BEFORE THE CALIFORNIA FISH AND GAME COMMISSION

A Petition to List All Populations of the Mountain Yellow-Legged Frog (*Rana muscosa* and *Rana sierrae*) as Endangered under the California Endangered Species Act

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CENTER FOR BIOLOGICAL DIVERSITY, PETITIONER

January 25, 2010

Notice of Petition

For action pursuant to Section 670.1, Title 14, California Code of Regulations (CCR) and Sections 2072 and 2073 of the Fish and Game Code relating to listing and delisting endangered and threatened species of plants and animals.

I. SPECIES BEING PETITIONED:

Common Name: mountain yellow-legged frog (southern mountain yellow-legged frog and Sierra Nevada mountain yellow-legged frog)
Scientific Name: *Rana muscosa* and *Rana sierrae*

II. RECOMMENDED ACTION: List as Endangered

The Center for Biological Diversity submits this petition to list all populations of the mountain yellow-legged frog in California the as endangered throughout their range in California, under the California Endangered Species Act (California Fish and Game Code §§ 2050 et seq., "CESA"). This petition demonstrates that the both the southern mountain yellow-legged frog (*Rana muscosa*) and the Sierra Nevada mountain yellow-legged frog (*Rana sierrae*) clearly warrant listing under CESA based on the factors specified in the statute.

III. AUTHOR OF PETITION:

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I hereby certify that, to the best of my knowledge, all statements made in this petition are true and complete.

Signature:

Date: January 25, 2010

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EXECUTIVE SUMMARY

This petition addresses the imperiled mountain yellow-legged frog (formerly known as the single species *Rana muscosa*). The mountain yellow-legged frog was recently re-described as two distinct species: the southern mountain-yellow-legged frog (*R. muscosa*), which occurs in the Transverse Ranges of Southern California and in the southern Sierra Nevada, and the Sierra Nevada mountain yellow-legged frog (*R. sierrae*), which occurs only in the Sierra Nevada (Vredenburg *et al.* 2007). This petition follows the terminology recommended by Vredenburg et al. 2007, and uses the vernacular term "mountain yellow-legged frog" to refer to *R. muscosa* and *R. sierrae* collectively. "Southern mountain yellow-legged frog" refers to *R. muscosa*, and "Sierra Nevada mountain yellow-legged frog" refers to *R. sierrae*.

The mountain yellow-legged frog is rapidly declining. Recent threats have exacerbated the downward population trend and have brought both *R. muscosa* and *R. sierrae* to the brink of extinction. These species face many escalating threats including the disease chytridiomycosis, introduced species, pesticides and contaminants, increased exposure to solar UV-b radiation, livestock grazing, recreation impacts, global climate change, and synergies between these factors. The mountain yellow-legged frog needs the protection of the California Endangered Species Act to ensure its survival.

PROCECURAL HISTORY

The California Fish & Game Commission ("Commission") has not yet protected mountain yellow-legged frog populations in California (*R. muscosa and R. sierrae*) under the California Endangered Species Act. Both *R. muscosa and R. sierrae* are recognized as Species of Special Concern by the California Department of Fish & Game. (Jennings and Hayes: Species of Special Concern, 1994, 74-79)

In 2002, in response to a 1995 federal petition to list the mountain yellow-legged frog and ongoing declines, the U.S. Fish and Wildlife Service (USFWS) listed a distinct population segment of the mountain yellow-legged frog (*R. muscosa*) in southern California as endangered under the federal Endangered Species Act (67 Fed. Reg., 44382-390, USFWS, 2002).[1] The southern Sierra population of *R. muscosa* is currently not protected as part of the southern California Distinct Population Segment of the mountain yellow-legged frog.

In response to a petition filed in 2000, the USFWS determined in 2003 that the Sierra Nevada distinct population segment of the mountain yellow-legged frog (*R. sierrae*) warranted listing under the federal Endangered Species Act, but that the listing was "precluded" due to other high priority listing actions (68 Fed. Reg. 2283, Jan. 16, 2003 - USFWS 2003). The Sierra Nevada mountain yellow-legged frog is a candidate for listing under the Federal Endangered Species Act.

[1] *See* 67 FR 16370 "Based on the differences between the ecological settings for the mountain yellow-legged frog in southern California (steep gradient streams) and the Sierra Nevada (high elevation lakes and slow moving portions of streams), elevation, and the importance of the southern California population to the entire range of this species, the mountain yellow-legged frogs inhabiting the mountains of southern California meet the significance criteria under our Policy Regarding the Recognition of Distinct Vertebrate Population Segments (61 FR 4722)."

The CESA Listing Process and Standard for Acceptance of a Petition

Recognizing that certain species of plants and animals have become extinct "as a consequence of man's activities, untempered by adequate concern for conservation," (Fish & G. Code § 2051 (a)), that other species are in danger of extinction, and that "[t]hese species of fish, wildlife, and plants are of ecological, educational, historical, recreational, esthetic, economic, and scientific value to the people of this state, and the conservation, protection, and enhancement of these species and their habitat is of statewide concern" (Fish & G. Code § 2051 (c)), the California Legislature enacted the California Endangered Species Act ("CESA").

The purpose of CESA is to "conserve, protect, restore, and enhance any endangered species or any threatened species and its habitat...." Fish & G. Code § 2052. To this end, CESA provides for the listing of species as "threatened"[2] and "endangered."[3] The Fish and Game Commission is the administrative body that makes all final decisions as to which species shall be listed under CESA, while the Department of Fish and Game is the expert agency that makes recommendations as to which species warrant listing. The listing process may be set in motion in two ways: "any person" may petition the Commission to list a species, or the Department may on its own initiative put forward a species for consideration. In the case of a citizen proposal, CESA sets forth a process for listing that contains several discrete steps.

Upon receipt of a petition to list a species, a 90-day review period ensues during which the Commission refers the petition to the Department, as the relevant expert agency, to prepare a detailed report. The Department's report must determine whether the petition, along with other relevant information possessed or received by the Department, contains sufficient information indicating that listing may be warranted. Fish & G. Code § 2073.5.

During this period interested persons are notified of the petition and public comments are accepted by the Commission. Fish & G. Code § 2073.3. After receipt of the Department's report, the Commission considers the petition at a public hearing. Fish & G. Code § 2074. At this time the Commission is charged with its first substantive decision: determining whether the petition, together with the Department's written report, and comments and testimony received, present sufficient information to indicate that listing of the species "may be warranted." Fish & G. Code § 2074.2. This standard has been interpreted by courts as the amount of information sufficient to "lead a reasonable person to conclude there is a substantial possibility the requested listing could occur." *Natural Resources Defense Council v. California Fish and Game Comm*. 28 Cal.App.4th at 1125, 1129. If the petition, together with the Department's report and comments received,

[2] "Threatened species" means a native species or subspecies of a bird, mammal, fish, amphibian, reptile, or plant that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of the special protection and management efforts required by this chapter. Fish & G. Code § 2067.
[3] "Endangered species" means a native species or subspecies of a bird, mammal, fish, amphibian, reptile, or plant which is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, overexploitation, predation, competition, or disease." Fish & G. Code § 2062

indicates that listing "may be warranted," then the Commission must accept the petition and designate the species as a "candidate species." Fish & G. Code § 2074.2.

Once the petition is accepted by the Commission, then a more exacting level of review commences. The Department has twelve months from the date of the petition's acceptance to complete a full status review of the species and recommend whether such listing "is warranted." Following receipt of the Department's status review, the Commission holds an additional public hearing and determines whether listing of the species "is warranted." If the Commission finds that the species is faced with extinction throughout all or a significant portion of its range, it must list the species as endangered. Fish & G. Code § 2062. If the Commission finds that the species is likely to become an endangered species in the foreseeable future, it must list the species as threatened. Fish & G. Code § 2067.

Notwithstanding these listing procedures, the Commission may adopt a regulation that adds a species to the list of threatened or endangered species at any time if the Commission finds that there is any emergency posing a significant threat to the continued existence of the species. Fish & G. Code § 2076.5.

1. POPULATION STATUS AND TRENDS

Mountain yellow-legged frog populations have been decimated in the last 10 years. Monitoring programs conducted by CDFG, USFS, USFWS, and academic researchers have tracked this unfortunate decline. In the Sierra Nevada region, many long-term surveys of both *R. muscosa* and *R. sierrae* populations are ongoing (e.g., CDFG High Mountain Lakes Project, USFS Sierra Nevada amphibian monitoring program, Yosemite and Sequoia-Kings Canyon National Parks monitoring and restoration programs, and efforts by researchers affiliated with a variety of academic institutions) and a large volume of data has been collected. In the Sequoia-Kings Canyon National Park, all lentic habitats were surveyed first in 1997, 2000, 2001, or 2002 (n=4822). All *R. sierrae*/*R. muscosa* populations found during the original surveys were resurveyed at least once (most 2-3 times) between 2005 and 2007. The original surveys found 558 mountain yellow-legged frog populations, and these populations were located primarily in the eastern half of the Park. Many populations were large, containing more than 100 post-metamorphic frogs.

Analysis of the resurvey results indicated that of the 558 mountain yellow-legged frog populations found during the original survey, **304 were extinct by 2005-2007 (54%).** This suggests an extinction rate of approximately **10% per year for the study area**. (Roland Knapp, pers. comm., 2008). This shocking statistic refers to the results of only one census area. The reviewer must keep in mind that a considerable amount of raw data exists that could be referenced to inform additional abundance and change estimates.

Over the past century, mountain yellow-legged frog populations have declined to such an extent that both species (*R. muscosa* and *R. sierrae*) currently are on a rapid trend to extinction in California (mountain yellow-legged frogs are already extinct in Nevada). Vredenburg et al. (2007) summarized the current status as follows:

> The mountain yellow-legged frog…once abundant in the Sierra Nevada of California and Nevada, and the disjunct Transverse Ranges of southern California, has declined precipitously throughout its range, even though most of its habitat is protected. The species is now extinct in Nevada and reduced to tiny remnants in southern California, where as a distinct population segment, it is classified as Endangered [under the federal Endangered Species Act]. Introduced predators (trout), air pollution and an infectious disease (chytridiomycosis) threaten remaining populations …. [S]urveys conducted since 1995 at 225 historic (1899–1994) localities from museum collections show that 93.3% (n=146) of *R. sierrae* populations and 95.2% (n=79) of *R. muscosa* populations are extinct. Evidence presented here underscores the need for revision of protected population status to include both species throughout their ranges.

Vredenburg et al. (2007) calculated extinction rates in the major geographic areas for mountain yellow-legged frog within the ranges of both species using comparisons of historic occupancy (1899–1994) versus current occupancy (1995–2005). This information is presented below and is summarized in Table 1. Of the 225 historic sites that Vredenburg et al. (2007) used for their analysis, only three *R. muscosa* sites and 11 *R. sierrae* sites contained frogs when resurveyed between 1995 and 2005. The authors estimate that "the extinction rate is 96.2% for *R. muscosa* and 92.5% for *R. sierrae*." Therefore, of the sites known to be occupied historically, less than 4% of *R. muscosa* sites and 8% of *R. sierrae* sites are still occupied today. Actual extinction rates may be higher. This suggests that both species face the very real risk of total extinction within our lifetimes.

A. *R. sierrae*

R. sierrae has declined dramatically throughout its range. Following is a summary of recent survey results of *R. sierrae* populations in Yosemite National Park, which data support the conclusion that this species continues to decline at an alarming rate. The reviewer should keep in mind that, according to the USFWS, the mountain yellow-legged frog populations within national park boundaries include the most extensive areas of robust extant populations (USFWS 2003).

Vredenburg et al. (2007) found the extinction rate for *R. sierrae* is 92.5%. The rate of loss for *R. sierrae* populations appears to be accelerating relative to the pre-1970 rate due to *Batrachochytrium dendrobatidis*. The degree of habitat fragmentation is much higher than historical accounts demonstrate and is increasing with the loss of additional populations (R. Knapp, pers. comm., 2008). Although the physical habitat at most occupied sites is essentially unchanged from historic conditions, trout presence has greatly reduced the suitability of thousands of sites, and without enhancement (i.e., trout removal) they will remain unsuitable (R. Knapp, pers. comm., 2008). Experts estimate that if current trends continue, extinction of *R. sierrae* would occur within our lifetime.

In Yosemite National Park, all lentic habitats were surveyed from 2000 to 2002 (n=3044). All *R. sierrae* populations found during this original survey were resurveyed at least once between 2005 and 2007. 285 *R. sierrae* populations were found during the original survey, and although widespread across the Park, most populations were very small (<5 frogs). The resurvey results indicated that of the 285 *R. sierrae* populations found during the original survey, 107 were extinct by 2005-2007 (37%). This suggests an extinction rate of approximately 7% per year. (Roland Knapp, pers. comm., 2008).

B. *R. muscosa*

In 2000, the USGS commenced extensive surveys for remaining southern mountain yellow-legged frog populations, and monitoring of those populations that are extant, throughout the historic range in southern California (Backlin et al. 2004). In addition to these surveys, Backlin et al. (2004) reviewed historic records from 1903 to 1994 and concluded that *R. muscosa* has disappeared from nearly all of its former range in southern California since the mid 1900s. Other researchers have supported these findings. Vredenburg et al. (2007) calculated a 98.1% extinction rate in the Transverse Ranges when comparing historic versus current site occupancy of all 53 known historically-occupied sites.

Southern California populations of *R. muscosa* have declined precipitously and face the imminent risk of extinction. The authoritative publication on southern California *R. muscosa* populations is Backlin et al. (2004). The following excerpt from Backlin et al. (2004) (emphasis added) illustrates the precarious status of these populations:

> Extensive surveys by the U. S. Geological Survey (USGS), U.S. Forest Service (USFS), and the California Department of Fish and Game (CDFG) have revealed eight remaining populations in isolated headwater streams (Backlin *et al.*, 2003). There are five known populations in the Angeles National Forest (ANF): Bear Gulch, Vincent Gulch, Little Rock Creek, Devil's Canyon and South Fork Big Rock Creek and three populations in the San Bernardino National Forest (SBNF): East Fork City Creek, Fuller Mill Creek and Dark Canyon. Sherri Sullivan (SBNF) and John Sunada (CDFG) rediscovered this last population in 2003. Three other recent populations have not been confirmed since the late 1990's. These include Hall Creek (SBNF), Lower Fuller Mill Creek (SBNF), and East Fork San Gabriel River (ANF) (Jennings, 1993, 1994, 1995, 1998, 1999….**All of the remaining MYLF populations in southern California are small (<100 adults). Some are estimated to be so extremely small (Fuller Mill Creek, Devil's Canyon, and Little Rock Creek; <20 adults), that they are highly susceptible to stochastic events and have little chance of long-term persistence without management intervention. Very small populations, consisting of less than 10 pairs, are likely to become extinct in the short term (Pimm *et al.*, 1988) and immediate conservation actions should be taken to stabilize and rebuild these populations.**

Based on extensive surveys conducted between 2000 and 2003, Backlin et al. (2004) arrived at adult population size estimates on a site-by-site basis ranging from as few as 8-9 adults (Little Rock Creek, 2003) to 54-92 adults (Bear Gulch Creek, 2003); Backlin et al. (2004) emphasize the ***extreme peril*** (i.e. high extinction risk) that the southern California population of *R. muscosa* faces.

The distribution of *R. muscosa* in the Sierra Nevada is bordered by the crest of Sierra Nevada. No populations occur east of the crest. The mountain ridges that separate the headwaters of the South Fork Kings River from the Middle Fork Kings River, from Mather Pass to the Monarch Divide, form the northern border of the range (Fig. 1, inset). Currently, only 2 of 26 historic survey sites support extant populations of *R. muscosa*; this decline represent an extinction rate of 92.3% (Vredenburg et al. 2007). In 2003 the USFWS considered listing the Sierra Nevada population of *R. muscosa* along with *R. sierrae* when it considered listing the Sierra Nevada Distinct Population Segment of the mountain yellow-legged frog. At the time of its consideration the phylogeny of the mountain yellow-legged frog had not been changed, and the entire Sierra Nevada population of mountain yellow-legged frogs was considered the same species.

For Sierra Nevada populations of *R. muscosa*, the rate of loss appears to have been quite constant for the past couple of decades, but the current rate is almost certainly much higher than the pre-1970 rate due to *Batrachochytrium dendrobatidis* ("chytrid fungus" or "Bd") (R. Knapp, pers. comm., 2008). Furthermore, the degree of habitat fragmentation is much higher than historical accounts demonstrate and is increasing with the loss of additional populations (R. Knapp, pers. comm., 2008). Although the physical habitat at most occupied sites is essentially unchanged from historic conditions, trout presence has greatly reduced the suitability of thousands of sites, and without enhancement (i.e., trout removal) they will remain unsuitable (R. Knapp, pers. comm., 2008). Experts estimate that extinction would occur within 20 years for *R. muscosa* populations in the southern Sierra Nevada (R. Knapp, pers. comm., 2008).

The southern Sierra population of *R. muscosa* is currently not protected as part of the listed southern California DPS of the mountain yellow-legged frog. The 2002 DPS listing decision included only the populations of the mountain yellow-legged frog in southern California (USFWS 2002).[4]

In the Sierra Nevada, Vredenburg et al. (2007) compared historic and current occupancy of *R. muscosa* in all 26 known historically-occupied sites, and documented a 92.3% extinction rate. In response to the rate and magnitude of these declines, the USFWS determined in 2003 that the Sierra Nevada distinct population segment of mountain yellow-legged frog warranted listing under the federal ESA, but that the listing was "precluded" due to other high priority listing actions (USFWS 2003). The USFWS is directed to make such a finding "solely on the basis of the best scientific and commercial data available," 16 U.S.C. § 1533(b)(1)(A). Any one of the following five listing factors can trigger a listing:

(A) the present or threatened destruction, modification, curtailment of its habitat or range;
(B) overutilization for commercial, recreational, scientific, or educational purposes;

[4] *See* 67 FR 16370 "Based on the differences between the ecological settings for the mountain yellow-legged frog in southern California (steep gradient streams) and the Sierra Nevada (high elevation lakes and slow moving portions of streams), elevation, and the importance of the southern California population to the entire range of this species, the mountain yellow-legged frogs inhabiting the mountains of southern California meet the significance criteria under our Policy Regarding the Recognition of Distinct Vertebrate Population Segments (61 FR 4722)."

(C) disease or predation;
(D) the inadequacy of existing regulatory mechanisms; or
(E) other natural or manmade factors affecting its continued existence.

