State of Sierra Frogs

A report on the status of frogs & toads in the Sierra Nevada & California Cascade Mountains

SIERRA NEVADA ALLIANCE

Keeping light in the range.

State of Sierra Frogs

A report on the status of frogs & toads in the Sierra Nevada & California Cascade Mountains

By Marion Gee, Sara Stansfield, & Joan Clayburgh

SIERRA NEVADA ALLIANCE

Keeping light in the range.

July 2008

www.sierranevadaalliance.org

Acknowledgements

The impetus for this report was the invaluable research on pesticides by Carlos Davidson, professor at San Francisco State University. Davidson, along with Amy Lind (US Forest Service), Curtis Milliron (California Department of Fish and Game), David Bradford (United States Environmental Protection Agency) and Kim Vincent (Graduate Student, San Francisco State University), generously donated their time and expertise to speak at two public workshops on the topics of Sierra frogs and toads as well as to provide comments for this document.

Our thanks to the other reviewers of this manuscripts including Bob Stack (Jumping Frog Research Institute), Katie Buelterman, Dan Keenan, and Genevieve Jessop Marsh.

This project was fortunate to receive contributions of photography and artwork from John Muir Laws, Elena DeLacy, Bob Stack, Ralph & Lisa Cutter and Vance Vredenburg. Photo credits are found with each caption.

This work was made possible by generous grants from the Rose Foundation for Communities and the Environment and the State Water Resources Control Board. Funding for this project has been provided in part through an Agreement with the State Water Resources Control Board (SWRCB) pursuant to the Costa-Machado Water Act of 2000 (Proposition 13) and any amendments thereto for the implementation of California's Non-point Source Pollution Control Program. The contents of this document do not necessarily reflect the views and policies of the SWRCB, nor does mention of trade names or commercial products constitute endorsement or recommendations for use.

The authors bear responsibility for any factual errors. Recommendations and views expressed are those of the Sierra Nevada Alliance and do not necessarily represent those of funders, reviewers or others who offered assistance to this report.

Cover Photo: "Foothill yellow-legged frog" courtesy of Ralph & Lisa Cutter.

Sierra Nevada Alliance

The Sierra Nevada Alliance has been protecting and restoring Sierra land, water, wildlife and communities since 1993. The Alliance unites hundreds of individuals and conservation groups to protect Sierra Nevada resources. The Alliance is driven by a vision of the Sierra where natural and human communities coexist in harmony; a Sierra where residents and visitors alike understand and value the unique qualities of the range and protect the places they love.

For more information or to obtain copies, visit our website or contact our office:

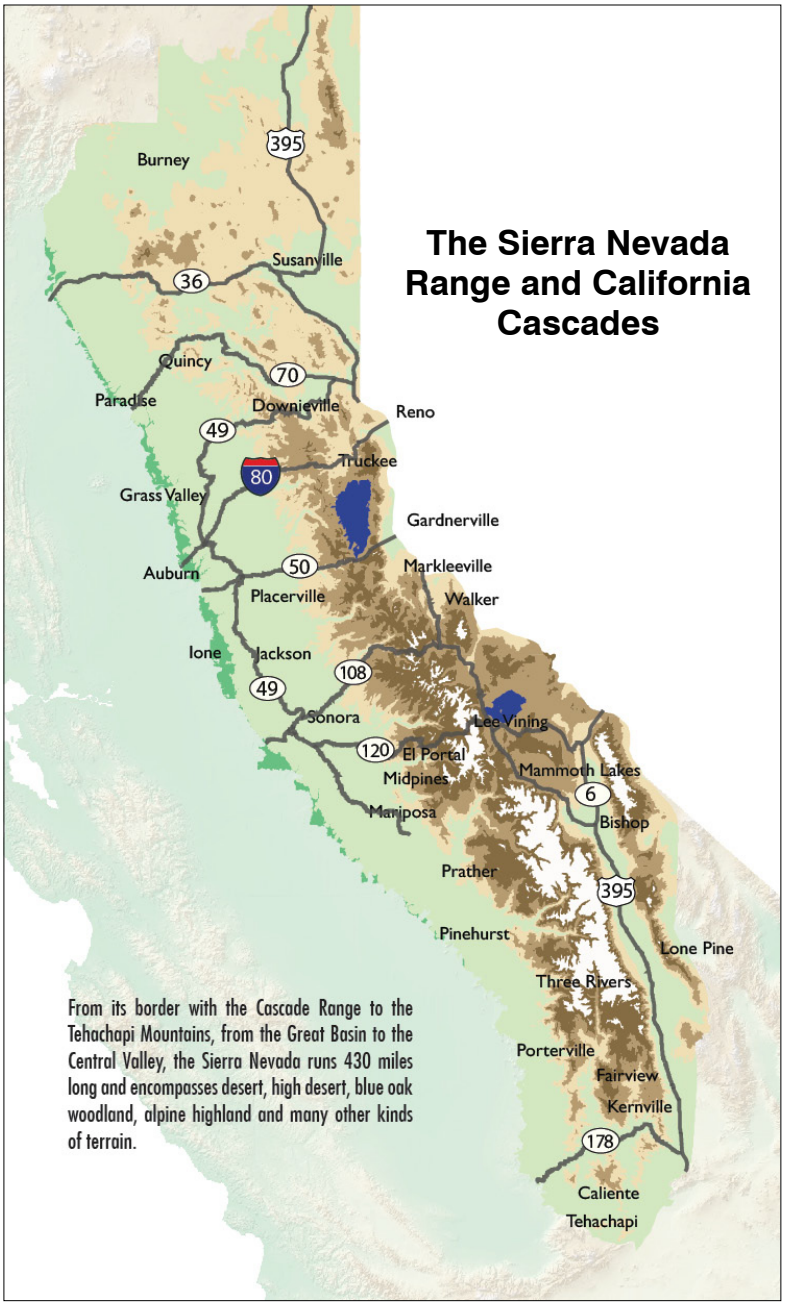
Sierra Nevada Alliance

P.O. Box 7989
South Lake Tahoe, CA 96158
Phone: 530.542.4546
Fax: 530.542.4570
Email: info@sierranevadaalliance.org
www.sierranevadaalliance.org

Table of Contents

Chapter One: Introduction

Sixty five million years after surviving the last great extinction, amphibians continue to live in extreme locations, from deserts to high mountain slopes, a testament to their resiliency and adaptability. Despite thriving for millions of years under a wide range of conditions, the end of the twentieth century saw an alarming rate of amphibian decline: 9 out of 34 known extinctions occurred in the past twenty years alone. In 2006, the Global Amphibian Assessment found that more than 40 percent of the world's 6000 labeled amphibian species have experienced recent declines and nearly a third are threatened with extinction.[1] According to Amphibian Ark Program Officer Kevin Zippel, "the world hasn't seen an extinction crisis like this since the dinosaurs died out."[2] In this climate of crisis, 2008 was named the Year of the Frog by the Amphibian Ark to raise awareness and promote action.



While not all species are declining, a disconcerting number of frogs are rapidly disappearing from around the world. In the Sierra Nevada and Cascade Range in California, dramatic changes to frog and toad populations are occurring.

For example, the California red-legged frog, the largest native frog in the western U.S., can no longer be found across 70 percent of its historic range in California and has almost completely disappeared from the Sierra foothills.[3] Even harder hit is the Sierra Nevada yellow-legged frog population, which, according to the U.S. National Park Service, has disappeared from over 95 percent of its historic habitat.[4]

It is within this context of amphibian population crisis that Professor Carlos Davidson of San Francisco State University teamed up with the Sierra Nevada Alliance in 2003 and applied for

and received funding from the State Water Quality Control Board to study pesticide residues in the bodies of frogs in the California Cascades and Sierra Nevada and the relationship of pesticide residues and frog population declines. This work inspired the Sierra Nevada Alliance to host two public workshops and to write a report on the state of Sierra and California Cascade frogs.

The frogs and toads of the Sierra Nevada and Cascade regions are amazing critters that inspire many of us who enjoy the Sierra with their singing, jumping and antics. The demise of frogs could have further serious implications for ecosystem function, biodiversity and medical studies. We hope this report raises awareness and public concern about the dramatically reduced frog and toad populations of the Sierra and California Cascade ranges.

