in the meadow habitats of the southern Cascades.	Yes.

Table 1—Summary of the evaluations of risk factors for the Cascades frog (continued)

Risk factor	Spatial extent of the risk	Duration and persistence	Intensity of the threat	Ecological permanence	Potential for management[a]	Weight of evidence	Jurisdiction of participating agencies
Recreational activities	Widespread but usually dispersed regionally.	Occurs most in summer months when frogs are active. Recreational activities expected to continue at current or increased levels for the long term.	Low to variable where only low-impact activities are permitted. May be locally high in areas where high recreation use occurs.	Impacts are reversible, but recovery time depends on habitat type and severity of impact.	Yes; management effectiveness potentially high but social considerations exist.	Direct documentation anecdotal; effects primarily inferred indirectly from impacts to habitat (meadows and riparian areas).	Yes; within jurisdiction of participating agencies.

[a] Potential for management to reverse or reduce impacts.
LVNP = Lassen Volcanic National Park;. NF = national forest; chytrid = chytridiomycosis.

Regardless, Davidson et al. (2012) did find residues of currently used pesticides (Chlorpyrifos, Dacthal, and Endosulfan), banned organochlorines, and polycyclic aromatic hydrocarbons (PCBs) in several of the frog tissues collected from the range of the Cascades frog. However, estimated exposure concentrations were extremely low. For example, endosulfan and trans-nonachlor were more than four orders of magnitude below short-term water-exposure concentrations known to be acutely lethal to amphibians (Davidson et al. 2012). The authors caution that there is no information on what concentrations of chemicals may cause sublethal effects and warn about falsely rejecting the entire pesticide hypothesis based on limited evidence (Davidson et al. 2012).

Pesticides can act synergistically with other stressors, which could render Cascades frogs more susceptible to other threats including aquatic pathogens such as *Aeromonas* bacteria or *Bd* (Blaustein et al. 2011, Davidson et al. 2007). A recent laboratory study, however, did not find any synergistic effects of *Bd* and endosulfan pesticide exposure on juvenile Cascades frogs (Reagan and Davidson 2012). In contrast, adult Woodhouse toads (*Bufo woodhousei*) experimentally infected with *Aeromonas hydrophila* bacteria and exposed to sublethal levels of the organophosphate pesticide malathion sustained higher mortality than infected toads that were not similarly pesticide dosed; susceptibility to disease appeared linked to suppressed immune responses (Taylor et al. 1999). Another study exposed foothill yellow-legged frogs (*Rana boylii*) to the pesticide carboryl and found that exposed frogs experienced reduced production of skin peptides that inhibit *Bd* growth in culture, suggesting that pesticide exposure may contribute to the frog's susceptibility to the disease (Davidson et al. 2007). Contaminants can also affect amphibians indirectly through food web changes (Blaustein et al. 2011). For example, low concentrations of malathion are not directly lethal to tadpoles but are highly lethal to zooplankton (Relyea and Diecks 2008).

Extent of risks related to airborne contaminants—
Currently, evidence suggests that airborne contaminants pose a low direct risk to Cascades frogs. However, complex interactions may exist between contaminants and other stressors that we are just beginning to examine. Such indirect effects would likely be strongest in low- to mid-elevation habitats downwind of agricultural areas.

Conservation options related to airborne contaminants—
We first must better understand the complex interactions of airborne contaminants with other primary stressors to Cascades frogs. With better information, it may be possible to influence the use of specific harmful contaminants to reduce impacts to at-risk populations.

Climate Change

Climate models estimate that temperatures in California will increase from 1.5 to 4.5 °C by the end of the 21st century (Cayan et al. 2008). Warmer temperatures are predicted to result in lower annual snowpack in the mountains (Cayan et al. 2008, Young et al. 2009), which in turn will affect the hydroperiod of small lakes and ponds. Reduced hydroperiods could directly reduce the amount of available habitat for all life stages of Cascades frogs and could increase the instances of stranding mortality of eggs and tadpoles, especially in meadow habitats in the southern Cascades where early pool drying is already causing egg and tadpole mortality (Pope et al. 2011). Because introduced fish occur in the majority of lakes in the Klamath Mountains, there may be an interactive effect of fish and climate change, with fish preventing breeding by Cascades frogs in some lakes and climate change increasing the likelihood of drying of shallow lakes and ponds that do not support fish (e.g., Lacan et al. 2008). Warmer temperatures could also affect the distribution of pathogens and their vectors, possibly exposing frogs to new pathogens (Blaustein et al. 2001).

Some climate change models predict more frequent anomalous weather events including storms, droughts, and severe winters (Groisman et al. 2004, Parmesan et al. 2000). Severe winters may force extended overwintering, which may increase the chance of overwinter mortality, or may weaken frogs so that they have increased susceptibility to other stressors during the summer active period. In addition, more frequent early-season storms would increase the likelihood of egg masses disconnecting from attachment substrates and drifting freely, resulting in more failed hatchings of eggs (Garwood et al. 2007).

Extent of risks related to climate change—

The risk to Cascades frogs from climate change is potentially high, particularly for populations that breed in ephemeral waters. More frequent weather extremes could increase in the probability of extirpations. This risk is greatest in the southern Cascades where the species is already rare and, therefore, highly susceptible to environmental stochasticity.

Conservation options related to climate change—

Agencies have the opportunity to develop and implement local measures to help mitigate the predicted effects of climate change on habitats. For example, the Lassen NF has altered breeding pools to increase their annual hydroperiods and decrease maximum summer water temperatures (Pope et al. 2011). Efforts are underway to expand mitigations to additional habitats on both public and private lands. More research is needed to provide a better understanding of climate effects on this species including how climate-change linked habitat alteration may affect Cascades frog population dynamics, and how climate changes may interact with other risk factors such as emerging pathogens.

Disease

Although amphibians are susceptible to a wide array of diseases, one disease has emerged as the greatest conservation concern for amphibians worldwide (Skerratt et al. 2007). Chytridiomycosis, an amphibian-specific fungal disease caused by *Bd* (Berger et al. 1998, Longcore et al. 1999), has been implicated in declines and extinctions of amphibian populations worldwide (e.g., Bosch et al. 2001, Lips et al. 2004), and in the Sierra Nevada of California (Briggs et al. 2010, Rachowicz et al. 2006, Vredenburg et al. 2010). It has been found in populations of Cascades frogs throughout the range in California (Piovia-Scott et al. 2011, Pope et al. 2011). Survival of juvenile frogs may be greatly reduced when they are infected by *Bd* (Garcia et al. 2006), but survival of adults appears minimally affected by the disease (Piovia-Scott et al. 2011, Pope et al. 2011). Recent lab and field research provides compelling evidence that an especially virulent strain of *Bd* was responsible for a significant die-off of juvenile frogs from a large population in the Klamath Mountains (Piovia-Scott et al. 2013).

Research is ongoing to explain among-population variation in resistance to *Bd* (Knapp et al. 2011, Piovia-Scott et al. 2013). One important finding is that large populations have a higher likelihood of persisting with the disease (Knapp et al. 2011), so continued efforts to increase local population sizes (e.g., by removing introduced trout from lakes) may also be important for improving chances of survival with the disease. A recently conducted 6-year study of five of the remaining populations of Cascades frogs in the Lassen area is providing a better understanding of the local temporal and spatial aspects of the disease-host dynamics and how they may relate to population persistence of Cascades frogs (Pope et al. 2011). Researchers are comparing apparent survival of frogs in relation to *Bd* zoospore loads and modeling individual variation in susceptibility.

We currently have a poor understanding about potential interactive effects of different amphibian diseases. In nature, multiple infectious organisms frequently infect hosts, but research examining the combined effects of multiple diseases is lacking (Blaustein et al. 2011). In addition, interactions between *Bd* and other nondisease factors are likely but not well understood. One study assessing the interaction between the pesticide carbaryl and susceptibility to *Bd* found that carbaryl reduced production of amphibian skin peptides that inhibit the growth of *Bd* (Davidson et al. 2007).

Other diseases may contribute to local anuran declines including *Saprolegnia* fungal infections (Blaustein et al. 1994b), iridovirus and bacterial infections (Carey et al. 1999), and trematode infections (Johnson et al. 1999). Research conducted in Oregon found *Saprolegnia ferax* and trematodes to be potentially important sources of mortality of Cascades frogs. *Saprolegnia ferax*, a species of water mold that commonly infects fish, has caused die-offs of eggs in Cascades frogs and western toads (*Bufo boreas*) in Oregon (Blaustein et al. 1994b, Kiesecker and Blaustein 1997). Kiesecker and Blaustein (1997) found that the communal egg-laying behavior of these species increased their risk of infection. Further, a synergistic effect may exist between UV-B radiation and *S. ferax* infection whereby together they reduce egg survival more than either stressor alone (Kiesecker and Blaustein 1995). Neither *S. ferax* nor massive die-offs of eggs, similar to those in Oregon, have been documented among the Cascades frog in California despite numerous egg mass surveys.

The family Iridoviridae contains five genera, some of which infect amphibians (Chinchar 2002, Green et al. 2002). All iridovirus-caused mortality in the United States has involved larval or metamorphosing salamanders, frogs, and toads (Green et al. 2002). In the Western United States, iridovirus-caused mortality may be much more common in salamanders than in frogs and toads (Green et al. 2002). Iridoviruses may move between fish and amphibians under natural conditions (Mao et al. 1999), raising the possibility that stocked fishes may act as vectors for iridoviruses (see “Introduced Fishes and Other Predators”).

Extent of risks related to disease—

Chytridiomycosis is present in Cascades frog populations across the range in California (Piovia-Scott et al. 2011, Pope et al. 2011). Based on the impact that *Bd* is having on amphibian populations worldwide, the risk of the disease to populations is high. However, extant populations appear to be coexisting with the pathogen at least in the short term. It appears that *Bd* is significantly reducing juvenile frog survival in many populations. Reduced recruitment resulting from the disease increases extinction risk.

Conservation options related to disease—

Research on the extent, impact, and epidemiology of *Bd* for the Cascades frog is a high priority. Considerable recent research has been undertaken to devise methods to combat the impacts of *Bd* on amphibians in the wild. Among the most promising is application of anti-*Bd* bacteria such as *Janthinobacterium lividum* to the skin of frogs to help protect them from the disease (Harris et al. 2009). Testing of the effectiveness of augmenting the skin of Cascades frogs with disease-fighting bacteria is ongoing and may be able to be used as a conservation tool in the southern Cascades in the near future. Additionally antifungal drugs such as itraconazaole and terbinafine hydrochloride have been used to treat diseased frogs with some success (Berger et al. 2010, Bowerman et al. 2010). Other mitigation efforts to increase population sizes of Cascades frogs may also help reduce their susceptibility to *Bd* because evidence suggests that large populations have a better chance of persisting with the disease compared to small populations (Knapp et al. 2011).

Fire Suppression

Issues related to fire management are diverse (see "Vegetation and Fuels Management," app. 5), but this section focuses specifically on fire-suppression activities that may affect Cascades frogs. The effects of fire suppression activities on native flora and fauna, and in particular amphibians, have not been studied well, so most evidence is anecdotal (Pilliod et al. 2003). Regardless, impacts have the potential to be strong only in the southern Cascades because in the Klamath Mountains the frog primarily occurs within subalpine aquatic habitats with long fire return intervals and in wilderness areas where fire suppression activities are less than they are closer to the wildland-urban interface. Fire suppression activities do occur regularly in the frog's lower elevation forested habitats outside of wilderness areas, and potential direct impacts include water drafting from ponds and streams, application of fire retardant, and construction of fuel breaks. These activities could also produce changes in aquatic and riparian habitats via sedimentation changes, alteration in down woody debris, and reduction (producing both positive and negative effects) in amounts of vegetation associated with the habitat. Only anecdotal evidence is available specific to Cascades frogs for any of these activities. In June 2008, northern California was struck by a severe dry lightning storm that started more than 2,700 fires. With dry conditions and heavy fuel loads, several strikes turned into major fires, including those in the Marble Mountains Wilderness, Trinity Alps Wilderness, and Lassen NF. In the Marble Mountains and Trinity Alps, no known Cascades frog populations were harmed because fire suppression activities occurred in lower elevations and wilderness edges, and the fires only patchily burned inside the areas where the majority of the frog populations are found. On the Lassen NF, fires got close to two southern populations of Cascades frogs and a fire line was placed on the ridge above one meadow population. In the following 3 years, no noticeable damage occurred to the population or its habitat from the fire suppression activities that occurred in the area.

Fire crews and other fire personnel attempt to minimize impacts to aquatic and semiaquatic species and their habitats, but inadvertent impacts can occur. During the severe 1987–1991 drought in California, fire suppression personnel in the Sierra Nevada were forced to take water from locations where aquatic amphibians and reptiles had often concentrated.

The construction of fire lines or firebreaks by firefighters using hand tools or machinery such as bulldozers may be extensive and result in habitat changes similar to those associated with road and road construction (see "Roads" section). Fire line or firebreak restoration features, such as water bars and revegetation, may mitigate erosion rates and roadlike effects (Pilliod et al. 2003). Sedimentation may be the most detrimental roadlike effect of firelining on amphibians, as unpaved roads are responsible for greater increases in sediment mobility and erosion than either logging or fire per se (Rieman and Clayton 1997). Mechanized equipment is not a permitted activity in wilderness areas for fire suppression.

Application of retardant has become an important wildlife issue (Pilliod et al. 2003). In large wildfires, large amounts of ammonia-based fire retardants and surfactant-based fire-suppressant foams are dropped from air tankers and sprayed from fire engines to slow or stop the spread of fire. Some fire-suppressant cocktails are toxic or hazardous to aquatic organisms (Buhl and Hamilton 2000, Gaikowski et al. 1996, MacDonald et al. 1996). Concerns regarding the effects of aerial application of fire retardant on aquatic systems and threatened, endangered, or candidate species were addressed in the Forest Service Chief's Record of Decision (USDA FS 2011). This directs tanker pilots to avoid aerial application of retardant or foam within 91 m of waterways. A "waterway" is considered to be any body of water including lakes, rivers, streams, and ponds irrespective of whether they contain aquatic life. This is considered binding direction, subject to qualifications and exceptions only as noted in the Decision Notice. However, accidental contamination of aquatic habitats can and has occurred, especially from aerial applications (Minshall and Brock 1991). For example, during fire-suppression activities, a direct "hit" of fire-retardant was dropped adjacent to the Buck's Lake Wilderness in a small mountain yellow-legged frog breeding pond. No studies occurred to determine the effects, but there was a noticeable decline in the tadpoles within this pond (Hopkins 2007).

Successful forest fire suppression over the past century has resulted in dense forests with very high fuel loads. The Forest Service initiated a program of active management to reduce fuel loading in an effort to reduce the intensity and extent of wildfires. Catastrophic fire can produce some of the most intensive and extensive changes in watershed condition of any disturbance (Kattelmann 1996). In addition, dense forests reduce snowpack on forested slopes and take up water for transpiration, resulting in reduced water yields downslope (Kattelmann 1996). These indirect large-scale effects of fire suppression can affect Cascades frog habitats by decreasing water input, altering peak flows, and increasing sediment yield.

Extent of risks related to fire suppression—
The impact of fire suppression activities on Cascades frogs is unlikely to be high across the majority of its range because much of the habitat occurs in wilderness and high-elevation areas with sparse vegetation, where fire-suppression activities are rarely conducted and mechanized equipment is not used (e.g., mechanized equipment generally is not allowed in wilderness areas). The risk is potentially high for Lassen NF populations primarily because so few populations and animals remain.

Conservation options related to fire suppression—
Management can influence fire suppression techniques and their mode of application to minimize impacts to the Cascades frog and its habitat. Caution will be most important in the Lassen area and outside wilderness areas in the Klamath Mountains. Minimum-impact fire suppression techniques that avoid aquatic habitats represent the best alternative to protecting Cascades frogs and their habitat. Controlled burns and forest thining of over-dense managed forests near populations of frogs in the southern Cascades and Klamath Mountains may reduce risk of high-intensity fire impacts and increase water yields to frog habitats.

Introduced (Nonnative) Fish and Other Predators

Most of the range of the Cascades frog in California was historically fish-free, both in the southern Cascades and Klamath Mountains, although a few watersheds such as the Pit and Feather River drainages historically contained native salmonids that overlapped with the distribution of the Cascades frog. Fish stocking has been widespread throughout the mountains of California starting in the early 1900s, though it was discontinued in the national parks in the 1980s (Knapp 1996). Recently in California, stocking has ceased in any waters known to support Cascades frogs or mountain yellow-legged frogs (ICF Jones & Stokes 2010). Although new stocking has ended, many populations of stocked fish are likely self-sustaining (Armstrong and Knapp 2004, Pope 2008a). Currently, the majority of large (> 2 ha), deep (> 3 m) lakes in the Klamath Mountains and southern Cascades support introduced populations of brook trout (*Salvelinus fontinalis*) or rainbow trout (*Oncorhynchus mykiss*) (Welsh et al. 2006). In addition, most perennial streams also support trout. The lake habitats are important for breeding and overwintering of Cascades frogs (Pope 2008a, Welsh et al. 2006). Surveys have shown that, where introduced trout are present, amphibians are often absent (Bradford 1989, Knapp 2005, Knapp and Matthews 2000, Welsh et al. 2006). Trout are effective predators of native ranid frogs (Vredenburg 2004), prevent dispersal (Bradford et al. 1993), and compete for food resources (Finlay and Vredenburg 2007, Joseph et al. 2011). Welsh et al. (2006) found that Cascades frogs were less likely to be found in water bodies with trout, and when they were found, numbers were depressed. When fish were removed from selected lakes in the Klamath Mountains, survival, recruitment, and population densities of Cascades frogs rapidly increased compared to fish-occupied control lakes (Pope 2008a).

Although no studies have specifically addressed the impact of introduced fish in the southern Cascades, the contribution of fish to population declines of Cascades frogs in lake habitats was likely similar to that in the Klamath Mountains. In LVNP, fish were stocked from 1928 or before through 1965 in 41 lakes. This represents most of the lakes in LVNP that could support fish. In 1966, fish stocking ceased in 14 lakes considered marginal habitat for fish, but continued in the 27 remaining previously stocked lakes through 1967. In 1968, a phase-out policy was implemented, resulting in the cessation of all stocking by 1980. Since cessation of stocking, fish have naturally extirpated from approximately 34 lakes in LVNP, but Cascades frog populations continued to decline (Stead et al. 2005) suggesting there are other stressors affecting population persistence and recovery (Fellers et al. 2008).

Introduced fish may interact with other risk factors to cumulatively affect Cascades frogs. For example, fish occur in the majority of deep lakes and reduce the likelihood of successful breeding in these waters, and climate change increases the likelihood of drying of shallow lakes and ponds that do not support fish (Lacan et al. 2008). Therefore, fish and climate change cumulatively reduce the amount of suitable breeding habitats. Introduced fish may also affect the balance of native predators and Cascades frogs. For example, high densities of aquatic garter snakes can affect Cascades frog populations where fish have already reduced population sizes (Pope et al. 2008).

Other predators may also affect Cascades frog populations. Stead and Pope (2010) propose that a proliferation of freshwater leeches (subclass Hirudinida) in the southern Cascades may negatively affect *R. cascadae* populations by preying on eggs and hatchlings and by contributing to the spread of pathogens and secondary parasites.

Extent of risks related to introduced fish and other predators—
The risks of introduced fish to Cascades frogs are high and widespread. Introduced fish are found over most of the California range of the species and are known to affect presence and densities of Cascades frogs. How important the role of stocking has been to the frog's decline in the southern Cascades is unclear. However, fish introductions across most of its California range coupled with evidence of a fish effect in the Klamath Mountains strongly implicates fish as a contributor to declines. Risks associated with the interactive effects of fish and other stressors (e.g., climate change, disease) may also be high.

Conservation options related to fish and other predators—
The stocking of fish in aquatic water bodies represents a management action over which participating agencies have the ability to exert both direct and indirect controls. Because stocking has occurred throughout the range of the frog, actions taken toward this factor have the potential to be far-reaching. Further, the rapid recovery of Cascades frog populations following fish removal in lentic systems indicates that fish removals have the potential to be effective restoration tools. Removal of fish from streams without the use of toxicants (e.g., rotenone) is extremely difficult, so lakes with natural fish barriers near their inlets and outlets are better targets than streams (Knapp et al. 2007).

Recent policy changes have been implemented in California regarding fish stocking in water bodies where species of special concern occur or may occur. Prompted by a 2006 lawsuit, the California Superior Court ruled in 2008 that the CDFW must consider the effects of hatchery operations and fish stocking on aquatic species of special concern when making stocking decisions (Pacific Rivers Council Center for Biological Diversity v. CDFG [now CDFW]. 2007. Case number 06 CS 01451, California Superior Court of Sacramento County). A joint CDFW/USFWS Hatchery and Stocking EIR/EIS was completed in January 2010 (ICF Jones and Stokes 2010). Included are measures to mitigate impacts of introduced fish, including not stocking any waters found to currently support Cascades frogs, and to develop basin-scale management plans within the range of Cascades frogs that include detailed objectives for both sport fisheries and protection and recovery of frog populations. Thus far, CDFW has stopped fish stocking in most water bodies known to support Cascades frogs, but has not begun any fish removal projects in the Klamath Mountains or southern Cascades.

Livestock Grazing

Livestock grazing has been considered the most widespread influence on native ecosystems of western North America (Fleischner 1994, Kattlemann 1996). Seasonal grazing of sheep and cattle across the mountains of California has occurred since the early 1800s and continues today, except in national parks (Fleischner 1994, Menke et al. 1996). Because of the long timeframe, we lack a clear ecological benchmark for determining the effects of grazing. Regardless, researchers have found widespread impacts, including loss of native species, changes in species composition, alteration of hydrology including lowered water tables, soil deterioration, degradation of fish and aquatic insect habitat, and changes in ecosystem structure and function (Belsky et al. 1999, Flenniken et al. 2001, Fleischner 1994, Kauffman and Krueger 1984). Where historical grazing has resulted in channel incision and lowered water tables, Cascades frogs may be affected by less available breeding habitat and shorter hydroperiods (Pope et al. 2011), but these long-term effects are difficult to quantify. Short-term direct impacts such as trampling and local water quality degradation are also a concern, especially in the southern Cascades where populations are small.

Currently, livestock grazing occurs throughout much of the range of the Cascades frog, but, at least on public lands, livestock distribution and numbers have been reduced dramatically compared to historical numbers. One recently discovered occupied Cascades frog site in Childs Meadow includes a portion of the Lassen NF that is currently grazed, but exclusion fencing is planned for around the breeding pool (Foote 2012). Occupied meadow sites on private lands both north and south of LVNP in the southern Cascades are still grazed. Much of the species' range in the Klamath Mountains is still grazed, although portions of the wilderness areas are inaccessible by cattle or are not permitted for grazing.

Minimal data exists on the impacts of livestock grazing on Cascades frogs; however, a research team in the Sierra Nevada recently assessed the short-term impacts of grazing on Yosemite toads (*Anaxyrus canorus*) through a 5-year exclosure experiment over nine meadows (Allen-Diaz et al. 2010, Lind et al. 2011, Roche et al. 2012). Within meadows, Yosemite toads breed in aquatic habitats similar to those of Cascades frogs, but they differ from the frogs in that after breeding and metamorphosis, toads leave the aquatic habitats and move into nearby upland habitats (Liang 2010). The researchers did not detect differences between grazed and ungrazed meadows in survival or abundance of Yosemite toads and saw no improvement in breeding habitat quality after cattle were removed from meadows (Lind et al. 2011, Roche et al. 2012). Two other studies assessing livestock grazing impacts on the Columbia spotted frog (*Rana luteiventris*) in pond habitats in northeastern Oregon also found no significant amphibian responses to grazing (Adams et al. 2009, Bull and Hayes 2000). A recent unpublished study assessing landscape-scale patterns of Cascades frog occurrence in relation to cattle grazing in wet meadow habitats of the Trinity Alps Wilderness found no relationship between grazing and frog occupancy (Cole and North 2010).

Extent of risks related to livestock grazing—
Livestock grazing is still fairly widespread throughout the California range of the Cascades frog. However, current risks related to ongoing livestock grazing for these frogs in California are likely low because livestock use has not been permitted for more than 10 years in most breeding habitats on public lands in the Lassen region where sensitive frog populations occur. Livestock numbers have been reduced on other public lands across the range, and recent studies have not found significant evidence of direct effects on meadow-associated amphibian population numbers

(e.g., Roche et al. 2012). However, even minimal effects such as trampling of a couple of adult frogs could be harmful to population persistence of some small populations in the southern Cascades. In addition, legacy effects to riparian and wet meadow habitats are likely extensive, especially in the southern Cascades and eastern Klamath Mountains. Although it is difficult to measure legacy effects or to separate them from legacy effects owing to other stressors such as logging or fire suppression, some montane meadows in northern California have become too degraded and desiccated to support appropriate habitats for Cascades frogs. However, there do remain many high-quality wet meadows on the Lassen NF and LVNP that support appropriate habitat for Cascades frogs but on which frogs are absent.