16 U.S.C. § 1533(a)(1).

At the time of the 12-month finding the agency placed the frog on the candidate list and assigned it a priority rank of 3 (the highest rank assignable for a DPS) based on the imminence and immediacy of the threat of extinction, stating: "We conclude that the overall magnitude of threats to the Sierra Nevada DPS of the mountain yellow-legged frog is high, and that the overall immediacy of these threats is imminent." The agency also noted that the factors leading to the frog's decline "are exacerbated by the effects that have been caused by non-native fishes, specifically the isolation of remaining mountain yellow-legged frog populations and habitat fragmentation" (USFWS 2003). Finally, the agency concluded that frog populations that have gone extinct "are unlikely to be recolonized due to both the isolation from, and lack of, connectivity to potential source populations" (USFWS 2006).

2. RANGE and DISTRIBUTION

A. Range Map from Vredenburg et al. 2007.

B. Current Distribution, Rate of Loss, Extinction Prediction, and Habitat Condition[5]

(1) Historic Distribution

Historically, mountain yellow-legged frogs were found throughout the higher elevations in the Transverse Ranges in southern California and in the Sierra Nevada of California and Nevada (USFWS 2002). Vredenburg *et al.* (2007) note that "[e]xtensive biological surveys conducted over a century ago concluded that *R. sierrae* and *R. muscosa* were the most abundant vertebrates in the high-elevation habitats of the Sierra Nevada (Grinnell & Storer 1924) and the Transverse Ranges (Storer 1925)."

In the Sierra Nevada of California and Nevada, mountain yellow-legged frogs historically ranged from southern Plumas County to southern Tulare County (Jennings and Hayes 1994), at elevations mostly above 1,820 meters (m) (6,000 feet (ft)). Populations were documented on the east and west sides of the Sierra crest in all major drainages from within the historic range (Zweifel 1955; Jennings and Hayes 1994; Knapp 1996). The known elevation range of the two species in the Sierra Nevada extended from 1,044 m (Pinkard Creek Meadow, Butte County: USFS 2000a) to over 3,650 m (near Desolation Lake, Fresno County: Mullally and Cunningham 1956). Although some populations clearly existed at low elevations, most populations occurred at the mid- to high-end of the elevation range (Zweifel 1955; Mullally and Cunningham 1956; Stebbins 1995). The historic distribution of the mountain yellow-legged frog complex was continuous at higher elevations in the Sierra Nevada (Jennings and Hayes 1994).

Mountain yellow-legged frogs historically occurred in Nevada in the vicinity of Lake Tahoe and northward on the slopes of Mount Rose (Linsdale 1940). Linsdale (1940) reported that frogs ranged from 6,300 feet to 9,300 feet, along small streams and in small shallow lakes in meadows. In the general vicinity of Incline Lake, mountain yellow-legged frogs were collected in the 1920s (Panik 1995a). Specific collection sites mentioned by Linsdale were as follows: 5.5 miles north of Incline at 9,300 feet, and Incline at the north end of Lake Tahoe; 3 miles south of Mount Rose at 8,500 feet; and at Lake Tahoe. Other specific historic collection sites have been recorded in Nevada: a single frog was collected ½ mile south of Mount Rose Summit at 8,500 feet, by J. M. Savage and C. F. Walker in 1955 (Panik 1995); and a single specimen was obtained at the Whittell Tract at Little Valley in the Carson Range (Ryser 1966, unpublished manuscript, as cited in Panik 1995). The most recent observations of mountain yellow-legged frogs in Nevada were by Fred Ryser, in the Tahoe Meadows area. Ryser stated that he saw "many" mountain yellow-legged frogs in Tahoe Meadows and in ponds near Galena Creek from about 1965 to 1984 (Ryser, pers. comm., as cited in Panik 1995). Mountain yellow-legged frogs are now extinct in Nevada.

Vredenburg *et al.* (2007).note that the historic range of *R. muscosa* covered a large swath of California's inland montane habitats:

> *Rana muscosa* once ranged from Palomar Mountain in San Diego County through

[5] In addition to the discussion herein, *see* USFWS, 2007a, 12-month finding for detailed data on Sierra Nevada populations of *R. muscosa* and *R. sierrae*.

> the San Jacinto, San Bernardino and San Gabriel Mountains of Riverside, San Bernardino and Los Angeles counties in southern California. These formed four isolated clusters of montane populations. In addition, the species occurred as an isolated cluster of populations on Breckenridge Mountain, south of the Kern River in Kern County, and in the Sierra Nevada in Tulare, Inyo and Fresno counties, extending north to Mather Pass. The distribution of *R. muscosa* in the Sierra Nevada is bordered by the crest of Sierra Nevada. No populations occur east of the crest. The mountain ridges that separate the headwaters of the South Fork Kings River from the Middle Fork Kings River, from Mather Pass to the Monarch Divide, form the northern border of the range.…*Rana muscosa* is extinct on Palomar and Breckenridge mountains.

Historical documentation reveals that mountain yellow-legged frogs occupied roughly 166 localities in creeks and drainages in the mountains of southern California (Jennings and Hayes 1994). The majority of the populations occupied habitat in creeks and drainages in the San Gabriel, San Bernardino, and San Jacinto Mountains of Los Angeles, San Bernardino, and Riverside Counties. Two outlying populations were documented on Palomar Mountain in San Diego County (Zweifel 1955).

According to Vredenburg, et al. (2007), "*Rana sierrae* once ranged from the Diamond Mountains north-east of the Sierra Nevada in Plumas County, California, south through the Sierra Nevada to the type locality, the southern-most locality (Inyo County). In the extreme north-west region of the Sierra Nevada, several populations occur just north of the Feather River, and to the east, there was a population on Mt Rose, north-east of Lake Tahoe in Washoe County, Nevada, but it is now extinct."

a. *R. sierrae*

Vredenburg et al. (2007) documented that *Rana sierrae* once ranged from the Diamond Mountains in Plumas County (north-east of the Sierra Nevada) south to Inyo County, on both sides of the Sierra crest. In more precise terms, the authors state:

> In the extreme north-west region of the Sierra Nevada, several populations occur just north of the Feather River, and to the east, there was a population on Mt Rose, north-east of Lake Tahoe in Washoe County, Nevada, but it is now extinct. West of the *R. sierrae* range is bordered by ridges that divide the Middle and South Fork of the Kings River, ranging from Mather Pass to the Monarch Divide. East of the Sierra Nevada crest, *R. sierrae* occurs in the Glass Mountains just south of Mono Lake (Mono County) and along the east slope of the Sierra Nevada south to the type locality at Matlock Lake (Inyo County). West of the Sierra Nevada crest, the southern part of the *R. sierrae* range is bordered by ridges that divide the Middle and South Fork of the Kings River, ranging from Mather Pass to the Monarch Divide. East of the Sierra Nevada crest, *R. sierrae* occurs in the Glass Mountains just south of Mono Lake (Mono County) and along the east slope of the Sierra Nevada south to the type locality at Matlock Lake (Inyo County).

b. *R. muscosa*

Rana muscosa once ranged from Palomar Mountain in San Diego County through the San Jacinto, San Bernardino and San Gabriel Mountains of Riverside, San Bernardino and Los Angeles counties in southern California. These formed four isolated clusters of montane populations. In addition, the species occurred as an isolated cluster of populations on Breckenridge Mountain, south of the Kern River in Kern County, and in the Sierra Nevada in Tulare, Inyo and Fresno counties, extending north to Mather Pass. *Rana muscosa* is extinct on Palomar and Breckenridge mountains.

R. muscosa populations in the Transverse Range of southern California are extremely imperiled. The historic distribution of *R. muscosa* in southern California has been reduced to 1 percent of its former range, occupying only eight known sites (Backlin et al. 2004; Vredenburg et al. 2007). Backlin et al. (2004) conducted presence/absence surveys of all eight known occupied sites and 21 additional sites with historic records of occupation or that contained suitable habitat; no frogs were found at the additional sites.[6] *R. muscosa* populations in southern California appear to have stabilized over the past few decades; however, the few remaining populations are at risk of total extirpation because of the high degree of habitat fragmentation and the lack of unaltered habitat. If current trends continue, extinction of the southern California populations is likely within our lifetimes.

2. Current Distribution

Existing populations of mountain yellow-legged frogs in the Sierra Nevada are restricted primarily to federally-managed national forests and national parks (USFWS 2003). In 2003, the U.S. Fish and Wildlife Service (USFWS) estimated that of the extant Sierra Nevada populations, 22 percent existed on national forest lands, although not all could be deemed breeding populations. USFWS (2003) also estimated populations within national park boundaries:

> In the national parks of the Sierra Nevada, there are 758 known sites with mountain yellow-legged-frogs, most of which occur within 59 different basins that have multiple breeding populations that are connected hydrologically, so that populations in each basin function as metapopulations. Within these 758 sites, 330 populations exist for which we have evidence of successful reproduction.

These 758 sites represent 78 percent of extant populations in the Sierra as of 2003, with less than half of these populations showing evidence of successful reproduction. However, the USFWS estimates are not robust because the percentages represent the number of occupied sites, not the number of individuals present at each site, and the methods for estimating population numbers were not standardized (USFWS 2003).

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[6] For a detailed description of survey and monitoring methodology and assumptions, please refer to Backlin et al. (2004).

3. ABUNDANCE – Population Estimates & Changes

Historically, mountain yellow-legged frogs were ubiquitous at higher elevations throughout the Transverse Ranges in southern California and the Sierra Nevada of California and Nevada (USFWS 2002). Vredenburg et al. (2007) note that "[e]xtensive biological surveys conducted over a century ago concluded that *R. sierrae* and *R. muscosa* were the most abundant vertebrates in the high-elevation habitats of the Sierra Nevada (Grinnell and Storer 1924) and the Transverse Ranges (Storer 1925)."

The current distribution of the mountain yellow-legged frog complex has contracted in geographic scope and population numbers, with the Sierra Nevada and Transverse Ranges in California supporting all extant populations. Vredenburg, et al. (2007) looked at range contraction as part of the genetic analysis study of the species. The authors looked at museum specimens and historic collection data, and compared this data to current documented mountain yellow-legged frog populations. They determined whether frogs were currently extant or extinct using data from extensive surveys conducted between 1995 and 2004 at more than 14,000 water bodies within the historic range of *R. muscosa* and *R. sierrae*. All suitable habitats at historic localities (i.e. including all water bodies located within the 1 km radius circle) were searched for all life stages using visual encounter surveys. Sites were categorized as 'extant' if one or more egg masses, tadpoles, subadults or adults were detected, and as 'extinct' if no life stages were found.

A. Historic Population Declines

A large body of scientific literature documents the precipitous decline of mountain yellow-legged frog populations (Knapp and Matthews 2000; Davidson et al. 2002; Rachowicz and Vredenburg 2004). The remaining populations of mountain yellow-legged frogs occur almost entirely on national forest and national park lands, yet "*R. muscosa* has declined precipitously, ***especially in the last three decades*** (Vredenburg, Fellers and Davidson, 2005)" (Vredenburg et al. 2007 (emphasis added). Today, few viable populations of *R. muscosa* and *R. sierrae* remain.

In the Sierra Nevada, Grinnell and Storer (1924) were the first researchers to document declines of mountain yellow-legged frogs. Survey and monitoring efforts over the past two decades continue to document declines and extensive extirpations (Hayes and Jennings 1986; Jennings and Hayes 1994; Bradford et al. 1994a; Jennings 1995, 1996; Stebbins and Cohen 1995; Drost and Fellers 1996; Knapp and Matthews 2000). The rate of decline appears to have accelerated in scope and rate between the 1970s and 1990s (USFWS 2003). Although population declines are documented throughout the Sierra Nevada, the USFWS (2003) concluded "[t]he most pronounced declines have occurred north of Lake Tahoe in the northernmost 125 km (78 mi) portion of the range, and south of Sequoia and Kings Canyon National Parks in Tulare County in the southernmost 50 km (31 mi) portion, where only a few populations remain (Fellers 1994; Jennings and Hayes 1994)."

4. NATURAL HISTORY—Species Description, Biology, and Ecology

A. Description

In general, mountain yellow-legged frogs are moderate-sized (ca. 40-80 mm SUL), highly variably colored frogs, with dorsal patterns ranging from discrete dark spots that can be few and large, smaller and more numerous ones with a mixture of size and shapes, irregular lichen-like patches (thus the name "*muscosa*"), or a poorly defined reticulum (Zweifel 1955). Adult frogs attain lengths of 67 mm in males, and 80 mm in females (Zweifel 1955, 1968), with average lengths of 56 mm for males and 59 mm for females (Wright and Wright 1949). Dorsal coloration and patterning is highly variable; colors on individuals are usually a mix of brown and yellow, but often with gray, red, or green-brown. Some individuals may be dark brown or gray with little pattern (Jennings and Hayes 1994). The posterior half of the upper lip is normally light colored. The throat is white or yellow, sometimes with mottling of dark pigment (Zweifel 1955). The ventral surface and under surfaces of the hind limbs are yellow, with ranges in hue from pale lemon yellow to an intense sun yellow (Wright and Wright 1949). The iris is gold with a horizontal black counter shading stripe (Jennings and Hayes 1994). Dorsolateral folds are present, but not usually prominent (Stebbins 1985). Mountain yellow-legged frogs have no vocal sacs, and the tympanum is smoother than in the foothill yellow-legged frog, *Rana boylii* (Wright and Wright 1949; Zweifel 1955). There is well-developed webbing on the hind feet (Wright and Wright 1949). Males average slightly smaller than females and have a swollen, darkened thumb (inner finger) base (Zweifel 1955).

Eggs of the mountain yellow-legged frog are laid in clumps, mostly globular in shape, with a diameter roughly 2.5 to 5 cm (1 to 2 in) across (Stebbins 1985). When eggs are close to hatching, egg mass volume may average 198 cubic cm (78 cubic in) (Pope 1999a). Eggs have three firm jelly-like transparent envelopes surrounding a grey-tan or black vitelline (egg yolk) capsule (Wright and Wright 1949).

The larvae (tadpoles) of this species generally are mottled brown in dorsal coloration with a golden tint and a faintly-yellow venter (underside) (Zweifel 1955; Stebbins 1985). Tadpoles can reach 72 mm (2.8 in) in length. The tadpole body is flattened and the tail musculature is wide, about 2.5 centimeters (cm) (1 in) or more, before tapering into a rounded tip (Wright and Wright 1949). The mouth has a maximum of 7 labial (lip) tooth rows (2– 3 upper and 4 lower) (Stebbins 1985). Larvae in the Sierra Nevada often take 2 to 4 years or more to reach metamorphosis (transformation from larvae to frogs) (Wright and Wright 1949; Bradford *et al.* 1993; Knapp and Matthews 2000).

B. Taxonomy

(1). *R. muscosa and R. sierrae*

The mountain yellow-legged frog is in the family of true frogs, Ranidae, which consists of frogs closely associated to aquatic habitats for breeding and foraging. They are a member of the *R. muscosa* complex, which in turn is part of the clade *Rana*, which also includes *R. aurora*, *R. boylii*, *R. cascadae*, *R. draytonii*, *R. luteiventris* and *R. pretiosa*

(Hillis and Wilcox, 2005). Relationships within this clade of frogs are not fully resolved and have gone through re-classifications. Mountain yellow-legged frogs were originally described by Camp (1917) as a subspecies of *Rana* boylii. Zweifel (1955) demonstrated that frogs from the high Sierra Nevada and the mountains of southern California were somewhat similar to each other, yet were distinct from the rest of the *R.* boylii (= boylei) group. Both *R. sierrae* and *R. muscosa* were grouped together as *R. muscosa* in by Zweifel (1955). Vredenburg (2007) considered the then recognized two subspecies of *R.* boylii to constitute separate species, and he selected the name *muscosa* for the mountain yellow-legged frogs thereby reducing *sierrae* to synonymy.

Macey et al. 2001 performed a genetic analysis on the mountain yellow-legged frog throughout its range. Researchers found statistical support to distinguish four evolutionarily distinct populations, including the northern Sierra Nevada, central Sierra Nevada, southern Sierra Nevada, and southern California mountains (San Bernardino, Los Angeles, and Riverside counties). At the time of the study, *R. sierrae* was not recognized as a distinct species from *R. muscosa*. Following the Macey study, Vredenburg demonstrated that the mountain yellow-legged frog comprises two diagnosable species - *R. muscosa* and *Rana sierrae* - on the basis of concordant molecular phylogenetic, morphologic, and acoustic data (Vredenburg *et al*. 2007). The following taxonomic descriptions are excerpted from Vredenburg *et al*. (2007):

***Rana muscosa* complex** Mountain yellow-legged frog
<u>*Rana sierrae*</u> Camp (1917), new status. Sierra Nevada yellow-legged frog *Rana* boylii *sierrae* Camp (1917). Original description. Type – MVZ 3734, an adult female collected by H.S. Swarth on 26 July 1912. Type locality – Matlock Lake, 3200 m elevation, Inyo County, California (36.761N, 118.361W). *Rana muscosa* Zweifel (1955). This author considered the then-recognized two subspecies of *R.* boylii to constitute separate species, and he selected the name *muscosa* for the mountain yellow-legged frog thereby reducing *sierrae* to synonymy.
<u>*Rana muscosa*</u> Camp (1917). Sierra Madre yellow-legged frog *Rana* boylii *muscosa* Camp (1917). Original description. Type – MVZ 771, adult female collected by J. Grinnell on 3 August 1903. Type locality – Arroyo Seco Canyon, 0 200 400 km 366 m elevation, 10 km north of Pasadena, Los Angeles County, California (34.211N, 118.171W). *Rana muscosa* Zweifel (1955). Raised to species status.

Vredenburg et. al. 2007 proposed splitting the taxa into two separate species for the first time, but the author's analysis of mtDNA data did not contradict the existing treatment of the southern California mountain yellow-legged frog in the literature.. The author notes that:

> [T]he following does not conflict with analyses of Hillis & Wilcox (2005) and Macey *et al.* (2001): (((pretiosa, luteiventris)boylii)(((aurora, cascadae)*muscosa*, *sierrae*)draytonii)). See further comments under *R. muscosa* account (below)…We revert to the vernacular name originally coined by Camp (1917) for this taxon, in order to stabilize names. Frogs belonging to our *R. muscosa* and *R. sierrae* have long been called mountain yellow-legged frogs, and to assign that name to one or the other of the two sister taxa would be arbitrary and lead to confusion. Accordingly, we recommend that collectively the frogs be called the *R. muscosa* complex, the mountain yellow-legged frogs.

They opine that "[c]orrect delineation of species boundaries is essential for conservation (Avise, 1989; Moritz, 2002). Recognition of *R. sierrae* and *R. muscosa*, together with evidence for high extinction rates (93–95%), reveals both species to be endangered under current IUCN criteria (Stuart *et al.*, 2004) and underscores the importance of managing frogs in the Sierra Nevada as two distinct species."

Rana sierrae differs from *R. muscosa* in having relatively shorter legs. When a leg is folded against the body the tibio-tarsal joint typically falls short of the external nares. The mating call of *R. sierrae* is significantly different from that of *R. muscosa* in having transitions between pulsed and noted sounds. In addition, the two species differ in mitochondrial DNA. These datasets are geographically concordant.