The Report briefly outlines the value of Sierra and Cascade frogs and toads, provides an overview of individual species experiencing declines, and explains the current stressors to those populations. Finally, the Alliance recommends some potential next steps to address these issues.

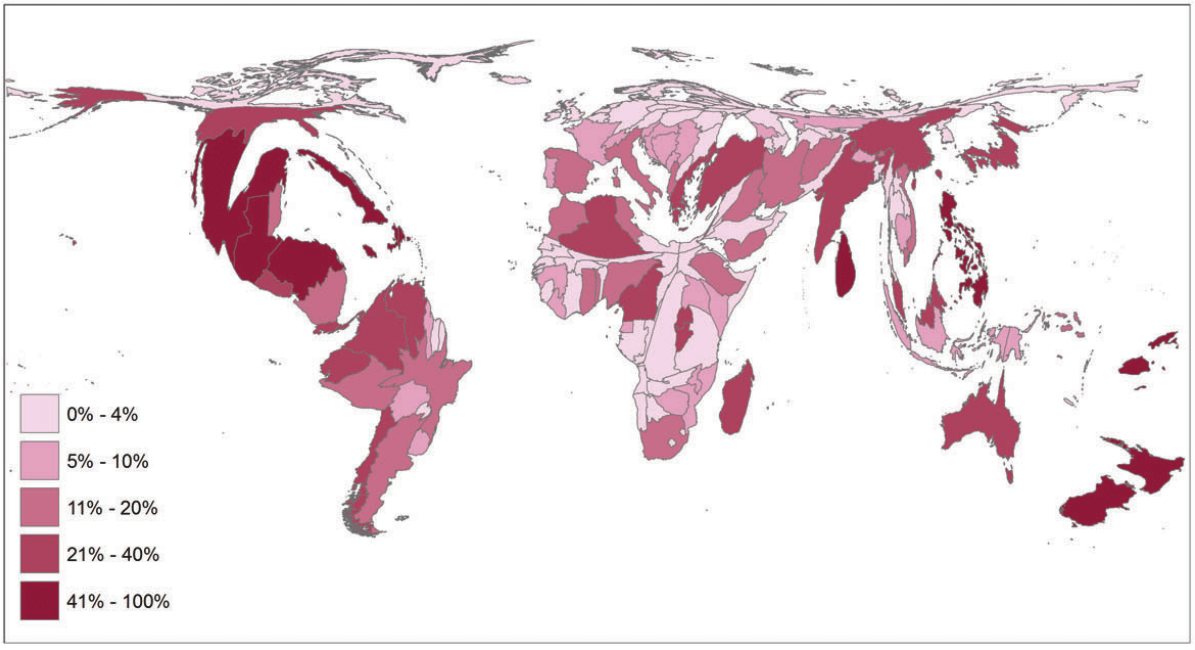
The Value of Sierra and Cascade Frogs and Toads

Frogs Play an Important Role in Ecosystem Function and Biodiversity

Throughout their various life stages, frogs and toads play an important role in the function of the ecosystems in which they live. As tadpoles, they help breakdown and cycle nutrients through their aquatic surroundings; without them sediment loads and algae growth increase, subsequently affecting water quality and aquatic health.[5] Both tadpoles and adult frogs are an important food source for predatory birds, snakes and mammals.

Tadpoles and adult frogs are an important food source for predatory birds, snakes and mammals.

Would Sierra ecosystems completely collapse with the disappearance of frogs and toads? Perhaps not, but as important links like frogs disappear, mammals, birds and fish will reduce in number and combined with other stressors, could eventually go extinct themselves.



Map courtesy of Vance Vredenburg, San Francisco State University.

This map shows the percentage of amphibian species in the top three categories of threat, which include: Critically Endangered, Endangered and Threatened.

One example of such interconnectedness is the Sierra garter snake, which has significantly declined as its main prey, the Sierra mountain yellow-legged frog population, plummeted.[6] Losing Sierra frogs and toads would be as Professor Reid Harris of Virginia's James Madison University said: "like losing a rivet on an airplane.... The extinction of a species weakens the interconnected web of the ecosystem. Eventually, the plane can lose enough rivets so the plane falls apart and drops out of the sky. Figuratively, the same thing happens when enough species become extinct and the ecosystem collapses."[7]

The preservation of biodiversity, that is the sum total of the genetic, species and ecosystem variations on Earth, is not just important for ethical, moral, and aesthetic reasons, but also for preventing the irretrievable loss of genetic codes and the collapse of ecosystems that provide us with life-sustaining services.[8]

Frogs are Indicators of Environmental Health

Amphibians may be our "slimy" canaries in the coal mine–their unique physiology makes them exceptional indicators of environmental health.[9] Their lives are equally split between land and water and their permeable skin make them a "sentinel" species that is attuned to changes to the land, water and air.[10] This makes them particularly sensitive to agricultural, industrial and pharmaceutical chemicals. Scientists are therefore especially concerned when one third of amphibians are experiencing massive declines; 40 percent of those known amphibian species are threatened with extinction, an unprecedented number for a vertebrate species.[11]

Amphibians may be our "slimy" canaries in the coal mine.

One example of the sensitivity of frogs to man-made chemicals is the problems some frogs have after exposure to an herbicide called atrazine. Atrazine is one of the most widely applied herbicides in the United States and, of all the states, California applies the largest amount of atrazine to its crops.[12] Studies done by Tyrone Hayes, Professor of Integrative Biology at the University of California, Berkeley, found that atrazine applied to frogs both in the lab and in the wild, results in increased stress responses and can lead to retarded growth and development and reduced immune function in frogs.[13] Hayes found that very small amounts can create hermaphroditism in frogs.[14] This is cause for concern in and of itself but also has implications for the health of the entire ecosystem, which includes humans. California farm workers that apply this herbicide have been found to have atrazine in their urine.[15] According to Hayes, while humans may be exposed in different ways "with continued exposure the same types of effects that occur in amphibians and lab rats, occur in humans."[16]

As far removed as they may seem from our daily lives, amphibians and humans are connected, and as these widespread changes, such as increased pesticides in the environment, climate change and habitat destruction, alter our environment, humans too may eventually feel the effects. Bob Drewes, curator of the Department of Herpetology at the California Academy of Sciences, summed up this dilemma: "people tend to forget that we live here too. Something is happening to the fundamental makeup of the globe...If it is indeed a human generated problem this whole environmental health thing, we are committing suicide and our first warning or one of our earliest warnings is the frog population."[17]

Frogs are a Valuable Resource for Medical Knowledge

As the rate of amphibian extinction increases, medicine is losing a valuable resource of potential cures. Frog and toad skins alone are the source of more than 200 beneficial alkaloids, such as a non-addicting painkiller 200 times more powerful than morphine.[18] Studies also suggest that the antibiotic properties of frog skin secretions may be used to create a new class of antibiotics that will help against hospital-acquired infections caused by drug resistant bacteria.[19]

Antibiotic properties of frog skin secretions may be used to create a new class of antibiotics.

The foothill yellow-legged frog, currently a California Species of Special Concern, contains beneficial compounds in its skin that are particularly resistant against *Candida albicans*, the opportunistic fungus that can infect the skin, intestines or orifices of humans with lowered immune systems.[20] Other ailments treated by molecules found in frogs and toads include: depression, stroke, seizures, Alzheimer's and cancer.[21]

Frogs may also hold key to the HIV/AIDS epidemic. Scientists at Vanderbilt University Medical Center in Nashville, Tennessee discovered chemicals isolated in the skin of three Australian frogs that are possible blockers of the HIV virus. These peptides are secreted by the frogs as a natural defense mechanism against foreign antibodies and injury. If the method by which the peptides kill the HIV virus is discovered, it may be possible to reproduce it as a preventive drug to use against HIV infection.[22]

If the rapid decline of amphibians, including Sierra and California Cascade frogs and toads, continues unchecked, we may never fully realize their medical potential.

Photo courtesy of Ralph and Lisa Cutter.