Conservation options related to livestock grazing—
The current altered condition of individual breeding pools within meadow habitats resulting from decades of livestock grazing is of concern for the conservation of the Cascades frog in the southern Cascades. Measures to restore hydrologic function to degraded meadows could benefit Cascades frogs by increasing available surface water habitat. Specific measures within meadows to increase the hydroperiod and decrease the temperature of important breeding pools could also help alleviate some of the legacy effects of livestock grazing. In addition, continued management of grazing activities will likely help minimize or eliminate potential ongoing impacts to this species and its habitat. Studies on the extent and scope of livestock grazing impacts to Cascades frog are needed.

Recreational Activities

The geographic range of the Cascades frog in California occurs primarily on public lands with about 5 percent on national park land and 62 percent on national forest lands (USDA FS 2001a). About half of the range on national forest lands occurs within designated wilderness areas where recreational use is limited to non-motorized and dispersed activities such as hiking, backpacking, fishing, and camping. Outside the wilderness areas and national parks, recreational activities can include motorized activities such as off-highway vehicle use that have the potential for greater impact. About 33 percent of the historical range of the Cascades frog in California lies on private lands with restricted public recreation (owned by timber companies), but some private lands with camps and lodges support heavy recreational use.

To date, no studies have specifically examined the impacts of recreational activities on Cascades frogs. However, some information exists on the effects of selected recreational activities on the aquatic habitats also used by Cascades frogs. The mid to high mountain lakes, streams, ponds, and wet meadows inhabited by Cascades frogs receive a disproportionate amount of recreational use through trail networks, campsites, angling opportunities, and swimming. Establishment of trails and camps has been shown to disturb vegetation and soil structure, resulting in changes in habitat structure and microclimate (Boyle and Samson 1985, Garton et al. 1977, Knight and Cole 1991). Anglers often create shoreline trails for access to fishing spots even at remote wilderness lakes. These activities that occur near high-elevation meadows, ponds, lakes and streams can result in increases in pool sediments, modification of pool mudflats, erosion, bank trampling, and vegetation disturbance (Bronmark and Hansson 2002). Generally, studies have found that recreation impacts can happen rapidly even with light use, whereas recovery occurs only after lengthy periods of no use (Cole and Marion 1988).

Studies examining the effects of recreational packstock (usually horses and mules used to assist travel into the backcountry) grazing on alpine meadow habitat have found significant changes in meadow structure resulting from horse and mule grazing (Cole et al. 2004; Moore et al. 2000; Olson-Rutz et al. 1996a, 1996b). These changes in meadow condition may affect breeding habitat of Cascades frogs. Cascades frogs typically breed in small potholes in meadows or fens, and shallow areas of ponds and lakes (see "Habitat Requirements in Ecology" section). These shallows are especially prone to damage by trampling of hikers, packstock, or off-highway vehicles. Recreational activities may also result in direct mortality to Cascades frogs through trampling (see Bartelt 1998).

Recreational activities that reduce habitat quality or frequently disturb normal basking and feeding behaviors of Cascades frogs can increase the glucocorticoid stress hormones in the frogs. Long-term physiological effects of glucocorticoid exposure include the suppression of growth, reproduction, and immune system components (Moore and Jessop 2003). Stress hormones in amphibians are also elevated by exposure to *Bd* and cause increases in metabolic rates which are energetically costly (Peterson 2012, Wack et al. 2012). The interactive effects of *Bd* and environmental stress on amphibians are currently being studied and initial results suggest that stressed Australian green treefrogs (*Litoria caerulea*) experience lower energy stores and lower survival when exposed to *Bd* compared to unstressed frogs (Peterson 2012).

Extent of risks related to recreational activities—

Recreational use through most of the range of the Cascades frog is light and dispersed, so risk associated with recreational activities is assumed to be low to moderate, depending on the geographic region and habitat type. In high-use areas, such as lakes outside of wilderness areas with road access, recreational activities likely have measurable impacts to frogs and habitats. Recreational impacts also act synergistically with other stressors to increase stress, which reduces the health and resilience of the frogs.

Conservation options related to recreational activities—
Encouraging diffuse recreation such as limiting the number of campers using lakes inhabited by Cascades frogs could further minimize potential impacts of recreational activities on the Cascades frogs. Recreational activities are within the direct purview of agencies participating in this assessment. A better understanding of how recreation-related impacts interact with other stressors is needed.

Relative Importance of Risk Factors

Southern Cascades

Because Cascades frogs have become so rare in the southern Cascades, any of the risk factors that affect frog survival or breeding habitat quality are important. Based on existing information, the current primary cause of low survival of frogs in the southern Cascades is *Bd* (Pope et al. 2011; Pope, n.d.). The degree to which *Bd* was responsible for the extirpations of Cascades frogs in LVNP is unknown, but the disease was likely a contributor. In addition, legacy effects from past disturbances such as grazing, logging, and road construction have likely contributed to shorter hydroperiods in breeding pools that result in poor annual survival of eggs and tadpoles. Other ongoing factors that contribute to habitat drying or physiological stress such as climate change, vegetation and fuels management, and recreation may have additional impacts on population persistence. Even without additional stressors, the species is at a risk of extirpation, therefore, active management may be needed to preserve and restore the distribution and genetic structure of the frogs in the southern Cascades.

Klamath Mountains

In the Klamath Mountains, introduced fish and *Bd* may be the most important threats to address for conservation of the Cascades frog. Data directly address the effects of fish on Cascades frogs in this region, fish stocking is widespread, and populations of Cascades frogs recover when fish are removed from lake habitats (Pope 2008a). *Bd* occurs in Cascades frog populations throughout the Klamath Mountains (Piovia-Scott et al. 2011). The apparent persistence of populations between 1999–2002 and 2008–2009 at the majority of sites surveyed suggests that widespread die-offs associated with the disease did not occur during this period (Piovia-Scott et al. 2011). However, the majority of population sizes are relatively small and recent data suggest that the disease may be affecting the survival of juvenile frogs, which may have eventual effects on population persistence. Recreation is in the second tier of importance because effects are widespread, frequent, persistent, and likely to interact with other stressors. However, the level of impact or risk to the Cascades frog as a result of recreational activities is not known.

Rangewide

The extent of risk for the Cascades frog from *Bd* is high. *Bd* has been detected across the range of the species in California, but the role it has played in population declines is just beginning to be understood. Based on data obtained thus far for this and other related species in the Sierra Nevada, *Bd* is a primary risk factor rangewide. Understanding how other risk factors and environmental factors interact with *Bd* will be important to predict regions of greatest conservation concern.

Climate change also poses a potentially high risk given the susceptibility of montane amphibians to climatic extremes such as drought. Successful metamorphosis is often dependent on snowmelt into the late summer to maintain water levels and temperatures for egg and tadpole growth. With introduced fish in many of the deeper lakes in the Klamath Mountains, increased desiccation of shallower pond and pool habitats could affect population persistence. Desiccation of breeding pool habitat in the southern Cascades is already a problem that could be exacerbated by hydrological changes resulting from climate change.

Understanding how these risk factors affect the Cascades frog will facilitate the development of a conservation strategy that can effectively address all of the risk factors together. Synergistic effects may exist between risk factors. Not recognizing these may result in the failure of management actions focused on only those factors that management can address. For example, breeding pool enhancements at Carter Meadow may increase survival to metamorphosis, but if *Bd* kills the newly metamorphosed frogs, then the increased survival does not result in increased abundances. Additional measures to reduce mortality from *Bd* would also be needed for a positive effect on population dynamics.

Existing Management and Research

Current research topics being conducted by the USDA Forest Service Pacific Southwest Research Station (PSW), University of California-Davis, and San Francisco State University, include (1) assessing the population dynamics (survival, immigration, emigration, population size, and population growth rates) of the remaining Cascades frog populations in the southern Cascades; (2) assessing the population-level effects of *Bd* on Cascades frogs throughout their range; (3) assessing the synergistic effects of pesticides and *Bd* on the survival of Cascades frogs; and (4) assessing the effects of cattle grazing on Cascades frog breeding success.

Conservation Options

Because Cascades frog populations are near depletion in the southern Cascades, more extensive measures may be appropriate there. Other measures provide more general guidelines to be applied throughout the California range of the species.

Within California in General

Provide for the ecological requirements and population viability of Cascades frogs—

- Increase the amount of fishless aquatic habitat by continuing CDFW's plan to not stock waters supporting Cascades frogs and by restoring selected aquatic habitats to a fishless condition.
- Determine population-level effects of *Bd* across the range and devise research techniques to reduce those effects.
- Institute a long-term, rangewide monitoring program in California.
- Determine effects of existing levels of management for vegetation and fuels management and livestock grazing.

Develop strategies for addressing high-priority information gaps—

- Determine the effectiveness of different active management approaches—such as modifying breeding pools, removing livestock from breeding habitats, thinning riparian vegetation in occupied streams to improve basking habitat, or thinning lodgepole pines (*Pinus contorta* Douglas ex Louden) adjacent to breeding pools in meadow habitats in the southern Cascades—by testing these methods and monitoring populations pre- and post-treatment.
- Investigate the genetic structure of Cascades frogs within California and compare to populations in Oregon and Washington to determine if the Cascades frog in California or in the southern Cascades is a Distinct Population Segment.

Southern Cascades

- On a site-by-site basis, implement targeted restoration actions (e.g., deepen and extend meadow breeding pool habitat, thin riparian vegetation) and monitor their effects on populations.
- Employ research techniques, such as bioaugmentation of anti-*Bd* skin microbes or the use of antifungal drugs, to reduce mortality of juvenile frogs caused by *Bd*.
- Inform landowners and other stakeholders about the status of Cascades frogs, with the goal of collaborating to protect and restore populations on private as well as public lands.
- Investigate the feasibility and options for translocation to historically occupied habitats in LVNP.
- Monitor remaining populations.

Other conservation options may become important during conservation strategy development; these should be considered for incorporation into the conservation strategy at that time.

Acknowledgments

We give our sincere thanks to all members of the Cascades Frog Working Group listed in appendix 6. It has been a long process and very much a tag-team effort. Particular thanks go to Melanie McFarland, who willingly and promptly responded to multiple requests for information, text, reviews, and perspectives. Because this document was written in conjunction with assessments for four other frog species, members of the other conservation teams also contributed to this document. Robert Bingham, Nichole Patrick, and Matt Wacker contributed to several of the risk factor sections. Linda Long formatted the final draft and Jan Werren produced the map. Bret Harvey, Mike Adams, Grant Hokit, and Dede Olson provided reviews and comments on an earlier draft of this document.

English Equivalents

When you know:	Multiply by:	To get:
Centimeters (cm)	0.394	Inches
Kilometers(km)	.621	Miles
Meters (m)	3.28	Feet
Hectares (ha)	2.47	Acres

References

Adams, M.J.; Hossack, B.R.; Knapp, R.A.; Corn, P.S.; Diamond, S.A.; Trenham, P.C.; Fagre, D.B. 2005. Distribution patterns of lentic-breeding amphibians in relation to ultraviolet radiation exposure in western North America. Ecosystems. 8: 488–500.

Adams, M.J.; Pearl, C.A.; McCreary, B.; Galvan, S.K.; Wessell, S.J.; Wente, W.H.; Anderson, C.W.; Kuehl, A.B. 2009. Short-term effect of cattle exclosures on Columbia spotted frog (*Rana luteiventris*) populations and habitat in northeastern Oregon. Journal of Herpetology. 43: 132–138.

Adams, M.J.; Schlinder, D.E.; Bury, R.B. 2001. Association of amphibians with attenuation of ultraviolet-b radiation in montane ponds. Oecologia. 128: 519–525.

Allen-Diaz, B.; Lind, A.; McIlroy, S,L.; Roche, L.; Grasso, R. [et al.]. 2010. Determining the effects of livestock grazing on Yosemite toads (*Bufo canorus*) and their habitat: Final report to USDA Forest Service Region 5. Vallejo, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region. 45 p.

Ankley, G.T.; Diamond, S.A.; Tietge, J.E.; Holcombe, G.W.; Jensen, K.M.; DeFoe, D.L.; Peterson, R. 2002. Assessment of the risk of ultraviolet radiation to amphibians. I. Dose-dependent induction of hind limb malformations in the northern leopard frog (*Rana pipiens*). Environmental Science and Technology. 36: 2853–2858.

Ankley, G.T.; Tietge, J.E.; Holcombe, G.W.; DeFoe, D.L.; Diamond, S.A.; Jensen, K.M.; Degitz, S.J. 2000. Effects of laboratory ultraviolet radiation and natural sunlight on survival and development of *Rana pipiens*. Canadian Journal of Zoology. 78: 1092–1100.

Anzalone, C.R.; Kats, L.B.; Gordon, M.S. 1998. Effects of solar UV-B radiation on embryonic development in *Hyla cadaverina*, *Hyla regilla*, and *Taricha torosa*. Conservation Biology. 12: 646–653.

Armstrong, T.W.; Knapp, R.A. 2004. Response by trout populations in alpine lakes to an experimental halt to stocking. Canadian Journal of Fisheries and Aquatic Sciences. 61: 2025–2037.

Aston, L.S.; Seiber, J.N. 1997. Fate of summertime organophosphate pesticide residues in the Sierra Nevada Mountains. Journal of Environmental Quality. 26: 1483–1492.

Bartelt, P.E. 1998. *Bufo boreas* (western toad) mortality. Herpetological Review. 29: 96.

Belden, L.K.; Blaustein, A.R. 2002. Exposure of red-legged frog embryos to ambient UV-B radiation in the field negatively affects larval growth and development. Oecologia. 130: 551–554.

Belden, L.K.; Wildy, E.L.; Blaustein, A.R. 2000. Growth, survival, and behaviour of larval long-toed salamander (*Ambystoma macrodactylum*) exposed to ambient levels of UV-B radiation. Journal of Zoology. 251: 473–479.

Belsky, A.J.; Matzke, A.; Uselman, S. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. Journal of Soil and Water Conservation. 54: 419–431.

Berger, L.; Speare, R.; Daszak, P.; Green, D.E.; Cunningham, A.A.; Goggin, C.L.; Slocombe, R.; Ragan, M.A.; Hyatt, A.D.; McDonald, K.R.; Hines, H.B.; Lips, K.R.; Marantelli, G.; Parkes, H. 1998. Chytridiomycosis causes amphibian mortality associated with population declines in the rain forests of Australia and Central America. Proceedings of the National Academy of Sciences of the United States of America. 95: 9031–9036.

Berger, L.; Speare, R.; Pessier, A.; Voyles, J.; Skerratt, L.F. 2010. Treatment of chytridiomycosis requires urgent clinical trials. Diseases Aquatic Organisms. 92: 165–174.

Berrill, M.; Bertram, S.; McGillivray, L.; Kolohon, M.; Pauli, B. 1994. Effects of low concentrations of forest-use pesticides on frog embryos and tadpoles. Environmental Toxicology and Chemistry. 13: 657–664.

Bidwell, J.R.; Gorrie, J.R. 1995. Acute toxicity of a herbicide to selected frog species. Perth, Australia: Department of Environmental Protection, Technical Series. 79: 8–9.

Blaustein, A.R.; Beatty, J.J.; Olson, D.H.; Storm, R.M. 1995. The biology of amphibians and reptiles in old-growth forests in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-337. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 98 p.

Blaustein, A.R.; Belden, L.K. 2003. Amphibian defenses against ultraviolet-B radiation. Evolution and Development. 5: 89–97.

Blaustein, A.R.; Han, B.A.; Reylea, R.A.; Johnson, P.T.J.; Buck, J.C.; Gervasi, S.S.; Kats, L.B. 2011. The complexity of amphibian population declines: understanding the role of cofactors in driving amphibian losses. Annals of the New York Academy of Sciences. 1223: 108–119.

Blaustein, A.R.; Hoffman, P.D.; Hokit, D.G.; Kiesecker, J.M.; Walls, S.C.; Hays, J.B. 1994a. UV repair and resistance to solar UVb in amphibian eggs: a link to population declines? Proceedings of the National Academy of Sciences of the United States of America. 91: 1791–1795.

Blaustein, A.R.; Hokit, D.G.; O'Hara, R.K.; Holt, R.A. 1994b. Pathogenic fungus contributes to amphibian losses in the Pacific Northwest. Biological Conservation. 67: 251–254.

Blaustein, A.R.; Kiesecker, J.M.; Chivers, D.P.; Hokit, D.G.; Marco, A.; Belden, L.K.; Hatch, A. 1998. Effects of ultraviolet radiation on amphibians: field experiments. American Zoologist. 38: 799–812.

Blaustein, A.R.; O'Hara, R.K. 1982a. Kin recognition in *Rana cascadae* tadpoles: maternal and paternal effects. Animal Behavior. 30: 1151–1157.

Blaustein, A.R.; O'Hara, R.K. 1982b. Kin recognition cues in *Rana cascadae* tadpoles. Behavioral and Neural Biology. 36: 77–87.

Blaustein, A.R.; O'Hara, R.K. 1987. Aggregation behavior in *Rana cascadae* tadpoles: association preferences among wild aggregations and responses to non-kin. Animal Behavior. 35: 1549–1555.

Blaustein, A.R.; O'Hara, R.K.; Olson, D.H. 1984. Kin preference behaviour is present after metamorphosis in *Rana cascadae* frogs. Animal Behavior. 32: 445–450.

Blaustein, A.R.; Olson, D.H. 1992. Amphibian losses in the Oregon Cascades Range [Abstract]. Bulletin of the Ecological Society of America. 73(2, Supplement): 113.

Blaustein, A.R.; Wake, D.B. 1990. Declining amphibian populations: a global phenomenon? Trends in Ecology and Evolution. 5: 203–204.

Blouin, M.S.; Brown, S.T. 2000. Effects of temperature-induced variation in anuran larval growth rate on head width and leg length at metamorphosis. Oecologia. 125: 358–361.

Borrel, A.E. 1924. Unpublished field notes. On file with: Museum of Vertebrate Zoology, University of California, Berkeley, CA 94720-3161.

Bosch, J.; Martinez-Solano, I.; Garcia-Paris, M. 2001. Evidence of a chytrid fungus infection involved in the decline of the common midwife toad (*Alytes obstetricans*) in protected areas of central Spain. Biological Conservation. 97: 331–337.

Bowerman, J.; Rombough, C.; Weinstock, S.R.; Padgett-Flohr, G.E. 2010. Terbinafine hydrochloride in ethanol effectively clears *Batrachochytrium dendrobatidis* in amphibians. Journal of Herpetological Medicine and Surgery. 20: 24–28.

Boyle, S.A.; Samson, F.B. 1985. Effects of non-consumptive recreation on wildlife. A review. Wildlife Society Bulletin. 13: 110–116.

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

Bradford, D.F. 1989. Allotropic distribution of native frogs and introduced fishes in high Sierra Nevada lakes of California: implication of the negative effect of fish introductions. Copeia. 1989: 775–778.

Bradford, D.F. 1991. Mass mortality and extinction in a high elevation population of *Rana muscosa*. Journal of Herpetology. 25: 174–177.

Bradford, D.F.; Knapp, R.A.; Sparling, D.W.; Nash, M.S.; Stanley, K.A. [et al.]. 2011. Pesticide distributions and population declines of California, USA, alpine frogs, *Rana muscosa* and *Rana sierrae*. Environmental Toxicology and Chemistry. 30: 682–691.

Bradford, D.F.; Stanley, K.A.; McConnell, L.L.; Tallent-Halsell, N.G.; Nash, M.S.; Simonich, S.M. 2010. Spatial patterns of atmospherically deposited organic contaminants at high-elevation in the southern Sierra Nevada mountains, California. Environmental Toxicology and Chemistry. 29: 1056–1066.

Bradford, D.F.; Tabatabai, F.; Graber, D.M. 1993. Isolation of remaining populations of the native frog, *Rana muscosa*, by introduced fishes in Sequoia and Kings Canyon National Parks, California. Conservation Biology. 7: 882–888.

Brattstrom, B.H. 1963. A preliminary review of the thermal requirements of amphibians. Ecology. 44: 238–255.

Briggs, C.J.; Knapp, R.A.; Vredenburg, V.T. 2010. Enzootic and epizootic dynamics of the chytrid fungal pathogen of amphibians. Proceedings of the National Academy of Sciences of the United States of America. 107: 9695–9700.

Briggs, J.L. 1987. Breeding biology of the Cascades frog, with comparisons to *R. aurora* and *R. pretiosa*. Copeia. 1987: 241–245.

Briggs, J.L.; Storm, R.M. 1970. Growth and population structure of the Cascades[sic] frog, *Rana cascadae* Slater. Herpetologica. 26: 283–300.

Bronmark, C.; Hansson, L.A. 2002. Environmental issues in lakes and ponds: current state and perspectives. Environmental Contamination. 29: 290–306.

Brown, C. 1997. Habitat structure and occupancy patterns of the montane frog, *Rana cascadae*, in the Cascades Range, Oregon, at multiple scales: implications for population dynamics in patchy landscapes. Corvallis, OR: Oregon State University. 161 p. M.S. thesis.

Brown, H. 2000. Personal communication (with M. McFarland). District fisheries biologist (retired), Lassen National Forest, Almanor Ranger District, 900 E. Hwy 36, P.O. Box 767, Chester, CA 96020. On file with: USDA Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Buhl, K.J.; Hamilton, S.J. 2000. Acute toxicity of fire-control chemicals, nitrogenous chemicals, and surfactants to rainbow trout. Transactions of the American Fisheries Society 129: 408–418.

Bull, E.L.; Hayes, M.P. 2000. Livestock effects on reproduction of the Columbia spotted frog. Journal of Range Management. 53: 291–294.

Bury, R.B. 1973. The Cascades frog, *Rana cascadae*, in the north Coast Range of California. Northwest Science. 47: 228–229.

Bury, R.B.; Major, D.J. 1997. Integrated sampling for amphibian communities in montane habitats. In: Olson, D.H.; Leonard, W.P.; Bury, R.B., eds. Sampling amphibians in lentic habitats: methods and approaches for the Pacific Northwest, Northwest Fauna 4. Olympia, WA: Society for Northwestern Vertebrate Biology: 75–82. Chapter 5.

Bury, R.B.; Major, D.J. 2000. Sampling pond amphibian communities in montane habitats. In: Bury, R.B.; Adams, M.J., eds. Inventory and monitoring of amphibians in North Cascades and Olympic National Parks, 1995–1998. Final report of the Forest and Rangeland Ecosystem Science Center in cooperation with Olympic National Park [20 December]. Corvallis, OR: U.S. Department of the Interior, U.S. Geological Survey: 45.

Cahill, T.A.; Carroll, J.J.; Campbell, D.; Gill, T.E. 1996. Air quality. In: Sierra Nevada ecosystem project: final report to Congress. Volume II. Davis, CA: Centers for Water and Wildland Resources, University of California-Davis: 1227–1262. http://www.ceres.ca.gov/snep/pubs. [Date accessed unknown].

California Department of Fish and Game [CDFG]. 1994. Adoption of regulations for suction dredge mining. Amended Draft Environmental Impact Report. Rancho Cordova, CA. 182 p.

California Department of Pesticide Regulation [CDPR]. 1989–2003. Pesticide use statistics. http://www.cdpr.ca.gov/docs/pur/purmain.htm. [Date accessed unknown].

California State Lands Commission [CSLC]. 1993. California's rivers: a public trust report. Sacramento, CA. 334 p.

Carey, C.; Cohen, N.; Rollins-Smith, L. 1999. Amphibian declines: an immunological perspective. Developmental and Comparative Immunology 23: 459–472.

Case, S.M. 1976. Evolutionary studies in selected North American frogs of the genus *Rana* (Amphibia, Anura). Berkeley, CA: University of California. 57 p. Ph.D. dissertation.

Case, S.M. 1978. Biochemical systematics of members of the genus *Rana* native to western North America. Systematic Zoology. 27: 299–311.

Cayan, D.R.; Maurer, E.P.; Dettinger, M.D.; Tyree, M.; Hayhoe, K. 2008. Climate change scenarios for the California region. Climatic Change. 87: 21–42.

Chen, C.Y.; Hathaway, K.M.; Folt, C.L. 2004. Multiple stress effects of Vision® herbicide, pH, and food on zooplankton and larval amphibian species from forest wetlands. Environmental Toxicology and Chemistry. 23: 823–831.

Chinchar, V.G. 2002. *Rana*viruses (family Iridoviridae): emerging cold-blooded killers. Archives of Virology. 147: 447–470.