(2) Systematics

(a) *R. muscosa*

Class: *Amphibia*
↗ Order: *Anura*
↗ Family: *Ranidae*
↗ Genus: *Rana*
↗ Species: *Rana muscosa* Camp, 1917

(b) *R. sierrae*

Class: *Amphibia*
↗ Order: *Anura*
↗ Family: *Ranidae*
↗ Genus: *Rana*
↗ Species: *Rana sierrae* Camp, 1917

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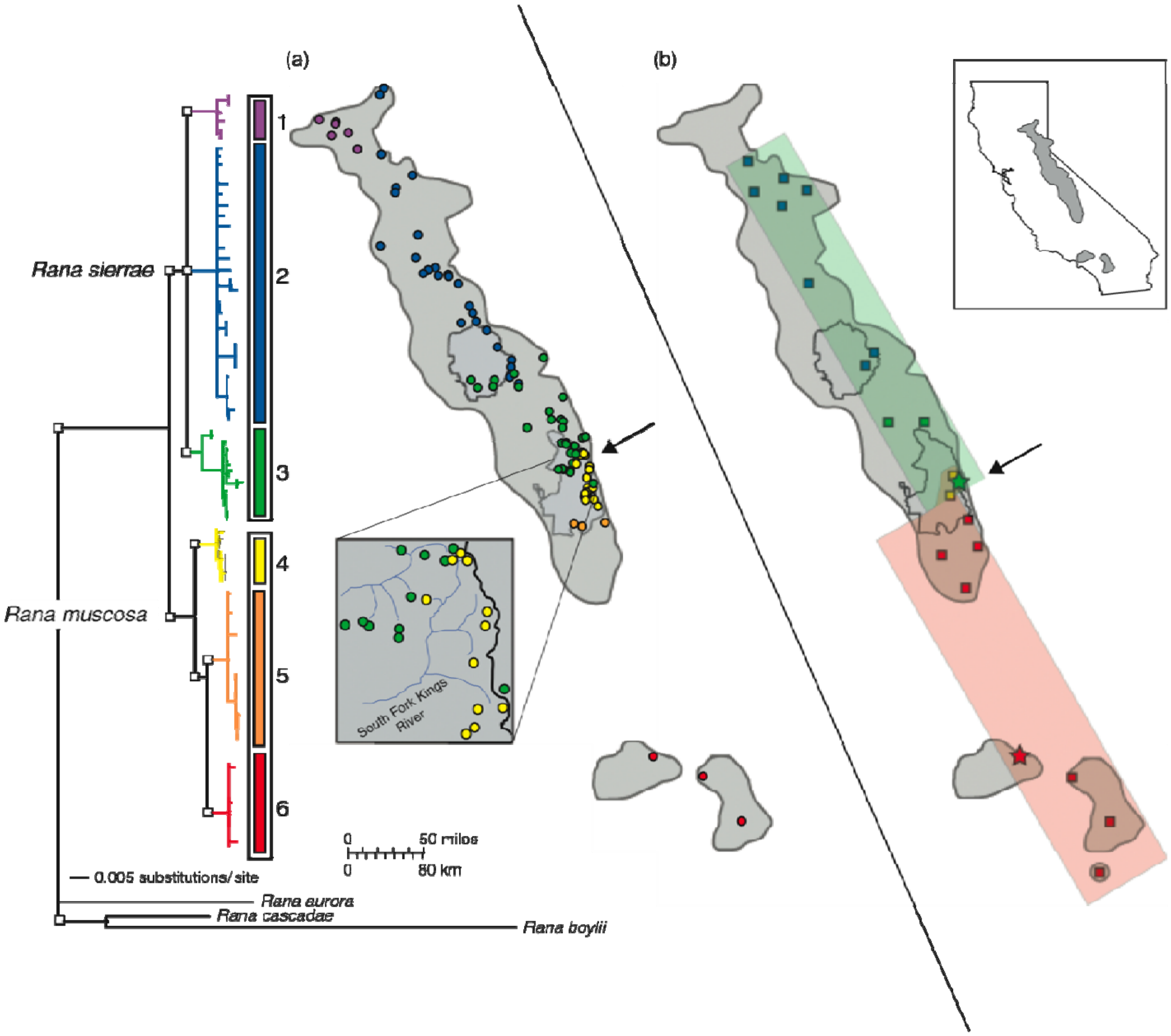

Figure 1 Collection locations of *Rana muscosa* and *Rana sierrae* used for genetic (a) and morphological (b) analyses. Bayes mtDNA phylogram, nodes with □ represent >95% posterior probabilities. Two major clades (*R. muscosa*, *R. sierrae*) and six minor clades (1–6) were identified from the mtDNA analysis. The mtDNA contact zone (arrow) between the species is located between the Middle and South Forks of the Kings River (inset). Morphological analysis identified two groups (b, green and red polygons) that are concordant with the major mtDNA clades, *R. muscosa* and *R. sierrae*. Localities of type specimens are shown as stars and were included in the morphological analysis. The type for *R. sierrae* occurs farther south than the others, and is separated from nearby *R. muscosa* by the crest of the Sierra Nevada (black line; inset).

C. Reproduction and Growth

The reproductive behavior for all mountain yellow-legged frogs is very similar. Breeding activity typically begins in April at lower elevations and in June or July at upper elevations, and continues for approximately a month (Zweifel 1955). At high elevations, mountain yellow-legged frogs breed soon after ice melt, in June or July (Grinnell and Storer 1924; Storer 1925; Wright and Wright 1949; Zweifel 1955). Females lay up to 800 eggs per mass (Zweifel 1955). Livezey and Wright (1945) report an average of 233 eggs per egg mass. Vredenburg *et al.* (in press) reported egg masses with as few as 15 eggs. Oviposition may occur in shallow water (Wright and Wright 1949) or deep water (Karlstrom 1962). Egg masses have been found attached to the lower sides of undercut banks or to rocks on the bottoms of streams (Zweifel 1955). Wright and Wright (1949) noted egg masses attached to banks of small streams. In the Sierra Nevada, the majority of breeding occurs in lakes and ponds, with the eggs attached to vegetation, banks, or rocks (V. Vredenburg, pers. comm., 2000).

Zweifel (1955) recorded hatching times ranging from 18-21 days in laboratory conditions. The length of the larval stage is variable and seems related to elevation and temperature. In lower elevations where summers are longer, tadpoles are thought to be able to grow to metamorphosis in a single season (Storer 1925). However, Vredenburg *et al.* (2005) report that throughout the Sierra, populations are clearly composed of three size classes that likely correspond to year classes. Larvae at high elevations or those subject to severe winters may not metamorphose until the end of their fourth summer (Vredenburg, *et al.* 2005).

Since tadpoles must overwinter at least once before metamorphosis, breeding sites are generally located in or connected to lakes and ponds that do not dry in the summer, and that are sufficiently deep (>2 m) so as to not freeze through in winter (Bradford 1983). Successful breeding occasionally has been observed in ponds less than 2 m deep (Pope 1999). Since mountain yellow-legged frog larvae and adults are susceptible to fish predation, successful breeding sites do not overlap with fish presence (Knapp and Matthews, 2000; Knapp *et al.*, 2003; Knapp, 2005; Vredenburg, unpublished data).data). Both mountain yellow-legged frogs and fish require permanent deep-water habitats. The presence of fish in suitable frog habitat precludes mountain yellow-legged frogs due to voracious predation by fish on frogs in all life stages. (Vredenburg *et al.*, 2005).2005; Knapp, pers. comm. 2009).

Larvae tend to gravitate towards warmer waters to elevate body temperatures as they develop (Bradford 1984), which may facilitate larval and metamorphic development by allowing for a higher metabolic rate (USFWS 2002). The time required to develop from fertilization to metamorphosis is variable, taking up to 3.5 years (Zweifel 1955; Vredenburg *et al.* 2005). Larvae may reach 72 mm total length, and usually transform during July or August (Wright and Wright 1949). Newly metamorphosed individuals are 20-27 mm (Wright and Wright 1949). Fellers *et al.* (2007) observed that during mid-summer surveys in the Sierra, "tadpole age classes are readily distinguished. First-year tadpoles are relatively small (< 40 mm total length), second-year tadpoles are appreciably larger with minute hind limbs (Gosner stage < 36; Gosner 1960), and third-year tadpoles have conspicuous hind limbs (Gosner stage > 36)." Male frogs develop secondary sexual characteristics when they achieve approximately 4.5 cm snout-vent length (Fellers *et al.*, 2007). Reproductive maturity is reached 3 to 4 years following metamorphosis (Zweifel 1955).

D. Movement

The mountain yellow-legged frog is a diurnal species that emerges from overwintering sites immediately following snowmelt (Zweifel 1955; Heller 1960). Mountain yellow-legged frogs usually are found within 1 m of water (Stebbins 1951; Mullally and Cunningham 1956; Karlstrom 1962). They are observed to rest on the bank or in clumps of vegetation and jump into the water when disturbed. They usually find refuge under rocks or crouch on the lake or stream bottom (Grinnell and Storer 1924; Storer 1925; Mullally and Cunningham 1956). Tadpoles resting in shallow water will swim to deeper areas when disturbed (Grinnell and Storer 1924). Mountain yellow-legged frogs have been found to modulate temperatures by basking in the sun, moving between water and land, and through micro-habitat selection. Bradford (1983) found at least 80% of frogs basking in the sun on wet soil in the morning. In the afternoon, they moved to shallow water near the shore, and then into deeper water at night. Tadpoles maintain high body temperatures by selecting warm shallow areas (Bradford 1983).

Mountain yellow-legged frogs do not have a distinct breeding migration, as adults spend most of their time in the vicinity of suitable breeding habitat (Bradford 1983). In some areas there is a seasonal movement from deeper lakes more favorable to overwintering to nearby areas that are more favorable to breeding (Matthews and Pope 1999; Vredenburg *et al.*, 2005). Adult mountain yellow-legged frogs typically move less than a few hundred meters (Vredenburg *et al.*, 2005). Juvenile dispersal is largely unknown, although Bradford *et al.* (1993) reported juveniles in small intermittent streams that might have been dispersing to permanent water.

(1) Sierra Nevada Mountain Yellow-Legged Frog - *R. sierrae*

Pope and Matthews (2001) conducted the first study to provide data over the entire activity cycle of mountain yellow-legged frogs in the Sierra Nevada, from the time adults emerged from overwintering habitat, to breeding and feeding sites, and then back to overwintering sites. Pope and Matthews (2001) tracked movement ecology and seasonal distribution of 500 mountain yellow-legged frogs in Dusy Basin, Kings Canyon National Park, using passive integrated transponder (PIT) surveys and visual encounter surveys during the summers of 1997 and 1998; they monitored the individual frogs through recapture surveys in both years throughout the frogs' activity cycle. The results of Pope and Matthews (2001) suggest a discernable movement pattern in which adult mountain yellow-legged frogs move between overwintering, breeding, and feeding sites, with a narrower distribution earlier and later in the season because of restricted overwintering habitat (deep lakes). Adults move to breeding sites as the lakes begin thawing then disperse to available aquatic habitats in midsummer (Pope and Matthews 2001). Fish-free lakes deeper than 1 m (3 ft) and with warm near-shore water temperatures had the highest summer densities and total numbers of frogs (Pope and Matthews 2001). The frogs also display high site fidelity (Pope and Matthews 2001) Site fidelity may be problematic given current conditions in the Sierra Nevada because frogs are returning to reuse degraded habitats (high elevation lakes with exotic trout or subject to drying out) (Matthews and Preisler, unpublished). The above indicates that designating fish-free, deeper lakes as refugia is a viable model for the protection of mountain yellow-legged frog populations. Recovery will require that fish be removed from critical water bodies. .

Pope and Matthews (2001) confirmed previously observed overland movements, but at further distances than ever before documented; 17% of the tagged frogs moved more than 66 m, and one frog moved approximately 1 km from a lake outside the study site to one within it (with an elevation gain of 72 m), the longest-recorded movement distance for the species. The mountain yellow-legged frogs in the study area used both terrestrial and aquatic movement pathways (Pope and Matthews 2001). Most movement occurred from the beginning of August to mid-September

(Pope and Matthews 2001), indicating that these two months are critically important for the survival and persistence of the species.

(2) Southern Mountain Yellow-Legged Frog - *R. muscosa*

Adult frogs in the San Bernardino Mountains have been observed on land during the winter months on sunny days (Mullally 1959). Frogs apparently must hibernate in water during the coldest winter months (Mullally 1959), probably because they can tolerate only limited dehydration (Hillman 1980). In the Sierra, tadpoles and adults generally overwinter under ice (Grinnell and Storer 1924; Mullally 1959).

The following excerpts from Backlin *et al.* (2004) describe *R. muscosa* seasonal activity and life cycles for all extant southern California populations surveyed in 2001-2003 (figure references omitted).

> In 2003, mountain yellow-legged frogs were active from May until the beginning of October, when temperatures began to get cooler. First year larvae were not observed until June and second year larvae were no longer observed after August. Metamorphs were not observed until July. Therefore we estimate that hatching occurred in mid to late May and that second year larvae metamorphosed between July and August. Because we seen [*sic*] only a few egg masses but many tadpoles at some locations, we assume that breeding and oviposition sites are extremely secretive.
>
> Of the 42 MYLF recaptures across all sites, 17 of the frogs showed no measurable movement across the four years we have been following them. The remaining 25 frogs moved between approximately 40 and 1494 meters with an average movement of 216 meters over four years. The distances measured are between the two most separated points at which each frog was detected, (not including distance traveled at any points between). There were two frogs that moved long distances. One frog in the East Fork of City Creek moved approximately 1494 meters between July 2001 and May 2002, and another frog in Little Rock Creek moved approximately 512 meters between June 2002 and August 2003. This frog in Little Rock Creek is a male frog that has separated from the bulk of the population in this stream. It is the only frog that has been located downstream of the natural fish barrier, and has been captured during three different surveys. This frog may be moving greater distances in search of a mate. If the frog in East Fork City Creek (moving 1494 m) and the frog in Little Rock Creek (moving 512 m) are removed from the analysis, the average distance traveled of the remaining 23 recaptured frogs with measurable movements is only 133 meters, and the average movement of the additional 40 total recaptured frogs (regardless of measurable movement) over the four field seasons (2000–2003) is only 68 meters. These data are consistent with the literature pertaining to MYLF frog movements in other geographic areas. In general, these frogs appear to have high site fidelity during the middle of their active season, with longer migratory and dispersal movements

> just after emergence from aestivation in the spring, and just before they return to their hibernacula in the fall ([citing] Matthews and Pope, 1999).

The seasonal activity/phenology of Sierra Nevada populations of *R. muscosa* is similar to that of the southern California populations, as is succinctly summarized by Backlin *et al.* (2004): "In general, these frogs appear to have high site fidelity during the middle of their active season, with longer migratory and dispersal movements just after emergence from aestivation in the spring, and just before they return to their hibernacula in the fall" (citing Matthews and Pope, 1999).

E. Feeding

Juvenile and adult mountain yellow-legged frogs feed primarily on adult forms of aquatic insects (Finlay and Vredenburg 2007) as well as other small terrestrial insects such as ants and bees (Jennings and Hayes 1994). Larger frogs are thought to feed preferentially upon terrestrial insects and adult stages of aquatic insects while on the shore and in shallow water (Bradford 1983). Feeding studies on Sierran mountain yellow-legged frogs are limited. Larvae graze on algae and diatoms in the silt along rocky bottoms in streams (Zeiner *et al.* 1988). An open or semi-open riparian canopy is needed to ensure that adequate sunlight reaches the stream to allow for frog basking behavior and for photosynthesis by benthic algae and diatoms that are food resources for frog larvae (USFWS 2006; Backlin *et al.* 2004).

In the Sierra Nevada, it has been observed that larger frogs take more aquatic insects than terrestrial insects (Jennings and Hayes 1994). Adult mountain yellow-legged frogs have been observed eating Yosemite toad (*Bufo canorus*) and Pacific treefrog (*Pseudacris regilla*) larvae (Mullally 1953; Zeiner *et al.* 1988; Pope 1999b; Feldman and Wilkinson 2000). Larvae graze on benthic detritus, algae, and diatoms along rocky bottoms in streams, lakes, and ponds (Bradford 1983; Zeiner *et al.* 1988). Larvae have also been observed eating conspecific eggs (Vredenburg 2000). In addition, larvae have been seen feeding on the carcasses of dead metamorphosed frogs (Vredenburg *et al.* 2003).

The southern California populations of *R. muscosa* are principally insectivorous, feeding on a wide variety of aquatic and terrestrial invertebrates. Remains found inside the stomachs of southern California frogs include beetles, flies, wasps, bees, ants, true bugs, and spiders (Long 1970). The riparian zone, with the associated vegetation, is necessary to maintain the prey base needed for the nutritional requirements of the mountain yellow-legged frog (USFWS 2006).

F. Ecological Niche

Historically, the mountain yellow-legged frog was a top aquatic predator and also a food source for other native vertebrates such as the mountain garter snake (*Thamnophis elegans elegans*), valley garter snake (*T. sirtalis fitchi*), Brewer's blackbird (*Euphagus cyanocephalus*), Clark's nutcracker (*Nucifraga columbiana*), coyote (*Canis latrans*), and black bear (*Ursus americanus*) (Camp 1917; Grinnell and Storer 1924; Mullally and Cunningham 1956; Bradford 1991; Jennings *et al.* 1992; Feldman and Wilkinson 2000; V. Vredenburg *et al.* 2005). The introduction of trout has altered dramatically these predator-prey relationships. Threats from introduced species are discussed in Section 8.

G. Mortality

Both *Rana sierrae* and *R. muscosa* face similar mortality risks. Life history characteristics such as overwintering under frozen lakes and multi-year larval development make the mountain yellow-legged frog susceptible to large scale die-offs (USFWS 2003). In lakes <4 m deep, overwintering frogs may die, apparently due to oxygen depletion, while tadpoles are able to survive (Bradford 1983). Conversely, in dry years tadpoles can be lost to desiccation in the late summer or fall (Mullally 1959).

Reported native predators of mountain yellow-legged frogs include western terrestrial garter snakes (*Thamnophis elegans*), Brewer's blackbirds (*Euphagus cyanocephalus*), Clark's nutcrackers (*Nucifraga columbiana*), coyotes (*Canis latrans*), and black bears (*Ursus americanus*) (Mullally and Cunningham 1956; Bradford 1991; Vredenburg, *et al.* in press). Additionally, cannibalism has been observed in the species (Heller 1960; Vredenburg, *et al.* in press).