Chapter Two: Biographies of Sierra and California Cascade Frogs and Toads

There are a number of species of frogs and toads in the Sierra Nevada, including the California toad, Pacific chorus "tree" frog and the non-native American bullfrog. But for the purposes of this paper we focus on the six native frogs and toads of the Sierra and California Cascades that are experiencing dramatic declines in population. Below are short biographies on the main frog populations found in these regions.

California Red-legged Frog [23]

Illustration courtesy of John Muir Laws.

The California red-legged frog is thought to be the inspiration for Mark Twain's short story "The Celebrated Jumping Frog of Calaveras County."

Scientific name: *Rana draytonii*

Description: The California red-legged frog is the largest native frog of the West and is distinguished by a grayish brown color and dark spots on its back. The adults range from 1.5 to 5 inches in length, females are longer than the males and both display a reddish or salmon colored tint along the belly and hind legs.

Habitat: The California red-legged frog prefers both ephemeral and permanent ponds, marshes, and creeks with still water.

Food: The adult California red-legged frog enjoys a wide variety of invertebrates and will also feed in limited amounts on three-spined stickleback fish, Pacific treefrogs and California mice.

Predators: Newts, bullfrogs, fish, garter snakes, great blue herons, raccoons, opossums and hawks.

Current Threats: Threats to their survival include the introduction of non-native species (such as bullfrogs), habitat loss and possibly the disease chytridiomycosis.

Range: The California red-legged frog is now absent from 70 percent of its historic range, completely vanishing from the Central Valley and nearly extirpated from the Sierra Nevada foothills. Currently, the only robust breeding populations remaining are found along the coast from Marin to San Luis Obispo counties.[24]

The California red-legged frog is now absent from 70 percent of its historic range.

Cascades Frog [25]

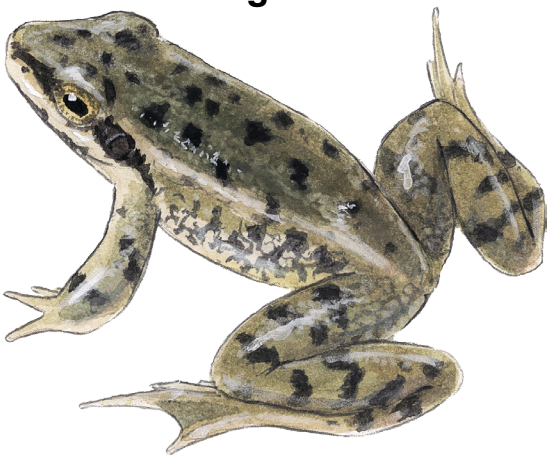


Illustration courtesy of John Muir Laws.

Scientists have found a relationship between increasing levels of upwind agricultural land use and declining Cascades frog populations.

Scientific name: *Rana cascadae*

Description: The Cascades frog ranges from brown to copper to tan with a yellowish tint to its belly and the backs of its legs. Their sides are cream and there are some dark spots along the

legs. Females are generally larger then males.

Habitat: Cascades frog adult habitat consists of open wetlands, moist meadows, small ephemeral and permanent still ponds at higher elevations, and sometimes along streams in lower elevations.

Food: Not known but thought to include a variety of invertebrates.

Predators: Water bugs, garter snakes, mustelid mammals, raccoons and some bird species. May include introduced fish.

Current Threats: The Cascades frog is most likely negatively affected by habitat destruction, the introduction of non-native predatory fish, airborne pollution, and climate change and UV-B radiation.

Range: The Cascades frog is no longer present in roughly 50 percent of its historical California range and from 99 percent of their range surrounding Mt. Lassen.[26] This frog can mostly be found in fragmented populations throughout the Cascade Mountains of Oregon and Washington.

The Cascades frog is no longer present in roughly 50 percent of its historical California range.

Foothill Yellow-legged Frog [27]

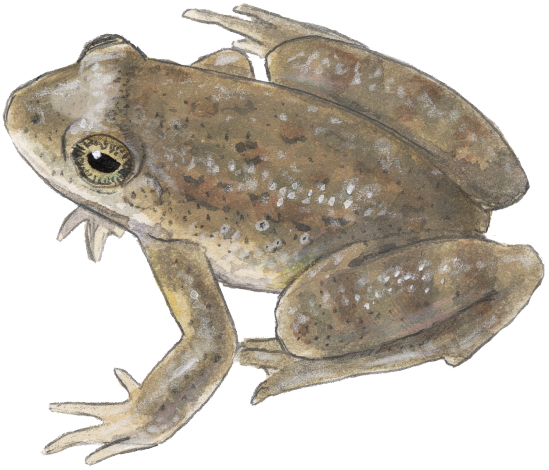


Photo courtesy of Ralph and Lisa Cutter.

Foothill yellow-legged frogs are threatened by dams and diversions throughout the west slope of the Sierra.

Scientific name: *Rana boylii*

Description: The foothill yellow-legged frog varies in color, ranging from gray to brown with red or olive tones on its back. Some are solid colored, while others display spots and coloring often corresponding to the rocks and sand in the area. The underside of their hind legs and underbelly are yellow while their snout is triangular in shape. This unique coloring often makes the foothill yellow-legged frog difficult to see in the wild. When the frog senses something approaching it often leaps into the water for safety, hiding among the rocks, silt or vegetation, making it even harder to spot.

Habitat: The foothill yellow-legged frog mates and lays its eggs in streams and rivers with pools and riffles. Their optimal breeding habitat includes shallow, flowing water with pebbles or cobbles on which they can attach their egg masses. Adults can be found along streams with rocky substrate or on open banks.

Food: Flies, moths, hornets, beetles, grasshoppers, water striders, snails, and terrestrial and aquatic insects.

Predators: Rough-skinned newts, American bullfrogs, introduced trout and warm water fish, green sunfish, Sacramento squawfish, and garter snakes.

Current Threats: Threats to the foothill yellow-legged frog population are due to loss of habitat from dams and diversions and the introduction of non-native species. Pesticide drift and the disease chytridiomycosis may also be linked to declines.

Range: Once considered common in the Sierra foothills, this frog's historic range stretched from southern Oregon down through the California coastal region and in nearly all west side drainages of the Sierra Nevada to about 6000 feet. Today, populations have disappeared in the Southern Sierra foothills while a recent study found only 12 percent of the streams in the Sierra foothills currently support foothill yellow-legged frog populations.

Only 12 percent of the streams in the Sierra foothills currently support foothill yellow-legged frog populations.

Southern Mountain Yellow-legged Frog [28]

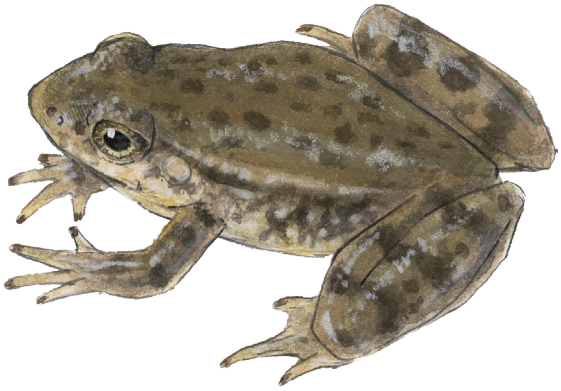


Illustration courtesy of John Muir Laws.

Southern mountain yellow-legged frogs have been experiencing mass die-offs, likely due to the spread of the disease chytridiomycosis.

Scientific name: *Rana muscosa*

Description: Southern mountain yellow-legged frogs are highly variable in color. This species is generally gray or reddish brown, with black or brown spots on its back. The undersides of the hind legs and underbelly are yellow or slightly orange. Although vary similar looking to the Sierra Nevada yellow-legged frog, this species has different mitochondrial DNA, slightly longer legs and a distinct mating call.

Habitat: Southern mountain yellow-legged frogs live in high elevation lakes, ponds, springs, streams and wet meadows and are never more than one or two meters away from water. This highly aquatic species even calls to potential breeding partners underwater. These frogs remain in the larval stage as tadpoles for one or more years, thus requiring an aquatic habitat deep enough to withstand drying up in the summer and freezing in the winter.