Cole, D.N.; Marion, J.L. 1988. Recreation impacts in some riparian forests of the Eastern United States. Environmental Management. 12: 99–107.

Cole, D.N.; Van Wagtendonk, J.W.; McClaran, M.P.; Moore, P.E.; McDougald, N. 2004. Response of mountain meadows to grazing by recreational packstock. Journal of Range Management. 57: 153–160.

Cole, E.M.; North, M. 2010. Unpublished data. On file with: Esther Cole, University of California-Davis, One Shields Ave., Davis, CA 95618.

Corn, P.S. 1994. What we know and don't know about amphibian declines in the West. In: Covington, W.W.; DeBano, F.L., tech. coords. Sustainable ecology systems: implementing an ecological approach to land management. Gen. Tech. Rep. RM-GTR-247. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest Range and Experiment Station: 59–67.

Cory, L.; Fjerd, P.; Serat, W. 1970. Distribution patterns of DDT residues in the Sierra Nevada mountains. Pesticide Monitoring Journal. 3: 204–211.

Datta, S.; Hansen, L.; McConnell, L.; Baker, J.; Lenoir, J.; Seiber, J.N. 1998. Pesticides and PCB contaminants in fish and tadpoles from the Kaweah River Basin, California. Bulletin of Environmental Contamination and Toxicology. 60: 829–836.

Davidson, C. 2004. Declining downwind: amphibian population declines in California and historic pesticide use. Ecological Applications. 14: 1892–1902.

Davidson C.; Benard, M.F.; Shaffer, H.B.; Parker, J.M.; O'Leary, C.; Conlon, J.M.; Rollins-Smith, L.A. 2007. Effects of chytrid and carbaryl exposure on survival, growth and skin peptide defenses in foothill yellow-legged frogs. Environmental Science and Technology. 41: 1771–1776.

Davidson, C.; Shaffer, H.B.; Jennings, M.R. 2002. Spatial tests of the pesticide drift, habitat destruction, UV-B, and climate-change hypotheses for California amphibian declines. Conservation Biology. 16: 1588–1601.

Davidson, C.; Stanley, K.; Simonich, S.M. 2012. Contaminant residues and declines of the Cascades frog (*Rana cascadae*) in the California Cascades, USA. Environmental Toxicology and Chemistry. 31(8): 1895–1902.

Dunlap, D.G. 1955. Inter- and intraspecific variation on Oregon frogs of the genus *Rana*. American Midland Naturalist. 54: 314–331.

EA Engineering, Science, and Technology [EA EST]. 1995. Rock Creek and Screwdriver Creek aquatic resource inventories. Final report prepared for the Lassen National Forest, Hat Creek Ranger District. 11 p. + appendixes. Unpublished report. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

EA Engineering, Science, and Technology [EA EST]. 1996. Aquatic resources survey of Deer and Mill Creek tributaries, volume 1 of 4. Report prepared for the Lassen National Forest. Report + Appendixes A–C. Unpublished report. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Edginton, A.N.; Sheridan, P.M.; Stephenson, G.R.; Thompson, D.G.; Boermans, H.J. 2004. Comparative effects of pH and Vision® herbicide on two life stages of four anuran amphibian species. Environmental Toxicology and Chemistry. 23: 815–822.

Fellers, G. 1995. Aquatic amphibian surveys. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Fellers, G. 1998. 1996–1997 Aquatic amphibian surveys. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Fellers, G.M. 2005. Unpublished data. On file with: National Biological Survey, Point Reyes National Seashore, 1 Bear Valley Road, Point Reyes Station, CA 94956.

Fellers, G.M. 2006. Unpublished data. On file with: National Biological Survey, Point Reyes National Seashore, 1 Bear Valley Road, Point Reyes Station, CA 94956.

Fellers, G.M.; Drost, C.A. 1993. Disappearance of the Cascades frog *Rana cascadae* at the southern end of its range, California, USA. Biological Conservation. 65: 177–182.

Fellers, G.M.; McConnell, L.L.; Pratt, D.; Datta, S. 2004. Pesticides in mountain yellow-legged frogs (*Rana muscosa*) from the Sierra Nevada Mountains of California, USA. Environmental Toxicology and Chemistry. 23: 2170–2177.

Fellers, G.M.; Pope, K.L;. Stead, J.E.; Koo, M.S.; Welsh, H.H., Jr. 2008. Turning population trend monitoring into active conservation: Can we save the Cascades frog (*Rana cascadae*) in the Lassen region of California? Herpetological Conservation and Biology. 3: 28–39.

Finlay, J.C.; Vredenburg, V.T. 2007. Introduced trout sever trophic connections between lakes and watersheds. Ecology. 88: 2187–2198.

Fite, K.V.; Blaustein, A.R.; Bengston, L.; Hewitt, H.E. 1998. Evidence of retinal light damage in *Rana cascadae*: a declining amphibian species. Copeia. 1998: 906–914.

Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. Conservation Biology. 8: 629–644.

Flenniken, M.R.; McEldowney, R.; Leininger, W.C.; Frasier, G.W.; Trlica, M.J. 2001. Hydrologic responses of a montane riparian ecosystem following cattle use. Journal of Range Management. 54: 567–574.

Folmar, L.C.; Sanders, H.O.; Julin, A.M. 1979. Toxicity of the herbicide glyphosate and several of its formulations to fish and aquatic invertebrates. Archives of Environmental Contamination and Toxicology. 8: 269–278.

Foote, R. 2012. Personal communication. Fish biologist, Lassen National Forest, Almanor Ranger District, 900 E. Hwy 36, PO Box 767, Chester, CA 96020.

Forman, R.T.T.; Alexander, L.E. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics. 29: 207–231.

Gaikowski, M.P.; Hamilton, S.J.; Buhl, K.J.; McDonald, S.F.; Summers, C.H. 1996. Acute toxicity of three fire-retardant and two fire-suppressant foam formulations to the early stages of rainbow trout (*Oncorhynchus mykiss*). Environmental Toxicology and Chemistry. 15: 1365–1374.

Garcia, T.S.; Romansic, J.M.; Blaustein, A.R. 2006. Survival of three species of anuran metamorphs exposed to UV-B radiation and the pathogenic fungus *Batrachochytrium dendrobatidis*. Diseases of Aquatic Organisms. 72: 163–169.

Garton, E.O.; Foin, T.C.; Bowen, C.W.; Everingham, J.M.; Schultz, R.O.; Holton, B., Jr. 1977. Quantitative studies of visitor impacts on environments of Yosemite National Park, California, USA and their implications for park management policy. Journal of Environmental Management. 5: 1–22.

Garwood, J.M. 2006. Natural history notes: *Rana cascadae* (Cascades frog). Tadpole predation. Herpetological Review. 37: 76.

Garwood, J.M. 2009. Spatial ecology of the Cascades frog: identifying dispersal, migration, and resource uses at multiple spatial scales. Arcata, CA: Humboldt State University. 97 p. M.S. thesis.

Garwood, J.M. [N.d.]. Unpublished data. On file with: USDA Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Garwood, J.M.; Knapp, R.A.; Pope, K.L.; Grasso, R.L.; Magnuson, M.L.; Maurer, J.R. 2013. Use of historically fishless high-mountain lakes and streams by nearctic River Otters (*Lontra canadensis*) in California. Northwestern Naturalist. 94: 51–66.

Garwood, J.M.; Larson, M. [N.d.]. Unpublished data. On file with: USDA Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Garwood, J.M.; Welsh, H.H., Jr. 2007. Ecology of the Cascades frog (*Rana cascadae*) and interactions with garter snakes and nonnative trout in the Trinity Alps Wilderness, CA; final report to California Department of Fish and Game and National Fish and Wildlife Foundation; DFG contract no. P0385107, NFWF contract no. 2004-0075-000. viii+74 p. On file with: USDA Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Garwood, J.M.; Wheeler, C.A. 2007. *Rana cascadae* predation. Herpetological Review. 38: 193–194.

Garwood, J.M.; Wheeler, C.A.; Bourque, R.M.; Larson, M.D.; Welsh, H.H., Jr. 2007. Egg mass drift increases vulnerability during early development of Cascades Frogs (*Rana cascadae*). Northwestern Naturalist. 88: 95–97.

Giesy, J.P.; Dobson, S.; Solomon, K.R. 2000. Ecotoxicological risk assessment of Roundup® herbicide. Reviews of Environmental Contamination and Toxicology. 167: 35–120.

Green, D.E.; Converse, K.A.; Schrader, A.K. 2002. Epizootiology of sixty-four amphibian morbidity and mortality events in the USA, 1996–2001. Annals of the New York Academy of Sciences. 969: 323–329.

Green, D.M. 1986a. Systematics and evolution of western North American frogs allied to *Rana aurora* and *Rana boylii*: electrophoretic evidence. Systematic Zoology. 35: 283–296.

Green, D.M. 1986b. Systematics and evolution of western North American frogs allied to *Rana aurora* and *Rana boylii*: karyological evidence. Systematic Zoology. 35: 273–282.

Grinnell, J.J.; Dixon, J.; Linsdale, J.M. 1930. Vertebrate natural history of a section of northern California through the Lassen Peak region. University of California Publications in Zoology. 25: 1–594.

Groisman, P.Y.; Knight, R.W.; Karl, T.R.; Easterling, D.R.; Sun, B.; Lawrimore, J.H. 2004. Contemporary changes in the hydrological cycle over the contiguous United States: trends derived from in situ observations. Journal of Hydrometeorology. 5: 64–85.

Hageman, K.J.; Simonich, S.L.; Campbell, D.H.; Wilson, G.R.; Landers, D.H. 2006. Atmospheric deposition of current-use and historic-use pesticides in snow at national parks in the western United States. Environmental Science and Technology. 40: 3174–3180.

Hanski, I.; Gilpin, M. 1991. Metapopulation dynamics: brief history and conceptual domain. Biological Journal of the Linnaean Society. 42: 3–16.

Harris R.; Brucker, R.; Minbiole, K.; Walke, J.; Becker, M.; Schwantes, C. [et al.]. 2009. Skin microbes on frogs prevent morbidity and mortality caused by a lethal skin fungus. ISME Journal. 3(7): 818–824.

Harris, R.R.; Fox, C.A.; Risser, R. 1987. Impacts of hydroelectric development on riparian vegetation in the Sierra Nevada region, California, USA. Environmental Management. 11: 519–527.

Hayes, M. [N.d.]. Unpublished data. On file with: Marc Hayes, Habitat Program of the Washington Department of Fish and Wildlife, 600 Capitol Way North, Olympia, WA 98501.

Hayes, M. 2005. Personal communication. Senior research scientist, Washington Department of Fish and Wildlife, 600 Capitol Way North, Olympia, WA 98501.

Hews, D.K.; Blaustein, A.R. 1985. An investigation of the alarm response in *Bufo boreas* and *Rana cascadae* tadpoles. Behavioral and Neural Biology. 43: 47–57.

Hildebrand, L.D.; Sullivan, D.S.; Sullivan, T.P. 1982. Experimental studies of rainbow trout populations exposed to field applications of Roundup herbicide. Archives of Environmental Contamination and Toxicology. 11: 93–98.

Hokit, D.G.; Blaustein, A.R. 1994. The effects of kinship on growth and development in tadpoles of *Rana cascadae*. Evolution. 48: 1383–1388.

Hokit, D.G.; Blaustein, A.R. 1995. Predator avoidance and alarm-response behaviour in kin-discriminating tadpoles (*Rana cascadae*). Ethology. 101: 280–290.

Hokit, D.G.; Blaustein, A.R. 1997. The effects of kinship on interaction between tadpoles of *Rana cascadae*. Ecology. 78: 1722–1735.

Hopkins, T. 2007. Personal communication. Fisheries biologist, Plumas National Forest, P.O. Box 11500, Quincy, CA 95971.

Howe, C.M.; Berrill, M.; Pauli, B.D.; Helbing, C.C.; Werry, K.; Veldhoen N. 2004. Toxicity of glyphosate-based pesticides to four North American frog species. Environmental Toxicology and Chemistry. 23: 1928–1938.

ICF Jones & Stokes. 2010. Hatchery and Stocking Program Environmental Impact Report/Environmental Impact Statement. Final. January. (ICF J&S 00264.08) (SCH #2008082025). Prepared for the California Department of Fish and Game and U.S. Fish and Wildlife Service, Sacramento, CA.

Jennings, M.R 1997. Unpublished letter (with attached correspondence to R. Knapp) to M. McFarland. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Jennings, M.R. 1996. Status of amphibians. In: Sierra Nevada ecosystem project: final report to Congress, volume II. Centers for Water and Wildland Resources Report 37. Davis, CA: University of California: 921–944. Chapter 31.

Jennings, M.R. 2006. Personal communication. Senior associate ecologist and herpetologist, Live Oak Associates, Inc., P.O. Box 2697, Oakhurst, CA 93644.

Jennings, M.R.; Hayes, M.P. 1994. Amphibian and reptile species of special concern in California. Rancho Cordova, CA: California Department of Fish and Game, Inland Fisheries Division. 255 p.

Johnson, M.; Speare, R. 2003. Survival of *Batrachochytrium dendrobatidis* in water: quarantine and control implications. Emerging Infectious Diseases. 9: 922–925.

Johnson, P.T.; Lunde, K.B.; Ritchie, E.G.; Launer, A.E. 1999. The effect of trematode infection on amphibian limb development and survivorship. Science. 284: 802–804.

Joseph, M.; Piovia-Scott, J.; Lawler, S.P.; Pope, K.L. 2011. Indirect effects of introduced trout on Cascades frogs (*Rana cascadae*) via shared aquatic prey. Freshwater Biology. 56: 828–838.

Kattelmann, R. 1996. Status of the Sierra Nevada. In: Sierra Nevada ecosystem project: final report to Congress, volume II. Centers for Water and Wildland Resources Report 37. Davis, CA: University of California: 866–899. Chapter 30.

Kauffman, J.B.; Krueger, W.C. 1984. Livestock impacts on riparian ecosystems and streamside management implications: a review. Journal of Range Management. 37: 430–438.

Kiesecker, J.M.; Blaustein, A.R. 1995. Synergism between UV-B radiation and a pathogen magnifies amphibian embryo mortality in nature. Proceedings of the National Academy of Sciences of the United States of America. 92: 11049–11052.

Kiesecker, J.M.; Blaustein, A.R. 1997. Influences of egg laying behavior on pathogenic infection of amphibian eggs. Conservation Biology. 11: 214–220.

Kiesecker, J.M.; Blaustein, A.R.; Belden, L.K. 2001. Complex causes of amphibian population declines. Nature. 410: 681–684.

Knapp, R.A. 1996. Non-native trout in natural lakes of the Sierra Nevada: an analysis of their distribution and impacts on native aquatic biota. In: Sierra Nevada ecosystem project: final report to Congress, volume III, assessments, commissioned reports, and background information. Centers for Water and Wildland Resources. Davis, CA: University of California: 363–407.

Knapp, R.A. 2005. Effects of nonnative fish and habitat characteristics on lentic herpetofauna in Yosemite National Park, USA. Biological Conservation. 121: 265–279.

Knapp, R.A.; Boiano, D.M.; Vredenburg, V.T. 2007. Removal of nonnative fish results in population expansion of a declining amphibian (mountain yellow-legged frog, *Rana muscosa*). Biological Conservation. 135: 11–20.

Knapp, R.A.; Briggs, C.J.; Smith, T.C.; Maurer, J.R. 2011. Nowhere to hide: impact of a temperature-sensitive amphibian pathogen along an elevation gradient in the temperate zone. Ecosphere. 2: 1–26.

Knapp, R.A.; Matthews, K.R. 2000. Non-native fish introductions and the decline of the mountain yellow-legged frog from within protected areas. Conservation Biology. 14: 428–438.

Knight, R.L.; Cole, D.N. 1991. Effects of recreational activity on wildlife in wildlands. Transactions of the 56th North American Wildlife and Natural Resources Conference. 56: 238–247.

Koo, M.S.; Vindum, J.V. ; McFarland, M. 2004. Results of 02-CS-11050650-029, the 2003 California Academy of Sciences survey: amphibians and reptiles of the Lassen National Forest. San Francisco, CA: California Academy of Sciences, Department of Herpetology. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130. 172 p.

Lacan, I.; Matthews, K.; Feldman, K. 2008. Interaction of an introduced predator with future effects of climate change in the recruitment dynamics of the imperiled Sierra Nevada yellow-legged frog (*Rana sierrae*). Herpetological Conservation and Biology. 3: 211–223.

Larson, D.J. 1996. Historical water-use priorities and public policies. In: Sierra Nevada Ecosystem Project. Final report to Congress. Volume II. Davis, CA: University of California, Centers for Water and Wildland Resources Report. (37): 163–185. Chapter 8.

Larson, M.D. 2012. Diet of the Cascades frog (*Rana cascadae*) as it relates to prey availability in the Klamath Mountains of northwest California. Arcata, CA: Humboldt State University. 71 p. M.S. thesis.

Lefcort, H.; Hancock, K.A.; Maur, K.M.; Rostal, D.C. 1997. The effects of used motor oil, silt and the water mold *Saprolegnia parasitica* on the growth and survival of mole salamanders (genus *Ambystoma*). Archives of Environmental Contamination and Toxicology. 32: 383–388.

Lehtinen, R.M.; Galatowitsch, S.M.; Tester, J.R. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. Wetlands. 19: 1–12.

Lenoir, J.S.; McConnell, L.L.; Fellers, G.M.; Cahill, T.M.; Seiber, J.N. 1999. Summertime transport of current-use pesticides from California's Central Valley to the Sierra Nevada mountain range, USA. Environmental Toxicology and Chemistry. 18: 2715–2722.

Levins, R. 1970. Extinction. Lecture Notes in Mathematics. 2: 75–107.

Leviton, A.E.; Gibbs, R.H., Jr. 1988. Standards in herpetology and ichthyology. Standard symbolic codes for institutional resource collections in herpetology and ichthyology. Suppl. no. 1: Additions and corrections. Copeia. 1988: 280–282.

Leviton, A.E.; Gibbs, R.H., Jr.; Heal, E.; Dawson, C.E. 1985. Standards in herpetology and ichthyology: Part I. Standard symbolic codes for institutional resource collections in herpetology and ichthyology. Copeia. 1985: 802–832.

Liang, C.T. 2010. Habitat modeling and movements of the Yosemite toad (*Anaxyrus* (= *Bufo*) *canorus*) in the Sierra Nevada, California. Davis, CA: University of California. 126 p. Ph.D. dissertation.

Licht, L.E. 1996. Amphibian decline still a puzzle. BioScience. 46: 172–173.

Licht, L.E. 2003. Shedding light on ultraviolet radiation and amphibian embryos. BioScience. 53: 551–561.

Licht, L.E.; Grant, K.P. 1997. The effects of ultraviolet radiation on the biology of amphibians. American Zoologist. 37: 137–145.

Lind, A.J.; Grasso, R.; Nelson, J.; Vincent, K.; Liang, C. 2011. Determining the effects of livestock grazing on Yosemite toads (*Bufo canorus*) and their habitat: final report addendum to USDA Forest Service Region 5. Vallejo, CA: U.S. Department of Agriculture, Forest Service, Region 5. 25 p.

Lips, K.; Mendelson, J.I.; Munoz-Alonso, A. [et al.]. 2004. Amphibian population declines in montane southern Mexico: resurveys of historical localities. Biological Conservation. 119: 555–564.

Long, L.E.; Saylor, L.S.; Soule, M.E. 1995. A pH/UV-B synergism in amphibians. Conservation Biology. 9: 1301–1303.

Longcore, J.E.; Pessier, A.P.; Nichols, D.K. 1999. *Batrachochytrium dendrobatidis* gen. et sp. nov., a chytrid pathogenic to amphibians. Mycologia. 91: 219–227.

MacDonald, S.F.; Hamilton, S.J.; Buhl, K.J.; Heisinger, J.F. 1996. Acute toxicity of fire control chemicals to *Daphnia magna* (Straus) and *Selenastrum capricornutum* (Printz). Ecotoxicology and Environmental Safety. 33: 62–72.

Mahaney, P.A. 1994. The effects of freshwater petroleum contamination on amphibian hatching and metamorphosis. Environmental Toxicology. 13: 259–265.

Mangels, F. 2002. Personal communication. Wildlife biologist (retired), USDA Forest Service, Shasta-Trinity National Forest, 204 West Alma, Mount Shasta, CA 96067.

Mann, R.M.; Bidwell, J.R. 1999. The toxicity of glyphosate and several glyphosate formulations to four species of southwestern Australian frogs. Archives of Environmental Contamination and Toxicology. 26: 193–199.

Mao, J.; Green, D.E.; Fellers, G.F.; Chinchar, V.G. 1999. Molecular characterization of iridoviruses isolated from sympatric amphibians and fish. Virus Research. 63: 45–52.

Maxell, B.A.; Hokit, D.G. 1999. Amphibians and reptiles. In: Joslin, J.; Youmans, H., comm. chairs. Effects of recreation on Rocky Mountain wildlife: a compendium of the current state of understanding in Montana. Kalispell, MT: Montana Chapter of the Wildlife Society, Committee on Effects of Recreation on Wildlife: 2.1–2.30.

McCarthy, M.A.; Parris, K. M. 2004. Clarifying the effects of toe clipping on frogs with Bayesian statistics. Journal of Applied Ecology. 41: 780–786.

McConnell, L.L.; LeNoir, J.S.; Datta, S.; Seiber, J.N. 1998. Wet deposition of current-use pesticides in the Sierra Nevada mountain range, California, USA. Environmental Toxicology and Chemistry. 10: 1908–1916.

McFarland, M. 2002. Unpublished data. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Megahan, W.F.; King, J.G.; Seyedbagheri, K.A. 1995. Hydrologic and erosional responses of a granitic watershed to helicopter logging and broadcast burning. Forest Science. 41: 777–795.

Menke, J.W.; Davis, C.; Beesley, P. 1996. Rangeland assessment. In: Menke, J.W.; Davis, C.; Beesley, P., eds. Sierra Nevada Ecosystem Project. Volume III, Sierra Nevada Ecosystem Project. Davis, CA: University of California, Centers for Water and Wildland Resources: 901–972. Chapter 22.

Middleton, E.M.; Herman, J. R.; Celarier, E.A.; Wilkinson, J.W.; Carey, C.; Ruskin, R.J. 2001. Evaluating ultraviolet radiation exposure with satellite data at sites of amphibian declines in Central and South America. Conservation Biology. 15: 914–929.

Mills, L.S.; Allendorf, F.W. 1996. The one-migrant-per-generation rule in conservation and management. Conservation Biology. 10: 1509–1518.

Minshall, G.W.; Brock, J. T. 1991. Observed and anticipated effects of forest fire on Yellowstone stream ecosystems. In: Keiter, R.B.; Boyce, M.S., eds. Greater Yellowstone ecosystem: redefining America's wilderness heritage. New Haven, CT: Yale University Press: 123–135.

Mitchell, D.; Chapman, P.; Long, T. 1987. Seawater challenge testing of Coho salmon smolts following exposure to Roundup herbicide. Environmental Toxicology and Chemistry. 6: 875–878.

Monsen, K.J.; Blouin, M.S. 2003. Genetic structure in a montane ranid frog: restricted gene flow and nuclear-mitochrondrial discordance. Molecular Ecology. 12: 3275–3286.

Monsen, K.J.; Blouin, M.S. 2004. Extreme isolation by distance in a montane frog. Conservation Genetics. 5: 827–835.

Moore, I.T.; Jessop T.S. 2003. Stress, reproduction, and adrenocortical modulation in amphibians and reptiles. Hormones and Behavior. 43: 39–47.

Moore, P.E.; Cole, D.N.; Wagtendonk, J.W.; McClaran, M.P.; McDougald, N. 2000. Meadow response to packstock grazing in the Yosemite Wilderness: integrating research and management. In: Cole, D.N.; McCool, S.F.; Borrie, W.T.; O'Loughlin, J., comps. Wilderness science in a time of change conference—Volume 5: Wilderness ecosystems, threats, and management. Proceedings RMRS-P-15-VOL-5. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station: 160–164.

Morris, D.P.; Zagarese, H.; Williamson, C.E.; Balseiro, E.G.; Hargreaves, B.R.; Modenutti, B.; Moeller, R.; Queimalinos, C. 1995. The attenuation of solar UV radiation in lakes and the role of dissolved organic carbon. Limnology and Oceanography. 40: 1381–1391.

Moyle, P.B.; Randall, P.J. 1998. Evaluating the biotic integrity of watersheds in the Sierra Nevada, California. Conservation Biology. 12: 1318–1326.

Murray, D.L.; Fuller, M.R. 2000. A critical review of the effects of marking on the biology of vertebrates. In: Boitani, L.; Fuller, T.K., eds. Research techniques in animal ecology: controversies and consequences. New York, NY: Columbia University Press: 15–64. Chapter 2.