Non-native predators include various introduced trout species; rainbow trout (*Oncorhynchus mykiss*), California golden trout (*Oncorhynchus mykiss aguabonita*), brook trout (*Salvelinus fontinalis*), and brown trout (*Salmo trutta*) have all been observed preying on mountain yellow-legged frogs. As early as the 1920s Grinnell and Storer (1924) observed trout predation and Needham and Vestal (1938) described golden trout predation. The impacts of non-native trout on the species are described further in Section 8 below.

Bradford (1991) observed a large scale die-off of mountain yellow-legged frogs from red-legged disease caused by a bacterium (*Aeromonas hydrophila*). Recently, a chytrid fungus has been found infecting mountain yellow-legged frogs (Fellers *et al.* 2001; Rachowicz *et al.* 2006). The impacts of disease on the species are described more fully in Section 6 below.

Little is known about adult longevity, but the species is presumed to be long-lived due to observed survival of adults for multiple years at study sites (Matthews and Pope 1999; USFWS 2003). Larval longevity is unusually protracted (1–4 years) (Vredenburg *et al.* 2005; Matthews and Miaud 2007). Matthews and Miaud (2007) used skeletochronology to determine the ages of 149 mountain yellow-legged frogs from 13 locations throughout their current range in the Sierra Nevada. Using bone growth as an indicator for age, they documented adult female frog ages ranging from 0–10 years from the point of metamorphosis (mean = 4.1 years) and adult males from 0–8 years (mean = 4.0 years). Matthews and Miaud (2007) concluded that total age (tadpole + post-metamorphic stages) would range up to14 years.

5. HABITAT REQUIREMENTS

Mountain frogs have evolved to fill a very specific ecological niche. The species inhabits ponds, lakes, and streams at moderate to high elevations (Mullally and Cunningham, 1956). The species is usually associated with montane riparian habitats in lodgepole pine, yellow pine, sugar pine,

white fir, whitebark pine, and wet meadow vegetation types (Zweifel 1955; Zeiner *et al.* 1988). Alpine lakes used by mountain yellow-legged frogs usually have margins that are grassy or muddy (Zweifel 1955), but they are not limited to this habitat. At lower elevations the frogs inhabit sandy or rocky shores (Zweifel 1955). Streams utilized vary from rocky, high gradient streams with numerous pools, rapids, and small waterfalls to those with marshy edges and sod banks (Zweifel 1955). However, the species seems to prefer streams of low gradient and slow or moderate flow, probably in order to avoid flood effects (Storer 1925; Stebbins 1951; Heller 1960). Reproduction also is not possible in high gradient streams, as tadpoles require slack water (R. Knapp, pers. comm., 2000). Very small, shallow streams are not frequently used (Mullally and Cunningham 1956), probably because they lack the water depth necessary for refuge and overwintering sites (Jennings and Hayes 1994); however, this habitat type will be used if there are large frog source populations nearby (V. Vredenburg, pers. comm., 2000). Aquatic substrates utilized are highly variable, from plunge pool habitats to fine sand, rubble, and boulder substrate. In Nevada, the mountain yellow-legged frog has declined dramatically in the last several decades (Bradford 1991; Bradford et al. 1994; Drost & Fellers 1996; Fellers & Drost 1993). Few if any of the Nevada populations of the species remain (Knapp, Pers. Comm., 2009).
Adult mountain yellow-legged frogs are typically found sitting on rocks along the shoreline, usually where there is little or no vegetation (Wright and Wright 1949). Tadpoles are found primarily in near-shore shallows (Storer 1925; Vredenburg *et al.* 2005). Most frogs are seen on a wet substrate within 1 m of the water's edge. Both adults and larvae are most frequently found in areas with shallow water, partly because these are the warmest areas (Bradford 1983), and also because these areas provide refuge from fish predation (Jennings and Hayes 1994). Mountain yellow-legged frogs are sometimes found sitting upon the edge of ice sheets, but this is only for a few days a year, in early springtime (V. Vredenburg, pers. comm., 2000). The frogs will move over ice to get to breeding sites (Vredenburg, unpublished data). Historically, some of the highest densities of frogs have been found at creek junctions with irregular banks and a variety of water depths, and at marshes on the edges of lakes (Mullally and Cunningham 1956).

There are some differences in the habitat characteristics of *R. mucosa* and *R. sierrae*. The geologic history of the Sierra Nevada is complex (House et al. 1998) and recent work on vertebrates in the area has shown that many species in the Sierran range show north to south phylogeographic breaks. The biogeographic break in the mountain yellow-legged frog, which occurs between the middle and south forks of the Kings River within Kings Canyon National Park is congruent with a pattern of fragmentation between northern and southern populations of co-distributed amphibian and reptilian species (Macey, et. al. 2001). The split in phylogeny of mountain yellow-legged frogs is congruent with genetic breaks between central and southern Sierra Nevada populations of other species including the toad *Bufo canorus* (Shaffer et al. 2000), the salamander *Ensatina eschscholtzii* (Moritz et al. 1992), the snake *Lampropeltis zonata* (Rodrıguez-Robles et al. 1999), and the newt *Taricha torosa* (Tan and Wake 1995). Combined data from study of these species suggests that the divergence was influenced by a common vicariant event (Macey, et. al. 2001).

Knapp et. al. (2003) created a regression model to decipher the effects of differing habitat parameters on presence or absence of mountain yellow-legged frogs. Results of the regression model created in the study show that five factors significantly contribute to the presence of mountain yellow-legged frogs, including water body depth, water body elevation, substrate composition, and lake isolation, and presence of trout. Water bodies occupied by larvae were deeper, had a greater percentage of the littoral zone dominated by silt, had more inlet streams, had more high-quality lakes within 1 km, and had a higher percentage of lakes in the drainage that were high quality. Provided that quality habitat exists, research found that the absence of fish appears to have the most significant effect on patch occupancy (Knapp et. al. 2003).

Previous studies have noted that mountain yellow-legged frogs in the Sierra Nevada occupy very different habitats than those in southern California (lakes, ponds, and occasionally streams vs. exclusively streams, respectively) (Knapp et al. 2003).

The U.S. Geological Survey (USGS) began to monitor the remaining populations of mountain yellow-legged frogs in southern California in 2000 (Backlin et al., 2004). Scientists monitored the remaining southern California populations and conducted additional surveys for mountain yellow-legged frogs at historical locations and other areas with suitable habitat from 2000 to 2003. Extensive surveys by the USGS, U.S. Forest Service (USFS), and California Department of Fish and Game (CDFG) revealed eight remaining populations in isolated headwater streams (Backlin et al. 2002). For these populations, researchers were able to determine very specific habitat parameters for the southern California populations:

> All of the wetland locations with current MYLF populations are remote sections of creeks or creek tributaries that are periodically disconnected from their corresponding main waterway. All are similar in that they contain flowing water with pooling areas. All creeks also have year-round water (in at least some portion of the reach). Creek widths were generally narrow, between one and three meters across on average. Reach lengths occupied by frogs varied from about 250 m (Dark Canyon) to >5000 m (East Fork City Creek). The riparian widths ranged from 8–25 m with canyon walls typically rising steeply on either side (Figure 25). Creek gradients were highly variable, from 7–34% (rise over run). Bank and pool substrates consisted of varying percentages of soil, sand, gravel cobble or rock (Figure 25). Pools were 1–10 m long, 0.5–7 m wide, and 0.01–1.8 m deep. All pools had some type of structure in the form of bank overhangs, downfall sticks, and/or rocks that could function as refugia for the MYLF, but there was minimal aquatic vegetation in the pools (Figure 26). Water chemistry parameters were within the expected range for this species. Ranges correspond to measurements recorded from all sites and all survey periods combined. The most consistent water parameter between all sites was pH which generally measured about 7–8. Conductance ranged from about 80–675 μm while dissolved oxygen (D.O.) was variable (23–128%; Figure 27) likely because measurements were taken at different times of the year from one site to the next (i.e., we expect higher 22 D.O. readings when water is flowing faster. In late fall, water flow slows, which causes pools to become more stagnant and therefore have lower D.O. readings). The range of water temperatures during the summer (June through August) at MYLF sites was between 9.0 ºC and 30.3 ºC with an average summer water temperature of 14.6 ºC (Figure 27). Egg masses were found at three pools. Eggs were found

between 3–30 (average 18) cm below the water surface, and water depths at the egg masses ranged from 7–40 (average 28) cm (Figure 28).

Southern California mountain yellow-legged frogs are diurnal (active during the daylight hours), highly aquatic frogs that occupy rocky and shaded streams with cool waters originating from springs and snowmelt (USFWS 2002). Water depth, persistence, and configuration (i.e., gently sloping shorelines and margins) appear to be important for mountain yellow-legged frogs, allowing for shelter from predators along shores or in deeper waters, and habitat for breeding, foraging, egg-laying, thermoregulation (to regulate the body temperature through behavior), and overwintering (Jennings and Hayes 1994). Backlin et al. (2004) describe both high site fidelity and movement distances of greater than 1 km.

Vredenburg et. al. (2004b) comparison analysis of mountain yellow-legged frog habitat compared stream-dwelling populations of frogs in the northern part of the Sierran range to frogs in the southern Sierran range. They compared this data to the pre-existing information on lake-dwelling populations of mountain yellow-legged frogs in the southern part of the Sierran range. The study focused on different life history requirements of mountain yellow-legged frogs to determine what types of habitat were most suitable for breeding and animal movement and habitat use. They found that the type of habitat used by frogs varied based on use function. Areas selected for egg laying were similar for all locations, with frogs using low-flow open canopy habitat to lay their eggs. Frogs in the northern Sierran range used more stream than pond habitats, whereas frogs in the southern range tended toward pond habitat. The use pattern of southern Sierran frogs, now classified as *R. muscosa*, reflects a similar habitat use patterns to the southern California populations of *R. muscosa* in the Transverse ranges (Vredenburg et. al. 2004b).

6. FACTORS AFFECTING ABILITY TO SURVIVE AND REPRODUCE (species subspecies, and/or population)

Many pre-existing factors are affecting the ability of the mountain yellow-legged frog to survive and reproduce. These factors have been divided and discussed in the next two sections. Section 7 provides general information on the modification and destruction of mountain yellow-legged frog habitat that threaten its survival. Section 8 gives detailed information about each identified threats to the species and its effect on the species' survivability.

A. Present or Threatened Modification or Destruction of Habitat

Modification of the natural habitat is the biggest factor contributing to the mountain yellow-legged frog's decline. The survival and reproduction of both *R. muscosa* and *R. sierrae* have been negatively impacted by several factors directly affecting the frogs' habitat. These factors include:

(1) Spread of Disease
(2) Predation by Introduced Species

(3) Contaminant Introduction Into Mountain Yellow-Legged Frog Habitat
(4) Synergistic Effects from Multiple Threats
(5) Competing Land Use Impacts
(6) Water Pollution
(7) Climate Change and Drought

Impacts to mountain yellow-legged frog habitat vary somewhat based on the geographic area where the populations are found.

Most of the known habitat for mountain yellow-legged frogs in the Sierra Nevada is in high elevation lakes, ponds, tarns, streams, and meadow wetlands within National Forests, Wilderness Areas, and National Parks. Therefore, direct habitat alteration through wholesale conversion to other uses is not a major threat to the frog. However, human activities such as fish stocking, cattle grazing, and chemical pollution through airborne drift potentially adversely affect frog habitat. Water diversions, logging, and road construction and improvements within the National Forests may also have negative impacts on frog habitat. The emergence of the amphibian chytrid fungus also can be described as an alteration of the frog's natural habitat.

Mountain yellow-legged frogs in southern California are found primarily on public land within the Angeles and San Bernardino National Forests where dams or diversions were placed in many of the major streams flowing through the southern California mountains historically inhabited by mountain yellow-legged frogs (USFWS 2002). These dams and diversions alter natural hydrologic flow and may negatively impact mountain yellow-legged frog breeding and foraging habitat and further exacerbate the decline of populations in southern California (USFWS 2002).

(1) Spread of Disease: Amphibian Chytrid Fungus

In the late 1990s a new disease was noticed in amphibian populations, independently in several widely separated and remote parts of the world. Berger et al. (1998) first identified a chytridiomycete fungus associated with diseased frogs at sites of frog die-offs in Australia and Central America. Longcore et al. (1999) isolated the fungus, and described the apparent disease-causing organism as a new genus and species of chytrid fungus, *Batrachochytrium dendrobatidis* (the disease caused by the fungus has been termed chytridiomycosis). Since that time, *B. dendrobatidis* has been identified in more than 100 amphibian species (e.g., Young et al. 2001; Lips et al. 2003; Berger et al. 2004) and has been implicated in many cases of population declines and possible extinctions throughout the world (e.g., Bosch et al. 2001; Muths et al. 2003; Lips et al. 2004).Skerrat, et. al (2009) proposed that the emergence and spread of Bd, which causes chytridiomycosis, is the most likely primary cause of most of enigmatic declines of frogs.

Chytridiomycosis causes mortality in post-metamorphic individuals of some amphibian species, including *R. muscosa* and R. sierrae (Berger et al. 1998; Nichols et al. 2001; Rachowicz and Vredenburg 2004; Rachowicz et al. 2006; Briggs et al. 2005).). Transmission of the disease occurs in water when a flagellated zoospore embeds itself in the keratin of the amphibian's skin. The zoospore then creates a cyst, or zoosporangium, from which new zoospores are subsequently released into the water (Longcore et al. 1999). The zoospore stage is short-lived outside the host

(Longcore et al. 1999) leading researchers to hypothesize that transmission occurs through direct transmission between uninfected and infected individuals (Rachowitz and Briggs 2007). Infection causes thickening, erosion, and occasional ulcerations of the skin (Berger et al. 1998; Pessier et al. 1999). The fatal effects of chytrid infection are not clear, but the infection is thought to interfere with oxygen exchange and osmoregulation (Voyles, et. al., 2009). Mortality from chytrid is primarily post-metamorphic, mostly due to the fact that keratin is only found in the mouthparts of tadpoles, but covers the entire skin of metamorphosed frogs (Berger et al. 1999).

a) Chytrid and Mountain Yellow-Legged Frogs

Chytridiomycosis has a devastating effect on mountain yellow-legged frogs. The earliest documented case of chytridiomycosis in mountain yellow-legged frogs is from 1998 at several sites in the northern Sierra Nevada in Yosemite National Park (Fellers et al. 2001). However, evidence from museum specimens suggests that *B. dendrobatidis* was present in *R. muscosa* just west of Kings Canyon National Park at least two decades earlier (Ouellet et. al., 2005) At least two specimens of Yosemite toad collected by Sherman and Morton during a die-off at Tioga Pass in the 1970s were infected with the chytrid fungus (Carey et al. 1999). Mortality rates from chytrid infection vary among amphibian species. Some widespread species, such as *Rana catesbeiana* (American bullfrog) (Daszak et al. 2004) and *Xenopus laevis* (Parker et al. 2002), appear to be carrier species, in which infected adults are apparently unaffected. Other species infected with chytrid, including the mountain yellow-legged frog, suffer mortality rates as high as 96% (Rachowitz et al. 2006). Mortality occurs primarily in post-metamorphic adults. Infected mountain yellow-legged frog tadpoles can carry the fungus in their mouthparts without experiencing increased mortality (Rachowicz and Vredenburg 2004). Mountain yellow-legged frog individuals can transmit *B. dendrobatidis* to each other, both within and between the tadpole and post-metamorphic stages (Rachowicz and Vredenburg 2004). Eggs likely cannot be infected with Bd), due to the lack of keratinized tissue in amphibian egg masses.

Briggs et. al. (2005) summarized the known impacts of chytrid on mountain yellow-legged frogs:

1) *R. muscosa* tadpoles can become infected through contact with infected individuals and/or *B. dendrobatidis* zoospores from culture, and carry and transmit the disease (Rachowicz and Vredenburg 2004). *R. muscosa*'s multiyear tadpole stage (up to three years [Zweifel 1955]) provides a potential within-species long-lived reservoir for the disease.

2) *R. muscosa* individuals infected during the tadpole stage die as they pass through metamorphosis (Rachowicz and Vredenburg 2004). L. J. Rachowicz et al. (2006) have shown through both laboratory and field experiments that virtually 100% of infected *R. muscosa* tadpoles die within a few weeks of metamorphosis.

3) Postmetamorphic *R. muscosa* individuals can become infected through contact with infected tadpoles, postmetamorphic individuals, and/or *B. dendrobatidis* zoospores. Infected postmetamorphic individuals in the laboratory die 5 weeks post-exposure (Rachowicz et al., 2006).manuscript). All stages of *R. muscosa* are highly aquatic, rarely moving more than 1 m from water (Bradford 1983), keeping them in contact with this water-borne pathogen.

Laboratory experiments by Rachowicz et al. (2006) found that 100% of infected *R. muscosa* developed fatal chytridiomycosis after metamorphosis, while uninfected individuals from a control group remained healthy. In a related field experiment, mountain yellow-legged frog tadpoles were caged at infected and uninfected sites, and 96% of the individuals that metamorphosed at infected sites died compared to 5% at the uninfected sites (Rachowicz et al. 2006).

Recent research has shown that this chytrid fungus is widely distributed throughout the Sierra Nevada. Several infected and uninfected populations were monitored in Sequoia and Kings Canyon National Parks over multiple years, documenting dramatic declines and extirpations in infected but not in uninfected populations (72 FR 69034). In the summer of 2005, 39 of 43 populations assayed in Yosemite National Park were positive for chytrid fungus (USFWS 2007). In many areas where detailed studies of the effects of chytrid fungus on the mountain yellow-legged frog are ongoing, substantial declines have been observed in recent years. For example, recent resurveys in Yosemite National Park indicated that mountain yellow-legged frogs were absent at 37% of 113 sites where they had been observed from 2000 to 2002. In 2005 in Sequoia and Kings Canyon National Parks, mountain yellow-legged frogs were not detected at 47% of sites where they had been recorded 3-8 years earlier (72 FR 69033). A compounding effect of disease-caused extinctions of mountain yellow-legged frogs is that recolonization may never occur, because streams connecting extirpated sites to extant populations now contain introduced fishes, which act as barriers to frog movement within metapopulations (Rachowicz et al. 2006; USFWS 2007).

(2) Predation by Introduced Species: Trout Stocking

Trout stocking programs in western North America were a common fisheries management practice throughout the 20th century. The fundamental motivation behind stocking non-native trout in naturally fishless lakes is the creation and maintenance of recreational fisheries where none formerly existed (Cowx 1994). Although it is estimated that fewer than 5% of high-elevation lakes in western North America originally contained fish, more than 95% of the larger (>2 hectare surface area) and deeper (>3 m maximum depth) lakes now contain non-native trout populations as a result of these stocking programs (Donald et al. 1980; Bahls 1992; Armstrong and Knapp 2004). The widespread introduction of trout has profoundly altered the ecosystems that support mountain yellow-legged frogs. Trout have been stocked into at least 80% of Sierra Nevada lakes (Knapp and Matthews 2000a; Knapp et al. 2003; Knapp 2005). The California Wildlife Action Plan prepared by CDFG (Bunn et al. 2007) identifies introduced trout as the "primary cause of decline" of the mountain yellow-legged frog in the Sierra Nevada. After surveying Sierra Nevada lakes, Bradford et al. (1998) concluded that "the most profound human impacts on aquatic communities in the High Sierra appear to be related to historical and on-going stocking of exotic fish species into High Sierra waters."