Food: Not reported. Observed eating Yosemite toad tadpoles and Pacific treefrog tadpoles.

Predators: Garter snakes, Brewer's blackbirds, coyotes, and introduced trout.

Current Threats: Introduction of non-native predatory species such as trout, habitat fragmentation, pesticide drift and the disease chytrid.

Range: Populations were abundant in the high elevation lakes of the Sierra Nevada in Butte, Plumas, Tulare, Inyo and Fresno counties. Currently, there are scattered and reduced populations across the historic range of the species. Of 86 population sites surveyed between 1915 and 1959, only 16 contained frogs in surveys conducted between 1989 and 1995. Another recent study showed the southern mountain yellow-legged frog and the Sierra Nevada yellow-legged frog to be absent from 92 percent of their historic range.[29] Most of the remaining populations are found in Sequoia, Kings Canyon, and the transverse ranges of Southern California.[30]

Sierra Nevada Yellow-legged Frog [31]

Photo courtesy of Ralph and Lisa Cutter.

The Sierra Nevada yellow-legged frog is threatened by introduced non-native fish and the disease chytrid.

Scientific name: *Rana sierrae*

Description: The biggest difference between the Sierra Nevada yellow-legged frog and the southern mountain yellow-legged frog is DNA; otherwise they are almost identical. Both highly variable in color, these species are generally gray or reddish brown, with black or brown spots. The undersides of the hind legs and underbelly are yellow or slightly orange. *Rana sierrae* differs from *Rana muscosa* in having relatively shorter legs and a different mating call.

Habitat: The Sierra Nevada yellow-legged frog lives at high elevation lakes, ponds, springs and streams.

Food: Not reported.

Predators: Trout, coyotes, birds, and garter snakes.

Current Threats: Population declines are due to many factors that may include the introduction of predatory non-native trout, airborne pollution, general population fragmentation and the disease chytridiomycosis.

Range: Sierra Nevada yellow-legged frogs restrict themselves to high elevation mountain lakes. Dispersed throughout the Sierra Nevada, from Plumas County to southern Tulare County, about 92 percent of the Sierra Nevada yellow-legged frogs have disappeared from their historic range within the last few decades.

About 92 percent of the Sierra Nevada yellow-legged frogs have disappeared.

Yosemite Toad [32]

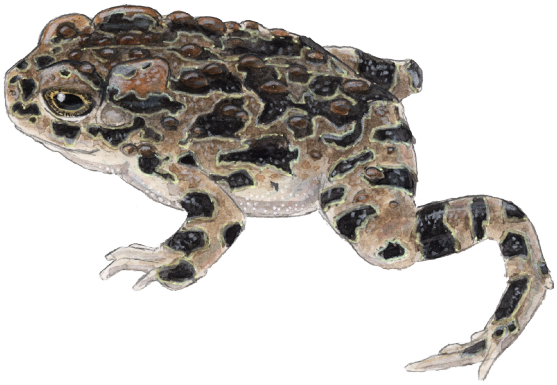


Illustration courtesy of John Muir Laws.

A drawing of the unique colors of a female Yosemite toad.

Scientific name: *Bufo canorus*

Description: Yosemite male and female toads differ greatly in color. The females and young of the Yosemite toads are pale and spotted with large, dark blotches on their backs while males are a yellow-green or dark olive with few large spots. The toad's skin is bumpy throughout and its eyes are closely set with horizontal pupils.

Habitat: Active in daytime, usually in sunny areas. Since this toad favors high mountain meadows in the Central Sierra, it typically dwells in wet meadows, along lake shores among willows, and at the borders of forests, though never far from a water source. The toad is dependant on rodent burrows and tunnels or other objects like logs for cover.

Food: Yosemite toads consume a variety of terrestrial and aquatic invertebrates such as beetles, weevils, flies, ants, bees, wasps, spiders, centipedes, ladybird beetles, dragonfly naiads, millipedes and mosquitoes.

Predators: Coyotes, birds, garter snakes, and southern mountain yellow-legged frogs.

Current Threats: Threats to the Yosemite toad may include habitat destruction or alteration, disease, pesticide drift, increased predation and prolonged drought.

Range: The Yosemite toad's range stretches north from Ebbetts Pass in Alpine County south to Fresno County usually at elevations of 8,500 to 10,000 feet. They favor high and open mountain meadows, willow thickets and nearby forests. The Yosemite Toad has disappeared from more than 50 percent of known recorded sites.

The Yosemite Toad has disappeared from more than 50 percent of known recorded sites.

Chapter Three: Current Stressors to Frog and Toad Populations

No one single issue is threatening all the frogs and toads of the world or Sierra Nevada. There are many stressors and threats, including the disease chytridiomycosis (chytrid), pesticides, introduced non-native species, climate change and habit destruction, alteration and fragmentation. Some threats have been clearly linked to frog declines, while other connections remain under study. It is likely that some combination of these issues is contributing to the significant drop in amphibian populations across the world. The following is an overview of some the major stressors known to date for Sierra and California Cascade frogs and toads.

The Disease Chytridiomycosis (Chytrid)

Chytrid is Causing the Decline of Over 200 Species

There are a number of diseases and parasites that affect frogs. One of the most alarming and highly visible contributors to worldwide amphibian decline is the spread of chytridiomycosis, a disease caused by the aquatic fungal pathogen *Batrachochytrium dendrobatidis*. For the purposes of this paper, we shorten the name of this disease from chytridiomycosis to chytrid.

While the origin, mode of spread, and mechanism by which it kills is still being debated among scientists, the fungus has been reported on six out of the seven continents, causing the decline or extinction of about 200 species of frogs.[33] Within the United States, chytrid has been detected in 15 different amphibian species.[34] Especially concentrated in frogs and toads of the Western United States, the disease completely wipes out some species while other carriers of the disease, like the American bullfrog, appear to be unaffected.[35]

Photo courtesy of Vance Vredenburg, San Francisco State University.

Mass die-offs of Sierra Nevada yellow-legged frogs as pictured are not an uncommon sight.

Origin, Spread and Life Cycle of Chytrid

Scientists have traced the earliest case of chytrid to an African clawed frog from a 1938 amphibian collection in South Africa.[36] Starting in the late 1930s, thousands of African clawed frogs were shipped across the world for use in pregnancy tests and as models for scientific study.[37] Both the African clawed frog and the American bullfrog seem to be immune to the pathogen and studies suggest they may be important vectors of transmitting this disease across the world.[38] Another theory, however, postulates that chytrid is endemic to regions throughout the world and that changes in climate and the lowering of amphibian immune systems due to pesticide use, habitat loss, etc. allowed the disease to thrive.[39] Debate still surrounds the exact means by which frogs in far-flung regions are becoming infected. While chytrid appears to only infect amphibians, its rapid spread through remote regions like the

Sierra Nevada suggests other hosts may exist.[40] A possible method of spread is by humans from the dirt carried on their shoes or car tires.[41] A study near Yosemite's high human trafficked areas found that the genotype distribution of chytrid suggests humans were a highly likely cause of dissemination.[42] Other suggested vectors besides other infected amphibians include mammals, birds and insects.[43] Chytrid, however, has yet to be found in the field without a frog host, but it can survive unaccompanied in sterile pond water for up to eight weeks.[44] The question remains unanswered, whether the fungal pathogen needs a host to survive and spread.

Debate still surrounds the exact means by which frogs in far-flung regions are becoming infected.