Nauman, R.S.; Dettlaff, Y. 1999. *Rana cascadae* (Cascades frog): predation. Herpetological Review. 30: 93.

Newcombe, C.P.; Jensen, J.O.T. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management. 16: 693–727.

Norris, R.M.; Webb, R.W. 1990. Geology of California. New York, NY: John Wiley & Sons, Inc. 392 p.

Nussbaum, R.A.; Brodie, E.D., Jr.; Storm, R.M. 1983. Amphibians and reptiles of the Pacific Northwest. Moscow, ID: Northwest Naturalist Books, The University of Idaho Press. 336 p.

O'Hara, R.K. 1981. Habitat selection behavior in three species of anuran larvae: environmental cues, ontogeny and adaptive significance. Corvallis, OR: Oregon State University. 146 p. Ph.D. dissertation.

O'Hara, R.K.; Blaustein, A.R. 1981. An investigation of sibling recognition in *Rana cascadae* tadpoles. Animal Behavior. 29: 1121–1126.

O'Hara, R.K.; Blaustein, A.R. 1985. *Rana cascadae* tadpoles aggregate with siblings: an experimental field study. Oecologia. 67: 44–51.

Olson, D.H. 1988. The ecological and behavioral dynamics of breeding in three sympatric anuran amphibians. Corvallis, OR: Oregon State University. 260 p. Ph.D. dissertation.

Olson, D.H. 1992. Ecological susceptibility of amphibians to population declines. In: Harris, R.R.; Kerner, H.M.; Erman, D.C., eds. Proceedings of the symposium on biodiversity of northwestern California. Berkeley, CA: University of California: 55–62.

Olson-Rutz, K.M.; Marlow, C.B.; Hansen, K.; Gagnon, L.C.; Rossi, R.J. 1996a. Packhorse grazing behavior and immediate impact on a timberline meadow. Journal of Range Management. 49: 546–550.

Olson-Rutz, K.M.; Marlow, C.B.; Hansen, K.; Gagnon, L.C.; Rossi, R.J. 1996b. Recovery of a high elevation plant community after packhorse grazing. Journal of Range Management. 49: 541–545.

Pahkala, M.; Räsänen, K.; Laurila, A.; Johanson, U.; Björn, L.O.; Merilä, J. 2002. Lethal and sublethal effects of UV-B/pH synergism on common frog embryos. Conservation Biology. 16: 1063–1073.

Palen, W.J.; Schindler, D.E.; Adams, M.J.; Pearl, C.A.; Bury, R.B.; Diamond, S.A. 2002. Optical characteristics of natural waters protect amphibians from UV-B in the Pacific Northwest. Ecology. 83: 2951–2957.

Parmesan, C.; Root, T.L.; Willig, M.R. 2000. Impacts of extreme weather and climate on terrestrial biota. Bulletin of the Meteorological Society of America. 81: 443–450.

Pearl, C.A.; Adams, M.J. 2005. *Rana cascadae* Slater, 1939: Cascades frog. In: Lannoo, M., ed. Amphibian declines: the conservation status of United States species. Berkeley, CA: University of California Press: 538–540.

Perkins, P.J.; Boermans, H.J.; Stephenson, G.R. 2000. Toxicity of glyphosate and triclopyr using the frog embryos teratogenesis assay—*Xenopus*. Environmental Toxicology and Chemistry 19: 940–945.

Perret, N.; Joly, P. 2002. Impacts of tattooing and PIT-tagging on survival and fecundity in the alpine newt (*Triturus alpestris*). Herpetologica. 58: 131–138.

Peterson, J.A.; Blaustein, A.R. 1991. Unpalatability in anuran larvae as a defense against natural salamander predators. Ethology, Ecology and Evolution. 3: 63–72.

Peterson, J.D. 2012. Physiological effects of chytridiomycosis, a cause of amphibian population declines. Auburn, AL: Auburn University. 80 p. Ph.D. dissertation.

Pilliod, D.S.; Bury, R.B.; Hyde, E.J.; Pearl, C.A.; Corn, P.S. 2003. Fire and amphibians in North America. Forest Ecology and Management. 178: 163–181.

Piovia-Scott, J.; Pope, K.L.; Lawler, S.P.; Cole, E.M.; Foley, J.E. 2011. Factors related to the distribution and prevalence of the fungal pathogen *Batrachochytrium dentrobatidis* in *Rana cascadae* and other amphibians in the Klamath Mountains. Biological Conservation. 144: 2913–2921.

Piovia-Scott, J.; Pope, K.L.; Rejmanek, D.; Worth, S.J. ; Lawler, S.P.; Foley, J.E. 2013. Unpublished manuscript. On file with: USDA Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Pope, K.L. [N.d.]. Unpublished data. On file with: USDA Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Pope, K.L. 2008a. Assessing changes in amphibian population dynamics following experimental manipulations of introduced fish. Conservation Biology. 22: 1572–1581.

Pope, K.L. 2008b. Population monitoring of remnant populations of Cascades frogs (*Rana cascadae*) in the Lassen Region of California. Final Report to the Lassen National Forest, December 2008. Unpublished report. On file with: USDA Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Pope, K.L.; Garwood, J.M.; Welsh, H.H., Jr.; Lawler, S.P. 2008. Evidence of indirect impacts of introduced trout on native amphibians via facilitation of a shared predator. Biological Conservation. 141: 1321–1331.

Pope, K.L.; Larson, M.D. 2010. Second year of population monitoring of remnant populations of Cascades frogs (*Rana cascadae*) in the Lassen area of California. Final report to the U.S. Fish and Wildlife Service, FWS #81420-8-H158. 28 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Pope, K.L.; Larson, M.D. 2011. Unpublished data. On file with: USDA Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Pope, K.L.; Larson, M.D. 2012. Unpublished data. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Pope, K.L.; Larson, M.D.; Piovia-Scott, J. 2011. Status of remnant populations of Cascades Frogs (*Rana cascadae*) in the Lassen area of California. Final report for year 2008 to the Lassen National Forest, ISA #05-06-03. 38 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville CA 96130.

Pope, K.L.; Piovia-Scott, J. 2010. Unpublished data. On file with: USDA Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Power, M.E. 1990. The importance of sediment in the grazing ecology and size class interactions of an armored catfish, *Aneistrus spinosus*. Environmental Biology of Fish. 10: 173–181.

Rachowicz, L.J.; Knapp, R.A.; Morgan, J.A.T. [et al.]. 2006. Emerging infectious disease as a proximate cause of amphibian mass mortality. Ecology. 87: 1671–1683.

Reagan, D.; Davidson, C. 2012. Unpublished data. On file with: Carlos Davidson, San Francisco State University, 1600 Holloway Ave., San Francisco, CA 94132.

Reid, L.M.; Dunne, T. 1984. Sediment production from forest road surfaces. Water Resources Research. 20: 1753–1761.

Relyea, R.A. 2005a. The lethal impact of Roundup on aquatic and terrestrial amphibians. Ecological Applications. 15: 1118–1124.

Relyea, R.A. 2005b. Pesticides and amphibians: the importance of community context. Ecological Applications 15: 1125–1134.

Relyea, R.A.; Diecks, N. 2008. An unforeseen chain of events: lethal effects of pesticides at sublethal concentrations. Ecological Applications. 18: 1728–1742.

Richardson, E.V.; Simons, B.; Karaki, S.; Mahmood, M.; Stevens, M.A. 1975. Highways in the river environment: hydraulic and environmental design considerations training and design manual. Washington, DC: U.S. Department of Transportation, Federal Highway Administration. 453 p.

Rieman, B.; Clayton, J. 1997. Wildlife and native fish: issues of forest health and conservation of sensitive fish species. Fisheries. 22: 6–15.

Roby, K. 2002. Personal communications (with M. McFarland). District fisheries biologist (retired), Lassen National Forest, Almanor Ranger District, 900 E. Hwy 36, PO Box 767, Chester, CA 96020. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Roche, L.M.; Allen-Diaz, B.; Eastburn, D.J. Tate, K.W. 2012. Cattle grazing and Yosemite toad (*Bufo canorus* Camp) breeding habitat in Sierra Nevada meadows. Rangeland Ecology and Management. 65: 56–65.

Sage, R.D. 1974. Unpublished field notes. On file with: Museum of Vertebrate Zoology, University of California-Berkeley, 3101 Valley Life Sciences Building, Berkeley, CA 94720-3160.

Scully, N.M.; Lean, D.S. 1994. The attenuation of ultraviolet radiation in temperate lakes. Archives für Hydrobiologie. 43: 135–144.

Seiber, J.N.; Woodrow, J.E.; David, M.D. 1998. Organophosphorus esters. In: Shibamoto, T., ed. Chromatographic analysis of environmental and food toxicants. Washington, DC: American Chemical Society Publications: 229-258.

Servizi, J.A.; Gordon, R.W.; Martens, D.W. 1987. Acute toxicity of Garlon 4 and Roundup herbicides to salmon, *Daphnia*, and trout. Bulletin of Environmental Contamination and Toxicology. 39: 15–22.

Sharsmith, C.W. 1961. A report on the status, changes and comparative ecology of selected back country meadows in Yosemite National Park that receive heavy visitor use. 58 p. Unpublished report. On file with: U.S. Department of the Interior, National Park Service, Yosemite National Park, El Portal, CA 95318.

Simons, L.H. 1998. *Rana cascadae* (Cascades frog): predation. Herpetological Review. 29: 232.

Skerratt L.F.; Berger L.; Speare R. [et al.]. 2007. Spread of chytridiomycosis has caused the rapid global decline and extinction of frogs. Ecohealth. 4: 125–134.

Slater, J.R. 1939. Description and life history of a new *Rana* from Washington. Herpetologica 1: 145–149.

Smith. G. 1998. Personal communication (with M. McFarland). Wildlife/range officer (retired), Lassen National Forest. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Smith, M.A.; Green, D.M. 2005. Dispersal and the metapopulation paradigm in amphibian ecology and conservation: Are all amphibian populations metapopulations? Ecography. 28: 110–126.

Spellerberg, I.F. 1998. Ecological effects of roads and traffic: a literature review. Global Ecology and Biogeography Letters. 7: 317–333.

Stead, J.E.; Pope, K.L. 2010. Predatory leeches (Hirudinida) may contribute to amphibian declines in the Lassen Region, California. Northwestern Naturalist. 91: 30–39.

Stead, J.E.; Welsh, H.H., Jr.; Pope, K.L. 2005. Census of amphibians and fishes in lentic habitats of Lassen Volcanic National Park: a report to the National Park Service. LVNP Study Number LAVO-00717. 77 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Stebbins, R.C. 1951a. Amphibians of western North America. Berkeley, CA: University of California Press. ix + 539 p.

Stebbins, R.C. 1951b. Unpublished field notes. On file with: Museum of Vertebrate Zoology, University of California-Berkeley, 3101 Valley Life Sciences Building, Berkeley, CA 94720-3160.

Stebbins, R.C. 2003. A field guide to western reptiles and amphibians. 3rd ed., revised. Boston, MA: Houghton Mifflin Company. xiv + 544 p.

Stuart, S.N.; Chanson, J.S.; Cox, N.A.; Young, B.E.; Rodrigues, A.S.L.; Fischman, D.L.; Waller, R.W. 2004. Status and trends of amphibian declines and extinctions worldwide. Science. 306: 1783–1786.

Sullivan, D.S.; Sullivan, T.P.; Bisalputra, T. 1981. Effects of Roundup® herbicide on diatom populations in the aquatic environment of a coastal forest. Bulletin of Environmental Contamination and Toxicology. 26: 91–96.

Sype, W.E. 1975. Breeding habits, embryonic thermal requirements and embryonic and larval development of the Cascades frog, *Rana cascadae* Slater. Corvallis, OR: Oregon State University. 113 p. Ph.D. dissertation.

Taylor, S.K.; Williams, E.S.; Mills, K.W. 1999. Effects of Malathion on disease susceptibility in Woodhouse's toads. Journal of Wildlife Diseases. 35: 536–541.

Thompson, D.G.; Wojtaszek, B.F.; Staznik, B.; Chartrand, D.T.; Stephenson, G.R. 2004. Chemical and biomonitoring to assess potential acute effects of Vision® herbicide on native amphibian larvae in forest wetlands. Environmental Toxicology and Chemistry. 23: 843–849.

Tietge, J.E.; Diamond, S.A.; Ankley, G.T.; DeFoe, D.L.; Holcombe, G.W.; Jensen, K.M.; Degitz, S.J.; Elonen, G.E.; Hammer, E. 2001. Ambient solar UV radiation causes mortality in larvae of three species of *Rana* under controlled exposure conditions. Photochemistry and Photobiology. 74: 261–268.

Trombulak, S.C.; Frissell, C.A. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology. 14: 18–30.

U.S. Department of Agriculture, Forest Service, [USDA FS]. 1993. FY 1993 Amphibian surveys. Unpublished report. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2001a. Sierra Nevada forest plan amendment (SNFPA) final environmental impact statement (FEIS). San Francisco, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2001b. Letter to Forest supervisors. Herbicides and ground/surface water monitoring. On file with: Pacific Southwest Region, 1323 Club Drive, Vallejo, CA 94592.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2001c. Unpublished geographic information system (GIS) data. On file with: Pacific Southwest Region, 1323 Club Drive, Vallejo, CA 94592.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2002. Unpublished data. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2011. Nationwide aerial application of fire retardant on National Forest System land. Record of Decision. Washington, DC: U.S. Department of Agriculture, Forest Service. 74 p.

U.S. Department of the Interior, National Park Service [USDI NPS]. 2005. Repave and rehabilitate a portion of the Lassen Volcanic National Park highway (mileposts 6.7 to 28.4) Environmental assessment. Unpublished report. Mineral, CA: U.S. Department of Interior, National Park Service.

Vindum, J.; Koo, M. 2003. Amphibians and reptiles of the Lassen National Forest: results of 02-CS-11050650-029. The 2002 California Academy of Sciences Survey. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Vos, C.C.; Chardon, J. P. 1998. Effects of habitat fragmentation and road density on the distribution pattern of the moor frog *Rana arvalis*. Journal of Applied Ecology. 35: 44–56.

Vredenburg, V. 2004. Reversing introduced species effects: experimental removal of introduced fish leads to rapid recovery of a declining frog. Proceedings of the National Academy of Sciences of the United States of America. 101: 7646–7650.

Vredenburg, V.T.; Knapp, R.A.; Tunstall, T.S.; Briggs, C.J. 2010. Dynamics of an emerging disease drive large-scale amphibian population extinctions. Proceedings of the National Academy of Sciences, USA. 107: 9689–9694.

Wack, C.L.; DuRant, S.E.; Hopkins, W.A.; Lovern, M.B.; Feldhoff, R.C.; Woodley, S.K. 2012. Elevated plasma corticosterone increases metabolic rate in a terrestrial salamander. Comparative Biochemistry and Physiology—Part A: Molecular and Integrative Physiology. 161: 153–158.

Wake, D.B. 1991. Declining amphibian populations. Science. 253: 860.

Wan, M.T.; Watts, R.G.; Moul, D.J. 1989. Effects of different dilution water types on the acute toxicity to juvenile Pacific salmonids and rainbow trout of glyphosate and its formulated products. Bulletin of Environmental Contamination and Toxicology. 43: 378–385.

Welsh, H.H., Jr.; Ollivier, L.M. 1998. Stream amphibians as indicators of ecosystem stress: a case study from California's redwoods. Ecological Applications. 8: 1118–1132.

Welsh, H.H., Jr.; Pope, K.L. 2004. Impacts of introduced fishes on the native amphibians of northern California wilderness areas. Final report to the California Department of Fish and Game. 22 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Welsh, H.H., Jr.; Pope, K.L.; Boiano, D. 2006. Subalpine amphibian distributions related to species palatability to non-native salmonids in the Klamath Mountains of northern California. Diversity and Distributions. 12: 298–309.

Wojtaszek, B.F.; Staznik, B.; Chartrand, D.T.; Stephenson, G.R.; Thompson, D.G. 2004. Effects of Vision® herbicide on mortality, avoidance response, and growth of amphibian larvae in two forest wetlands. Environmental Toxicology and Chemistry. 23: 832–842.

Wollmuth, L.P.; Crawshaw, L.I.; Forbes, R.B.; Grahn, D.A. 1987. Temperature selection during development in a montane anuran species, *Rana cascadae*. Physiological Zoology. 60: 472–480.

Young, C.A.; Escobar-Arias, M.I.; Fernandes, M. [et al.]. 2009. Modeling the hydrology of the climate change in California's Sierra Nevada for subwatershed scale adaptation. Journal of the American Water Resources Association. 45: 1409–1423.

Zabik, J.M.; Seiber, J.N. 1993. Atmospheric transport of organophosphate pesticides from California's Central Valley to the Sierra Nevada mountains. Journal of Environmental Quality. 22: 80–90.

Zustak, J.; Mangels, F. 2002. Personal communication. Fisheries biologist, USDA Forest Service, Shasta-Trinity National Forest, P.O. Box 1185, Weaverville CA 96093; Wildlife biologist, U.S. Department of Agriculture, Forest Service, Shasta-Trinity National Forest, 204 West Alma, Mount Shasta, CA 96067.

Appendix 1: Agency Direction

USDA Forest Service

The National Forest Management Act requires the Secretary of Agriculture to specify guidelines for land and management plans developed to achieve goals which "provide for diversity of plant and animal communities" [16 USC 1604 (g)(3)(B)] as part of its multiple-use mandate.

Within the range of the Cascades frog in California, management of National Forest System (NFS) lands fall under the direction of different land and resource management plans (LRMPs) and include those developed for the Lassen National Forest (NF), Shasta-Trinity NF, and Klamath NF. These plans were developed using the direction provided in the 1982 Planning Rule. This rule has since been superseded by the new Planning Rule released on April 9, 2012 (36 CFR Part 219). The transition provisions of the 2012 Rule are listed at 36 CFR 219.17. At 219.17(c), and state that "This part supersedes any prior planning regulation. No obligations remain from any prior planning regulation, except those that are specifically included in a unit's existing plan. Existing plans will remain in effect until revised."

Although management direction for aquatic areas differs slightly among the forests, all three forest plans include direction specific for management and protection of aquatic and riparian-dependent species, including habitat for the Cascades frog. In areas of NFS lands that are available for multiple-use management (e.g., most nonwilderness areas), riparian and aquatic ecosystems receive special consideration through the designation of riparian management zones. Riparian management zones are land area allocations designated around all water bodies and fluvial systems to ensure riparian-dependent resources receive primary emphasis and serve to help maintain the integrity of aquatic ecosystems. In general, only activities that contribute to the maintenance or restoration of riparian-driven objectives and goals are permitted.

In addition to management direction contained in forest plans for the protection and restoration of aquatic and riparian habitats, the USDA Forest Service Pacific Southwest Region (Region 5) includes the Cascades frog on its Sensitive Species List (USDA FS 1998). The Sensitive Species List is derived from the Forest Service Manual (FSM 2670.5) for those plant and animal species identified by a regional forester for which population viability is a concern, as evidenced by:

1. Significant current or predicted downward trends in population numbers or density.
2. Significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution.

Forest Service Manual 2672.1 states that sensitive species of native plants and animals must receive special management emphasis to ensure their viability and to preclude trends toward endangerment that would result in the need for federal listing. Sensitive species cannot be affected without an analysis of significance of adverse effects on the populations, their habitat, and on the viability of the species in the area covered by the forest LRMP. For all Forest Service planned, funded, executed, or permitted programs and activities, a review for possible effects on endangered, threatened, proposed, or sensitive species is conducted through a Biological Assessment (FSM 2670) and Evaluation (FSM 2672.4). Biological Assessment and Evaluation objectives are to:

1. Ensure that Forest Service actions do not contribute to loss of viability of any native or desired nonnative plant or animal species or contribute towards trends for federal listing of any species;
2. Comply with the requirements of the Endangered Species Act that actions of federal agencies not jeopardize federally listed species or adversely modify their critical habitat; and
3. Provide a process and standard by which threatened, endangered, proposed, and sensitive species receive full consideration in the decisionmaking process.

It should be noted that the 2670 portion of the FSM is in the process of revision to reflect the 2012 Planning Rule. Meanwhile, however, the affected national forests are guided by their individual forest LRMPs.

National Park Service

The guiding principles for managing biological resources on National Park Service (NPS) lands include maintenance of animal populations native to park ecosystems, or more specifically:

> "...preserving and restoring the natural abundances, diversities, dynamics, distributions, habitats, and behaviors of native plant and animal populations and the communities and ecosystems in which they occur; restoring native plant and animal populations in parks when they have been extirpated by past human-caused actions; and minimizing human impacts on native plants, animals, populations, communities, and ecosystems, and the processes that sustain them" (NPS 2006).

These guiding principles also commit NPS to "work with other land managers to encourage the conservation of the populations and habitats of these species outside parks whenever possible," including a commitment to "participate in local and regional scientific and planning efforts, identify ranges of populations of native plants and animals, and develop cooperative strategies for maintaining or restoring these populations in the parks."

The Resource Management Plan for Lassen Volcanic National Park (LVNP) (NPS 1999) recognizes that Cascades frog populations have declined in the park and provides management language relevant to Cascades frog conservation:

1. Maintain, rehabilitate, and perpetuate water and aquatic systems to preserve their inherent natural integrity.
2. Populations of endangered, threatened, and other species of concern are protected from population decline and are monitored sufficiently to detect significant changes in population trends.
3. The health of Lassen region ecosystems, of which park lands are only a part, will be preserved as a result of cooperative work among federal, state, and private entities.
4. Exotic animal species that have the potential to substantially disrupt native animal populations or plant communities are eliminated or controlled.
5. Extirpated animal species are, to the extent feasible, restored in accordance with NPS policy.

Broad-based resurveys of historical survey localities initiated in the 1990s have provided insights into the status of the amphibian assemblages found in LVNP (Fellers and Drost 1993, Fellers et al. 2008, NPS 1999; see also "Status" section for LVNP). During comprehensive surveys of lentic waters in the park conducted in 2004 (Stead et al. 2005), a few Cascades frogs were found in the vicinity of Juniper Lake at the south edge of the park. Resurveys in 2005 and 2006 revealed only one adult female frog remaining. All resurveys of this area since 2007 have been unsuccessful at finding frogs and currently no known Cascades frogs remain in LVNP (Pope et al. 2011).

Fish stocking in LVNP had begun prior to the establishment of the park in 1916 and continued until 1980. A gradual phase-out was initiated in 1968. By 1975, stocking was restricted to four lakes (Butte, Crystal, Manzanita, and Summit Lakes) and two streams (Kings Creek and Hot Springs Creek). Fish stocking was discontinued at all sites within the park in 1992 (Stead et al. 2005). Because of the long history of stocking, it is unclear which lakes and streams were naturally barren, which contained fish, and what species of fish are native to each system. As of 2004, 16 percent (9 of 57) of the park's lakes still supported introduced fish, including brook trout (*Salvelinus fontinalis*), rainbow trout (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), and Lahontan redside (*Richardsonius egregious*) (Stead et al. 2005).

California Department of Fish and Wildlife (CDFW)

The state of California considers the Cascades frog to be a "Species of Special Concern" (SSC). This is an administrative designation and carries no formal legal status. The intent of designating SSCs is to:

- Focus attention on animals at conservation risk by the department, other state, local and federal governmental entities, regulators, land managers, planners, consulting biologists, and others;
- Stimulate research on poorly known species;
- Achieve conservation and recovery of these animals before they meet California Endangered Species Act criteria for listing as threatened or endangered.

An SSC is a species, subspecies, or distinct population of an animal native to California that currently satisfies one or more of the following (not necessarily mutually exclusive) criteria:

- Is extirpated from the state or, in the case of birds, in its primary seasonal or breeding role;
- Is listed as federally, but not state, threatened or endangered;
- Meets the state definition of threatened or endangered but has not formally been listed;
- Is experiencing, or formerly experienced, serious (noncyclical) population declines or range retractions (not reversed) that, if continued or resumed, could qualify it for state threatened or endangered status;
- Has naturally small populations exhibiting high susceptibility to risk from any factor(s) that, if realized, could lead to declines that would qualify it for state threatened or endangered status.

More information about SSCs is available at http://www.dfg.ca.gov/wildlife/nongame/ssc/index.html.

The California Environmental Quality Act (CEQA; California Public Resources Code §§ 21000-21177, 1970) requires state agencies, local governments, and special districts to evaluate and disclose impacts from "projects" in the state. Section 15380 of the CEQA Guidelines clearly indicates that SSCs should be included in an analysis of project impacts if they can be shown to meet the criteria of sensitivity outlined therein.