The introduction of trout into mountain yellow-legged frog habitats presents a serious problem. Fish did not occur in much of the high elevation habitat of California until the late nineteenth century (Moyle 1976; Jennings 1988; Moyle et al. 1996). Introduction of trout into high elevation lakes and streams has resulted in significant predation on frogs (Bradford 1989; Jennings et al. 1992; Bradford et al. 1993; Bradford et al. 1998; Knapp and Matthews 2000;

Knapp et al. 2001; Matthews et al. 2001; Knapp et al. 2003; Vredenburg 2004; Knapp 2005; Rachowicz et al. 2006). For many decades biologists have recognized that introduced species of fish are responsible for limiting the distribution of mountain yellow-legged frogs in the Sierra Nevada (Grinnell and Storer 1924; Cory 1963; Bradford 1989; Knapp and Matthews 2000, Knapp et al. 2003).1989). High rates of predation by trout have been documented for both tadpoles (Hayes and Jennings 1988) and adults (Needham and Vestal 1938).

a. *Studies of Trout Related Mountain Yellow-Legged Frog Declines*

Knapp and Matthews (2000) completed a comprehensive study of the influence of introduced trout on the mountain yellow-legged frog in the southern Sierra. The study compared 1,059 lakes on Park Service land (Kings Canyon) with 1,205 lakes on immediately adjacent Forest Service land (John Muir Wilderness) that are heavily stocked with fish. Fish stocking was stopped in the National Parks in 1977, but it continues on the National Forests lands. As a result many water bodies within the National Parks lack fish relative to similar habitats in the National Forests. In the National Forests, mountain yellow-legged frog adults were found in only 4% and frog larvae in only 3% of the surveyed water bodies. In the National Park adults were found in 31% and frog larvae were found in 20% of the surveyed water bodies.[7] Population abundance was correspondingly much lower within the National Forest.[8] Knapp and Matthews (2000) concluded that, "fish presence was an important reason, and perhaps the primary reason for the decline of mountain yellow-legged frogs in many areas of the Sierra."

In an earlier study Bradford (1989) documented that mountain yellow-legged frog tadpoles were not found to coexist with fish in 67 lakes in Sequoia and Kings Canyon National Parks. A similar pattern was shown by Zardus et al. (1977) for an additional 133 lakes in the region. Where frogs and fish did co-occur, they appeared to be utilizing different micro habitats. In one such lake, tadpoles were found in a shallow rocky area inaccessible to fish (Bradford et al. 1994a). At other sites the frogs utilized small bodies of water lacking fish and then retreated to the lakes when these areas dried (Bradford et al. 1993). The long larval stage (one to two and one half years) of mountain yellow-legged frog tadpoles makes them extremely vulnerable to predation by introduced aquatic predators (Bradford 1989; Bradford et al. 1993). Careful study of the distributions of introduced trout and mountain yellow-legged frogs for several years has shown that introduced trout have had negative impacts on mountain yellow-legged frogs over much of the Sierra Nevada (Bradford 1989; Knapp 1996; Knapp and Matthews 2000; Knapp 2005).

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[7] While the Knapp and Mathews study primarily is about why mountain yellow-legged frogs have declined, the fact that the formerly ubiquitous frogs were absent from 96% of the USFS water bodies and 67% of the NPS water bodies is itself extremely compelling evidence of the current endangered status of the species.

[8] In Kings Canyon, populations of more than 20 adult frogs were found at 10% of lakes surveyed, and only at 1% of lakes in the John Muir Wilderness. Populations of more than 50 adult frogs were at 6% and more than 100 adults at 4%of Kings Canyon lakes, while only at 0.5% and 0.3%, respectively, of lakes in John Muir Wilderness.

Bradford (1989) and Bradford et al. (1993) concluded that introduced trout eliminate many populations of mountain yellow-legged frogs and that the presence of trout in intervening streams sufficiently isolates other frog populations so that re-colonization after stochastic (random, naturally occurring) local extirpations is essentially impossible. This mechanism is sufficient to explain the elimination of Sierran mountain yellow-legged frogs from many of the sites they once inhabited. Wherever the two species co-occur, trout are likely to eliminate mountain yellow-legged frogs or keep populations low and limit dispersal. The widespread occurrence of introduced trout in the mountains of the Sierra may make it very difficult to reverse the decline of the species.

b. Impacts of Trout Stocking on Sierran Ecosystems

Trout stocking has implications that reach beyond the impacts to the mountain yellow-legged frog. Introduction of trout has had sweeping implications for other species as well. The alteration of zooplankton and benthic macroinvertebrate communities in high elevation aquatic systems due to introduced fish is well documented (see Brooks and Dodson 1965; Northcote et al. 1978; Anderson 1980; Bradford et al. 1989; Mittelbach et al. 1995; Knapp 1996; Bradford et al. 1998; Carlisle and Hawkins 1998; Knapp et al. 2001a.). These organisms are critical to maintaining healthy, functioning ecosystems. Fisk et al. (2007) looked at the evolutionary impacts of introduced trout on *Daphnia*, a primary prey item for fish. *Daphnia* are especially vulnerable to fish predation due to their relatively large body sizes and poor swimming abilities. However, *Daphnia* are capable of rapid evolutionary response to changing environmental conditions. Study results showed that *Daphnia* populations co-existing with fish have undergone rapid adaptive reductions in body size and in the timing of reproduction (Fisk et al. 2007). This in turn has resulted in shifting evolutionary pressures with impacts on other species that rely on *Daphnia* as a food source. Removal of *Daphnia* and other zooplankton negatively effects ecosystem biodiversity, processes and productivity (see Brett et al. 1994; Elser et al. 1995; Knapp 1996; Sarnelle and Knapp, 2005; Herbst et al. 2009). The loss of zooplankton raises concerns about trophic disruption in mountain yellow-legged frog habitat (e.g., Finlay and Vredenburg 2007).

The loss of both zooplankton and frogs by trout predation has had great impacts on other native species (such as co-occurring amphibians, aquatic insects, and garter snakes) thus altering their composition and distribution (Bradford, 1989; Jennings et al. 1992; Bradford et al. 1993; Bradford et al. 1998; Knapp and Matthews 2000; Knapp et al. 2001; Matthews et al. 2001; Knapp et al. 2003; Vredenburg 2004; Knapp 2005; Rachowicz et al. 2006). One predator species that has been co-affected by trout stocking is the mountain garter snake (*Thamnophis elegans elegans*). Matthews et al. (2002) found that "the probability of finding snakes in lakes with amphibians was 30 times greater than in lakes without amphibians. Furthermore, lakes with snakes had higher numbers of amphibians within 1 km than did lakes without snakes." This data suggest a high correlation between amphibian presence and garter snake presence. Matthews et al. (2002) note "based on these data, we suggest that the introduction of nonnative trout has led not only to the decline of amphibians but also to the decline of garter snakes...the introduction of trout into an ecosystem can have serious effects, not just on their prey but also on other predators in the ecosystem."

Image from USFS Pacific Southwest Research Station

Trout stocking has huge implications for overall biodiversity. Predation by trout on multiple species in the high Sierras has undoubtedly altered the food web of aquatic ecosystems of the high Sierras, triggered trophic cascades in some areas, and impacted the presence and abundance of other native species that have predator and/or prey relationships with mountain yellow-legged frogs (see Bradford 1989; Bradford et al. 1993; Knapp 1996; Jennings 1996; Knapp et al. 2001a; Schindler et al. 2001; Matthews et al. 2002; Sarnelle and Knapp 2004, 2005; Harper-Smith et al. 2005; Fisk et al. 2007; Latta et al. 2007). Harper-Smith et al. (2005) looked at the impacts of trout on multivariate community level impacts on multiple species of the Sierras using structural food webs, and found that lakes where trout were present had dramatically simplified food webs, and smaller species diversity when compared to lakes that did not have fish. Knapp (2005) studied the impacts of introduced trout in Yosemite National Park, finding that trout introductions have resulted in considerable alteration of Yosemite's herpetofauna for multiple species including the mountain yellow-legged frog, Pacific treefrog (*Hyla regilla*) mountain garter snake (*Thamnophis elegans elegans*) and Sierra garter snake (*Thamnophis couchi couchi*).

c. Trout Removal Studies

Further affirmation of the negative impacts of trout is seen in recent predator removal studies. The negative impacts of trout stocking on mountain yellow-legged frog have been indirectly confirmed by the success of trout removal projects in bolstering mountain yellow-legged frog repopulation. Vredenburg et al. (2004a) looked at the impacts of trout removal over a seven-year period in Kings Canyon National Park. Trout removal was conducted in 5 lakes, and 16 nearby lakes were used as controls, 8 with introduced trout and 8 without. One year after removals began, researchers observed significant differences in the number of mountain yellow-legged frogs in removal lakes as compared with control lakes. After 3 years without fish predators, frog populations in trout removal lakes were not distinguishable statistically from control lakes without fish. In further studies Knapp et al. (2007) found that removing trout from lakes led to significant increases in overall mountain yellow-legged frog population density. Mountain yellow-legged frog populations increased significantly in trout-removal lakes when compared to increase in containing control lakes with trout during the same time period (Knapp et al. 2007).

(3) Pesticides and Other Contaminants

Over 1 billion pounds of pesticides are used each year in the United States to control weeds, insects and other organisms (Gilliom et al. 2007). A 2006 USGS report (USGS Fact Sheet 2006–3028 - updated in 2007) regarding pesticides in U.S. waters found that:

> At least one pesticide was detected in water from all streams studied and … pesticide compounds were detected throughout most of the year in water from streams with agricultural (97 percent of the time), urban (97 percent), or mixed-land-use watersheds (94 percent). In addition, organochlorine pesticides (such as DDT) and their degradates and by-products were found in fish and bed-sediment samples from most streams in agricultural, urban, and mixed-land-use watersheds—and in more than half the fish from streams with predominantly undeveloped watersheds. Most of the organochlorine pesticides have not been used in the United States since before the NAWQA studies began, but their continued presence demonstrates their persistence in the environment.

a. Pesticide Drift

Aerial pesticide applications typically result in a loss of 40% to drift (Cox 1995). The amount of drift has been characterized as "considerable" by the National Research Council and is thought to vary from 5% (under optimal low wind conditions) to 60% (under more typical conditions) (National Research Council 1993). The Office of Technology Assessment estimates that about 40% of an aerial insecticide application leaves the target area and that less than 1% actually reaches the target pest (U.S. Congress Office of Technology Assessment 1990). The typical range for drift is 100 meters to 1,600 meters (Cox 1995). However, longer ranges have been documented. For example, drift from orchard applications in Vermont exceeded 2 miles; pesticides applied to wheat fields in Colorado drifted between 5 and 10 miles; applications in California drifted 4 miles from an oat field; and drift has been seen 10 to 50 miles from applications in central Washington (Cox 1995).

The waters of the Sierra Nevada are not immune to impacts from pesticide drift. Pesticides used in the Central Valley are transported on wind currents or as part of eastbound storm systems into the Sierra Nevada (Cahill et al. 1996; Aston and Seiber 1997; Seiber et al. 1998). Samples of snow collected at 7,000 feet have revealed the presence of toxic organophosphates such as diazinon, malathion, and chlorpyrifos residues (Aston and Seiber 1997; Seiber et al. 1998). The use of these and other second generation pesticides has increased greatly since the 1970s, when declines of mountain yellow-legged frogs were first observed. Little currently is known about the fate of these chemicals in high elevation aquatic habitats historically occupied by the mountain yellow-legged frog (Boyer and Grue 1995).

Lenoir et al. (1999) studied pesticide drift from the San Joaquin Valley by looking at high volume air, dry deposition, and surface water samples in both the Central Valley and at different elevations in Sequoia National Park. In 1998, the year of the study, over 60% of the total pesticide usage in the state of California was sprayed in the San Joaquin Valley. Pesticides applied to this area volatilize under warm temperatures typical of the valley and are transported through the atmosphere to be deposited in the cooler, higher elevation regions of the Sierra Nevada Mountains. Residues from several pesticides were detected at high elevations in Sequoia National Park, and the residues in highest concentration correlated with the application of chemicals from farming areas in the Central Valley (Lenoir et al. 1999).

b. Impacts of Pesticides on Amphibians

Amphibians are extremely susceptible to many deleterious effects of pesticides introduced into the natural environment, since they inhabit aquatic habitats throughout their entire life cycle, making them especially susceptible to chemical contamination of their aquatic environment in both the juvenile and adult life phases (Reylea 2005). Pesticides can harm amphibians in different ways. At high concentrations they are lethal to amphibian eggs, larvae, and adults (Spalding et al. 2009). Many studies have demonstrated that pesticide residues in water, sediment, and aquatic vegetation can harm amphibians in aquatic environments by delaying or altering larval development, or by reducing breeding or feeding activity (Beaties and Tyler-Jones 1992; Corn and Vertucci 1992; Hall and Henry 1992; Berrill et al. 1993, 1994, 1995, 1998; Boyer and Grue 1995). Many pesticides currently in use in the Central Valley can potentially disrupt endocrine systems, adversely affecting adult breeding and embryonic larval development (Colburn et al. 1996; Hayes 1997).

In a USGS study, pesticides from the Central Valley were found to impact frog species in the Sierra Nevada mountain range (Sparling et al. 2001). The study found a close correlation between declining populations of frogs and exposure to agricultural pesticides. Particularly, the study found three chemicals - diazinon, endosulfan, and chlorpyrifos - at toxic levels in over half of frogs tested. The study found that the most drastic population declines of several frog species (red-legged frog, *Rana aurora*, yellow-legged frog, *Rana boylii*, mountain yellow-legged frog, and Yosemite toad, *Bufo canorus*) (Sparling et al. 2001).

Studies have shown that certain listed amphibian species may be more susceptible to the negative effects of pesticides than their non-threatened counterparts. Sparling and Fellers (2009) examined the chronic toxicity of two of the most commonly used insecticides in the Central Valley, chlorpyrifos and endosulfan, on larval Pacific treefrogs (*Pseudacris regilla*) and foothill yellow-legged frogs (*Rana boylii*). Sensitivity to exposure to chlorpyrifos and endosulfan varied between the two species of frogs. The estimated median lethal concentration, or LC50, for chlorpyrifos was 365 µg/L in *P. regilla* and 66.5 µg/L for R. boylii. Likewise, the time to metamorphosis increased with concentration of chlorpyrifos in both species. Cholinesterase activity, a key step of metamorphosis, declined with exposure concentration (at Gosner stage 42 to 46 metamorphs of both species). Results of the study showed that the effects of these chemicals were more deleterious to *R. boylii* than to *P. regilla* (Sparling and Fellers 2009).

c. Impacts of Pesticides on Mountain Yellow-Legged Frogs

Since mountain yellow-legged frogs spend a high percentage of their life cycle in water, moving through the interface of water and air, and respire through their skin, they are at high risk of exposure. Pesticides, often insoluble in water, tend to concentrate on the surface of a water body, a place where mountain yellow-legged frogs move through often, heightening their risk (Cory et al. 1970). These risks have not gone unnoticed by scientists. Spalding and Fellers (2009) discuss the implications of their study on pesticide drift on mountain yellow-legged frog conservation issues:

> Environmentally realistic concentrations of insecticides in the Sierra Nevada Mountains of California may have the ability to inflict serious damage on native amphibians. In comparison to those 18 of several other species, *Pseudacris regilla* populations seem to be stable or declining at a slower rate. A possible cause of their relative success is their reduced dependence on standing water. *P. regilla* adults lay their eggs in water and move to upland habitat shortly afterwards; hatching is rapid compared to some of the other species; and time to metamorphosis is less than that of *R. boylii*. The congeneric mountain yellow-legged frog, which is federally endangered in the southern end of its distribution, can be exposed to water borne contaminants for two to three summers as tadpoles before metamorphosing. Thus exposure to chlorpyrifos and endosulfan poses serious risk to amphibians in the Sierra Nevada Mountains.

Other studies have looked at the effects of pesticides on mountain yellow-legged frogs at environmentally realistic concentrations. Fellers et al. (2004) measured pesticide concentrations in mountain yellow-legged frogs from two areas in the Sierra Nevada. The first area (Sixty Lakes Basin, Kings Canyon National Park) had a large and apparently healthy population of frogs. The second area (Tablelands, Sequoia National Park) had large populations of yellow-legged frogs at one time which were extirpated by the early 1980s. The Tablelands is exposed directly to prevailing winds from agricultural regions in the San Joaquin Valley to the west. An experimental reintroduction of mountain yellow-legged frogs in 1994 to 1995 was deemed unsuccessful (Fellers et al. 2007). In 1997, the last 20 reintroduced frogs that could be found were collected from the Tablelands. Researchers measured pesticide concentrations in both the recaptured frog tissue and the water in Tablelands and at reference sites at Sixty Lakes. In frog tissues, dichlorodiphenyldichloroethylene (DDE) concentration was one to two orders of magnitude higher than the other organochlorines (Fellers et al. 2004). Both g-chlordane and trans-nonachlor were found in significantly greater concentrations in Tablelands frog tissues compared with Sixty Lakes. Organophosphate insecticides, chlorpyrifos, and diazinon were observed primarily in surface water with higher concentrations at the Tablelands sites. No pesticide concentrations were significantly higher in the Sixty Lakes samples compared to Tablelands samples, suggesting that pesticide drift is significantly affecting the Tablelands site (Fellers et al. 2007).

(4) Synergistic Effects from Multiple Threats

a. Combined Effects of Pesticides and Other Threats

When combined, many of the threats faced by the mountain yellow-legged frog can have especially deleterious effects. Although fish stocking has undisputedly played a major role in the decline of mountain yellow-legged frogs in the Sierra Nevada, there is ample documentation that the species has declined even in areas where there is an absence of introduced fish. For example, surveys for *R. muscosa* in fishless areas of Sequoia and Kings Canyon National Parks from 1989-1990 revealed that frogs had disappeared from approximately half of historic localities within the last three decades (Bradford et al. 1994). Drost and Fellers (1996) noted that frog populations have disappeared from sites that either never were planted with fish or that are too small or ephemeral to support fish, for example, complete disappearance of the species from Tuolumne Meadows and the Tioga Pass area in Yosemite National Park, where there are extensive meadow pools and marshes which are effectively isolated from fish. Clearly fish stocking alone does not adequately explain the overall decline of the species, and there are other factors or combinations of factors that contribute significantly to frog disappearances, such as chytrid and pollutants.