The life cycle of the amphibian chytrid fungus, B. dendrobatidis, which causes the disease chytridiomycosis, is also little understood. Its motile spores invade the natural protein layer in the skin called keratin (like that found in human finger nails) around the mouths of tadpoles and in the skin of adult and juvenile frogs.[45] The spores reproduce asexually and, when mature, are released into the water to infect new amphibian hosts or re-infect the original host.[46] While tadpoles carry the disease and may infect new hosts, they remain unaffected until they transform into adult frogs. The way in which the fungus affects the adult frogs is still unknown as some become sick and die while others live with the fungus.[47]

Impacts of Chytrid on Sierra and California Cascade Frogs and Toads

The Sierra Nevada yellow-legged frog and the mountain yellow-legged frog populations are particularly affected by chytrid; in the past few years their numbers declined by 95 to 98 percent even in protected areas like Yosemite National Park.[48] Within the Sierra Nevada, massive die-offs have been documented since 2001 and these yellow-legged frog populations have disappeared from more than 90 percent of their historic range as a result of this disease and other factors like fish stocking.[49]

Scientists are currently focusing their studies on the Sierra Nevada yellow-legged frog and the mountain yellow-legged frog because frog population surveys and genetic studies conducted since 1995 make a comprehensive study of chytrid possible.[50] In the early 1900s, amphibians were the most numerous vertebrates found in the high Sierra, according to surveys done by Joseph Grinell; by the 1990's, frogs were absent from 32 percent of their historical range in Yosemite National Park. The remaining populations were often no more than a few individual frogs.[51]

The Sierra Nevada yellow-legged frog and the mountain yellow-legged frog populations are particularly affected by chytrid.

A recent scholarly article published in the Proceedings of the National Academy of Sciences studied these Sierra Nevada and mountain yellow-legged frogs using collection sites north and south of Yosemite National Park and came to two important conclusions regarding the nature of chytrid's spread and reproduction. First, it appears chytrid was a novel pathogen introduced to the Sierra but is now endemic to certain regions and amphibian populations of the Sierra.[52] Temperature, water flow and the density of hosts are important factors that can determine the effects of chytrid in individual species.[53] Secondly, the study came closer to understanding how chytrid reproduces. It appears that the fungal pathogen commonly reproduces asexually but there is some evidence that points to sexual reproduction, which results in resistant chytrid spores that may be able to persist outside amphibian hosts and could make re-introduction of frog species difficult.[54] While recent studies have not come to definitive conclusions other than frogs are dying in record numbers and chytrid seems to be a main factor, studies like this are important in improving understanding of the disease and its spread in order to prevent further local extinctions.

Further Research and Potential Solutions

While successful strategies to control the pathogen in captivity have been found, controlling the pathogen in the wild remains undiscovered.[55]

Some have suggested the use of fungicides to treat infected frogs, but this could have negative effects on the rest of the environment and will not prevent re-infection.[56] Another suggestion is to create an "Amphibian Ark," collecting individual species and protecting them in zoos, universities and other institutions until it is safe to reintroduce them into the wild.[57] While it is important to preserve breeding pairs of these species, there are many problems with this approach, including low success rates with captive breeding, inability to select for resistance to disease and inability to address underlying environmental factors such as habitat loss, climate change and chemical contamination that may be contributing to declines.

According to a recent article by David Wake of UC Berkeley and Vance Vredenburg of San Francisco State University, these massive declines in amphibian populations are a sign that a "wave of extinction is either upon us or is posed to have a profound impact."[58] But there are a few rays of hope. A few Sierra frogs were discovered to have the disease yet appear to be unaffected, suggesting that some frogs may be developing a resistance to chytrid.[59]

Another study by Reid Harris and colleagues of James Madison University found that the application of the "friendly" bacteria *Janthinobacterium lividum* to mountain yellow-legged frogs exposed to chytrid kept them alive.[60] This friendly bacteria is a potential defense against chytrid as it occurs naturally in the skin of amphibians. Populations of amphibians that have survived outbreaks were found to have higher concentrations of this bacteria.[61]

Some steps could be taken now, but before we can adequately manage the crisis of amphibian population declines, further research is needed to understand and proactively alleviate the true cause(s) of the declines, whether it is pesticide use, a changing climate, invasive species, chytrid, some combination of any and all these factors.

Frogs are Susceptible to Chemical Contaminants

The permeable skin of amphibians, as well as their dependence on both land and water, makes them particularly susceptible to chemical contaminants such as pesticides, heavy metals, acidification and nitrogen pollution.[62] The effects of these different contaminants can be both direct and indirect and vary in their lethality. Direct effects of chemical contaminants include: growth, development and behavioral abnormalities, weakened immune systems that make them susceptible to disease and UV radiation, and disrupted endocrine systems causing sexual mutations[63]. Changes to the food web caused by contaminants can also indirectly affect the health of amphibian populations.[64]

In the Sierra Nevada and California Cascade ranges there are an overwhelming number of contaminants to consider. Heavy metals such as mercury are a part of our mining legacy and are found throughout Sierra rivers, streams and lakes.[65] Nitrogen pollution from agricultural runoff, livestock operations and automobile emissions in the Sierra also affect aquatic environments and frog reproduction and survival.[66] For the purposes of this report, we will only be exploring pesticide drift from the Central Valley. To find out more about chemical contaminants and Sierra frogs see Appendix A: Further Resources.

Pesticides in the Sierra Nevada and California Cascade Ranges

At this time, the U.S. Environmental Protection Agency allows the use of over 19,000 pesticides throughout the United States, including insecticides, herbicides, and fungicides.[67] The exact relationship between pesticide use and amphibian population declines is difficult to determine because of the compounding effects of the many different chemicals in use—both pesticides and others—over the past 100 years. This makes research on this topic complicated. Typically, experiments are restricted to a particular species, a particular location and a small number of pesticides, making it difficult to generalize about population-level effects.

Pesticides used in California are documented in field and laboratory studies as the cause for an array of amphibian maladies and even death.

Pesticides used in California are documented in field and laboratory studies as the cause for an array of amphibian maladies and even death. Decreased immune function is one side effect. UC Berkeley scientists found that the application of four herbicides, three insecticides and two fungicides used to replicate real world environmental conditions resulted in depressed immune systems that allowed test tadpoles to develop meningitis, among other problems.[68] Tadpoles were also slower in completing their metamorphosis to adult frogs, reducing their chances of survival. The combinations of pesticides could also result in death. When pesticides were mixed and applied to simulate conditions of a Nebraska cornfield, 35 percent died while only 4 percent died when the pesticides were applied individually.[69]

Dr. Gary Fellers of the U.S. Geological Survey and Dr. Donald Sparling of Southern Illinois University recently discovered pesticide products that were also lethal to amphibians Their study demonstrated that three heavily used pesticides in the Central Valley (chlorpyrifos, diazinon and malathion), which can also be found in the Sierra Nevada, break down into products that are lethal to foothill yellow-legged frog tadpoles.[70] Results showed chloroxon and maloxon, breakdown products of chlorpyrifos and malathion respectively, were lethal to test tadpoles and approximately 100 times more toxic than their parent compounds while diazoxon, the breakdown product of diazinon, was only 10 times more toxic.[71]

Research studies have also documented the transport and deposition of these deadly pesticides originating in the Central Valley into the Sierra Nevada. Pesticides have been found in high elevation Sierra lakes and streams and on foliage far from where they were originally applied. Zabick and Sieber found pesticide residues (chlorpyrifos, diazinon, and parathion) in wintertime air and precipitation samples from sites at 1,748 and 6,300 feet in elevation in Sequoia National Park.[72] In the same locations, Aston and Seiber also found summertime transport and deposition of pesticide residues on foliage.[73]

Pesticides have been found in high elevation Sierra lakes and streams and on foliage.

While some studies focus on understanding the various and specific ways in which pesticides affect frog health or identifying how pesticides are spread to seemingly pristine areas, research conducted by Carlos Davidson at San Francisco State University concentrated on better defining the relationship between pesticide drift and local frog declines. Davidson found declines of Cascades frogs are strongly associated with the amount of agricultural land use upwind from a site.[74] He mapped 59 historic locations for the Cascades frog, determined current population status, and examined a number of site characteristics that are correlated with specific mechanisms of decline.[75] Over all sites, the percentage of upwind agriculture land for sites where the Cascades frog had disappeared was 4.6 times greater than sites this frog still inhabited.[76] There is, then, a strong relationship between increasing levels of upwind agriculture land-use and the percentage of sites from which frogs have been extirpated.[77] Similar patterns were found for three other Sierra Nevada frogs: the California red-legged frog, the foothill yellow-legged frog and the mountain yellow-legged frog. A more recent spatial study conducted by Davidson found a similar association between declines and upwind pesticide use.[78]

Several challenges remain in studying pesticides and their effects. To find out whether or not pesticides actually cause declines, researchers need to simultaneously determine their presence in frogs in the field, and find out if they are linked to declines in these populations. Furthermore, by the time declines have been documented, populations may be threatened with extinction, precluding the possibility of examining pesticide levels in the frogs themselves. By definition, we can measure pesticide levels in non-declining populations, but can only speculate on the causes of past and unobservable declines.