Sections 15063 and 15065 of the CEQA Guidelines, which address how an impact is identified as significant, are particularly relevant to SSCs. In assigning "impact significance" to populations of nonlisted species (including SSCs), analysts usually consider factors such as population-level effects, proportion of the taxon's range affected by a project, regional effects, and impacts to habitat features. More information about CEQA and CEQA guidelines is available at http://ceres.ca.gov/ceqa/stat.

Sport take of Cascades frogs with a fishing license is prohibited (Title 14, Section 5.05), and scientific take is regulated by permit (Title 14, Section 650).

CDFW/USFWS Hatchery and Stocking Environmental Impact Report/ Environmental Impact Statement (EIR/EIS)—
For over a century, CDFW has been operating a statewide system of fish hatchery facilities that rear and subsequently release millions of fish into state waters. After the passage of CEQA in 1970, CDFW continued to operate its hatchery facilities and stocking of fish without undertaking a CEQA impact evaluation. Stocking activities were considered exempt from CEQA review on several grounds, including Section 15301 (j) of the state CEQA Guidelines, which specifically provides an exemption from CEQA review to fish stocking conducted by California Department of Fish and Game. Prompted by a 2006 lawsuit, the California Superior Court ruled in 2008 that the CDFW must consider the effects of hatchery operations and fish stocking on sensitive aquatic species when making stocking decisions (Pacific Rivers Council Center for Biological Diversity v. California Department of Fish and Game. 2007. Case number 06 CS 01451, California Superior Court of Sacramento County). A joint CDFW/U.S. Fish and Wildlife Service (USFWS) Hatchery and Stocking EIR/EIS was completed in January 2010 (ICF Jones & Stokes 2010). In this document, predation and competition impacts of introduced fish on Cascades frogs are acknowledged. Measures to mitigate the impact include not stocking any waters found to currently support Cascades frogs and to develop basin-scale management plans within the range of Cascades frogs that include detailed objectives for both sport fisheries and protection and recovery of populations of the frog.

U.S. Fish and Wildlife Service

The overarching mission of the USFWS "is, working with others, to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people." The long-term goals of the USFWS relevant to this assessment include:

- Recovery of threatened and endangered species
- Protection and conservation of trust species
- Habitat conservation

The recovery of threatened and endangered species, and the ecosystems on which they depend, fall under USFWS responsibilities under the Endangered Species Act.

References

Fellers, G.M.; Drost, C.A. 1993. Disappearance of the Cascades frog *Rana cascadae* at the southern end of its range, California, USA. Biological Conservation. 65: 177–182.

Fellers, G.M.; Pope, K.L.; Stead, J.E.; Koo, M.S.; Welsh, H.H., Jr. 2008. Turning population trend monitoring into active conservation: Can we save the Cascades frog (*Rana cascadae*) in the Lassen region of California? Herpetological Conservation and Biology. 3: 28–39.

Forest Service Manual 2670. Threatened, endangered, and sensitive plants and animals. Washington, DC: U.S. Department of Agriculture, Forest Service.

Forest Service Manual 2670.5. Definitions. Chapter 2670—Threatened, endangered, and sensitive plants and animals. Washington, DC: U.S. Department of Agriculture, Forest Service.

Forest Service Manual 2672.4. Biological evaluations. Chapter 2672—Planning for management and recovery. Washington, DC: U.S. Department of Agriculture, Forest Service.

ICF Jones & Stokes. 2010. Hatchery and stocking program environmental impact report/environmental impact statement. Final. January. (ICF J&S 00264.08) (SCH #2008082025). Prepared for the California Department of Fish and Game and U.S. Fish and Wildlife Service, Sacramento, CA.

Pope, K.L.; Larson, M.D.; Piovia-Scott, J. 2011. Status of remnant populations of Cascades Frogs (*Rana cascadae*) in the Lassen area of California. Final report for years 2008–2010 to the US Forest Service, Lassen National Forest, ISA #05-06-03. 38 p. Unpublished report. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville CA 96130.

Stead, J.E.; Welsh, H.H., Jr.; Pope, K.L. 2005. Census of amphibians and fishes in lentic habitats of Lassen Volcanic National Park: a report to the National Park Service. LVNP Study Number LAVO-00717. Unpublished report. On file with: USDA Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521. 77 p.

U.S. Department of Agriculture, Forest Service [USDA FS]. 1998. Region 5 sensitive species list. San Francisco, CA: Pacific Southwest Region.

U.S. Department of the Interior, National Park Service [NPS]. 1999. Assessment of amphibians found in national parks in the Sierra Nevada of California. Report of the U.S. Department of the Interior, National Park Service, Point Reyes National Seashore, Point Reyes, California.

U.S. Department of the Interior, National Park Service [NPS]. 2006. Management policies 2006. Washington, DC. 168 p. http://www.nps.gov/policy/mp2006.pdf.

Appendix 2: Museum Standard Symbolic Codes

Documentation of records from museum collections in the text are listed according to the standard symbolic code for each institution based on Leviton et al. (1985), and its update (Leviton and Gibbs 1988).

Institution	Symbolic code
American Museum of Natural History (New York)	AMNH
California Academy of Sciences (San Francisco)	CAS
California Academy of Sciences—Stanford University Collection	CAS-SU
California State University Chico[a]	CSUC
Los Angeles County Natural History Museum	LACM
Museum of Vertebrate Zoology (University of California at Berkeley)	MVZ
Oregon State University Museum of Natural History	OS
Texas Cooperative Wildlife Collection (Texas A&M University)	TCWC
University of Michigan Museum of Zoology	UMMZ
United States National Museum (Smithsonian Institution)	USNM

[a] Institution lacks a standard symbolic code, for which one was added.

Appendix 3: Status—Administrative Units

This appendix provides information on distribution and abundance for individual administrative units that encompass at least a portion of the recent historical range of the Cascades frog in California as currently understood (see "Systematics and Taxonomy in Ecology" section). This includes all national forest and national park units. Shasta-Trinity National Forest (NF) lands administered by the Lassen NF (e.g., the Pit River area) are discussed below, and are considered to be within the southern Cascades in the conservation assessment. The Shasta-Trinity NF includes lands in both the Klamath Mountains and southern Cascades.

Lassen National Forest

Pre-1980—

The Lassen NF is the federal unit with the most historical data on Cascades frogs in California, including more than 250 specimens from at least 39 localities on the forest or its vicinity. Cascades frogs were historically present in the western and much of the southern portions of the Lassen NF and vicinity that encompass the tributaries of Deer and Butte Creeks, the tributaries of the North Fork and West Branch Feather River, and Mill and Battle Creeks. Records extend back to the 1920s, when survey parties associated with the Museum of Vertebrate Zoology began collecting data across an elevational transect at the latitude of the recently established Lassen Volcanic National Park (LVNP) (Grinnell et al. 1930). In 1923, Cascades frogs were collected from three localities on the forest, Butte Meadows (MVZ 9108) and Jonesville (MVZ 10357) in Butte County; and Chester (MVZ 10358) in Plumas County. In 1924, four additional localities were collected; Battle Creek Meadows near Mineral (MVZ 9982, 10002–10003, 10010–10011, 10027) and Summit Creek, 3.2 km east of Mineral (MVZ 10001, 10008–10009, 10012, 10023) in Tehama County; and Warner Creek near Chester (CAS-SU 2083) and Willow Lake, northwest of Chester (MVZ 10021–10022) in Plumas County. In 1926, the Mineral/Battle Creek Meadows locality was recollected (CAS 218397, 218407). In 1928, Joseph Grinnell collected nine Cascades frogs from Martin Creek near Mineral (MVZ 10875–10883). At the close of the 1920s, Cascades frogs had been recorded from nine different localities on the Lassen NF and vicinity.

Only two localities were recorded during the 1930s. In 1934, the Warner Creek locality was recollected (UMMZ 77904); and an unverified Cascades frog was collected along the North Fork of the Feather River above Chester (UMMZ 77903).

Four records exist for the 1940s, all from previously unrecorded localities. In 1945, Thomas Rodgers collected a Cascades frog along Deer Creek 17.6 km west-southwest of Lake Almanor (Plumas County). In 1946, five Cascades frogs were collected from Little Grizzly Valley at points 8 km (MVZ 56841–56844) and 9.8 km (MVZ 56840) west of Longville also in Plumas County. In 1948, D. Issac collected one frog from the Deer Creek Guard Station (CSUC 1420). In 1949, two Cascades frogs were collected from Elam Creek near Deer Creek Meadows (CAS-SU 11061–11062). At the close of the 1940s, Cascades frogs had been recorded from 14 different localities on the Lassen NF and vicinity.

Four records also exist for the 1950s, all from previously unrecorded localities. In 1950, a Cascades frog was collected from Kimshew Creek, 6.4 km east of Sterling City (MVZ 56839). In 1952, Thomas Rodgers collected 15 Cascades frogs in August from Coon Hollow, a tributary of the West Branch of the Feather River (MVZ 57338–57532); and Richard Zweifel recollected this locality, taking three frogs in October (MVZ 58165–58166, 59656). In 1954, Bayard Brattstrom collected 22 Cascades frogs from the vicinity of Lee's Camp, 8 km southeast of Drakesbad (LACM 13408–13427, 74422–74423). In 1959, Alan Ziegler collected 22 Cascades frogs from Butt Creek 12.8 km south of Chester (MVZ 69499, 69501–69521). At the close of the 1950s, Cascades frogs had been recorded from 19 different localities on the Lassen NF and vicinity.

The number of records peaked during the 1960s, when 80 Cascades frogs were collected from 17 different localities, 14 of which had not been previously recorded. In 1960, 18 Cascades frogs were recorded from southwest Deer Creek Meadows (CSUC 1070–1087), four frogs were collected at Jonesville (CSUC 1033–1036), one frog was collected 0.8 km east-northeast of the Butte Meadows store (CSUC 1032), 11 frogs were collected from Coon Hollow (CSUC 1021–1031), three frogs were collected along Mill Creek, 3.2 km downstream from Highway 36 (CSUC 1037–1039), and six frogs were collected from upper Butt Creek, 0.3 km southwest of [Lake] Almanor (CSUC 1040–1045). One last frog collected in 1960 was taken from Anderson Fork (CSUC 1020), which at 230 m (750 ft) represents the extreme low-elevation outlier for the species in California. In 1961, one frog was collected along Mill Creek just north of Highway 36 (CSUC 1058); one frog was collected along Mill Creek southeast of Camp Tehama (CSUC 1088); six frogs were collected along Little Grizzly Creek in Grizzly Meadows (CSUC 1091–1097); seven more frogs were collected from Coon Hollow (CSUC 1051–1057); one frog was collected along Butte Creek from each of 12.8 km (CSUC 1059), 14.5 km (CSUC 1060), and 16.0 km (CSUC 1061) east of Jonesville; four frogs were collected from Yellow Creek, 1.2 km upstream from Humbug Valley (CSUC 1062–1065), and two frogs were collected from Warner Creek (5059') 11.3 km NW of Chester (CSUC #1049–1050). In 1966, four Cascades frogs were collected from Fanani Meadows along Butt Creek (CSUC 1066–1069); and one frog was collected 1.6 km east of the Coon Hollow-Skyway junction (CSUC 1545). In 1967, the Fanani Meadows locality was recollected and one frog was taken (UMMZ 223093). At the close of the 1960s, Cascades frogs had been recorded from 32 different localities on the Lassen NF and vicinity.

During the 1970s, 45 Cascades frogs were collected from seven different localities on the Lassen NF and vicinity; all seven of these localities had not been previously recorded. In 1971, one frog was collected from Hot Springs Creek, Plumas County (AMNH A86584); two frogs were collected from Warner Valley Camp (AMNH A86585–A86586); and three frogs were collected along Warner Creek, 6.4 km north and 11.2 km west of Chester (AMNH A86587–A86589). In 1972, 16 Cascades frogs were collected along Domingo Creek, a tributary of the North Fork of the Feather River (LACM 76638–76653); and 19 frogs were collected from Willow Lake and adjacent Willow Creek northwest of Chester (LACM 76617–76635). In 1974, two frogs were collected from Beauty Lake in the Caribou Wilderness by T. Rodgers (Jennings 1997). In 1975, two frogs were collected from along Little Grizzly Creek, 1.9 km west of upper Yellow Creek Road (CAS 178503–178504) and one frog was collected at Chester (CAS 178493). At the close of the 1970s, Cascades frogs had been recorded from 39 different localities on the Lassen NF and vicinity. No data are available for the late 1970s, but based on information through the early 1970s, none of the limited information available suggested that Cascades frogs had declined on the Lassen NF.

Post-1980—

More than 200 hours of systematic surveys addressing ranid frogs conducted at the Butte Meadows and Jonesville historical localities in 1981 and 1983 failed to detect any Cascades frogs (Hayes, n.d.). No additional forestwide and vicinity survey data are known to be available for the 1980s.

In their summary on amphibian declines, Davidson et al. (2002) included 32 historical Cascades frog sites (defined therein as pre-1990) associated with the Lassen NF based on the data from Jennings and Hayes (1994). Their summary indicated that 3 percent (n = 1) of these historical sites were still occupied in the early 1990s.

Since 1993, both informal amphibian surveys (e.g., USDA FS 1993; EA EST 1995, 1996) and formal amphibian surveys using visual encounter survey methods

(Fellers 1995, 1998; Koo et al. 2004; Vindum and Koo 2003; Welsh and Pope 2004) have been conducted on the Lassen NF to assess the relative distribution and abundance of amphibian species, including the Cascades frog. Although most surveys were geographically widespread and included sites that had been occupied historically, only three sites were found to contain the Cascades frog in the Lassen region (excluding the LVNP portion).

Informal surveys in 1993 detected the first two LNF populations of the Cascades frog (USDA LNF 1993), as confirmed by Dr. Gary Fellers. Subsequent surveys by Fellers in 1993, 1994, 1996, and 1997 covered approximately 152 total sites forestwide (Fellers 1995, 1998). The only additional populations of Cascades frogs detected during these efforts were found on Shasta-Trinity NF lands administered by the Lassen NF (see section for Shasta-Trinity NF below); no additional populations were found in the bulk of the survey area in the Lassen region. In 1995, approximately 120 sites, representing a total of 14 miles of tributary streams to Deer and Mill Creeks, were surveyed, but no Cascades frogs could be confirmed (EA EST 1996). Surveys during 2001, covering 22 sites on the Almanor Ranger District, revealed no Cascades frogs (USDA LNF 2002). Surveys conducted again in 2002 on the Almanor Ranger District covered more than 130 acres of wet meadow/riparian habitat and 29 miles of stream habitat, yet no additional sites containing the Cascades frog were found (Vindum and Koo 2003). In 2002, formal visual encounter surveys of 76 lentic water bodies in the Thousand Lakes Wilderness were conducted and no Cascades frogs were found (Welsh and Pope 2004). In 2002, 386 water bodies in the Caribou Wilderness were searched and no Cascades frogs were found (Welsh and Pope 2004). This area encompasses Beauty Lake, from which two Cascades frogs were collected during the 1970s (see “Pre-1980” section). In 2003, forestwide surveys covered approximately an additional 690 acres of wet meadow/riparian habitat and 56 miles of stream habitat (Koo et. al. 2004) and only three “sites” were found to have the Cascades frog (all were previously known populations in tributaries to the Pit River, on Shasta-Trinity NF lands administered by the Lassen NF, see below).

In the Butte Creek drainage, frogs are known to have persisted from 1993 to 2005 in Colby Creek, a small headwater tributary (USDA LNF 1993; Fellers 1995, 1998, 2005). Frogs were not found in the drainage during follow up surveys in 2006 (Fellers 2006) but were found again in 2007 through 2012 (Pope and Larson 2012). The frogs have been monitored since 2008 and the adult population is estimated to be between two and seven frogs (Pope and Larson 2012).

In the Deer Creek drainage, frogs are known to be persisting in a small headwater tributary (Fellers 1995, 1998; Pope and Larson 2012, Pope et al. 2011; Vindum and Koo 2003). Additionally, in 2002 one adult was observed by a Lassen NF fisheries biologist (Roby 2002) in another upper Deer Creek tributary, Alder Creek, roughly 3 air miles from the extant population. A population of Cascades frogs was discovered in Childs Meadow on Gurnsey Creek by biologists from The Nature Conservancy and Lassen NF in 2010 and another population was found in Round Valley by a Sierra Pacific Industries biologist in 2009. A second small population was found in 2012 by a Collins Pine Company biologist, L. Thomasma, about 1 km from Round Valley and within the same drainage system (Pope and Larson 2012).

Frogs were incidentally seen at two localities within the North Fork Feather River drainage. In 1996, one adult was observed in Butt Creek (Brown 2000) and in 1998, one adult was observed in Warner Creek (Smith 1998). Frogs (one adult and two subadults) were observed in Warner Creek during surveys in 2002 (Vindum and Koo 2003). A frog and tadpoles were found in Warner Meadow in 2010 (Pope et al. 2011).

In the Pit River drainage (Shasta-Trinity NF land administered by the Lassen NF), frogs have been observed in Rock Creek and neighboring Screwdriver Creek since 1994 (EAEST 1995). In 2002, one adult and one subadult were observed by Lassen NF Fisheries biologist M. McFarland in a portion of a small unnamed tributary of Rock Creek (McFarland 2002). This same drainage was surveyed more extensively in 2003 and two adults and one juvenile were observed (Koo et al. 2004). Frogs were again found in the Rock Creek drainage, including the tributary, in 2009 (Pope and Larson 2010). Breeding Cascades frogs have not been found on Rock Creek but have been found in a pond at the headwaters of Screwdriver Creek, which is an adjacent tributary to the Pit River, since 1996 (Fellers 1998, Koo et. al. 2004, Pope et al. 2011). After breeding, most frogs move into the perennial waters of Screwdriver Creek, up to 2 km downstream of the pond (Pope et al. 2011). They also are known to move into the Rock Creek drainage, so the Rock Creek and Screwdriver Creek frogs are likely one population. Likely, more than 40 adult frogs remain in this population (Pope et al. 2011).

In 2006, two meadows, Old Cow Creek and Cutter Meadow, on lands managed by W.M. Beaty & Associates, Inc. but near Shasta-Trinity NF land administered by the Lassen NF were discovered to support Cascades frogs. These populations have been monitored between 2008 and 2011 and likely support close to 100 frogs each (Pope et al. 2011).

Lassen Volcanic National Park

Pre-1980—

Similar to Lassen NF, LVNP is relatively data rich historically with more than 130 specimens from at least 16 different localities. LVNP was established in 1917, but historical records of Cascades frogs from LVNP date from the 1920s, and scattered data indicate that the species was common. In 1923, Leo Wilson collected 20 Cascades frogs from upper Warner Creek (MVZ 9087–9106). In 1924, four Cascades frogs were collected from "The Falls Creek," 3.2 km west of Black Butte on Mount Lassen Road (MVZ 10005, 10013–10015); one frog was collected from "Boomer Lake", 4 km southwest of Black Butte (MVZ 10004), and Adrey Borrel and Joseph Grinnell collected seven frogs from Lake Helen at the southern base of Lassen Peak (MVZ 10006–10007, 10016–10020). Borrel (1924) described Cascades frogs as abundant at Lake Helen. In 1925, three additional frogs were collected from Lake Helen (MVZ 10063, 10065–10066) and two frogs were collected from Emerald Lake (MVZ 10062–10064). Grinnell et al. (1930) recorded "one frog for nearly every meter around the lake" from the 1925 visit to Emerald Lake. In 1926, four Cascades frogs had been collected from Manzanita Lake (MVZ 10140–10143) and one frog was taken from a small lake, probably Conard Lake, 6.4 km due south of Lassen Peak (CAS 218398). By the close of the 1920s, Cascades frogs had been recorded from eight different localities within LVNP, which represented at all eight localities surveyed within the park.

Only two localities were collected during the 1930s. Two Cascades frogs were taken from the creek at Manzanita Lake (CAS 218449-218450) and two frogs were collected from a small lake (probably Shadow Lake) 4.8 km southwest of Summit Lake (CAS 218391, 218448).

In the 1940s, only one locality was collected; the creek at the outflow of Manzanita Lake was recollected, four frogs were taken (MVZ 41237-41240).

During the 1950s, five localities were recorded, two of which were new. In 1951, one frog was collected at Manzanita Creek (OS 6189); Stebbins (1951b) found 13 or more frogs at small pools (Stebbins 1951b, in Fellers and Drost 1993). In 1952, four frogs were collected at Snow Pond (MVZ 57087–57088, 57707–57708), one frog was collected at Emerald Lake (MVZ 57083), and five frogs were collected at Dersch Meadows (MVZ 5708957091, 57709–57710). In 1954, one frog was collected 1.6 km east of Drakesbad (UMMZ 119019).

No records exist for the 1960s.

During the 1970s, Cascades frogs were collected from five localities within LVNP, three of which had not been previously recorded. In 1972, two frogs were taken from the north arm of Rice Creek (LACM 76636–76637). In 1973, seven frogs were collected from Kings Creek Meadow (MVZ 136131–136137). In 1974, Dersch Meadows was revisited, at which time Richard Sage collected 48 Cascades frogs (MVZ 148944–148988, 175949–175954). Also in 1974, two frogs were collected from Emerald Lake (MVZ 136125–136126). In 1975, one frog was collected along a stream 0.4 km north of Crumbaugh Lake (MVZ 136127), and 6 additional frogs were collected from Dersch Meadows (MVZ 136138–136143). Dersch Meadows is the most heavily collected historical locality within LVNP; 59 frogs were collected over the interval 1952–1975. No collections exist during the 1970s after 1975. By the close of the 1970s, Cascades frogs had been recorded from 16 localities within LVNP, of which collections existed for 15 (Fellers and Drost 1993). At least through the mid-1970s, available data provide no indication that Cascades frogs were declining.

Post-1980—

We are not aware of any survey data from the 1980s for LVNP.

Surveys completed in the early 1990s indicate that the Cascades frog was already rare in LVNP (Fellers and Drost 1993, Jennings and Hayes 1994). Surveys in 1990 failed to reveal Cascades frogs at 10 historical sites in LVNP (Jennings 2006). Davidson et al. (2002) included these same six unoccupied historical Cascades frogs sites (defined therein as pre-1990) in their summary of amphibian declines. In 1991, Fellers and Drost (1993) found Cascades frogs at only 1 of 50 sites that included the 16 pre-1980 localities. At the only site where frogs were found, Crumbaugh Lake, only two frogs were detected and no evidence of breeding was recorded. Resurvey of this site in 1992 failed to detect frogs.

More recent surveys (1999–2002) have detected frogs at only 4 of 400 sites surveyed that included both sites within LVNP and the immediate vicinity (G. Fellers, pers. comm., in Pearl and Adams 2005). Moreover, population sizes appeared small at all four sites. As of 2002, frogs were no longer found at two of these four sites (G. Fellers, pers. comm., in Pearl and Adams 2005).

Extensive surveys of lentic habitats in LVNP in 2004 (Stead et al. 2005) found only three frogs at or near Juniper Lake. Resurveys in this area in 2006 and 2007 found only one adult female at this site. In 2008, 2009, and 2011 no frogs were found (Pope et al. 2011, Pope and Larson 2012). There are no known locations with Cascades frogs remaining in LVNP.

Shasta-Trinity National Forest

Pre-1980—

Some historical data for Cascades frogs exist for the Shasta-Trinity NF. Records from this national forest and vicinity extend back to the 1890s, when Cloudsley Rutter and Frederick Chamberlain collected two Cascades frogs from lower Cliff Lake (USNM 38832–38833), and William Osgood collected one frog at each of Warmcastle Soda Springs in Squaw Creek Valley (USNM 45877) and Deer Flat (USNM 45878).

One additional record was obtained in the 1900s: three Cascades frogs were taken from Gumboot Lake (CAS 13303–13305).

Two locality records were obtained during the 1910s, when Tracy Storer collected two frogs 0.8 km west of Sisson (now Mount Shasta City; MVZ 5567–5568) and an additional frog 2.4 km west of Sisson (MVZ 5566).

No locality records exist for the 1920s.

Cascades frogs were recorded from five localities on the Shasta-Trinity NF during the 1930s. In 1932, five frogs were collected from the Dale Meadows on Mount Eddy (MVZ 17937–17939). In 1934, two frogs were collected at Dale Creek on Mount Eddy (MVZ 17942–17943); one frog was collected 0.8 km southwest of Weed (MVZ 17941); two frogs were collected from Crater Lake on Mount Eddy (MVZ 17948–17949); and two frogs were collected from Wagon Valley Creek also on Mount Eddy (MVZ 17946–17947). In 1939, four Cascades frogs were collected on Bear Creek, 8 km southeast of Bartle (CAS 218393–218396).

Three locality records exist for the 1940s. In 1941, one Cascades frog was collected at each of Castle Lake (MVZ 37088) and Baird Land, about 0.4 km northwest of the State Fish Hatchery in Mount Shasta City (MVZ 37128). In 1946, Thomas Rodgers collected two Cascades frogs along Pole Creek, 32 km northwest of Fall River Mills (MVZ 56845–56846).