The effects of pesticides can be compounded with existing environmental stressors. Environmental contaminants and disease may synergistically contribute to amphibian population declines. Metts et al. (2005) makes an important point about synergistic effects:

> Although many studies have examined lethal-limits of pesticides on amphibians, environmental concentrations are frequently not high enough to induce direct amphibian mortality. Consequently, assessing the sublethal effects of pesticides may be more relevant. Current research suggests that exposure of amphibians to certain chemicals affects behavior (Marian, et. al., 1983; Bridges, 1997) and development (Bridges, 2000). Additionally, these sublethal effects can be exacerbated by environmental factors such as competition and predation (Boone & Semlitsch, 2001; Relyea & Mills, 2001).

i. Pesticides and Disease

Of great concern is the possibility that pesticide pollutants act as environmental stressors, rendering mountain yellow-legged frogs more susceptible to aquatic pathogens such as red-leg disease or the chytrid fungus (Carey 1993; Carey and Bryant 1995; Jennings 1996; Drost and Fellers 1996; Carey et al. 1999; Davidson et al. 2007). The red-leg disease pathogen historically has been considered opportunistic, infecting only injured or immuno-suppressed amphibians, but not healthy individuals (Anver and Pond 1984; Cahill 1990; Carey 1993; Carey and Bryant 1995; Carey et al. 1999). Recent research indicates that sub-lethal levels of organophosphate pesticides in combination with normal background levels of red-leg bacteria may result in fatal infections to amphibians (Taylor et al. 1999).[9] Taylor et al. (1999) linked exposure to malathion with increased disease susceptibility or suppressed immune responses in adult Woodhouse's toads (*Bufo woodhousi*). Malathion is readily taken up through the skin, respiratory system, or gastrointestinal tract (Gunther et al. 1968). It is unknown how much malathion currently is applied in or drifts into the Sierra Nevada, but in the 1980s, malathion was applied annually to almost 5 million hectares in the United States (Smith 1987).

Davidson et al. (2007) looked at the combined effects of pesticide-induced immunosuppression and chytrid fungus on amphibians. Research examined the effects of pesticide and chytrid interactions on frogs using laboratory experiments to investigate whether low, sub-lethal doses of carbaryl, a common, current-use pesticide, affected foothill yellow-legged frog (*Rana boylii*) susceptibility to chytrid fungus. The foothill yellow-legged frog's skin peptides strongly inhibited chytrid growth in vitro, which may explain why chytrid exposure did not result in significant mortality on its own. However, skin peptide defenses were significantly reduced after exposure to carbaryl, suggesting that pesticides may inhibit immune defense and increase susceptibility to disease.

ii. Pesticides and Introduced Trout

In a separate study, Davidson and Knapp (2007) looked at pesticide impacts on mountain yellow-legged frogs and their relationship to other environmental stressors, specifically non-native trout, as it relates to the decline of this species. Investigators looked at the relative effects of fish and pesticides on the mountain yellow-legged frog using detailed data sets from a large portion of its historic range. Habitat characteristics and the presence/absence of mountain yellow-legged frog and fish were quantified at 6,831 sites. Pesticide use upwind of each site was calculated from pesticide application records and predominant wind directions. Davidson and Knapp (2007) found the probability of mountain yellow-legged frog presence was significantly reduced by the presence of both fish and pesticides. The landscape-scale effect of pesticides was much stronger than that of fish, but the degree to which a site was sheltered from the predominant wind (and associated pesticides) was also a significant predictor of mountain yellow-legged frog decline (Davidson and Knapp 2007). The study suggests that windborne pesticides are contributing to amphibian declines in pristine locations, even in places where introduced trout are absent.

b. Introduced Trout and Disease

It has been hypothesized that introduced fish may act as a vector for new diseases to infect *R. muscosa*. A study conducted by Mao et al. (1999) shows that a virus is capable of being transmitted from fish to amphibians under natural conditions, evidence that this pathway is possible, and perhaps even probable. The study is the first to isolate identical iridoviruses from

[9]Taylor et al. (1999) exposed Woodhouse's toads (*Bufo woodhousi*) to the "red-leg" bacterium *Aeromonas hydrophila*, and external high, low, or no doses of field grade malathion. Disease susceptibility and mortality were significantly increased in toads exposed to both high and low doses of malathion.

wild sympatric fish (threespine stickleback, *Gasterostelus aculeatus*) and amphibians (the red-legged frog, *Rana aurora*). The Mao et al. (1999) study strengthens the suggestion that fish may serve as a reservoir for amphibian viruses. There is also the possibility that disease could be spread by humans from a sick population of frogs to healthy ones.

Significant questions remain regarding the taxonomy of aquatic Sierra pathogens, and their relationship to the ecology of montane amphibian species, including the mountain yellow-legged frog. If the pathogens are native to the Sierra Nevada (which is unknown for the chytrid fungus), it may be that they are taking advantage of environmental stressors which render amphibians more susceptible to disease. A number of environmental stressors could theoretically have such an effect, including UV-radiation, climate change, chemical pollution, extremely cold temperatures, or even excessive handling (Carey 1993; Sherman and Morton 1993; Carey and Bryant 1995; Jennings 1996; Drost and Fellers 1996; Carey et al. 1999; Taylor et al. 1999, Davidson et al. 2007).

(5) UV Radiation

Ultraviolet (UV) radiation is emitted by the sun, and levels of UV radiation have increased slightly over historic levels as a result of thinning of the Earth's protective ozone layer. Increasing UV radiation is of concern as a potential cause of amphibian declines because many observed declines are occurring at high elevations where UV exposure may be greater than at lower elevations. Indeed, field and laboratory experiments in which different amphibian life stages (e.g., eggs, tadpoles) are exposed to different intensities of UV radiation suggest that survival of eggs and tadpoles of several amphibian species can be reduced by exposure to UV radiation (Knapp, pers. comm.., 2009; see http://www.mylfrog.info/threats/uvradiation.html).

Aquatic habitats in the Sierra Nevada receive high doses of UV radiation due to their high elevation and extraordinary water clarity. However, recent research indicates that the distribution of mountain yellow-legged frogs in the Sierra Nevada is not correlated with UV exposure (Adams et al. 2001). In addition, experiments with Sierran frogs and toads, including mountain yellow-legged frogs, indicate that current levels of UV radiation do not cause reduced survival (Vredenburg 2002).

(6) Land Use Planning Impacts

a. Fire and Fire Management

Mountain yellow-legged frogs are generally found at high elevations in wilderness areas and national parks where vegetation is sparse and fire suppression activities are implemented infrequently. Potential impacts to the species resulting from fire management activities include: Water drafting (taking of water) from occupied ponds and lakes, resulting in direct mortality or rendering the habitat unsuitable for reproduction and survivorship; construction of fuel breaks either by hand or heavy equipment, potentially resulting in erosion and siltation of habitat; fire suppression with water applications or fire retardants; and increased human activity in the area, potentially disrupting mountain yellow-legged frog behavior (66 FR 2293).

In some areas within the range of the mountain yellow-legged frog, long-term fire suppression has changed forest structure and conditions where fire severity and intensity are higher (McKelvey et al. 1996). Prescribed fire has been used by land managers to achieve various silvicultural objectives, including the reduction of fuel loads. In some systems, fire is thought to be important in maintaining open aquatic and riparian habitats for amphibians (Russel et al. 1999). But severe and intense wild fires may reduce the ability of amphibians to survive such a fire. However, amphibians display adaptive behavior that may minimize mortality from fire, by taking cover in wet habitats or taking shelter in subterranean burrows, though the moist and permeable skin of amphibians increases their susceptibility to heat and desiccation (Russel et al. 1999). Neither the direct nor indirect effects of prescribed fire or wildfire on the mountain yellow-legged frog have been studied, but because the species generally occupies high elevation habitat, fire and fire management activities are not a likely risk to this species in much of its range.

i. Fire Retardant

Fire retardant chemicals contain a mixture of substances that may be harmful to amphibians, including nitrogen and various surfactants. Laboratory tests of these chemicals have shown that they can cause mortality in fishes and aquatic invertebrates by releasing surfactants and ammonia when they are added to water (Hamilton et al. 1996), and similar effects are likely on amphibians. Therefore, if fire retardant chemicals were dropped in or near mountain yellow-legged frog habitat, they could have negative effects on individuals. A 2007 Biological Opinion by the National Marine Fisheries Service (NMFS) found that the aerial application of fire retardant by the U.S. Forest Service would jeopardize the continued existence and recovery of threatened and endangered species under its purview. (NMFS, 2007). The Fish and Wildlife Service released a similar biological opinion in 2008. (USFWS, 2008).

Importantly, the mountain yellow-legged frog in southern California occurs in only eight small populations all within the San Bernardino and Angeles National Forests. The loss of even one population due to a fire retardant drop would be a significant effect to this species. Further, given the small population sizes, the loss of even one or a few frogs from a population could be a significant effect to this species.

In summary, the mountain yellow-legged frog is highly susceptible to the effects of fire retardants due to the toxicity of fire retardants to aquatic species, the potential for fires within habitat, the amount of time spent in the tadpole stage, the small numbers of remaining occurrences and the small numbers of frogs in each occurrence. Thus, a fire retardant drop in occupied mountain yellow-legged frog habitat is likely to result in an appreciable reduction in the distribution and reproduction of the southern California distinct population segment of this species. Therefore, we conclude that this activity would reduce appreciably the likelihood of the species' survival and recovery in the wild, and is likely to jeopardize its continued existence.

b. Livestock Grazing

Cattle grazing in high elevation wetland habitats may have adverse impacts on frog habitats by reducing vegetative cover, creating excess nitrogen pollution, increasing siltation of breeding ponds, altering the local hydrology through erosion and lowering of the water table, and crushing embryos and larvae, as well as breeding adults (Jennings 1988; Jennings and Hayes 1994). The impacts of livestock grazing on high elevation wetland ecosystems are well documented (Jennings 1996; Knapp and Matthews 1996; and authorities cited within). Livestock can remove and trample riparian and wetland vegetation (Kauffman and Krueger 1984; Marlow and Pogacnik 1985) used for cover and egg laying by frogs. Cattle also markedly alter the physical characteristics of stream margins because they tend to concentrate there (Belsky et al. 1999) and stream banks are more susceptible to trampling because of high soil moisture (Marlow and Pogacnik 1985). Trampling often increases soil compaction and stream bank erosion, filling in pools, and making stream channels wider and shallower (Duff 1977; Kauffman et al. 1983; Kauffman and Krueger 1984; Bohn and Buckhouse 1985). Mountain yellow-legged frogs need deep pools to overwinter. Livestock grazing can increase erosion of connecting stream channels, lowering the water table, and eliminating ephemeral and even permanent water bodies (Meehan and Platts 1978; Armour et al. 1994) used by frogs for breeding. Grazing can also eliminate undercut banks (Duff 1977; Platts 1981) used by frogs for cover. Grazing may also pollute sensitive aquatic habitat through input of excessive nitrogen, which can lead to increased levels of aquatic bacteria (Stephenson and Street 1978).

Disturbance of current or historic mountain yellow-legged frog habitat due to livestock grazing has been documented in many of the National Forests. For example, in the Inyo National Forest grazing impacts to riparian and aquatic organisms, damage to springs and wet meadows, and changes in channel morphology and pool depth have occurred in many areas that currently are or previously were suitable frog habitat (Kattlemann and Embury, 1996). Hansen (1980) noted that occurrence of mountain yellow-legged frogs on the Kern Plateau in Sequoia National Forest "may be of considerably more limited occurrence than in the past due to habitat modifications, particularly cattle grazing in the meadows." These impacts were reported at numerous localities on the Kern Plateau (Christopher 1994), in Cottonwood Basin and McAfee Meadow Research Natural Area on the east slope of the White Mountains (Giuliani 1996), in Crooked Meadows (Knapp 1993a), Dry Creek (Knapp 1993), and Cold Meadow (Knapp 1994).

In Crooked Meadows, Knapp (1993a) noted a negative correlation between grazing impacts and numbers of frogs. Knapp found no frogs in the lower portion of the meadow, which had been incised due to grazing practices, and was wide and shallow with no undercut banks. The ungrazed portions of the meadow contained the best frog habitat (the stream was deep and narrow, and there were overhanging banks for cover from predators) and most of the frogs. The depth of the largest pond had been reduced by sediment deposition from grazing practices. Knapp felt that as a result of this habitat alteration, the overwinter survival of tadpoles may have been decreased, as they need a certain depth of unfrozen water to survive winter (Knapp 1993).

In summary, historic grazing activities likely modified the habitat of the mountain yellow-legged frog throughout its range. Although grazing pressure has been significantly reduced from historic levels, grazing may continue to contribute to localized degradation and loss of suitable habitat, negatively affecting mountain yellow-legged frog populations.

c. Recreation

Recreation is the fastest growing use of national forests. As such, its impacts on the mountain yellow-legged frog are likely to continue and to increase (USDA 2001). Recreational activities take place throughout the Sierra Nevada and have significant negative impacts on several plant and animal species and their habitats (USDA 2001a). To further recreational opportunities and angling success, non-native trout stocking programs in the Sierra Nevada started in the late 19th Century (Bahls 1992; Pister 2001). Trout stocking throughout the range of the mountain yellow-legged frog has contributed to the decline of this species (see Predation, Factor C, below). The recreational impact of anglers at high mountain lakes has been severe in the Sierra Nevada, with most regions reporting a level of use greater than that which the fragile lakeshore environments can withstand (Bahls 1992).

Recreation may threaten all life stages of the mountain yellow-legged frog through direct disturbance resulting from trampling by humans, packstock, or vehicles, including off-highway vehicles; harassment by pets; and associated habitat degradation (Cole and Landres 1996; USFS 2001). Studies have not been conducted to determine whether recreational activities are contributing to the decline of the mountain yellow-legged frog, and recreation has not been implicated as a cause of major decline of the mountain yellow-legged frog.

i. Off-Road Vehicles

Off-road vehicles (ORVs) have increased the accessibility of remote areas, creating the potential for damage in places that were previously protected. For example, when campsites in riparian areas are created and become established, riparian vegetation is often cut for fuel, erosion of heavily used areas occurs, and litter and water pollution become common (Bury 1980). In addition, when riparian areas are used by ORVs, there is also a good chance for gas and oil pollution from leaks and spills.

ORV use can lead to the death of amphibians due to direct kills, however, the elimination and degradation of vegetation and critical habitat by ORVs has a larger, long-term impact. In addition to loss of vegetation and destruction of habitat, road traffic and the use of off-road vehicles can cause increased sedimentation and chemical contamination that can be detrimental to adjacent aquatic systems; large amounts of sediment can prove detrimental and even lethal to amphibians. Welsh and Olliver (1998) found a lower density of tailed frogs (*Ascaphus true*, a Species of Special Concern in California), Pacific giant salamanders (*Dicamptodon tenebrosus*) and southern torrent salamanders (*Rhyacotriton variegatus*, a Species of Special Concern in California) in streams adjacent to road construction in Redwood National Park.

Routes, trails and the use of ORVs can create barriers to necessary movement (i.e., movement for migration, breeding, foraging). Studies have found a higher proportion of dead frogs and toads on routes with higher traffic volumes. Although this may result from higher direct mortality, it may also occur because traffic changes movement patterns and interrupts anuran behavior (Fahrig et al. 1995).

In a literature review discussing the impacts of forest management practices on amphibians in North America, DeMayndier and Hunter (1995) contend that forest roads can lead to long-term changes in habitat because routes increase fragmentation and decrease the permeability of the landscape. Marcot et al. (1997) also report that roads can fragment some reptile habitats. Routes and trails that serve as barriers to amphibian and reptile movements can cause populations to become isolated and more susceptible to detrimental genetic and environmental consequences. Barriers also cause difficulties for amphibian populations that migrate between aquatic breeding ranges and upland home ranges and may prevent populations from successfully breeding (i.e., Red-legged frog, *Rana aurora*, California Species of Special Concern, Federally Threatened).

Amphibians are susceptible to direct mortality from off-road vehicle use, especially during dispersal and migration; however, they are more greatly affected by the associated loss of vegetation that causes the degradation of critical habitat. Marcot et al. (1997) state that "off-road vehicle use has become a major threat to reptiles" while various studies suggest that ORVs are also a threat to amphibians (DeMaynadier and Hunter 1995; Maxell and Hokit, 1999). Managers should be concerned about "the potential impacts of secondary roads on sensitive species and should construct fewer and narrower roads with little or no verge clearance (DeMaynadier and Hunter, 2000)." Maxell and Hokit (1999) recommend that roads and trails avoid water bodies, wetlands and areas that are key habitat for amphibians and reptiles.

d. Overexploitation

Numerous museum specimens taken from many localities (Jennings and Hayes 1994) attest to the fact that mountain yellow-legged frogs have been collected for scientific purposes for many decades. These collections probably did not have a significant effect, although local populations may have been impacted by extensive scientific collecting. Currently very little scientific collecting occurs in the Sierra Nevada, and virtually no collecting occurs in southern California with the exception of the mountain yellow-legged frog captive breeding program (http://www.sandiegozoo.org/conservation/animals/amphibians/mountain_yellow-legged_frog_hopping_for_survival/). Irresponsible or un-permitted scientific or amateur collecting could seriously jeopardize smaller populations. Any local extinctions would further isolate the remaining populations and probably accelerate the time to extinction for the entire complex.

Scientific research may also cause stress to mountain yellow-legged frogs through disturbance, including disruption of the species' behavior, handling individuals, and injuries associated with marking and tracking individuals. Scientific research has also resulted in the death of numerous individuals through the collection of museum specimens (Zweifel 1955; Jennings and Hayes 1994). However, this is a relatively minor threat. Of greater concern are researchers contributing to the spread of pathogens via clothing and sampling equipment as they move between water bodies and populations (Bradford 1991; Bradford et al. 1994a; Fellers et al. 2001). Given the uncertainty surrounding the potential for researchers to contribute to the spread of pathogens, researchers have begun to implement equipment sterilization procedures between survey sites (Knapp 2002; Vredenburg, 2002).

(7) Water Pollution

Water pollution is a major threat to amphibians. Pollution can come in many forms. Siltation of breeding grounds can impact oxygen exchange and smother amphibian eggs (Smith and Keinath 2007). Siltation can result from many land management uses, including off-road vehicle use and fire control (see discussion above). Additionally, nitrogen pollution can kill amphibians and impact their prey sources (Rouse et al. 1999). Nitrates are of low toxicity but can cause health problems when reduced to nitrites. Nitrate can be reduced to nitrite in the gastrointestinal tract of amphibians, especially in younger animals (Marco et al. 1999; Marco and Blaustein 1999). Marco et al. (1999) found that moderate exposure to nitrates and nitrites resulted in reduced feeding activity, disequilibrium, physical abnormalities, paralysis, and even death among some tadpoles and young frogs. Levels of nitrite considered safe for human drinking water killed over half of Oregon spotted frog (*Rana pretiosa*) tadpoles after 15 days of exposure. Pesticide pollution is also known to have multiple deleterious effects on amphibians (see discussion above). These sources are discussed in other sections, but are generally categorized as water pollution.