Carlos Davidson proposed a novel strategy to deal with this sampling dilemma. Davidson identified two nearby regions where the Cascades frog lived. This species has disappeared almost entirely in one half of its range in California while healthy populations remain in another region. Davidson also identified a non-declining species, the Pacific treefrog, whose populations remain healthy in both areas. By studying

Photo courtesy of Ralph and Lisa Cutter.

The Pacific treefrog was used as a surrogate for extinct Cascade frog populations to test the theory that pesticides were leading to local declines of the Cascades frog.

pesticide residues in both species, Davidson tried to determine whether pesticide levels were elevated in treefrogs in the region where the Cascades frog is no longer found. By using the non-declining treefrog as a biological proxy for the extinct populations of Cascades frog, he hoped to test the hypothesis that increased levels of pesticide residues contributed to the decline of Cascades frogs.

Results of this research, however, found that the Pacific treefrog is not a good surrogate for pesticide levels in Cascades frogs.[79] Only for the pesticide Endosulfan sulfate are residues in treefrogs a reasonably good proxy for this chemical in Cascades frogs. For Endosulfan sulfate the study did not find an association between residue levels and declines of Cascades frogs. In 2005, however, 528 different pesticides were used in California. The Davidson study tested for 76 different chemicals, 17 of which were detected and only 7 of which could be mapped and analyzed, which leaves a number of untested pesticides that could potentially be affecting this particular species.[80] While Davidson's most recent study did not find a substantiated relationship between pesticides and the Cascades frog decline, pesticide drift from the Central Valley in statistical analyses does appear to line up with frog declines in the Sierra Nevada.[81] Further research is needed, however, to consider the many other pesticides that may be affecting frogs and how those pesticides may be working concurrently with other stressors to cause reduced Sierra and Cascade amphibian populations.

Introduction of Predatory Non-native Species

Fish Stocking Once Fish-less Lakes is Devastating Some Frog Populations

Historically, about 99 percent of Sierra lakes above 7,000 feet were fish-less due to steep cascades and waterfalls and other fish barriers.[82] However, for the past century, the Sierra's larger high elevation lakes have been stocked with non-native trout to increase recreational fishing opportunities. Species used in stocking include rainbow trout, brook trout, golden trout, cutthroat trout and brown trout. The introduced trout are aggressive predators that not only feed on the tadpoles and adult frogs, but also on their food sources like mayflies and dragonflies.[83] These non-native fish populations are now self-sustaining. Today, about 95 percent of the larger, deeper lakes of the

About 99 percent of Sierra lakes above 7,000 feet were fish-less due to steep cascades and waterfalls and other fish barriers.

Photo courtesy of Ralph and Lisa Cutter.

A high Sierra lake with Sierra Nevada yellow-legged tadpoles.

western United States are stocked or are occupied by non-native trout.[84]

The impacts have been devastating for Sierra frogs and toads. As early as 1924, the correlation between introduced fish and frog decline was recognized by the naturalist Joseph Grinnell: "It is a commonly repeated observation that frogs, in tadpole form at least, do not occur in lakes which are stocked with trout."[85]

As early as 1924, the correlation between introduced fish and frog decline was recognized.

Several recent studies demonstrated that the removal of non-native fish could be a viable method of reversing the decline of Sierra frogs. These studies showed that the short term populations rebounded after non-native fish removal, although monitoring is still required to determine the long term effectiveness of this strategy.[86]

Sierra Nevada and mountain yellow-legged frogs have been particularly hard hit by fish stocking and fish removal appears to be a viable tactic to help in their recovery. Vance Vredenburg's study of the mountain yellow-legged frog in the Sixty-Lake Basin of Kings Canyon National Park found that one year after removing non-native fish using extensive gill netting, a dramatic increase in the number of frogs was observed in comparison to the "control" lakes where no fish were removed. Three years after removal, frog populations were about the same for the lakes with fish removed as the frog control lakes (fish-less lakes that supported frog populations before the study was conducted). The discovery of egg masses showed that these populations were successfully breeding.[87]

Roland Knapp and Danny Boiano repeated this study on the mountain yellow-legged frog in another series of lakes in the Humphreys and LeConte Basins in the John Muir Wilderness. Surveys found that average tadpole density and average frog density varied lake to lake, but the lakes where fish were removed showed significantly greater densities in comparison to the fish control lakes. These findings proved that Vredenburg's earlier study results could be replicated in other watersheds of the Sierra. Frogs were able to disperse and colonize adjacent waters beyond the lake in which fish were removed.[89]

The California Department of Fish and Game (CDFG) took notice of this research and initiated its first fish removal management for native fauna restoration in the Big Pine Basin, Inyo County, in 1998. CDFG is currently including selective fish removal projects as a part of their High Elevation Lakes Aquatic Biodiversity Management project. This pilot study, covering 28 lakes in the Eastern Sierra, is being conducted to help to protect and restore local frog and other native fauna populations, while also maintaining a sufficient number of fisheries to preserve recreational opportunities for anglers.[90]

While these and other studies establish fish removal as a useful tool in rehabilitating Sierra frog species, other causes of decline, like pesticide drift and chytrid, if not addressed, may reduce the effectiveness of fish removal. The frogs in the Sixty-Lake Basin study by Vredenburg were able to repopulate areas after fish were removed but were then devastated by outbreaks of chytrid.[91] The presence of introduced fish furthermore forced frog populations into isolation and reduced their numbers, contributing to the devastation that chytrid wreaked on these populations.[92]

Selective fish removal is only a partial solution for frog declines. Education is an important component as well. Many fish-less water reserves have been stocked in the past by recreational fishermen without consent. CDFG and other state and federal agencies and local conservation groups need to educate recreational users about fish removal and its benefits to prevent fish removal projects from being negated incidentally or intentionally.

The American Bullfrog is a Voracious Predator of Sierra Frogs

The largest of all the North American frogs, the American bullfrog is a voracious predator and will eat small mammals, birds, fish, reptiles, and other amphibian tadpoles and eggs and is suspected of bring a vector for the chytrid disease.[93] Mostly introduced to the wild from frog farms, bullfrogs have quickly proliferated and become a threat to

Illustration courtesy of John Muir Laws.

The American bullfrog may be negatively affecting foothill yellow-legged and California red-legged frog populations.

biodiversity in the Sierra. Their large size, vast range and generalized eating practices make it easy for the American bullfrog to adapt. They can live in the wild for eight to ten years and can lay enormous egg masses that contain as many as 20,000 eggs.[94]

Studies done on Sierra frogs showed that bullfrog tadpoles and foothill yellow-legged frog tadpoles compete for food in the larval stage, resulting in a 48 percent reduction in survivorship of foothill yellow-legged frog tadpoles and a 24 percent decrease in their mass at metamorphosis.[95] A similarly structured study found that bullfrogs have a detrimental effect on California red-legged frogs as well; less than 5 percent of the red-legged frog tadpoles in the presence of bullfrog tadpoles survived.[96] It remains difficult to articulate the exact impact the American bullfrog has on Sierra frog species decline with so many other factors implicated in their decreasing numbers. However, it is clear they are a significant threat to declining Sierra and Cascade frog populations.

Bullfrog tadpoles and foothill yellow-legged frog tadpoles compete for food in the larval stage.