During the 1950s, Cascades frogs were identified from four different localities, only one of which had been previously recorded. In 1953, at least two different collections comprising a total of seven frogs were made in the vicinity of Bartle (MVZ 60494–60498; UMMZ 110131, 110133); two frogs were collected 3.2 km south of the Mount Shasta State Fish Hatchery along the South Fork of the Sacramento River (MVZ 60499, UMMZ 110132); and one frog was taken 6.4 km east of Bartle (MVZ 110134). In 1959, the Dale Creek Meadows locality on Mount Eddy was recollected, at which time nine Cascades frogs were taken (MVZ 71062–71070). By the close of the 1950s, Cascades frogs had been recorded from at least 17 different localities on the Shasta-Trinity NF and vicinity.

Cascades frogs were recorded from three localities during the 1960s. In 1960, four frogs were collected from Moosehead Creek (MVZ 70511–70514) and one frog was collected from Upper Nash Mine (CAS 91517). The latter was one of the localities summarized in the synoptic brief of Bury (1973) on Cascades frogs in the North Coast Range of California. In 1962, 10 Cascades frogs were collected from Colby Creek Meadow (MVZ 74315–74324).

During the 1970s, Cascades frogs were identified from six localities, only one of which had been previously recorded. In 1970, two frogs were taken 0.2 km northwest of Upper Canyon Creek Lake (MVZ 94817–94818). In 1971, four frogs were collected from Black Basin in the Deer Creek drainage (MVZ 97943-97946), and four additional frogs were collected from Ward Lake in the Swift Creek drainage (MVZ 97948–97951). In 1975, three Cascades frogs were taken from Colby Meadow (MVZ 136128–136130), and six frogs were collected along the Union Creek trail in the Trinity Alps Wilderness Area (MVZ 136144–136149). A sighting of unknown origin also exists in the Shasta-Trinity NF database for 1975 for one adult frog in Big Bear Lake in the Bear Creek drainage. By the close of the 1970s, Cascades frogs had been recorded from no fewer than 25 different localities on the Shasta-Trinity NF and vicinity. Available data provide no evidence for or against the decline of Cascades frogs on the Shasta-Trinity NF through the 1970s.

Post-1980—

From 1982 to 2001, Mangels (2002) compiled field maps of Cascades frog sightings from the Shasta-Trinity NF. These records lack precise dates and were predominantly collected through methods other than formal amphibian surveys including fish distribution/population surveys, aquatic habitat surveys, during fieldwork related to livestock grazing management, and recreation or other nonbusiness activities; many sites were visited multiple times (Zustak and Mangels 2002). Localities included the following drainage basins:

1. Klamath River drainage (Klamath River, Elk Creek, Ukonom Creek, other small tributaries), Trinity River (Stuart Fork Trinity River, North Fork Trinity River, Little North Fork Trinity River, East Fork Trinity River, Stuart Fork Trinity River, Swift Creek, Coffee Creek, Canyon Creek, and other small tributaries), Scott River and South Fork Scott River, Salmon River (South Fork Salmon River, North Fork Salmon River, Little North Fork Salmon River, Wooley Creek, other small tributaries);

2. Sacramento River drainage (Sacramento River, South Fork Sacramento River, North Fork Sacramento River, Middle Fork Sacramento River, Castle Creek, other small tributaries), and McCloud River. Only three of the sites had observations of more than 10 adult frogs including the following: 12 adults were seen in Toad Lake, Middle Fork Sacramento River drainage; and 10 to 20 adults were observed in Landers Creek Meadow, Trinity River drainage. All the latter records were for 1995.

In 1990, Marc Hayes and Mark Jennings collected Cascades frogs at the McCloud River below Colby Meadow (CAS 176557–176560; n = 4), Mumbo Lake (CAS 176530; n = 1), Gumboot Creek at Road 26 (CAS 176531–176551, 180306–180307; n = 21); and a small unnamed pond 1.6 km north of Picayune Lake (CAS 176552–176555; n = 4). These collections and associated observations of additional Cascades frogs were part of the basis of comments that the species could still be commonly observed north and west of the McCloud River in California (Jennings and Hayes 1994).

In their summary on amphibian declines, Davidson et al. (2002) included 26 historical Cascades frogs sites (defined therein as pre-1990) associated with the Shasta-Trinity NF based on the data from Jennings and Hayes (1994). Their summary indicated that 77 percent (n = 20) of these historical sites were still occupied in the early 1990s.

Between July 1999 and August 2002, formal amphibian surveys of all lentic habitats were conducted in the Trinity Alps Wilderness west of Highway 3 (Welsh et al. 2006). Of 380 water bodies surveyed, 58.7 percent (n = 223) were found to support at least one individual of any life stage of Cascades frogs (Welsh et al. 2006). Evidence of reproduction (egg masses or larvae) was recorded at 30.5 percent (n = 116) of the sites. The maximum number of adult Cascades frogs found at any site was 32 and the maximum number of larvae was 4,000. All localities were from the central and eastern portions of the wilderness.

Klamath National Forest

Pre-1980—

Only four verifiable historical records of Cascades frogs exist for the Klamath NF and vicinity. The earliest records date from 1914, when Halstead G. White collected five Cascades frogs from the T.H. Benton estate along Butte Creek (Siskiyou County; MVZ 7497–7501); this location is about 24 km south of the Oregon state line.

One record exists from the 1920s. Halstead recollected the Benton estate along Butte Creek in August 1920, where he took 16 Cascades frogs (MVZ 7502–7517).

One record exists from the 1930s. David H. Johnson collected three frogs from Antelope Creek in September 1933 (MVZ 17940, 17944–17945).

No records exist for the 1940s and 1950s. An unconfirmed record exists for Duck Lake near the town of Callahan on Highway 3, but the basis of this record is unclear.

One record exists from the 1970s. In 1973, Kurt Rademacher collected one Cascades frog from the Sky High Lakes in the Marble Mountain Wilderness (MVZ 107354).

Post-1980—

No records or survey data exist for the Klamath NF during the 1980s but some data are available for the 1990s. In their summary on amphibian declines, Davidson et al. (2002) included two historical Cascades frogs sites (defined therein as pre-1990) associated with the Klamath NF based on the data from Jennings and Hayes (1994). Their summary indicated that 100 percent of these historical sites were still occupied in the early 1990s.

Positive sighting maps for the Klamath NF show that Cascades frogs were observed in Antelope Creek (pre-1980 historical locality), the vicinity of Tamarack Spring, and Trail Creek; however, no additional data exist for the Cascades frog records from these localities.

Systematic surveys of segments of the Klamath NF were not initiated until 2001. Complete visual encounter surveys of all lentic habitats were conducted in the Marble Mountains and Russian Wildernesses between July 2001 and July 2002 (Welsh et al. 2006). Approximately 250 water bodies were searched in the Marble Mountains, and 54 water bodies were searched in the Russian Wilderness. Cascades frogs were recorded from 32 percent of the water bodies in the Marble Mountains (n = 80) and at 31 percent of water bodies in the Russian Wilderness (n = 17). However, evidence of reproduction (egg masses or tadpoles) were found at only 11 percent of sites in the Marble Mountains (n = 28) and at only 5.5 percent of sites in the Russian Wilderness (n = 3). Further, adult and larval numbers observed seemed low. The maximum number of adults found at any site was 26 in the Marble Mountains and 19 in the Russian Wilderness; the maximum number of tadpoles was 5,950 in the Marble Mountains and 130 in the Russian Wilderness (Welsh et al. 2006). Besides these wilderness surveys, one adult Cascades frog was recorded from a permanent pond in the Sugar Creek Watershed and 62 tadpoles were found in a wet meadow in the Meeks Meadow Creek Watershed north of the Russian Wilderness boundary (Welsh et al. 2006).

References

Borrel, A.E. 1924. Unpublished field notes. On file at: Museum of Vertebrate Zoology, University of California, Berkeley, CA.

Brown, H. 2000. Personal communication (with M. McFarland). District fisheries biologist (retired), Lassen National Forest, Almanor Ranger District, 900 E. Hwy 36, P.O. Box 767, Chester, CA 96020. On file with: USDA Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Bury, R.B. 1973. The Cascades frog, *Rana cascadae*, in the north Coast Range of California. Northwest Science. 47: 228–229.

Davidson, C.; Shaffer, H.B.; Jennings, M.R. 2002. Spatial tests of the pesticide drift, habitat destruction, UV-B, and climate-change hypotheses for California amphibian declines. Conservation Biology. 16: 1588–1601.

EA Engineering, Science, and Technology [EA EST]. 1995. Rock Creek and Screwdriver Creek aquatic resource inventories. Final Report prepared for the Lassen National Forest, Hat Creek Ranger District. 11 pp. + appendices. Unpublished report. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

EA Engineering, Science, and Technology [EA EST]. 1996. Aquatic resources survey of Deer and Mill Creek tributaries, volume 1 of 4. Report prepared for the Lassen National Forest. Report + Appendices A-C. Unpublished report. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Fellers, G.M. 1995. Aquatic amphibian surveys: Lassen National Forest. Unpublished report prepared for the Lassen National Forest. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Fellers, G.M. 1998. 1996–97 Aquatic amphibian Surveys; Lassen National Forest. Unpublished report. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Fellers, G.M. 2005. Unpublished data. On file with: National Biological Survey, Point Reyes National Seashore, 1 Bear Valley Road, Point Reyes Station, CA 94956.

Fellers, G.M. 2006. Unpublished data. On file with: National Biological Survey, Point Reyes National Seashore, 1 Bear Valley Road, Point Reyes Station, CA 94956.

Fellers, G.M.; Drost, C.A. 1993. Disappearance of the Cascades [sic] frog *Rana cascadae* at the southern end of its range, California, USA. Biological Conservation. 65: 177–182.

Grinnell, J.J.; Dixon, J.; Linsdale, J.M. 1930. Vertebrate natural history of a section of northern California through the Lassen Peak region. University of California Publications in Zoology. 25: 1–594.

Hayes, M. [N.d.]. Unpublished data. On file with: Marc Hayes, Habitat Program of the Washington Department of Fish and Wildlife, 600 Capitol Way North, Olympia, WA 98501.

Hayes, M. 2005. Personal communication. Senior research scientist, Habitat Program of the Washington Department of Fish and Wildlife, 600 Capitol Way North, Olympia, WA 98501.

Jennings, M.R.; Hayes, M.P. 1994. Amphibian and reptile species of special concern in California. Rancho Cordova, CA: California Department of Fish and Game, Inland Fisheries Division.

Jennings, M.R 1997. Unpublished letter (with attached correspondence to R. Knapp) to M. McFarland. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Jennings, M. 2006. Personal communication. Senior associate ecologist and herpetologist, Live Oak Associates, Inc., P.O. Box 2697, Oakhurst, CA 93644.

Koo, M.S.; Vindum, J.V.; McFarland, M. 2004. Results of 02-CS-11050650-029, the 2003 California Academy of Sciences survey: amphibians and reptiles of the Lassen National Forest. San Francisco, CA: California Academy of Sciences, Department of Herpetology. Unpublished report. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130. 172 p.

Mangels, F. 2002. Personal communication. Wildlife biologist (retired), USDA Forest Service, Shasta-Trinity National Forest, 204 West Alma, Mount Shasta, CA 96067.

McFarland, M. 2002. Unpublished data. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Pearl, C.A.; Adams, M.J. 2005. *Rana cascadae* Slater, 1939: Cascades Frog. In: Lannoo, M., ed. Amphibian declines: the conservation status of United States species. Berkeley, CA: University of California Press: 538–540.

Pope, K.L.; Larson, M.D. 2010. Second year of population monitoring of remnant populations of Cascades frogs (*Rana cascadae*) in the Lassen area of California. Final report to the U.S. Fish and Wildlife Service, FWS #81420-8-H158. 28 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Pope, K.L.; Larson, M.D. 2012. Unpublished data. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Pope, K.L.; Larson, M.D.; Piovia-Scott, J. 2011. Status of remnant populations of Cascades frogs (*Rana cascadae*) in the Lassen area of California. Final report for years 2008–2010 to the U.S. Forest Service, Lassen National Forest, ISA #05-06-03. 38 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Roby, K. 2002. Personal communications (with M. McFarland). District fisheries biologist (retired), Lassen National Forest, Almanor Ranger District, 900 E. Hwy 36, PO Box 767, Chester, CA 96020. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Sage, R.D. 1974. Unpublished field notes. On file with: Museum of Vertebrate Zoology, University of California-Berkeley, 3101 Valley Life Sciences Building, Berkeley, CA 94720-3160.

Smith. G. 1998. Personal communication (with M. McFarland). Wildlife/range officer (retired), Lassen National Forest. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Stead, J.E.; Welsh, H.H., Jr.; Pope, K.L. 2005. Census of amphibians and fishes in lentic habitats of Lassen Volcanic National Park: a report to the National Park Service. LVNP Study Number LAVO-00717. 77 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Stebbins, R.C. 1951b. Unpublished field notes. On file with: Museum of Vertebrate Zoology, University of California-Berkeley, 3101 Valley Life Sciences Building, Berkeley, CA 94720-3160.

U.S. Department of Agriculture, Forest Service, [USDA FS]. 1993. FY 1993 Amphibian surveys. Unpublished report. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

U.S. Department of Agriculture, Forest Service[USDA FS]. 2002. Unpublished data. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Vindum, J.V.; Koo, M.S. 2003. Amphibians and reptiles of the Lassen National Forest: the results of 02-CS-11050650-029, the 2002 California Academy of Sciences survey. 78 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville CA 96130.

Welsh, H.H., Jr.; Pope, K.L. 2004. Impacts of introduced fishes on the native amphibians of northern California wilderness areas. Final report to the California Department of Fish and Game, 30 March. 22 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Welsh, H.H., Jr.; Pope, K.L.; Boiano, D. 2006. Subalpine amphibian distributions related to species palatability to non-native salmonids in the Klamath Mountains of northern California. Diversity and Distributions. 12: 298–309.

Zustak, J.; Mangels, F. 2002. Personal communication. Fisheries biologist, USDA Forest Service, Shasta-Trinity National Forest, P.O. Box 1185, Weaverville CA 96093; Wildlife biologist, U.S. Department of Agriculture, Forest Service, Shasta-Trinity National Forest, 204 West Alma, Mount Shasta, CA 96067.

Appendix 4

Surveys in the Southern Cascade Range since 1980

Years	Location and extent[a]	Effort	Cascades frog detections	Description	Reference
1981, 1983	Butte Meadows and Jonesville	200 hours	None	Systematic surveys	Hayes 2005
1990	Lassen Volcanic National Park	10 historical sites	None		Jennings 2006
1991	Lassen Volcanic National Park	50 sites	One site	Formal visual encounter surveys	Fellers and Drost 1993
1993	Forestwide	106 sites	Two locations and include first observations of extant populations on Lassen National Forest	Informal visual encounter surveys conducted by Lassen National Forest seasonal personnel under supervision of Lassen National Forest permanent biologists	USDA FS 1993
1993–1994	Deer and Mill Creek watersheds (including some sites in the Butte Creek watershed)	40 sites	Two locations (same as 1993 Lassen National Forest survey)	Formal visual encounter surveys	Fellers 1995
1994	Rock Creek, tributary to the Pit River	4.25 noncontiguous stream miles	Two locations that may represent one population	Informal visual encounter surveys	EA EST 1995
1995	Lassen National Forest	60 sites	Two sites (same as 1993 Lassen National Forest survey)	Formal visual encounter surveys	Fellers 1995

Surveys in the Southern Cascade Range since 1980 (continued)

Years	Location and extent[a]	Effort	Cascades frog detections	Description	Reference
1995	Deer and Mill Creek tributaries	120 sites (totaling 14 stream miles)	Possible but could not be confirmed	Informal visual encounter surveys	EA EST 1996
1996–1997	Lassen National Forest, Caribou and Thousand Lakes Wilderness	112 sites	Three (two sites are same as 1993 Lassen National Forest survey)	Formal visual encounter surveys	Fellers 1998
2001	Almanor Ranger District, geographically widespread	22 sites	None	Informal visual encounter surveys	USDA FS 2002
2002	Almanor Ranger District, geographically widespread	Approximately 56.0 ha of meadow, 46.7 km of stream	Two sites (one site is same as 1993 Lassen National Forest survey)	Formal visual encounter surveys	Vindum and Koo 2003
2003	Lassen National Forest	Approximately 280 ha of meadow, 91.8 km of stream	Five sites including four found in prior surveys	Formal visual encounter surveys	Koo et al. 2004
2002	Thousand Lakes Wilderness	All lentic water bodies	None	Formal visual encounter surveys	Welsh and Pope 2004
2002	Caribou Wilderness	Over 300 water bodies	None	Formal visual encounter surveys	Welsh and Pope 2004
2004	Lassen Volcanic National Park	All lentic water bodies	One site	Formal visual encounter surveys	Stead et al. 2005
2007–2011	Lassen National Forest, adjacent private lands, Lassen Volcanic National Park	50 historical or unsurveyed sites	11 sites including six found in prior surveys	Formal visual encounter surveys	Pope and Larson 2011, Pope et al. 2011

[a] Surveys include those on Shasta-Trinity National Forest lands administered by the Lassen National Forest.

References

EA Engineering, Science, and Technology [EA EST]. 1995. Rock Creek and Screwdriver Creek aquatic resource inventories. Final report prepared for the Lassen National Forest, Hat Creek Ranger District. 11 p. + appendixes. Unpublished report. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

EA Engineering, Science, and Technology [EA EST]. 1996. Aquatic resources survey of Deer and Mill Creek tributaries, volume 1 of 4. Report prepared for the Lassen National Forest. Report + Appendixes A–C. Unpublished report. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Fellers, G. 1995. Aquatic amphibian surveys. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Fellers, G. 1998. 1996–1997 Aquatic amphibian surveys. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Fellers G.M.; Drost, C.A. 1993. Disappearance of the Cascades frog *Rana cascadae* at the southern end of its range, California, USA. Biological Conservation. 65: 177–182.

Hayes, M. 2005. Personal communication. Senior research scientist, Washington Department of Fish and Wildlife, 600 Capitol Way North, Olympia, WA 98501.

Jennings, M. 2006. Personal communication. Senior associate ecologist and herpetologist, Live Oak Associates, Inc., P.O. Box 2697, Oakhurst, CA 93644.

Koo, M.S.; Vindum, J.V. ; McFarland, M. 2004. Results of 02-CS-11050650-029, the 2003 California Academy of Sciences survey: amphibians and reptiles of the Lassen National Forest. San Francisco, CA: California Academy of Sciences, Department of Herpetology. 172 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Pope, K.; Larson, M. 2011. Unpublished data. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Pope, K.; Larson, M.; Piovia-Scott, J. 2011. Status of remnant populations of Cascades frogs (*Rana cascadae*) in the Lassen Area of California. Report to the Lassen National Forest. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Stead, J.; Welsh, H.H., Jr.; Pope, K. 2005. Census of amphibians and fishes in lentic habitats of Lassen Volcanic National Park: a report to the National Park Service LVNP Study Number: LAVO-00717. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Lassen Volcanic National Park, PO Box 100, Mineral, CA 96063.

U.S. Department of Agriculture, Forest Service, [USDA FS]. 1993. FY 1993 Amphibian Surveys. Unpublished report. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2002. Unpublished data. On file with: Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Vindum, J.; Koo, M. 2003. Amphibians and reptiles of the Lassen National Forest: results of 02-CS-11050650-029. The 2002 California Academy of Sciences Survey. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville, CA 96130.

Welsh, H.H., Jr.; Pope, K.L. 2004. Impacts of introduced fishes on the native amphibians of northern California wilderness areas. Final report to the California Department of Fish and Game, 30 March. 22 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 1700 Bayview Drive, Arcata, CA 95521.

Appendix 5: Other Risk Factors

The following risk factors were identified because of their potential to negatively affect individuals or populations of Cascades frogs or their habitat. In an initial evaluation, they were deemed not to be of current or expected future major risk to the conservation of the species; however, they may be of concern at a local or regional level and may interact with other risk factors.

Habitat Loss

Direct habitat loss is one of the most visible causes of amphibian population declines (Lehtinen et al. 1999, Stuart et al. 2004). Habitat loss for many amphibians can be attributed to the conversion of wetlands to urban or agricultural use (Corn 1994). Much of the Cascades frog range is on public lands including wilderness areas or national parks at higher elevations. Thus, except in limited areas, opportunities for urbanization are lacking. However, increased population growth and development in northern California may put Cascades frog populations at risk from this kind of habitat loss in the future.

Other opportunities for habitat loss are a function of other risk factors discussed in their respective sections (e.g., see sections on "Introduced Fish and Other Predators" and "Recreation, Water Development, and Diversion").

Extent of risks—

Direct habitat loss by urbanization and agriculture is low risk for Cascades frogs because much of the species' range occurs on public lands. Habitat loss via urbanization and development is not currently considered to be significant, but may have local importance in parts of the species' range in California. Continued development in California may increase the importance of this factor in the future. However, other risk factors (e.g., introduced fish) may result in habitat loss and have severe consequences.

Conservation options—

Authorization and analysis of proposals for development and urbanization are directly within the jurisdiction of agencies participating in this conservation assessment through agency planning processes. Consideration of impacts to populations of Cascades frogs or their habitat could prevent unnecessary losses to populations and habitats.

Locally Applied Pesticides

In forested areas of California, pesticides are used to control rodents, insects, fungi, noxious weeds, and brush. In the past, aerial spraying of herbicides was experimented with on national forest lands, but was mostly terminated when water quality tests found that the herbicides were entering watercourses (USDA FS 2001b). In recent years, nearly all herbicide application on Forest Service lands is conducted via backpack sprayers, as this mode of ground application affords greater control of the spray direction and coverage. During the National Environmental Policy Act process for any project involving the application of a pesticide, buffers are designated around streams and water bodies to protect aquatic species from adverse effects. Buffer distances are determined depending on potential toxic effects of each herbicide type, the potential for them to enter the ground water or move offsite, and the known aquatic species that could be affected downstream.

The most common pesticides used on national forests in descending order of frequency are glyphosate, triclopyr, clopyralid, hexazinone, aminopyralid, chlorsulfuron, imazapyr, and aluminum phosphide (for burrowing rodents). Common surfactants include R-11, methylated seed oil (Hasten), methylated seed oil/silicone blend (Syl-tac), and dyes, including highlight blue, bas-oil red, and colorfast purple. Surfactants assist the herbicide with adhering to plant surfaces, and dyes assist with viewing where areas have been recently sprayed. Glyphosate has been studied for its potential to affect amphibians. In general, the isopropylamine salt of glyphosate, the active ingredient in Roundup® and Rodeo®, has been found to be practically nontoxic to frogs (Mann and Bidwell 1999). These commercial herbicides, however, may contain or be combined with surfactants such as polyethoxylated tallowamine (POEA), which have been shown to be toxic to aquatic life, including several species of ranid frogs (Folmar et al. 1979, Howe et al. 2004, Mann and Bidwell 1999, Mitchell et al. 1987, Servizi et al. 1987, Wan et al. 1989). Surfactants may affect aquatic organisms by damaging gills, which may be why tadpoles were found to be more sensitive to the full Roundup formulation of glyphosate than juveniles or adults (Bidwell and Gorrie 1995, Mann and Bidwell 1999). A recent study showing high toxicity of larval and postmetamorphic northern leopard frogs (*Rana pipiens*) to Roundup[1] may also be a function of POEA (Relyea 2005a); this study did not separate the effects of glyphosate and surfactant. Nevertheless, several studies (Giesy et al. 2000, Hildebrand et al. 1982, Mitchell et al. 1987, Sullivan et al. 1981, Thompson et al. 2004, Wojtaszek et al. 2004) have concluded that glyphosate-based herbicides under normal usage do not pose a hazard to aquatic environments where both the glyphosate and surfactant would be diluted by large or flowing bodies of water or protected by a terrestrial buffer. Past water quality monitoring in Region 5 of the USDA Forest Service has concluded that glyphosate (and triclopyr) are

---

[1] Use of trade or firm names in this publication are for reader information and do not imply endorsement of the U.S. Department of Agriculture of any product or service.

rarely detected in surface water when these herbicides are used with stream buffers (USDA FS 2001b). Triclopyr (Garlon®) and clopyralid (Transline®) are used to control noxious weeds. Both pesticides are applied from backpack sprayers, and use near water is avoided. Triclopyr, especially in its formulation marketed as Garlon 4, approaches the toxicity of surfactants used with various herbicides in terms of its effects on African clawed frog (*Xenopus laevis*) embryos (Perkins et al. 2000). Garlon 3A is the amine formulation of triclopyr (triclopyr TEA); is water-soluble, less volatile, and less toxic than Garlon 4 (Perkins et al. 2000) because it tends not to penetrate tissue or bioaccumulate. Berrill et al. (1994) measured the toxicity of three chemicals including triclopyr and hexazinone to embryos and tadpoles of three frog species. Embryos were not affected by triclopyr, whereas tadpoles became unresponsive to prodding (reflecting avoidance response) at exposures of 1.2 ppm (or higher) and mortality at higher doses (2.4 and 4.8 ppm). Tadpoles whose behavioral responses were affected recovered within 3 days. No effects to either embryos or tadpoles were observed from exposure to hexazinone.