(8) Climate Change

a. Hydrological Changes in the Sierra Nevada Mountains

Anthropogenic global climate change has already altered the hydrology of montane regions. In the western United States, the following trends have been observed over the past century: an earlier streamflow by one to four weeks due to early snowmelt, a decrease in the percentage of precipitation that falls as snow, a decrease in mountain snow-water equivalent, increased frequency of heavy precipitation events as well as increased frequency of periods of drought, and a decrease in the duration and extent of snow cover (Bates 2008). On average, early spring snowpack in the Sierra Nevada has decreased by 10% (1.5 million acre-feet) (DWR 2008). Studies project that extreme precipitation events during the winter will increase in the Sierra Nevada by 10-20% by 2040-2060 (Leung et al. 2004). Furthermore, by 2050, the Sierra Nevada snowpack is projected to decrease 25%-40% from its historic average (DWR 2008). Longer dry periods will be interspersed with heavy precipitation events, and droughts will increase in frequency.

Climate modeling indicates that on average, California will experience higher temperatures in all seasons (Bates 2008; Chung et al. 2009). Warming temperatures will cause a shift to more winter precipitation from snow to rain, reducing snowpack and leading to shifts in the timing of runoff as well as decreased spring and summer runoff (Chung et al. 2009; Kapnick and Hall 2009). Wildfire risk will also increase with a drying climate in the Sierra Nevada (Westerling et al. 2009).

Most researchers believe that deeper, permanent pools of water historically provided refugia for aquatic amphibian populations during periods of prolonged drought, allowing replenishment of peripheral populations through re-colonization (Bradford et al. 1993; Knapp 1996; Drost and Fellers 1996). California has undergone two major drought periods since the 1970s, after which mountain yellow-legged frog declines were first observed. Either drought period could have limited the ability of frogs to successfully breed in ephemeral pool habitat. Climate change may increase incidents of drought, rendering frog populations more vulnerable to drought-related extinction events (Bradford et al. 1993; Knapp 1996; Drost and Fellers 1996).

b. Observed Effects on Amphibians

The changing climate has had several negative observed effects on amphibians. These can be broken down into three general categories. First, there is a direct effect on life history in terms of altered behavior, reproduction, body condition, and survivorship (Wake 2007). Reading (2006) found a significant relationship between warmer years and the decline in body condition and size of female toads. During normal winters in hibernation, the amphibian metabolism drops to very low levels. As temperature increases during the winter, so does metabolism. This depletes the amphibians' stores of energy and leads to decline of body condition upon spring thaw (Reading 2006). This in turn leads to fewer eggs produced and lower recruitment (Reading 2006). Furthermore, higher spring temperatures have been positively correlated with longer time spent at the tadpole stage and higher tadpole mortality (McMenamin et. al. 2008). These effects will be felt by all amphibians impacted by increased temperatures from climate change, including the mountain yellow-legged frog.

Second, climate change negatively impacts the habitat types used by mountain yellow-legged frogs. Studies project that extreme precipitation events during the winter will increase in the Sierra Nevada by 10-20% by 2040-2060 (Leung et al. 2004). Furthermore, by 2050, the Sierra Nevada snowpack is projected to decrease 25%-40% from its historic average (DWR 2008). Longer dry periods will be interspersed with heavy precipitation events, and droughts will increase in frequency. An increased number of drought years will result in the drying of ponds during the relatively long time to metamorphosis (2-4 years) of the mountain yellow-legged frog.

Third, rising temperatures in montane regions have already put breeding pools closer to the optimum temperature for diseases such as chytrid fungus which have caused mass die-offs of amphibians in other parts of the world. Susceptibility to disease may also be enhanced by the decline in body condition following the winter hibernation period (Convention 2008).

c. Projected Changes in the Mountain Yellow-Legged Frog Range and Their Effects

Lacan et al. (2008) investigated the potential impacts of climate change on mountain yellow-legged frog habitat. Between-year variation in snowpack (from 20 to 200% of average) and summer rainfall cause large fluctuations in volume of small lakes in the higher elevation (above 3,000 meters) Sierra Nevada, which are important habitat for the imperiled mountain yellow-legged frog. Climate change is predicted to increase these fluctuations, potentially leading to more frequent summer lake drying of shallow, fishless ponds where most mountain yellow-legged frog breeding and larval development occurs today. The study explored the interaction between water availability and the abundance and recruitment of mountain yellow-legged frogs by mapping the Dusy Basin lakes with GPS, calculating water volumes in a low-snowpack and a high-snowpack year (2002 and 2003), and counting individual mountain yellow-legged frogs.

Mountain yellow-legged frog recruitment, or repopulation from metamorphosed individuals, is greatly impacted by drought. Lacan et al. (2008) found that lakes that dried up in 2002 were repopulated by adults in 2003, without any recruitment of metamorphosed frogs from previous year's tadpoles, but lakes that retained water, even with notable volume decreases showed tadpole-to-subadult recruitment in the following year. Subsequent studies showed significantly greater abundance of metamorphs in permanently wet lakes than in lakes that had dried even once during the 10 years. Similarly, those lakes that had retained water during any two preceding years had significantly more metamorphs than lakes that had dried up during that period (Lacan et al. 2008). The results of the study suggest that any increase in drying of small ponds will severely reduce frog recruitment, and thereby reduce overall mountain yellow-legged frog habitat.

It is very likely that global climate change will negatively impact the mountain yellow-legged frog and result in a further decline in the species. Moreover, climate modeling indicates that on average, California will experience higher temperatures in all seasons and decreased spring and summer runoff due to decrease in snowpack (Chung et al. 2009). With rising temperatures, the body condition of frogs when they emerge from hibernation will likely continue to decline. Increased early season temperatures may also induce earlier breeding, in turn leading to slower body development, increased mortality, smaller body size at metamorphosis, a lower rate of survival to sexual maturity, and reduced fecundity (Convention, 2008).

B. Other Factors that may lead to extinction of the Mountain Yellow-Legged Frog

Many of the remaining populations of the Sierra mountain yellow-legged frog are small and isolated remnants, and are especially vulnerable to random natural events that could quickly extirpate them. It is a widely recognized principle that, in general, small populations are more vulnerable to extinction than large ones (Pimm 1991; Noss and Cooperrider 1994). Noss and Cooperrider (1994) identified four major factors that predispose small populations to extinction: (1) Environmental variation and natural catastrophes like unusually harsh weather, fires, or other unpredictable environmental phenomena; (2) chance variation in age and sex ratios or other population parameters (demographic stochastisity); (3) genetic deterioration resulting in inbreeding depression and genetic drift (random changes in gene frequencies); and (4) disruption of metapopulation dynamics (i.e., some species are distributed as systems of local populations linked by occasional dispersal, which wards off demographic or genetic deterioration).

It is likely that some, or a combination of these factors, contribute to an increased probability of extinction of local populations and the entire Sierra Nevada population of the mountain yellow-legged frog. When effective population size is small, the negative consequences can be demographic (e.g., not enough individuals of a given sex) or genetic (e.g., inbreeding depression), and can predispose these populations to a higher risk of extinction. The population genetics and metapopulation dynamics of the Sierran mountain yellow-legged frog have not been thoroughly investigated, but the connectivity of smaller populations within the Sierra Nevada population of the mountain yellow-legged frog likely is substantially reduced compared to the recent past. Bradford et al. (1993) delineated networks of sites where *R. muscosa* was found in Sequoia and Kings Canyon National Parks which were connected to one another via fishless streams. They compared the present fishless networks to those expected for the same sites had fish not been introduced to the parks, and concluded that the present connectivity networks consist of a mean average of only 1.4 sites (connectivity average 0.43), whereas the former networks averaged 5.2 sites (connectivity average 4.15). Bradford et al. (1993) concluded that there had been a 10-fold decrease in the connectivity (the mean number of potential dispersal links per network) of frog populations in these drainages.

The Sierra Nevada population of the mountain yellow-legged frog consists of mostly small isolated populations, and is particularly vulnerable to some or all of the effects of chance listed above. Given the low probability of improving the status of the Sierra Nevada population of the mountain yellow-legged frog under the status quo, the probability of small population size playing a role in the extinction of one or more local populations within the next few years is high. Any local extirpations will further isolate the remaining populations and probably reduce the time to extinction for the entire Sierra Nevada population of the mountain yellow-legged frog.

7. NATURE, DEGREE, AND IMMEDIACY OF THREAT

Currently, the mountain yellow-legged frog faces a variety of habitat threats that extend beyond habitat modification and loss. In fact, the remaining populations of mountain yellow-legged frogs exist almost entirely on protected land in mountainous areas of California and part of Nevada, yet the species has declined dramatically in the last several decades (Bradford 1991; Fellers and Drost 1993; Bradford et al. 1994; Drost and Fellers 1996). Existing habitat protection measures have been insufficient in protecting the species.

In 2002 the USFWS listed the southern California population of *R. muscosa* as endangered under the Endangered Species Act (USFWS 2002). The USFWS determined that the population of *R. muscosa* in the Transverse Ranges was a Distinct Population Segment, and found that it is “at high risk of extirpation because very few locations remain, the locations are isolated from one another, and each location likely contains only a small number of frogs.” The USFWS (2002) further noted:

> Few populations and restricted habitat make the southern California DPS of mountain yellow-legged frog susceptible to extinction or extirpation from all or a portion of its range due to random events such as fire, flood or drought. In addition, small population size may increase the susceptibility of the remaining mountain yellow-legged frog populations in southern California to extirpation from random demographic, environmental and/or genetic events (Shaffer 1981, 1987; Lande 1988; Noss and Cooperrider 1994; Meffe and Carroll 1997, Primack 1998). Finally, disruption of source population and dispersal dynamics (e.g., source populations that provide individuals that can disperse to other populations or colonize new areas which assists in the stability and recovery of the species) may increase the risk of extinction of the southern California populations of the frog (Noss and Cooperrider 1994).

USFWS (2002) also noted that “[d]emographic events that may put small populations at risk involve chance variation in age, sex ratios, and other population characteristics, which can change birth and death rates (Shaffer 1981, 1987; Lande 1988; Noss and Cooperrider 1994; Meffe and Carroll 1997).” Another concern is skewed sex ratios (Jennings 1995) and reduced genetic variation due to small, isolated populations because this “may make any species less able to successfully adapt to future environmental changes (Shaffer 1981, 1987; Noss and Cooperrider 1994, Primack 1998)” (USFWS 2002).

Finally, with regard to extinction risk, USFWS (2002) concluded that such risk was real and imminent:

> We believe that the connectivity of populations within this DPS has been substantially reduced compared to the recent past. Loss of one or more of the remaining populations within the southern California DPS would cause the remaining populations to become even more isolated from one another, thereby reducing the likelihood of its long-term survival and recovery.

8. IMPACT OF EXISTING MANAGEMENT EFFORTS

A. Federal Management Provides Insufficient Protection

Current management has been inadequate to prevent the decline of the Sierran mountain yellow-legged frog (*Rana sierrae*), the Sierran population of the southern mountain yellow-legged frog, and the southern California population of the mountain yellow-legged frog (*Rana muscosa*). Existing management mechanisms recognize that the frog is imperiled, but are extremely vague and inadequate to ensure the survival of these animals in the wild. Most habitat for the mountain yellow-legged frog is contained on federally managed lands, yet existing management practices have not mitigated threats to the species. Vredenburg et al. (2007) project a trajectory of extinction for both *R. muscosa* and *R. Sierrae* unless protective measures are taken. Immediate action is necessary to implement management mechanisms to control threats to both species of mountain yellow-legged frog.

(1) Current Management Practices

Several federal management plans are in place in the range of the mountain yellow-legged frog. Many of these documents have general action plans for conservation of the species, but many of these plans have not been fully implemented.

a. General Plans

i. Forest Management Indicator Species FEIS

In 2007 the Forest Service adopted the revised Forest Management Indicator Species (FMIS) plan. This document proposed to manage forest service resources in the Sierra Nevada based on ecosystems. To coalesce existing management plans with the new plan the individual Forest Land and Resource Management Plans (forest plans) for the 10 National Forests in the Sierras, and the 2001 and 2004 Sierra Nevada Forest Plan Amendments (SNFPA) were used to determine the current Forest Service management activities in the Sierra Nevada. The FMIS proposed 6 different alternatives that employed different methodologies to determine the major habitat types and ecosystem components affected by existing management activities. Ultimately Alternative 6 was adopted in the FEIS and Record of Decision. This represented a sharp reduction in the number and type of indicator species that would be tracked by the Forest Service.

The chosen alternative used several "indicator species" to make management decisions for different ecosystems. These species are supposed to serve as an overall indicator of the ecological health of an area. They also allow the Forest Service to reduce management costs by observing a single species to determine actions taken on forest service lands. The FMIS uses the yellow warbler (*Dendroica petechia*) as the an indicator species for riparian areas, and unspecified aquatic macroinvertebrates as indicators for lacustrine and riverine environments (FMIS, Table 14). Mountain yellow-legged frogs occupy habitats that may be categorized as lacustrine, riverine, or possibly riparian. However, yellow warblers and unspecified macroinvertebrates are not reliable indicators of mountain yellow-legged frog health. These species do not face the same threats to survival (*see* Section 8, above). The FMIS does not require that adequate monitoring will be done or data gathered to provide the Forest Service with the information it would need to take adequate steps to ensure the mountain yellow-legged frog is out of jeopardy.

b. National Forest Land Management Plans

i. Sierra Nevada Forest Plan Amendment

In 2004 the Forest Service adopted an integrated strategy for vegetation management in the Sierra Nevada forests. This plan amends the land and resource management plans for the Humboldt-Toiyabe, Modoc, Lassen, Plumas, Tahoe, Eldorado, Stanislaus, Sierra, Sequoia, and Inyo National Forests, and the Lake Tahoe Basin Management Unit. The goal of the SNFPA was to develop a plan that is aggressive enough to reduce the risk of wildfire to communities in the urban-wildland in the Sierra Nevada national forests.

The Sierra Nevada Framework Record of Decision was originally adopted in 2001 along with an Environmental Impact Statement (EIS). It was initially drafted to focus on forest timber harvesting issues as they pertain to the spotted owl, but it evolved to achieve other conservation goals for the various National Forests of the Sierra Nevada region. One of these stated conservation goals in the Sierra Nevada Framework was to "protect and restore aquatic, riparian, and meadow ecosystems and provide for the viability of native plant and animal species associated with these ecosystems" (2001 Sierra Nevada Framework Record of Decision Sierra). The plan was revised in a supplemental EIS (SEIS) in 2004 to include new scientific research for the area and incorporate new management strategies (2004 SNFPA Final Supplemental Environmental Impact Statement, January 2004).

Management of aquatic resources in the Sierra Nevada is vital to the mountain yellow-legged frog. The 2001 Record of Decision states that, "the aquatic, riparian and meadow conservation strategy will provide clean water, functioning aquatic ecosystems, and environmental conditions that contribute to viable populations of associated species" (2001 SNFROD). The plan sought to establish Riparian Conservation Areas (RCAs) along streams and around water bodies "to (1) preserve, enhance and restore habitat for riparian and aquatic-dependent species, (2) ensure water quality is maintained or restored, (3) enhance habitat for species associated with the transition zone between upslope and riparian areas, and (4) provide greater connectivity of riparian habitats within watersheds" (2001 SNFROD). Furthermore, the Record of Decision identifies Critical Aquatic Refuges (CARs) to "preserve, enhance and restore habitats for sensitive or listed species and contribute to their viability and recovery." Specifically, the SNFPA establishes 21 CARs to assess individual project impacts to important habitats for mountain yellow-legged frogs and other species (SNFPA Final EIR, p. 207).

In January 2004 the Forest Service amended the Sierra Nevada Forest Plan (Framework) to improve protection of old forests, wildlife habitats, watersheds and communities in the Sierra Nevada mountains and Modoc Plateau. The revised plan did little to incorporate specific management for threats to the mountain yellow-legged frog into the revised framework. The Framework (2004 Framework, Section 3.2.2.8) states:

> In 1999, a team of agency managers and researchers agreed that a mountain yellow-legged frog conservation assessment and strategy was needed to provide for the protection and conservation of this species. The Forest Service and the California Department of Fish and Game approved preparation of a mountain yellow-legged frog conservation assessment and strategy. In 2000, a working group of biologists from the Forest Service, National Park Service, USDI Fish and Wildlife Service, and California Department of Fish and Game and research scientists was established to complete this effort. The conservation assessment is still in preparation and is unavailable for incorporation into this analysis.

To date work has not been completed on the conservation assessment and strategy. The SMFPA is therefore inadequate in establishing any concrete, definitive, or enforceable protections for the mountain yellow-legged frog.

ii. Sequoia National Forest

Sequoia National Forest is covered under the SNFPA. Additionally, the Giant Sequoia National Monument is in the process of completing a management plan. The draft EIS is anticipated in September of 2009. Currently management for the Giant Sequoia National Monument is guided by the Sequoia National Forest Land and Resource Management Plan (Forest Plan), as amended by the 1990 Mediated Settlement Agreement (MSA) and the 2001 Sierra Nevada Forest Plan Amendment (2001 Amendment), and must be in compliance with the presidential proclamation establishing the Giant Sequoia National Monument (Proclamation).

iii. Inyo National Forest

Inyo National Forest is part of the SNFPA. Land management for the Inyo National Forest is guided by the 1988 Land Management Plan. Decisions for some areas of the Inyo and Sierra National Forests are contained in the 2001 Wilderness Plan for the John Muir, Ansel Adams, and Dinkey Lake Wilderness Areas. The 2001 plan states that "multi-agency coordination is necessary to manage wildlife species in wilderness are the Sierra Nevada bighorn sheep and the mountain-yellow-legged frog" (Wilderness Plan, Chapter 3 p. 9). The plan goes on to state that "In the case of the mountain yellow-legged frog management, fish stocking and fishing must be managed by the California Department of Fish and Game in order to ensure the recovery of frog populations in the wilderness. The Forest Service manages the trail system, trailhead quotas, camping, and packstock grazing that lead to, or occur in frog habitat." Clearly this plan calls upon agency guidance to come up with comprehensive plans to manage mountain yellow-legged frog habitat.

iv. Stanislaus National Forest

Stanislaus National Forest is part of the SNFPA. Land management decisions for the Stanislaus National Forest are guided by the 1991 Forest Plan which does not address the mountain yellow-legged frog.

v. Eldorado National Forest

Eldorado National Forest is part of the SNFPA. All protection mechanisms for the mountain yellow-legged frog are contained within these plans.

vi. Tahoe National Forest/Lake Tahoe Basin

The Tahoe National Forest and the Lake Tahoe Basin are covered as part of the SNFPA. The Lake Tahoe Basin Management Unit has been working on revising the 1988 Forest Plan since 2004. On June 30, 2009 a U.S. District Court enjoined the Forest Service from using the 2008 Planning Rule to revise the land management plans of the national forests (*Citizens for Better Forestry, et. al., v. U.S. Department of Agriculture*, C-08-9927 CW). This decision has invalidated the 2008 Planning Rules, and subsequently the Forest Service announced that it "will be using procedures of the 1982 planning rule and is working on how best to transition to these procedure." (Press Release from Region 5 Planning, August 12, 2009).

vii. Plumas National Forest

The Plumas National Forest is covered as part of the SNFPA. Land management decisions for Plumas National Forest are guided by the Plumas Land and Resource Management Plan of 1988.

viii. Lassen National Forest

Lassen National Forest is covered as part of the SNFPA. Land management decisions are guided by the 1992-1993 Land and Resource Management Plan.

ix. Land Management Plan for Southern California National Forests.