Projects across the world as well as suggestions by researchers, however, could be applied to the Sierra to prevent and contain the further spread of the American bullfrog. In addition, restoring habitat more suitable to native rather than invasive species could also help contain the American bullfrog. Another tool could be the careful management of dams to replicate scouring floods, timing them so as not to interfere with native frog breeding while also reducing habitat for exotic species like the American bullfrog.[97] Similarly, livestock grazing, if suitably applied, could maintain vegetation structure that favors native salamanders and red-legged frogs over the American bullfrog.[98] The Bullfrog Project, run by Dr. Purnima Govindarajulu at the University of Victoria in British Columbia, takes a more comprehensive approach, using public outreach, monitoring and research to prevent bullfrog expansion and to restore native frogs.[99]

Habitat Destruction, Alteration and Fragmentation

Land Use Development Is Destroying and Impairing Frog Habitat

Sierra frogs and toads are particularly sensitive to land use development because their different life stages play out in aquatic, riparian and terrestrial habitats so that changes in any one of those habitats can affect local populations.[100] Habitat can be affected in a number of ways: it can be completely destroyed and lose all biological function; it can be altered so that function is impaired; and, it can be fragmented when isolated patches are no longer linked due to habitat destruction.[101] Fragmentation can also indirectly affect Sierra frogs and toads by isolating populations resulting in the loss of genetic diversity over time and reducing frogs' and toads' ability to adapt to changing environmental conditions. [102]

In the continental United States, 91 percent of river lengths were developed by 1988. In the Sierra, two-thirds of riparian habitat is privately owned and developed or at risk of development.[103] Land use development is increasing as the Sierra is the third fastest growing region in the state and current projections expect a tripling of the Sierra population from 600,000 to between 1.5 and 2.4 million by 2040.[104] It is not just the developed

In the Sierra, two-thirds of riparian habitat is privately owned and developed or at risk of development.

footprint of commercial buildings and residential housing, but the roads connecting developed areas that create barriers between frog habitats. In the Sierra Nevada, counties built 348 miles of new city and county roads between 1990 and 2003.[105]

Photo courtesy of Autumn Bernstein.

The number of residential building permits increased by 22 percent between 1990 and 2004. Encroaching development not only destroys habitat but can make it more difficult for amphibian populations to move.

Professor Carlos Davidson of San Francisco State and co-researchers, mapped the declines of eight California amphibians including: the Yosemite toad, the foothill yellow-legged frog, the California red-legged frog, the Cascades frog and the mountain yellow-legged frog. While a number of possible factors of amphibian decline were compared to the patterns of decline, the study found that urbanization was a contributing cause of decline for the California red-legged and foothill yellow-legged frogs.[106]

Dams and Diversions Alter and Fragment Frog Habitat

Twenty-three of the 24 major watersheds in the Sierra are dammed or diverted, altering and fragmenting historic habitat for species like the foothill yellow-legged frog. On the west slope of the Sierra, where most of the major dams are located, there has been a sharp decline of the foothill yellow-legged frog.[107] Changes caused by dams vary watershed to watershed, but there are commonly observed downstream impacts that can affect the breeding behavior and the health of Sierra frog populations including:

- Prevention of sediment from moving downstream results in the loss of exposed river bar habitat, an important breeding ground for frogs.[108]
- Release of water that does not necessarily reflect natural environmental conditions can destroy egg masses and tadpoles if peak flows are allowed after breeding activity occurs.[109]
- Reduction in flow levels and large floods allow riparian vegetation to grow beyond pre-dam conditions, encouraging the development of sandy berms and smaller, deeper channels that are not ideal habitat for frogs like the foothill yellow-legged frog.[110]
- Lowering of water temperatures in the summer can affect egg and larvae development.[111]
- Altering habitat favors introduced exotic species (like the American bullfrog).
- Changing flow levels also affects the number and type of macro invertebrates upon which Sierra frog species normally feed.[112]

Populations of the foothill yellow-legged frog on the Trinity River below the Lewiston dam just outside the Sierra range were the subject of a study by researcher Amy Lind of the U.S. Forest Service. Lind and colleagues studied the changes in breeding habitat as a result of the dam's construction and examined the timing of water releases from the dam and its effects on the breeding behavior and success of this frog.[113] The ideal breeding habitat of these frogs, the study defined, consists of slower, shallow water near gravel bars.[114] Using comparison of GIS data before and after the dam, the researchers found that 94 percent of the foothill yellow-legged frog habitat and breeding grounds were lost as a result of the dam's construction and operation.[115] In addition, they conducted surveys of the natural and restored bars on the Trinity River between 1991 and 1994 during peak breeding season and compared the results to the timing of peak flows. Breeding populations responded favorably to the "bank feathering" restoration efforts. The only year in which a significant number of egg mass

Researchers found that 94 percent of the foothill yellow-legged frog habitat and breeding grounds were lost as a result of the Lewiston dam.

and larvae survived to metamorphosis was 1994, when high flows were released earlier, more closely mimicking natural high spring runoff.[116] In contrast, 1991 and 1992 saw high flow releases later than what was occurring on naturally flowing river tributaries nearby; as a result all egg masses laid before the releases were lost and the only larvae found later in the summer were hatched from egg masses laid after those peak flows.[117]

In a later study, Lind and others went a step further to understand how dam management changes a natural flow regime and affects tadpole survival and development. They found that the population effects to the foothill yellow-legged frog were not observed until three years after the high pulses of water and that the more harmful pulses occur more frequently on regulated rivers with dams.[118] Using different venues, such as a river and an artificial stream, they also tested the response of tadpoles to changes in water velocity, finding that as velocity increases, tadpoles becomes less active and hide in the rocky substrate, increasing their risk of predation by fish.[119] Tadpoles, as a result of the higher water velocities, are also more likely to be smaller, less developed and less likely to survive to adulthood.[120]

Grazing and Ranching Can Benefit or Damage Frog Habitat

Management of cattle grazing can positively or negatively affect Sierra frog and toad populations. In the past, free range livestock was considered destructive to frogs. Livestock grazing can cause trampling of frogs and toads, and loss of habitat and food sources due to vegetation changes.[121] In the past some believed that grazing needed to be completely eliminated in certain habitats to allow Sierra frog and toad populations to recover.[122] This "no grazing" theory is now being challenged. New studies show that certain regimes of grazing and careful management may actually be beneficial to wildlife, including frogs.[123]

An ongoing study of the Yosemite toad conducted by the USFS Sierra Nevada Research Center is investigating the connection between livestock grazing and toad populations to determine the effects to their habitat. Before, grazing was

Photo courtesy of Ralph and Lisa Cutter.

The Yosemite toad has disappeared from 50 percent of its known habitat.

restricted to during the breeding season of the toad but no study had yet to qualify the relationship between grazing and toad populations.[124] This adaptive management study is comprised of two parts. The first part analyzes grazing history and other factors like disease, comparing those patterns with toad occupancy. The second part of the study uses different grazing treatments to ultimately help direct future management decisions.[125] Randomly selected lots were used for four different types of treatment:

- Fenced off entire mountain meadows with no grazing.
- Fenced off toad breeding areas within meadows being grazed.
- Unfenced meadow with grazing across the entire meadow in accordance with the Sierra Nevada Forest Plan Standards & Guidelines.
- Reference meadow with no grazing within recent history.[126]

Though it is still ongoing, this integrative study will help scientists and resource managers better understand how multiple factors such as grazing, water quality and disease are affecting Yosemite toad populations. This study will help managers and ranchers make better decisions about how grazing should be undertaken for multiple benefits.

Besides grazing regimes, scientists are finding that livestock ponds may also provide environmental benefits and important habitat for threatened species like the California red-legged frog.[127] As the landscape's natural wetlands were slowly lost to agriculture, wildlife progressively became dependant on these livestock ponds. In

the Sierra foothills below 3,500 feet, red-legged frog habitat is now on private lands, which includes livestock operations.[128]

Not all livestock ponds provide favorable environments for amphibians. Some ponds dry up before the breeding season is over. Other ponds large enough to support wildlife like frogs can also provide habitat for predatory non-native fish and the American bullfrog. Many livestock ponds have also lost their cost-effectiveness and ranchers have allowed them to fill up with sediment or become overgrown.[129] Similarly, the costs of environmental permits to restore livestock ponds and the fears of regulatory burdens for reporting listed species on their property have pushed ranchers to abandon ponds.[130]

Photo courtesy of Elena DeLacy, American Rivers Conservancy

This juvenile California red-legged frog was found in Spivey Pond in El Dorado County.