Additive, multiplicative, or synergistic effects of herbicides with other risk factors have only recently begun to be studied among amphibians, and remain unstudied in Cascades frogs. Both Chen et al. (2004) and Edginton et al. (2004) found that the Vision® formulation of glyphosate increased in toxicity to the embryonic and larval stages of green frogs (*Rana clamitans*) and northern leopard frogs at higher pH treatments (≥7.5). Recently, Relyea (2005b) also emphasized the importance of examining pesticide effects in a community context. In an outdoor mesocosm experiment using larvae of three anuran species (gray treefrog [*Hyla versicolor*], American toad [*Bufo americanus*], and northern leopard frog), zooplankton, and algae, where combinations of predators (no predators; red-spotted newts [*Notophthalmus viridescens*]; and larval diving beetles [*Dytiscus* sp.]) and pesticides (no pesticides, the insecticide Malathion®, and the herbicide Roundup) were manipulated, Roundup (at a level of 1.3 mg of active ingredient/L) had substantial direct negative effects on the tadpoles, reducing total tadpole survival and biomass by 40 percent. However, Roundup had no indirect effects on the amphibian community via predator survival or algal abundance.

Extent of risks related to locally applied pesticides—
Pesticides are not often applied in or near waters across the majority of the Cascades frog range in California because the land is within designated wilderness areas, national parks, or in other sensitive habitat designations (meadow habitats in Lassen National Forest (NF). Outside of these protected areas, legal local spraying of pesticides may accidentally affect short-term water quality but is unlikely to have long-lasting or widespread effects on Cascade frog populations in California.

Unregulated use of pesticides associated with illegal use of public lands (e.g., illegal marijuana plantations) may affect local frog populations but very little information is known about amounts or types of pesticides applied.

Management considerations related to locally applied pesticides—
Continued regulation of locally applied pesticides to prevent impacts to Cascades frogs and their aquatic habitats would minimize potential impacts to this species. This is of particular importance in the southern Cascades where the species is rarest. Agencies participating in this conservation assessment have direct jurisdiction over this activity.

Mining

Several types of mining have occurred in the California range of the Cascades frog. Among these, hydraulic mining of placer deposits, instream and terrace mining of aggregate material, and suction dredge gold mining are discussed below as potential contributors to Cascades frog declines.

Hydraulic mining—
Hydraulic mining methods consisted of using water to erode away hillsides of placer (gravel, sand, or silt) deposits (CSLC 1993). Hydraulic mining drastically alters water quality and stream geomorphology by releasing pollutants such as acid, cadmium, mercury, and asbestos in waterways (CSLC 1993, Larson 1996). This practice has been outlawed since 1884, but its effects on water pollution may still be apparent in portions of the mid-elevation Pit and Feather River systems within the range of Cascades frogs. No studies of Cascades frogs have focused on any of these pollutants.

Aggregate mining—
Aggregate mining is conducted to obtain materials used in construction, such as roads, highways, and buildings. Industries performing such mining often prefer instream to terrace mining, as the aggregate requires minimal sorting and washing (CSLC 1993). Instream mining affects the geomorphology of rivers by changing sediment transport regimes, eroding beds and banks, and incising channels (CSLC 1993). Terrace mining, which occurs outside of the wetted perimeter of the river but within the floodplain, may result in creating large ponds filled by ground water; in flood events, these ponds may become connected to the river (CSLC 1993). Aggregate operations are typically found in larger riverine channels, downstream, and outside the range of the Cascades frog. Yet, the USDA Forest Service maintains a few small quarries for road construction, maintenance, and road treatments that occur within the Cascades frog range.

Suction-dredge gold mining—

Suction-dredgers seeking gold use a method in which water, sediment, and rocks are extracted from portions of streams and rivers and sorted to obtain gold (CSLC 1993). These activities may increase suspended sediment, change the geomorphology of the stream, directly remove aquatic organisms (potentially including Cascades frogs), and rearrange the substrate of streams (CDFG [now CDFW] 1994). Suction dredging activities have the potential to trap and kill juvenile or adult frogs using the stream corridor during the active season (see CDFG 1994). Since 2009, all California instream suction dredge mining has been suspended following the Governor's signature on state law SB 670, which prohibits the use of vacuum or suction dredge equipment in any California river, stream or lake, regardless of whether the operator has an existing permit issued by the state. The moratorium does not apply to suction dredging operations performed for the regular maintenance of energy or water supply management infrastructure, flood control, or navigational purposes.

Extent of risks related to mining—

Mining was common in the Klamath Mountains and has permanently altered numerous waterways within the range of the Cascades frog. It was much less common in the southern Cascades and has had minimal long-term consequences to frog habitats. Currently, mining is localized and rarely occurs within the range of the frog. Legacy effects of mining may be significant to habitats, but there is minimal risk of new impacts.

Conservation options related to mining—

Most mining activities do not currently overlap with Cascades frog's habitat. Continuing the ban on suction dredging would minimize potential future impacts to populations and habitats. Mining is within the jurisdiction of agencies participating in this assessment. Additional restoration of remnant tailing ponds that serve as habitat for invasive species such as American bullfrogs (*Lithobates catesbeiana*) could help alleviate indirect effects of mining resulting from the spread of detrimental invasive species.

Research Activity

Researchers have the potential to negatively affect anuran populations by handling or marking animals, attracting predators in numbers or frequencies greater than typical background levels, or spreading pathogens among water bodies via clothing and equipment. Currently, evidence is lacking to suggest that research activities have negatively affected Cascades frog populations. Andrew Blaustein, Gary Fellers, Deanna Olson, Karen Pope, Justin Garwood, and Hart Welsh have studied Cascades frogs intensively at several sites over several-year periods, and have not found evidence that their activities have negatively influenced frog survival (Blaustein and Wake 1990, Blaustein et al. 1995, Fellers and Drost 1993, Garwood 2009, Pope 2008, Pope et al. 2011,Welsh et al. 2006). Effects from these investigators are unlikely, but cannot be unequivocally excluded.

Historically, handling and marking of animals has been viewed as innocuous, but recent work addressing marking techniques (Murray and Fuller 2000) and pathogen epidemiology has led to a reassessment of this view. A review of studies involving toe-clipping to mark individual animals has revealed an incremental decrease in survivorship with each additional toe clipped, where previous analyses of the same data had revealed no effect across low numbers of clips (McCarthy and Parris 2004). No effects on survival or body condition have been found using passive integrated transponder tags, but comparison to unmarked reference animals have been restricted to laboratory analyses (Perret and Joly 2002), leaving open the question of how well such analyses translate to field conditions. Further, the poorly understood epidemiology of aquatic pathogens (e.g., chytrids, water molds; see section on “Disease”) has focused attention on their transmission between water bodies, and between diseased and healthy animals. Researchers now disinfect all sampling gear between surveys at different lakes, wash all sampling gear between frogs and use clean gloves or wash hands before handling a new animal (e.g., Johnson and Speare 2003, Piovia-Scott et al. 2011).

Extent of risks related to research activity—
Researchers typically have their study species’ best interest in mind when designing their studies. As long as researchers are aware of potential risks, take precautions to minimize those risks, and communicate with each other to reduce duplication in activities that may damage habitats or harass animals, then the extent of risks related to research activities should be minimal.

Conservation options related to research activity—
Agencies participating in this conservation assessment have a large amount of control over the extent and distribution of research activities. It is important that managers ensure that researchers consider potential impacts of their actions prior to initiating research and incorporate means to assess those impacts while conducting research. If risks are deemed to be stronger than benefits, research activities should be halted. Promotion of prophylactic measures that prevent disease transmission serves to mitigate potential risk from researchers moving among sites and handling multiple individuals.

Restoration Activities

Restoration refers to a large suite of activities that may involve remediation or restoration of degraded habitats, some of which have the potential to influence Cascades frogs. Historically limited, habitat restoration has become a prominent activity addressing degraded habitat, and is expected to become even more important in the future. Habitat restoration efforts may be diverse, but several categories of restoration may be important to Cascades frogs. These include:

- Fish removal from Cascades frog habitats—Fish removal may be the most significant restoration activity for Cascades frogs in lentic habitats. Population densities have increased significantly following fish removal and frogs have dispersed to previously unoccupied habitats. Recent experiments with mountain yellow-legged frogs (Vredenburg 2004, Knapp et al. 2007) and Cascades frogs (Pope 2008) have been successful at increasing abundances of frog populations. See sections on Introduced Fish and Other Exotic Predators and Existing Management and Research for more information.
- Meadow restoration activities that create ponded habitats such as "plug and pond" methods—Some restoration activities to raise the water table out of incised stream channels involve creation of ponded habitats. While a raised water table and ponded habitat per se may represent a benefit, ponded habitat with an inappropriate structure constructed within the dispersal range of bullfrog-occupied sites may negatively influence Cascades frogs.
- Meadow restoration efforts designed to reduce encroachment of lodgepole pines (*Pinus contorta* Douglas ex Loudon) into meadow systems (see Sharsmith 1961). This may improve breeding habitats by reducing shading (solar exposure is important for embryonic development) and, potentially increasing water availability by raising the water table.
- Efforts designed specifically to improve breeding conditions for Cascades frogs—Efforts have been initiated to augment pools in a few meadows on the Lassen NF to increase the hydroperiod and provide cool water refuges for larvae. The Forest Service expanded or deepened five known breeding pools, supplemented water inflow at two, and dug seven additional pools (Pope et al. 2011). They have begun monitoring of egg mass and larval survival in these restored habitats.

Monitoring is needed to evaluate both the positive and negative effects of various types of restoration on Cascades frogs.

Extent of risks related to restoration—
Restoration activities are anticipated to increase within the range of the Cascades frog in California. Some activities such as fish removals and breeding habitat improvement projects are designed to specifically improve conditions for Cascade frog populations and have minimal risk involved. Risks associated with other projects with different goals, such as restoring meadow hydrology and vegetation, are less clear and may be positive or negative. The potential effects of restoration techniques such as "pond and plug" have just begun to be examined in relation to positive and negative effects to native amphibians.

Conservation options related to restoration—
Restoration efforts are promising for preserving and improving population persistence of Cascades frogs. Restoration of fishless waters would greatly contribute to the conservation of this species. In addition, breeding habitat enhancement could improve tadpole survival to metamorphosis, and localized vegetation thinning could increase appropriate basking habitats. Examination of potential watershed-level efforts to increase water input and persistence to meadow habitats in the southern Cascades could also be valuable for improving aquatic habitat conditions in a changing climate. Restoration, through regional planning processes, is under the jurisdiction of agencies participating in this conservation assessment. Science and monitoring is needed to inform how different types of restoration may affect Cascades frogs and their habitat, from both short- and long-term perspectives.

Roads

Roads are prominent features throughout the Cascades frog range outside of wilderness areas, and include all types, from little-used logging roads to major interstate highways. Six major highways (Interstate 5 and Highways 32, 36, 44, 89, and 299) partly or completely fragment portions of the Cascades frog range in California. Interstate 5 runs between the populations in the Klamath Mountains to the west and southern Cascade Range to the east. Roughly 62 percent of the Cascades frog range occurs on national forest lands that contain a total of 115 km of paved roads (primary/secondary highways and improved paved roads), 258 km of gravel roads, 1714 km of dirt roads (dirt and unimproved dirt roads) and 300 km of trails (USDA FS 2001c).

The degree to which roads affect Cascades frogs has not been studied, and depends on many factors such as road density, road type, and traffic intensity. Most populations of Cascades frogs are not likely to be affected by roads directly (i.e., via mortality from collision with vehicles) because the frogs rarely move away from water so would have little reason to cross a road surface. However, indirect effects to their habitats and dispersal ability may be significant. At least eight physical characteristics of the environment may be altered by roads: soil density, temperature, soil water content, light, dust, surface-waterflow, pattern of runoff, and sedimentation (Trombulak and Frissell 2000). Because Cascades frogs depend on aquatic habitats for survival and successful recruitment, changes in the hydrology of the high mountain lake, meadow, and stream systems they inhabit, may be detrimental. These areas can be affected by fluctuations in the frequency or magnitude of peak and debris flows of adjacent streams. Because Cascades frogs require breeding sites that are sufficiently deep to avoid drying or freezing of eggs or larvae, fluctuations that ultimately cause a reduction in available water could severely affect recruitment. In contrast, a drastic increase in flooding or debris flows could dislodge, bury, or destroy eggs deposited in pond shallows (see "Habitat Requirements in Ecology" section).

Roads may also serve as barriers to frog movement. Road crossings of water courses may block in-channel migrations and dispersal events because culverts are too steep, become blocked by debris, or become disconnected from the streambed (i.e., hanging culverts). Research on habitat fragmentation is biased towards highly fragmented landscapes, but one study was done in Europe on the moor frog (*Rana arvalis*) in lessfragmented habitat (Vos and Chardon 1998). This study revealed that roads increase isolation, and therefore contribute to habitat fragmentation (Vos and Chardon 1998). The study also showed that even in a relatively large and stable habitat patch, the effects of habitat fragmentation on frog populations were strongly negative (Vos and Chardon 1998). Barriers or partial barriers as a result of fragmentation may have a strong effect on populations of Cascades frog if they operate as metapopulations (Bradford 1991). Barriers, such as roads, could prevent recolonization of locations where extirpations have occurred.

Maintenance and use of roads have the potential to contribute at least five different general classes of chemicals to the environment: heavy metals, salt, organic molecules, ozone, and nutrients (Trombulak and Frissell 2000). These chemicals plus pollution from vehicular emissions and road runoff contain various toxic chemicals that can have negative effects on amphibian populations, including reduced survival, deformities in tadpole oral cavities, elevated levels of stress hormones, and inhibited growth and metamorphosis (Lefcort et al. 1997, Mahaney 1994, Welsh and Ollivier 1998). Similarly, roads may cause increases in sedimentation and water pollutants (Spellerberg 1998).

Direct transfer of sediment (and other material) to streams and other water bodies at road crossings is an inevitable consequence of road construction (Richardson et al. 1975). The surfaces of unpaved roads can route fine sediments to streams, lakes, and wetlands, increasing turbidity of the water (Reid and Dunne 1984). High concentrations of suspended sediment may directly kill aquatic organisms and impair aquatic productivity (Newcombe and Jensen 1996). The effects are further heightened if the sediments contain toxic materials (Maxell and Hokit 1999). Increased sedimentation may also reduce availability of important food resources for tadpoles like algae (Power 1990). Fine sediment deposits also tend to fill pools and smooth gravel beds, degrading habitats (Forman and Alexander 1998).

New road construction often facilitates increased human use of newly roaded areas. An increase in human activity may increase direct and indirect road effects previously discussed. Much of Cascades frog habitat lies within national forests, which have many roads, and some conversion of unimproved roads to more developed roads occurs over time; thus, significant opportunity exists for increased human use and vehicular traffic in that landscape. National parks and wilderness areas are unlikely to expand their road networks (NPS 2005), so an increase in human use in these areas, which may result from population growth, will not be facilitated by new road construction or conversion toward more developed roads. However, increased use of existing roads can be anticipated.

Extent of risks related to roads—

In Lassen Volcanic National Park (NP) and wilderness areas in the Klamath Mountains, the risks related to roads are low. However, outside these areas, and particularly on private lands and on the Lassen and Klamath NFs, risks associated with population isolation and habitat alteration are expected to be moderate.

Conservation options related to roads—

Agencies manage road construction, planning, and proliferation to minimize impacts to aquatic habitats. Special attention in areas known to be upstream of Cascades frog breeding habitats would minimize potential short- or long-term impacts to these sensitive areas. These activities are within the jurisdiction of agencies participating in this conservation assessment.

UV-B Radiation

Increases in mid-range ultraviolet radiation (UV-B; 290-320 nanometers) resulting from depletion of atmospheric ozone are hypothesized to contribute to amphibian declines (Blaustein and Wake 1990, Wake 1991). Yet, experimental and field studies addressing UV-B are controversial and have produced mixed results (Licht and Grant 1997), suggesting that the actual effects on amphibian growth and survivorship vary across a variety of conditions (e.g., species, life stages, and habitats) and that this factor is, at best, limited in its ability to explain declines (Licht 2003).

To date, much work on UV-B has involved experiments that address the vulnerability of the embryos and newly laid eggs of several amphibian species found in western North America. This work has shown that the direct effects of exposure to elevated UV-B resulted in reduced hatching success, reduced larval growth rates, or sometimes increased physical abnormalities (Anzalone et al. 1998, Belden et al. 2000, Blaustein et al. 1994b). Differences in responses among species have been attributed in part to differences in the behavioral, physiological, and molecular defenses these amphibians possess against UV-B (Blaustein and Belden 2003); for example, Pacific treefrogs (*Pseudacris regilla*), Columbia spotted frogs (*Rana luteiventris*), northern red-legged frogs (*Rana aurora*), and Oregon spotted frogs (*Rana pretiosa*) possess two to five times as much of the UV-B damage repair enzyme photolyase as Cascades frogs, western toads, and long-toed salamanders from western Oregon (Blaustein et al. 1998).

Most studies of UV-B effects on amphibians have focused on the egg stage, but some studies have shown that the effects of exposure can extend beyond the egg stage (e.g., Ankley et al. 2000, 2002). In particular, some ranid frog species appear most susceptible to UV-B exposure between hatching and late larval stages of development (Ankley et al. 2002, Tietge et al. 2001). Further, the possibility that UV-B exposure of embryos may have more subtle effects than direct mortality remains poorly studied. In studies in which embryos and tadpoles of the northern red-legged frog were exposed to sublethal UV-B levels, exposed animals had depressed growth rates when compared to a control group (Belden and Blaustein 2002). Little has been done to address UV-B effects on the postmetamorphic stages of anurans, although Fite et al. (1998) described retinal damage found in adult wild-collected Cascades frogs as similar to UV-B-induced retinal damage in adult northern leopard frogs as evidence that Cascades frogs are exposed to increased UV-B radiation; unexposed Cascades frogs were not available for controls.

Although field and laboratory experiments suggest that embryos and larvae of some ranid frogs can either be killed or sustain sublethal damage from UV-B exposure, information from the environments in which these life stages exist suggest that habitat conditions for large geographic areas in western North America limit UV-B exposure (Licht 1996, 2003). Notably, the realization that dissolved organic material (DOM) or dissolved organic carbon (DOC) can effectively absorb UV-B (Morris et al. 1995, Scully and Lean 1994) has refocused attention on the levels of these solutes in the aquatic habitats amphibians use. Levels of DOM/DOC in 85 percent of 136 western toad breeding sites in the Cascade Mountains of Oregon and Washington were sufficient to reduce UV-B to levels below those that Blaustein et al. (1994a) had found to affect embryos (Palen et al. 2002). Further, the percentage of these breeding sites over which UV-B radiation did not reach the potentially harmful levels that Blaustein et al. (1994a) described were similar for three other montane species: Cascades frog, northwestern salamander (*Ambystoma gracile*), and long-toed salamander (Palen et al. 2002). In addition, Adams et al. (2001) examined the distribution of three amphibians in the montane Pacific Northwest and found that Cascades frogs were most likely to breed in fishless shallow ponds with relatively low transmission of UV-B radiation. Davidson et al. (2002) examined the spatial pattern of population declines in Cascades frogs as well as six other anuran species to see if patterns were consistent with what might be expected with a UV-B effect (e.g., an increase in declines at higher elevations and more southern latitudes, coincident with altitudinal and latitudinal patterns of increased UV-B). They found no significant pattern of change in occupancy with elevation; a decrease in occupancy with elevation would be expected if declines were the result of UV-B. Most recently, Adams et al. (2005) compared amphibian presence to site-specific estimates of UV-B levels in 683 ponds and lakes in across a broad geographic range in western North America that included sites in Olympic NP in western Washington state and Sequoia-Kings Canyon NPs in the southern Sierra Nevada. Of eight amphibian species examined, only three species (long-toed salamanders, Pacific treefrogs, and roughskin newts [*Taricha granulosa*]) showed relationships with UV-B that were potentially attributable to negative effects. No relationship was found between the occupancy of lakes and ponds by Cascades frog and UV-B dose in Olympic NP, the only location that Adams et al. (2005) studied in which Cascades frogs were present.

Failure to reveal a convincing link between amphibian declines and UV-B may result from the fact that significant effects are more likely if UV-B interacts with another stressor. Kiesecker et al. (2001) hypothesized that periodic mass mortality of toad embryos in Oregon resulted from a synergism between UV-B radiation, the pathogenic watermold *Saprolegnia ferax*, and the climatic event El Niño. Long et al. (1995) found that embryos of northern leopard frogs exposed to levels of UV-B and low pH that were nonlethal when each was individually applied produced significant mortality when the same levels of each stressor were applied simultaneously. A similar synergism between UV-B and low pH was observed for embryos of the common frog, *Rana temporaria* (Pahkala et al. 2002). Kiesecker and Blaustein (1995) found that exposing Cascades frog embryos to UV-B increased mortality from *S. ferax* over embryos treated by the same levels of each alone. Many other additive or synergistic effects are possible, but remain unstudied in Cascades frogs.

Extent of risks related to UV-B radiation—
Increased UV-B radiation does not appear to be a primary factor in the rangewide decline of Cascades frogs. However, the synergistic relationships between UV-B, other stressors, and frog declines is poorly understood, so UV-B has the potential

to contribute to declines in ways that remain unidentified. Moreover, levels of ambient UV-B appear to be still on the increase (Middleton et al. 2001) so effects of increased UV-B on Cascades frogs may occur at some threshold level that becomes manifest in the future.

Conservation options related to UV-B radiation—
At this time, UV-B radiation does not warrant management consideration. Should the risk level for this risk factor increase, effective management would require coordination of agencies outside the jurisdiction of those involved in this assessment. Agencies responsible for Cascades frog management could participate in guiding the development of the management and science to inform this issue.

Vegetation and Fuels Management

Vegetation and fuels management encompasses all management activities that alter vegetation structure and composition, including timber harvest, fuels management, salvage logging, and prescribed fire. Changes in vegetation, shade, and woody debris can alter breeding, active-season, refuge, and overwintering habitat quality. Changes in vegetation can also influence soil stability, erosion, and sediment loading to aquatic habitats. These activities can pose a risk to Cascades frogs in areas of their range where such activities are permitted (e.g., national forest lands outside of wilderness areas).

The effects of controlled burns for fuel reduction on fauna, including Cascades frogs, are poorly understood (Pilliod et al. 2003). Prescribed fire could benefit Cascades frogs if it reduced the risk of future high-intensity wildfire or reduced encroachment of woody vegetation into meadows that provide aquatic habitat for frogs. One hypothesis for the declines of this species in the Lassen area is the loss of open meadow habitat resulting from fire suppression (Fellers and Drost 1993). Some of the Cascades frog range is on granitic soils, so improperly implemented prescribed burning could be risky because erosion rates of burned areas on such soils can be 66 times as great as in undisturbed watersheds, and can elevate annual sediment yields for 10 years or more (Megahan et al. 1995).

Extent of risks related to vegetation management—
Overall, the risk of vegetation and fuels management activities is low because most of the range of the Cascades frog is protected. If activities occur in areas adjacent to habitat for Cascades frogs on Forest Service lands, vegetation management activities are generally on a small scale and closely regulated. Outside of these areas, risk depends on a project's scale, intensity, and proximity to Cascades frog populations. Fire management that preserves open aquatic habitats may benefit the species in the longterm.

Conservation options related to vegetation management—
Precautions taken to minimize potential impacts, such as sediment loading, to Cascades frog habitats would reduce risks associated with vegetation and fuels management. On a smaller scale, selected actions intended to reduce lodgepole pine encroachment in meadows or to thin overstory vegetation in riparian areas may benefit habitat for Cascades frogs because all life stages of Cascades frogs use open habitats. These activities are directly within the jurisdiction of agencies participating in this conservation assessment.

Water Development and Diversion

Water developments, such as dams and diversions, can radically change aquatic habitats and are a prominent component of the landscape in the Sierra Nevada Forest Planning Area (Harris et al. 1987, Moyle and Randall 1998), and Klamath Mountains. Most major water development and diversions, whether assessed based on number, scale, or size, have occurred at lower elevations (Moyle and Randall 1998), and much of them below 1219 m, or below much of the elevation range over which Cascades frogs are known to occur (see “Status” section). However, dams and water diversions also exist in higher elevation areas that have more overlap with the Cascades frog range. Purposes of these water developments are varied but primarily include hydroelectric power generation and water storage.