In 2005 The Forest Service released a combined Land Management Plan for the National Forests of southern California, including the Cleveland National Forest, the San Bernardino National Forest, the Angeles National Forest, and the Los Padres National Forest (2005 Southern

California Forest Land Management Plan). Each National Forest has its own chapter, entitled a Land Management Plan Strategy to achieve certain goals specific to that national forest.

The Management Strategies for each individual National Forest that harbors mountain yellow-legged frog populations is described below. These Management Strategies fail to address all of the existing threats to the mountain yellow-legged frog and other imperiled species.

In 2008 the Center for Biological Diversity and other conservation groups filed suit against the Forest Service and U.S. Fish and Wildlife Service for violations of the ESA and in particular for the inadequacies in the Biological Opinion for the southern California National Forest Land Management Plans (*CBD et al. v. USFWS, et al.* Case No. C 08-1278-MHP (N.D. Cal.)). On June 8, 2009, the court found the biological opinion inadequate.

A second case was filed by both the California Resources Agency and a coalition of environmental groups challenging the Plans under NEPA and NFMA (*California Resources Agency, et al., v. USDA*, et al., Case Nos. 08-01185-MHP & 08-03884-MHP (N.D. Cal.)). On September 9, 2009, the court found the plans to be inadequate in several important respects including the failure of the Forest Service to consider alternative monitoring and evaluation requirements under the plans.

Although these lawsuits have not yet been fully resolved, they do demonstrate the inadequacy of effective management plans for endangered species in the existing Forest Service Land Management Plans.

(a) San Bernardino National Forest

The San Bernardino Forest Strategy contains a discussion of protection of mountain yellow-legged frog habitat. It discusses habitat enhancement and possible reintroduction of captured frogs from the San Diego Zoo to appropriate habitat. The plan makes conservation of mountain yellow-legged frog habitat a priority over other uses. However, most conservation management measures are vague and may not ensure protection of the species within the forest.

(b) Angeles National Forest

The Angeles Forest Strategy designates Critical Biological Zones for mountain yellow-legged frogs and their habitat. It suggests several strategies for the species, such as habitat protection, habitat restoration, fire control management planning, and invasive species removal to help support the mountain yellow-legged frog. However, Strategy makes no guarantees that these plans are actually being implemented on the ground.

c. National Parks and Monuments

i. Sequoia and Kings Canyon National Park

In 2007 the National Park Service released the Sequoia and Kings Canyon General Management Plan. These plans set up a comprehensive framework for future land use planning decisions in the parks. The EIS for this plan states that the plan "is not likely to adversely affect" mountain yellow-legged frog or its habitat (Sequoia Kings Canyon General Management Plan FEIS, Volume 2B, 2007).

Park management at Sequoia and Kings Canyon National Parks has been actively experimenting with trout removal within the park. Currently, the park is working on a fish eradication EIS for several lakes in the National Parks. This EIS, which is entitled an Aquatic Management Plan, will set goals for removal of trout from up to 60 lakes in the National Parks. Eradication will be conducted using rotenone, a powerful aquatic chemical that can effectively remove trout. (http://parkplanning.nps.gov/projectHome.cfm?parkID=342&projectId=17157).

ii. Yosemite National Park

In response to the precipitous decline of the mountain yellow-legged frog, Yosemite National Park is developing a high-elevation aquatic resources plan to provide a framework for restoring and maintaining high elevation aquatic ecosystems in Yosemite National Park. The Park Service solicited some public comment on the plan, but has not released an Environmental Impact Statement about the plan. The Park expects to release the draft EA in 2010-2009. The plan seeks to halt the decline of native amphibian populations and to restore species within their natural range, and to be prepared for new challenges that may threaten high elevation aquatic ecosystems including emergency infections of disease and climate change (High Elevation Aquatic Resources Management Plan TML, June 2008).

Currently, Yosemite National Park actively manages aquatic ecosystems by conducting ongoing water quality monitoring, restoration and research. This includes efforts such as the experimental removal of non-native fish from six sites, or 5% of lakes/ponds with fish in the park (Restoration of Yellow-Legged Frogs: Experimental Fish Removal, June, 2008), the reintroduction of Sierra Nevada yellow-legged frogs into fishless lakes to study reestablishment success and to determine what allows some populations of frogs to persist with chytrid fungus, and an intensive study of all lakes and ponds in Yosemite to develop a better understanding of these environments to make informed management decisions regarding these resources (http://www.nps.gov/yose/naturescience/aquatic-resources-man-plan.htm).

The High Elevation Aquatic Resources Plan would consider mechanical removal of non-native fish from water bodies in select drainage basins to restore natural biodiversity. Restoration of Sierra Nevada yellow-legged frogs, Yosemite toads, and other species to suitable locations within their historic range would also be considered. Furthermore, the park promises to develop Best Management Practices (BMPs) for recreational and administrative use of high-elevation aquatic ecosystems to ensure that park resources and values remain unimpaired. BMPs would include preventive measures to avoid the introduction or spread of non-native species or pathogens that may threaten native species or their habitats. These measures would evaluate human use within aquatic environments in order to ensure that human use does not result in loss of ecological function (High Elevation Aquatic Resources Management Plan TML, June 2008; http://www.nps.gov/yose/parkmgmt/aquatic.htm).

iii. Devil's Postpile National Monument

Devils Postpile National Monument was established in 1911 by presidential proclamation. The 798-acre monument rests along the Middle Fork San Joaquin River on the Sierra Nevada's western slope and was established to preserve the columnar formation, Devils Postpile, and 101-foot Rainbow Falls. A comprehensive management plan that provides a broad, long-term vision for management of Devils Postpile National Monument has never been developed. All management directions for the monument were previously provided through Yosemite and Sequoia and Kings Canyon National Parks.

Historically the Devil's Postpile area contained suitable habitat for the mountain yellow-legged frog (Roland Knapp, pers. comm., 2009). The Devil's Postpile does not harbor any Mountain yellow-legged frog populations. On June 15, 2009, National Park Service staff announced that a General Management Plan (GMP) would be developed to guide future management decisions for the Monument (74 Fed. Reg. 28273). This GMP will allow the Forest Service to officially address many management concerns for listed species in the Devil's Postpile area. This plan will be consistent with National Park Service Planning Program Standards and will give the Park Service the opportunity to address threats to the mountain yellow-legged frog. To date, no formal framework has been proposed to support protection of the mountain yellow-legged frog in this document.

B. State and Local Management Provides Insufficient Protection

(1) California Department of Fish and Game Fish Stocking Programs

Currently, the California Department of Fish and Game (CDFG) stocks approximately 1,000 bodies of water within the state with fish. In the past 6 years, CDFG has planted more than 49 million combined salmon and trout annually in hundreds of locations in California (CDFG, History of the Hatchery and Stocking Program). The stocking program is now guided in part by Fish and Game Code Section 13007 (passed through AB 7), which mandates nearly one-third of fees collected from issuing sport fishing licenses be deposited into the Hatchery and Inland Fisheries Fund and used for the management, maintenance and capital improvement of California's fish hatcheries. It is anticipated the production of trout species will increase as a result of the implementation of Fish and Game Code Section 13007. Effective management tools must be put in place to insure the increased numbers of hatchery fish are stocked in appropriate watersheds that do not put the mountain yellow-legged frogs in jeopardy.

The negative effects of non-native trout on mountain yellow-legged frogs are well-documented (see Section 8, above). In October 2006 the Pacific Rivers Council and the Center for Biological Diversity filed suit against CDFG over the Department's failure to complete an environmental review of the impacts of fish stocking on sensitive aquatic species throughout the state, such as the mountain yellow-legged frog. In May of 2007, Judge Patrick Marlette of the Sacramento Superior Court ruled that California's fish stocking program must comply with the California Environmental Quality Act ("CEQA") and ordered the CDFG to conduct a public review of the program's impacts (*Pacific Rivers Council, et. al., v. California Department of Fish and Game*, Case No. 06 CS 01451).

Following this litigation, CDFG agreed to interim restrictions on stocking of trout in California waters to limit harm to native fish and amphibians while the agency completes an environmental impact report under the California Environmental Quality Act (November 20, 2008 Agreement). The restrictions, which are expected to last one year, prohibit the Department from stocking trout where species that are sensitive to stocking are known to be present and where the agency has yet to conduct surveys for sensitive species. Sensitive species include California golden trout, Santa Ana sucker, mountain yellow-legged frog, and Cascades frog. This agreement is a first step in effective resource management for the mountain yellow-legged frog, but it is an *interim* agreement. Permanent protection and management decisions are necessary to reduce trout predation of mountain yellow-legged frogs.

California hatcheries have been in operation since before 1867 in the Sierra Nevada. Many of the early stocking efforts were done by private individuals. The State of California, through CDFG, has records of stocking going back to 1890. Over the years, CDFG has utilized a variety of delivery methods to stock fish in designated water bodies throughout the state. Pack mules have been used to haul fish to lakes in remote areas of the state. An aerial planting program got its start in 1948, using low-flying planes to drop fingerling trout into inaccessible lakes. Aerial stocking has been particularly detrimental to the mountain yellow-legged frog, because it has allowed trout to be planted in very high-elevation, naturally fishless lakes.

CDFG also allows private stocking of fish, including trout, by permit. Individuals who want to stock fish can apply for a Private Stocking Permit which allows stocking in certain waters of the State upon CDFG review and payment of a fee (Regulations Governing Private Stocking of Plants and Animals, Non-Commercial). Following the 2008 settlement to *Pacific Rivers Council* case the Department of Fish and Game revised their regulations regarding Private Stocking Permits. All existing permits that were active from 2004-2008 were allowed to be continued upon renewal of the permit. Private stocking that does not undergo proper environmental review may have impacts on the mountain yellow-legged frog in watersheds that are hydrologically connected to frog habitat.

An effective CDFG fish stocking management agreement is vital to the success of other mountain yellow-legged frog recovery programs. An attempted reintroduction of mountain yellow-legged frogs in the Inyo National Forest is illustrative of the problems with fish stocking in the Sierra. Roland Knapp began reintroducing mountain yellow-legged frogs to Maul Lake, in the Hall Research Natural Area in 1993. The lake had been painstakingly cleared of fish, and the frogs successfully overwintered. More frogs were reintroduced in the summer of 1994, but approximately 1,000-2,000 fingerling trout were subsequently air dropped into the lake. The voracious trout predated on the fledgling population of frogs and the project had to be abandoned (Knapp and Matthews 1998). This is a graphic example of the disastrous consequences of the non-native fish stocking procedure of CDFG. Currently there is no programmatic CDFG policy to avoid stocking water bodies where mountain yellow-legged frogs are present.

The Fish and Game CEQA review of trout stocking in California must incorporate existing mountain yellow-legged frog populations and potential mountain yellow-legged frog habitat when evaluating the appropriateness of fish stocking. This document has the potential to make many positive changes for the species, but it will not encompass all management concerns. Invasive trout is just one of the many threats faced by the mountain yellow-legged frog. Reducing trout stocking will prevent mountain yellow-legged frog habitat from being further degraded, but it will not remove existing trout from all the naturally fishless areas of California previously impacted by stocking. Furthermore, reducing trout stocking will do nothing to address other threats, such as pesticide contamination, chytrid fungus outbreaks, and climate change.[10]

C. Current Research on the Species

An assortment of monitoring programs and studies addressing mountain yellow-legged frog biology and population trends, fish predation and removal, disease, pesticide impacts, and other topics are underway in the Sierra Nevada and Southern California. For the past decade, scientists from CDFG, the National Park Service, the U.S. Geological Survey, the U.S. Forest Service, a variety of academic institutions, and independent researchers have been engaged in mountain yellow-legged frog monitoring, restoration planning, fish removal projects, emerging disease (chytrid) research, and larger ecosystem studies. The following section presents a selection of some of these efforts.

(1) Sierra Nevada Monitoring Programs and Studies

a. California's High Mountain Lakes Project

California Department of Fish and Game
Project leader: Curtis Milliron

The large-scale California Department of Fish and Game (CDFG) High Mountain Lakes Project began in 2001 to enhance assessment and management of California's high elevation aquatic resources. A series of basin management plans are being developed to address fisheries management and mountain yellow-legged frog conservation. The Big Pine Basin plan has been completed and can be downloaded from the following web link: http://www.dfg.ca.gov/habcon/conproj/big_pine.html.

b. Sierra Nevada Amphibian Monitoring Program

USDA Forest Service
Contact: Cathy Brown (cathybrown@fs.fed.us)
In 2002, the USFS initiated a long-term bioregional monitoring program for the Yosemite toad and mountain yellow-legged frog in the Sierra Nevada. The program will assess the status and trend of populations and habitat throughout the region (Cathy Brown, pers. comm., 2009).

[10] Apparently CDFG is in the process of developing several Aquatic Biodiversity Management Plans for trout removal in Region 6, and may be implementing the program in regions 2 and 4 in the future (Roland Knapp, pers. comm.. 2009). The status of these Aquatic Biodiversity Management Plans is unclear, as there is no published information on the CDFG web site regarding these plans.

c. Ongoing Restoration of Mountain Yellow-legged Frogs and High Mountain Lakes and Streams in Sequoia and Kings Canyon National Parks, California

National Park Service
Project leader: Danny Boiano (danny_boiano@nps.gov)
Since 2001 Sequoia and Kings Canyon (SEKI) National Park scientists have been restoring mountain yellow-legged frog habitat by reestablishing naturally fishless high mountain lakes via fish eradication methods. The nine lakes that were restored from 2001–2007 showed an average 14-fold increase in frog numbers. The SEKI restoration and monitoring efforts also have shown that it is possible for abundant frog populations to survive and reproduce after becoming infected with chytridiomycosis if they occupy ecologically functional, fish-free habitat.

d. Yosemite National Park Mountain Yellow-legged Frog Restoration

Project leader: Steve Thompson, Yosemite National Park, Wildlife Management Branch, (steve_thompson@nps.gov)
Comprehensive surveys of mountain yellow-legged frog populations were conducted beginning in 2000 with the goal of providing information on source populations and identification of suitable sites for reestablishing frog populations (sites where introduced fish had been removed). The restoration project has proceeded in a limited manner due to the emergence of Bd and the subsequent extirpation of many source populations within the Park.

(2) Research on the fungal pathogen *Batrachochytrium dendrobatidis* (Bd)

(a) Sierra Nevada
Sierra Nevada researchers include: Dr. Cherie Briggs (UC Santa Barbara), Dr. Vance Vredenburg (SF State University), Dr. Roland Knapp (UC Santa Barbara)
Researchers are examining all aspects of the pathogen and resulting disease, including: origin, transmission, genetics, and the potential for frog populations to survive and recover after an outbreak. A larger effort that encompasses Sierra Nevada efforts is being coordinated by Partners for Amphibian and Reptile Conservation (PARC), website: http://www.parcplace.org/Bd_conference.html.

(3). Long-term monitoring and restoration study of *R. muscosa*

US Geological Survey, San Diego, CA
Project leader: Robert Fisher; contact Adam Backlin (abacklin@usgs.gov)
Long-term monitoring and restoration of all Southern California populations continues. Next steps for restoration of this species include implementing a captive breeding program to both protect current populations from catastrophic events and provide a source for reintroducing frogs into unoccupied sites within the frog's former range.

(4). Captive Breeding Program: Conservation and Research of Endangered Species
Zoological Society of San Diego, San Diego, CA;
Project leaders: Frank Santana (fsantana@sandiegozoo.org) and Jeffrey Lemm (jlemm@sandiegozoo.org)

CRES received 80 tadpoles in August 2006 as part of an emergency salvage plan. The tadpoles were recovered from drying pools in the Dark Canyon area of the San Jacinto Mountains. As of December 2007, 60 tadpoles have metamorphosed into frogs and the remaining tadpoles are developing very quickly. The two main goals of the program are to develop a successful breeding protocol for the mountain yellow-legged frog and to headstart frogs for release into the wild. http://cres.sandiegozoo.org/projects/rb_frog_yellow.html

9. RECOMMENDED MANAGEMENT AND RECOVERY ACTIONS

Although a comprehensive recovery strategy has not been developed for mountain yellow-legged frog populations, available research points to several management actions needed to conserve the species. These actions should focus on preventing further loss of and on preserving the remaining genetic and ecological diversity found within the range of the species. Recommended management actions include but are not limited to the following:

- Protect mountain yellow-legged frog habitat from habitat degradation related to livestock grazing, off-road vehicles, urban sprawl and other factors.

- Conduct research on the impacts of pesticides on mountain yellow-legged frogs and ban use of pesticides in the Central Valley with known negative impacts on frog populations.

- Take steps to stop the spread of chytrid fungus by limiting travel to areas where frogs have tested positive for the disease, requiring researchers to follow strict hygienic protocols, and educating the public about not handling or transporting frogs.

- Cease all stocking of trout in lakes with mountain yellow-legged frogs and in lakes in the same sub-watershed with mountain yellow-legged frogs.

- Non-native trout should be removed from many lakes to allow further recovery of mountain yellow-legged frogs. Fish removal should also be planned for whole watersheds in order to allow development of mountain yellow-legged frog meta-populations, increasing the species resilience to individual population extinctions related to disease and other factors.

10. INFORMATION SOURCES

For a list of references cited in this petition and persons providing unpublished information see Literature Cited section below. Copies of references (except for those marked with an asterisk) are also being provided to the Commission in electronic format on a disk.

Available specimen collection records can be viewed at the UC Berkeley Museum of Vertebrate Zoology and the California Academy of Sciences.

11. DETAILED DISTRIBUTION MAP

The map provided above from Vreeland 2007 provides appropriate delineation for the distribution of the species.

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(All references are also provided to the Commission in electronic form on a disk except those marked with an asterisks*)

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