Dams likely to be found in Cascades frog areas may raise the levels of existing lakes or ponds or flood meadow habitat, eliminating or in some cases creating Cascades frog habitat. Diversions may alter the hydrology and water retention at a site potentially affecting breeding.

Major water projects within the southern Cascades that overlap with the species’ range are limited to the Pit River system and North Fork Feather River (e.g., Lake Almanor, Butt Valley Reservoir). Selected smaller water projects are located within the West Branch Feather River watershed (e.g., Snag Lake and Philbrook Lake). Elsewhere, the headwater reaches of a number of drainages (e.g., Butte Creek, Deer Creek, Mill Creek, Battle Creek) with current or historical Cascades frog populations remain hydrologically undeveloped. Major water projects within the Klamath Mountains include Shasta and Trinity Dams on the upper Sacramento River and upper Trinity River systems, respectively. In addition to these, about 15 small lakes and meadow systems in the known historical range of the Cascades frog in California have some form of hydrological development. The majority of these consist of small dam structures to raise the water level of an existing water body (e.g., Gumboot Lake). However, most of the headwater area of the Klamath Mountains lacks water development.

Extent of risks related to water development and diversions—
Existing dams and diversions are not a widespread risk for Cascades frogs (although, through initial development of such structures, they may have eliminated critical areas of historical habitat and increased fragmentation). Most of the Cascades frog range is at relatively high elevations where water development and diversion projects are few and are generally small. However, where dams and diversions occur, local impacts can be significant and permanent.

Conservation options related to water development and diversions—
Preventing or mitigating future water development and diversion projects where they overlap with Cascades frog habitat would minimize impacts to Cascades frogs. Permitting for water developments and diversion are directly or indirectly within the jurisdiction of agencies participating in this conservation assessment.

References

Adams, M.J.; Hossack, B.R.; Knapp, R.A.; Corn, P.S.; Diamond, S.A.; Trenham, P.C.; Fagre, D.B. 2005. Distribution patterns of lentic-breeding amphibians in relation to ultraviolet radiation exposure in western North America. Ecosystems. 8: 488–500.

Adams, M.J.; Schlinder, D.E.; Bury, R.B. 2001. Association of amphibians with attenuation of ultraviolet-b radiation in montane ponds. Oecologia. 128: 519–525.

Ankley, G.T.; Diamond, S.A.; Tietge, J.E.; Holcombe, G.W.; Jensen, K.M.; DeFoe, D.L.; Peterson, R. 2002. Assessment of the risk of ultraviolet radiation to amphibians. I. Dose-dependent induction of hind limb malformations in the northern leopard frog (*Rana pipiens*). Environmental Science and Technology. 36: 2853–2858.

Ankley, G.T.; Tietge, J.E.; Holcombe, G.W.; DeFoe, D.L.; Diamond, S.A.; Jensen, K.M.; Degitz, S.J. 2000. Effects of laboratory ultraviolet radiation and natural sunlight on survival and development of *Rana pipiens*. Canadian Journal of Zoology. 78: 1092–1100.

Anzalone, C.R.; Kats, L.B.; Gordon, M.S. 1998. Effects of solar UV-B radiation on embryonic development in *Hyla cadaverina*, *Hyla regilla*, and *Taricha torosa*. Conservation Biology. 12: 646–653.

Belden, L.K.; Blaustein, A.R. 2002. Exposure of red-legged frog embryos to ambient UV-B radiation in the field negatively affects larval growth and development. Oecologia. 130: 551–554.

Belden, L.K.; Wildy, E.L.; Blaustein, A.R. 2000. Growth, survival, and behaviour of larval long-toed salamander (*Ambystoma macrodactylum*) exposed to ambient levels of UV-B radiation. Journal of Zoology. 251: 473–479.

Berrill, M.; Bertram, S.; McGillivray, L.; Kolohon, M.; Pauli, B. 1994. Effects of low concentrations of forest-use pesticides on frog embryos and tadpoles. Environmental Toxicology and Chemistry. 13: 657–664.

Bidwell, J.R.; Gorrie, J.R. 1995. Acute toxicity of a herbicide to selected frog species. Perth, Australia: Department of Environmental Protection, Technical Series. 79: 8–9.

Blaustein, A.R.; Beatty, J.J.; Olson, D.H.; Storm, R.M. 1995. The biology of amphibians and reptiles in old-growth forests in the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-337. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 98 p.

Blaustein, A.R.; Belden, L.K. 2003. Amphibian defenses against ultraviolet-B radiation. Evolution and Development. 5: 89–97.

Blaustein, A.R.; Hoffman, P.D.; Hokit, D.G.; Kiesecker, J.M.; Walls, S.C.; Hays, J.B. 1994a. UV repair and resistance to solar UVb in amphibian eggs: a link to population declines? Proceedings of the National Academy of Sciences of the United States of America. 91: 1791–1795.

Blaustein, A.R.; Hokit, D.G.; O'Hara, R.K.; Holt, R.A. 1994b. Pathogenic fungus contributes to amphibian losses in the Pacific Northwest. Biological Conservation. 67: 251–254.

Blaustein, A.R.; Kiesecker, J.M.; Chivers, D.P.; Hokit, D.G.; Marco, A.; Belden, L.K.; Hatch, A. 1998. Effects of ultraviolet radiation on amphibians: field experiments. American Zoologist. 38: 799–812.

Blaustein, A.R.; Wake, D.B. 1990. Declining amphibian populations: a global phenomenon? Trends in Ecology and Evolution. 5: 203–204.

Bradford, D.F. 1991. Mass mortality and extinction in a high elevation population of *Rana muscosa*. Journal of Herpetology. 25: 174–177.

California Department of Fish and Game [CDFG]. 1994. Adoption of regulations for suction dredge mining. Amended Draft Environmental Impact Report. Rancho Cordova, CA. 182 p.

Chen, C.Y.; Hathaway, K.M.; Folt, C.L. 2004. Multiple stress effects of Vision® herbicide, pH, and food on zooplankton and larval amphibian species from forest wetlands. Environmental Toxicology and Chemistry. 23: 823–831.

Corn, P.S. 1994. What we know and don't know about amphibian declines in the West. In: Covington, W.W.; DeBano, F.L., tech. coords. Sustainable ecology systems: implementing an ecological approach to land management. Gen. Tech. Rep. RM-GTR-247. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest Range and Experiment Station: 59–67.

California State Lands Commission [CSLC]. 1993. California's rivers: a public trust report. Sacramento, CA. 334 p.

Davidson, C.; Shaffer, H.B.; Jennings, M.R. 2002. Spatial tests of the pesticide drift, habitat destruction, UV-B, and climate-change hypotheses for California amphibian declines. Conservation Biology. 16: 1588–1601.

Edginton, A.N.; Sheridan, P.M.; Stephenson, G.R.; Thompson, D.G.; Boermans, H.J. 2004. Comparative effects of pH and Vision® herbicide on two life stages of four anuran amphibian species. Environmental Toxicology and Chemistry. 23: 815–822.

Fellers, G.M.; Drost, C.A. 1993. Disappearance of the Cascades frog *Rana cascadae* at the southern end of its range, California, USA. Biological Conservation. 65: 177–182.

Fite, K.V.; Blaustein, A.R.; Bengston, L.; Hewitt, H.E. 1998. Evidence of retinal light damage in *Rana cascadae*: a declining amphibian species. Copeia. 1998: 906–914.

Folmar, L.C.; Sanders, H.O.; Julin, A.M. 1979. Toxicity of the herbicide glyphosate and several of its formulations to fish and aquatic invertebrates. Archives of Environmental Contamination and Toxicology. 8: 269–278.

Forman, R.T.T.; Alexander, L.E. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics. 29: 207–231.

Garwood, J.M. 2009. Spatial ecology of the Cascades frog: identifying dispersal, migration, and resource uses at multiple spatial scales. Arcata, CA: Humboldt State University. 97 p. M.S. thesis.

Giesy, J.P.; Dobson, S.; Solomon, K.R. 2000. Ecotoxicological risk assessment of Roundup® herbicide. Reviews of Environmental Contamination and Toxicology. 167: 35–120.

Harris, R.R.; Fox, C.A.; Risser, R. 1987. Impacts of hydroelectric development on riparian vegetation in the Sierra Nevada region, California, USA. Environmental Management. 11: 519–527.

Hildebrand, L.D.; Sullivan, D.S.; Sullivan, T.P. 1982. Experimental studies of rainbow trout populations exposed to field applications of Roundup herbicide. Archives of Environmental Contamination and Toxicology. 11: 93–98.

Howe, C.M.; Berrill, M.; Pauli, B.D.; Helbing, C.C.; Werry, K.; Veldhoen N. 2004. Toxicity of glyphosate-based pesticides to four North American frog species. Environmental Toxicology and Chemistry. 23: 1928–1938.

Johnson, M.; Speare, R. 2003. Survival of *Batrachochytrium dendrobatidis* in water: quarantine and control implications. Emerging Infectious Diseases. 9: 922–925.

Kiesecker, J.M.; Blaustein, A.R. 1995. Synergism between UV-B radiation and a pathogen magnifies amphibian embryo mortality in nature. Proceedings of the National Academy of Sciences of the United States of America. 92: 11049–11052.

Kiesecker, J.M.; Blaustein, A.R.; Belden, L.K. 2001. Complex causes of amphibian population declines. Nature. 410: 681–684.

Knapp, R.A.; Boiano, D.M.; Vredenburg, V.T. 2007. Removal of non-native fish results in population expansion of a declining amphibian (mountain yellow-legged frog, *Rana muscosa*). Biological Conservation. 135: 11–20.

Larson, D.J. 1996. Historical water-use priorities and public policies. In: Sierra Nevada Ecosystem Project. Final report to Congress. Volume II. Davis, CA: University of California, Centers for Water and Wildland Resources Report. (37): 163–185. Chapter 8.

Lefcort, H.; Hancock, K.A.; Maur, K.M.; Rostal, D.C. 1997. The effects of used motor oil, silt and the water mold *Saprolegnia parasitica* on the growth and survival of mole salamanders (genus *Ambystoma*). Archives of Environmental Contamination and Toxicology. 32: 383–388.

Lehtinen, R.M.; Galatowitsch, S.M.; Tester, J.R. 1999. Consequences of habitat loss and fragmentation for wetland amphibian assemblages. Wetlands. 19: 1–12.

Licht, L.E. 1996. Amphibian decline still a puzzle. BioScience. 46: 172–173.

Licht, L.E. 2003. Shedding light on ultraviolet radiation and amphibian embryos. BioScience. 53: 551–561.

Licht, L.E.; Grant, K.P. 1997. The effects of ultraviolet radiation on the biology of amphibians. American Zoologist. 37: 137–145.

Long, L.E.; Saylor, L.S.; Soule, M.E. 1995. A pH/UV-B synergism in amphibians. Conservation Biology. 9: 1301–1303.

Mahaney, P.A. 1994. The effects of freshwater petroleum contamination on amphibian hatching and metamorphosis. Environmental Toxicology. 13: 259–265.

Mann, R.M.; Bidwell, J.R. 1999. The toxicity of glyphosate and several glyphosate formulations to four species of southwestern Australian frogs. Archives of Environmental Contamination and Toxicology. 26: 193–199.

Maxell, B.A.; Hokit, D.G. 1999. Amphibians and reptiles. In: Joslin, J.; Youmans, H., comm. chairs. Effects of recreation on Rocky Mountain wildlife: a compendium of the current state of understanding in Montana. Kalispell, MT: Montana Chapter of the Wildlife Society, Committee on Effects of Recreation on Wildlife: 2.1–2.30.

Megahan, W.F.; King, J.G.; Seyedbagheri, K.A. 1995. Hydrologic and erosional responses of a granitic watershed to helicopter logging and broadcast burning. Forest Science. 41: 777–795.

McCarthy, M.A.; Parris, K. M. 2004. Clarifying the effects of toe clipping on frogs with Bayesian statistics. Journal of Applied Ecology. 41: 780–786.

Middleton, E.M.; Herman, J. R.; Celarier, E.A.; Wilkinson, J.W.; Carey, C.; Ruskin, R.J. 2001. Evaluating ultraviolet radiation exposure with satellite data at sites of amphibian declines in Central and South America. Conservation Biology. 15: 914–929.

Mitchell, D.; Chapman, P.; Long, T. 1987. Seawater challenge testing of Coho salmon smolts following exposure to Roundup herbicide. Environmental Toxicology and Chemistry. 6: 875–878.

Morris, D.P.; Zagarese, H.; Williamson, C.E.; Balseiro, E.G.; Hargreaves, B.R.; Modenutti, B.; Moeller, R.; Queimalinos, C. 1995. The attenuation of solar UV radiation in lakes and the role of dissolved organic carbon. Limnology and Oceanography. 40: 1381–1391.

Moyle, P.B.; Randall, P.J. 1998. Evaluating the biotic integrity of watersheds in the Sierra Nevada, California. Conservation Biology. 12: 1318–1326.

Murray, D.L.; Fuller, M.R. 2000. A critical review of the effects of marking on the biology of vertebrates. In: Boitani, L.; Fuller, T.K., eds. Research techniques in animal ecology: controversies and consequences. New York, NY: Columbia University Press: 15–64. Chapter 2.

Newcombe, C.P.; Jensen, J.O.T. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. North American Journal of Fisheries Management. 16: 693–727.

Pahkala, M.; Räsänen, K.; Laurila, A.; Johanson, U.; Björn, L.O.; Merilä, J. 2002. Lethal and sublethal effects of UV-B/pH synergism on common frog embryos. Conservation Biology. 16: 1063–1073.

Palen, W.J.; Schindler, D.E.; Adams, M.J.; Pearl, C.A.; Bury, R.B.; Diamond, S.A. 2002. Optical characteristics of natural waters protect amphibians from UV-B in the Pacific Northwest. Ecology. 83: 2951–2957.

Perkins, P.J.; Boermans, H.J.; Stephenson, G.R. 2000. Toxicity of glyphosate and triclopyr using the frog embryos teratogenesis assay—*Xenopus*. Environmental Toxicology and Chemistry 19: 940–945.

Perret, N.; Joly, P. 2002. Impacts of tattooing and PIT-tagging on survival and fecundity in the alpine newt (*Triturus alpestris*). Herpetologica. 58: 131–138.

Pilliod, D.S.; Bury, R.B.; Hyde, E.J.; Pearl, C.A.; Corn, P.S. 2003. Fire and amphibians in North America. Forest Ecology and Management. 178: 163–181.

Piovia-Scott, J.; Pope, K.L.; Lawler, S.P.; Cole, E.M.; Foley, J.E. 2011. Factors related to the distribution and prevalence of the fungal pathogen *Batrachochytrium dentrobatidis* in *Rana cascadae* and other amphibians in the Klamath Mountains. Biological Conservation. 144: 2913–2921.

Pope, K.L. 2008. Assessing changes in amphibian population dynamics following experimental manipulations of introduced fish. Conservation Biology. 22: 1572-1581.

Pope, K.L.; Larson, M.D.; Piovia-Scott, J. 2011. Status of remnant populations of Cascades Frogs (*Rana cascadae*) in the Lassen area of California. Final report for years 2008-2010 to the US Forest Service, Lassen National Forest, ISA #05-06-03. 38 p. Unpublished report. On file with: U.S. Department of Agriculture, Forest Service, Lassen National Forest, 2550 Riverside Drive, Susanville CA 96130.

Power, M.E. 1990. The importance of sediment in the grazing ecology and size class interactions of an armored catfish, *Aneistrus spinosus*. Environmental Biology of Fish. 10: 173–181.

Reid, L.M.; Dunne, T. 1984. Sediment production from forest road surfaces. Water Resources Research. 20: 1753–1761.

Relyea, R.A. 2005a. The lethal impact of Roundup on aquatic and terrestrial amphibians. Ecological Applications. 15: 1118–1124.

Relyea, R.A. 2005b. Pesticides and amphibians: the importance of community context. Ecological Applications 15: 1125–1134.

Richardson, E.V.; Simons, B.; Karaki, S.; Mahmood, M.; Stevens, M.A. 1975. Highways in the river environment: hydraulic and environmental design considerations training and design manual. Washington, DC: U.S. Department of Transportation, Federal Highway Administration. 453 p.

Scully, N.M.; Lean, D.S. 1994. The attenuation of ultraviolet radiation in temperate lakes. Archives für Hydrobiologie. 43: 135–144.

Servizi, J.A.; Gordon, R.W.; Martens, D.W. 1987. Acute toxicity of Garlon 4 and Roundup herbicides to salmon, *Daphnia*, and trout. Bulletin of Environmental Contamination and Toxicology. 39: 15–22.

Sharsmith, C.W. 1961. A report on the status, changes and comparative ecology of selected back country meadows in Yosemite National Park that receive heavy visitor use. 58 p. Unpublished report. On file with: U.S. Department of the Interior, National Park Service, Yosemite National Park, El Portal, CA 95318.

Spellerberg, I.F. 1998. Ecological effects of roads and traffic: a literature review. Global Ecology and Biogeography Letters. 7: 317–333.

Stuart, S.N.; Chanson, J.S.; Cox, N.A.; Young, B.E.; Rodrigues, A.S.L.; Fischman, D.L.; Waller, R.W. 2004. Status and trends of amphibian declines and extinctions worldwide. Science. 306: 1783–1786.

Sullivan, D.S.; Sullivan, T.P.; Bisalputra, T. 1981. Effects of Roundup® herbicide on diatom populations in the aquatic environment of a coastal forest. Bulletin of Environmental Contamination and Toxicology. 26: 91–96.

Thompson, D.G.; Wojtaszek, B.F.; Staznik, B.; Chartrand, D.T.; Stephenson, G.R. 2004. Chemical and biomonitoring to assess potential acute effects of Vision® herbicide on native amphibian larvae in forest wetlands. Environmental Toxicology and Chemistry. 23: 843–849.

Tietge, J.E.; Diamond, S.A.; Ankley, G.T.; DeFoe, D.L.; Holcombe, G.W.; Jensen, K.M.; Degitz, S.J.; Elonen, G.E.; Hammer, E. 2001. Ambient solar UV radiation causes mortality in larvae of three species of *Rana* under controlled exposure conditions. Photochemistry and Photobiology. 74: 261–268.

Trombulak, S.C.; Frissell, C.A. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology. 14: 18–30.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2001b. Letter to Forest supervisors. Herbicides and ground/surface water monitoring. On file with: Pacific Southwest Region, 1323 Club Drive, Vallejo, CA 94592.

U.S. Department of Agriculture, Forest Service [USDA FS]. 2001c. Unpublished geographic information system (GIS) data. On file with: Pacific Southwest Region, 1323 Club Drive, Vallejo, CA 94592.

U.S. Department of the Interior, National Park Service [USDI NPS]. 2005. Repave and rehabilitate a portion of the Lassen Volcanic National Park highway (mileposts 6.7 to 28.4) Environmental assessment. Unpublished report. Mineral, CA: U.S. Department of Interior, National Park Service.

Vos, C.C.; Chardon, J. P. 1998. Effects of habitat fragmentation and road density on the distribution pattern of the moor frog *Rana arvalis*. Journal of Applied Ecology. 35: 44–56.

Vredenburg, V. 2004. Reversing introduced species effects: experimental removal of introduced fish leads to rapid recovery of a declining frog. Proceedings of the National Academy of Sciences of the United States of America. 101: 7646–7650.

Wake, D.B. 1991. Declining amphibian populations. Science. 253: 860.

Wan, M.T.; Watts, R.G.; Moul, D.J. 1989. Effects of different dilution water types on the acute toxicity to juvenile Pacific salmonids and rainbow trout of glyphosate and its formulated products. Bulletin of Environmental Contamination and Toxicology. 43: 378–385.

Welsh, H.H., Jr.; Ollivier, L.M. 1998. Stream amphibians as indicators of ecosystem stress: a case study from California's redwoods. Ecological Applications. 8: 1118–1132.

Welsh, H.H., Jr.; Pope, K.L.; Boiano, D. 2006. Subalpine amphibian distributions related to species palatability to non-native salmonids in the Klamath Mountains of northern California. Diversity and Distributions. 12: 298–309.

Wojtaszek, B.F.; Staznik, B.; Chartrand, D.T.; Stephenson, G.R.; Thompson, D.G. 2004. Effects of Vision® herbicide on mortality, avoidance response, and growth of amphibian larvae in two forest wetlands. Environmental Toxicology and Chemistry. 23: 832–842.

Appendix 6: Cascades Frog Working Group

Aguilar, Bernard
Associate Fisheries Biologist
California Department of Fish and Wildlife
P.O. Box 1640
Weaverville, CA 96093
(530) 778-0218
(530) 778-3979 (fax)
baguilar@dfg.ca.gov

Arnold, Jonathan
Forester
Lassen Volcanic National Park
P.O. Box 100
Mineral, CA 96063-0100
(530) 595-4444 x5171
(530) 595-3262
jonathan_arnold@nps.gov

Bolster, Betsy
Staff Environmental Scientist, retired
(Statewide Coordinator for Conservation of Amphibians and Reptiles)
California Department of Fish and Wildlife
Wildlife Branch, Nongame Wildlife Program
1812 9th St.
Sacramento, CA 95811
(916) 445-3684
(916) 445-4048 (fax)
bbolster@dfg.ca.gov

Brown, Catherine
Monitoring Team Leader
Sierra Nevada Monitoring Strategy
Pacific Southwest Research Station
USDA Forest Service
800 Buchanan Street
Albany, CA 94710
(510) 559-6433 – Albany
(209) 532-3571 x241 – Sonora
(510) 559-6499 (fax)
cathybrown@fs.fed.us

Garwood, Justin
Biologist
California Department of Fish and Wildlife
50 Ericson Court
Arcata, CA 95521
(707) 825-4723

Jennings, Mark R.
Herpetologist/Fishery Biologist
Rana Resources
P.O. Box 2185
Davis, CA 95617-2185
(530) 753-2727
(530) 753-2727 (fax)
Ranaresources@aol.com

Lehr, Stafford
Fisheries Branch Chief
California Department of Fish and Wildlife
830 S Street
Sacramento, CA 95811
(916) 327-8840
slehr@dfg.ca.gov

Macfarlane, Diane
Threatened, Endangered, and Sensitive Species Program Leader
Ecosystem Management Staff
Pacific Southwest Region
USDA Forest Service
1323 Club Drive
Vallejo, CA 94592
(707) 562-8931
(707) 562-9054 (fax)
dmacfarlane@fs.fed.us

McAllister, Robert
Fisheries Biologist
California Department of Fish and Wildlife
(530) 225-2866
bmcallis@dfw.ca.gov

McFarland, Melanie
Forest Fisheries Biologist
Ecosystems Staff
Supervisor's Office
Lassen National Forest
USDA Forest Service
2550 Riverside Drive
Susanville, CA 96130
(530) 252-6663
(530) 252-6428 (fax)
mmcfarland02@fs.fed.us

Pearl, Christopher A.
Wildlife Biologist
U.S. Geological Survey Forest and Rangeland Ecosystem Science Center
777 NW 9th St., Suite 400
Corvallis, OR 97330
(541) 750-1011
(541) 753-6848 (fax)
christopher_pearl@usgs.gov

Perrot, Laurie
Environmental Coordinator
Supervisor's Office
Tahoe National Forest
USDA Forest Service
631 Coyote Street
P.O. Box 6003
Nevada City, CA 95959
(530) 478-6244
(530) 478-6109 (fax)
lperrot@fs.fed.us

Pope, Karen
Wildlife Biologist
Redwood Sciences Laboratory
Pacific Southwest Research Station
USDA Forest Service
1700 Bayview Drive
Arcata, CA 95221
(707) 825-2957
(707) 825-2901 (fax)
kpope@fs.fed.us

Welsh, Hart H., Jr.
Research Wildlife Ecologist
Redwood Sciences Laboratory
Pacific Southwest Research Station
USDA Forest Service
1700 Bayview Drive
Arcata, CA 95221
(707) 825-2956
(707) 825-2901 (fax)
hwelsh@fs.fed.us

This publication is available online at www.fs.fed.us/psw/. You may also order additional copies of it by sending your mailing information in label form through one of the following means. Please specify the publication title and series number.

Fort Collins Service Center

Web site	http://www.fs.fed.us/psw/
Telephone	(970) 498-1392
FAX	(970) 498-1122
E-mail	rschneider@fs.fed.us
Mailing address	Publications Distribution Rocky Mountain Research Station 240 West Prospect Road Fort Collins, CO 80526-2098

Pacific Southwest Research Station
800 Buchanan Street
Albany, CA 94710