The re-discovery of red-legged frogs in Calaveras County and a study in the East Bay Regional Park District illustrate that Sierra frog and toad population health and sustainable grazing and ranching may not be mutually exclusive.[131]

Climate Change

Climate change is a stressor that Sierra frogs must cope with in addition to a variety of other factors. Climate change impacts such as warming temperatures, reduced snow pack, earlier spring runoff and flooding, increased UV-B exposure and drought are either happening or predicted to happen throughout the Sierra Nevada range.[132] These changes can have disastrous direct and indirect effects on already stressed Sierra frog and toad species.

Warming temperatures and the earlier advance of spring appear to directly affect amphibian health in a number of ways. Sierra frogs and toads, in comparison with other species, with their permeable skins, unshelled eggs and multiple life stages, may be more sensitive to slight changes in temperature and moisture as a result of climate change.[133] Hibernation and breeding in frogs are determined by changes in temperature; frogs and toads that become active earlier and begin breeding are made vulnerable to spring flooding and freezing.[134] These changes can also cause decreased growth rates, smaller mature frogs and increased mortality in temperate amphibians.[135] Recently, a field study in the U.K. by C.J. Reading of the Centre for Ecology and Hydrology found the occurrence of milder winters resulted in a reduction in female body size and fertility.[136]

In addition, climate changes can be more favorable to some parasites and disease. There is currently much scientific debate on whether climate change is responsible for creating the conditions that have allowed chytrid to spread and thrive.[137]

For more on climate change impacts in the Sierra Nevada, read the Sierra Nevada Alliance's Sierra Climate Change Toolkit, available for free at www.sierranevadaalliance.org.

Chapter Four: Next Steps to Preserve Sierra and California Cascade Frogs and Toads

Individual Actions

Educate Yourself and Others about Amphibian Declines. No problem can be solved without an educated and concerned public. Help spread the word to others about severe declines of Sierra frogs and toads to increase concern and support for the actions noted below. Contact the Sierra Nevada Alliance for copies of this report or contact organizations doing education on frogs and toads. See Appendix A: Further Resources for a list of helpful websites and organizations.

Join conservation groups working on federal hydropower dam re-licensing. Right now in the Sierra, there are about 50 hydropower dams being re-licensed and not only do those licenses determine things like water flow levels and timing, they also last for 30 to 50 years. The re-licensing process is an important time to get information and make changes to dam operations for multiple benefits. Your voice for Sierra and Cascade frogs can help ensure their needs are met in how rivers are operated below dams. Contact the California Hydropower Reform Coalition, listed in the Resource section, to find the nearest group near you working on dam relicensing.

Help Prevent the Spread of Chytrid. If you hike, fish, or camp in the mountains it is important to prevent the spread of chytrid. Be careful to not move frogs, water, and other things of that nature from one location to another. Wash your gear and allow for drying time before continuing to the next location. If you come across a die-off of frogs (more than one frog dead in one location), do not handle the frogs but report the event and exact location to Vance Vredenburg at vancev@sfsu.edu.

Actively participate in County and City General Plan Updates. Decisions by local governments about where to grow and how to grow determine the future of frog habitat. Work with local organizations, city and county governments, ranchers and farmers to save open space and working landscapes. Contact the Sierra Nevada Alliance Sustainable Land Use Campaign (530-542-4546) to find local non-profits working on general planning issues or contact your local city and county planning office to learn about local planning in your area.

Participate in local amphibian survey and monitoring programs. In the United States, surveys are being coordinated by the North American Amphibian Monitoring Program (NAAMP), which is sponsored by the U.S. Geological Survey. Visit their web site for more information at www.pwrc.usgs.gov/naamp. These programs provide educational materials that will help you learn to identify the frogs and toads in your surroundings.

Support conservation organizations that are actively involved in issues concerning frogs and toads. Join organizations like the Jumping Frog Research Institute, Defenders of Wildlife and the Pacific Rivers Council that are doing important work to ensure the future survival of Sierra frogs and toads. See Appendix A: Further Resources for contact information.

If you are a farmer or rancher, learn more about the benefits of restoring ponds on your property. Implementing sustainable livestock and farming operations that benefit frogs can also benefit your economic bottom line. Contact the Jumping Frog Research Institute for more on this topic.

Local, State and Federal Agency and Government Actions

Re-operate Dams to Assist in Frog Recovery. As noted above, the hydropower dam re-licensing process is an important time to get information and make changes to dam operations for multiple benefits. Some pertinent conditions to consider for frogs in this process include water temperature criteria, continual monitoring of the effects of the new license as well as flow levels and timing. In general, a beneficial management strategy to help frogs like the foothill yellow-legged frog and other native species would be to make dams mimic some natural flow cycles. This would include allowing for occasional scouring floods, which are not only part of the natural regime but will help prevent the expansion of invasive species like the American bullfrog and help maintain frogs' bar habitat and breeding grounds.[138] While compromise is necessary in negotiating dam operating conditions with so many competing interests, the needs of frogs and other native species can be accommodated and should remain important considerations.

Map and Inventory Critical Frog Habitat. Currently, 70 percent of Sierra Nevada counties do not have any mapping or inventories of endangered critical habitat and 85 percent of Sierra Nevada counties do not have habitat conservation plans (HCP), natural community conservation plans or conservation banks.[139] Getting this information can help cities and counties develop informed policies that will identify and protect important habitat for native species, including Sierra frogs and toads. It is impossible to protect a valued community resource when you do not know where it is.

Adopt Condensed and Clustered Development Patterns to Preserve Open Space. Condensed and clustered development patterns preserve open space, ranch and farmland, and prevent habitat loss and fragmentation. Read the Sierra Nevada Alliance's publications Planning for the Future, Dangerous Development, and Planning for Water-Wise Development in the Sierra for more information. These publications are available for free at the website www.sierranevadalliance.org.

Implement the Global Warming Solutions Act and Reduce Greenhouse Gas Emissions. California should continue to be a leader in reducing world-wide emissions and preventing catastrophic warming scenarios that will make it extremely hard for amphibians to adapt. Ensure the Sierra Nevada and Cascade regions are included in the implementation of state climate change plans and look for co-benefit strategies that help frogs and amphibians while reducing greenhouse gases.

Make Climate Adaptation a Priority. Adapting to the climate changes already set in motion by past emissions is critically needed. Invest more time and funding in state efforts to help California adapt to these changes. Use the basic principles found in the Sierra Climate Change Toolkit in adaptation planning, which include reducing other stressors to increase resiliency, using adaptive management strategies to maintain flexibility, monitoring changes in order to inform those strategies and identifying future changes through modeling to target critical future habitat.

Regulate use of pesticides to protect frogs and toads. The California Department of Pesticide Regulation and the Environmental Protection Agency should evaluate how to better protect Sierra frogs and toads when registering pesticides for use.

Provide funding and incentives for rural counties and cities to better plan to protect frogs and toads. Rural counties and cities need funding support to help map and inventory endangered critical habitat for frogs and toads. Getting the right tools to local Sierra cities and counties could help them develop policies that will identify and protect important habitat for native species, including Sierra frogs and toads.

Sierra and Cascade Frogs and Toads Forever.

Sierra and Cascade frogs and toads need our help now to ensure their continued existence. A variety of stressors are contributing to significant population declines and action on many levels is needed. Not only do we need further research to better understand the exact mechanisms leading to their declines, but we need to act on issues we already know threaten frogs and toads. Together we can create an amphibian future that is diverse, vibrant, and enchanting, as long as we commit to that future and act today.

Photo courtesy of Robert Stack, Jumping Frog Research Institute.

You can prevent Sierra frogs and toads, like this California red-legged frog, from disappearing forever.

Appendix A: Further Resources[140]

General Information

Amphibian Conservation Action Plan (ACAP)
www.amphibiaweb.org/declines/acap.pdf
The World Conservation Union brought together a diverse range of conservation organizations and governmental agencies to create the Amphibian Conservation Action Plan (ACAP) in 2005.

Amphibiaweb
www.amphibiaweb.org//index.html
This University of California website is an online database of all amphibian species based on scholarly research. Entries include photos, sound files, literature references and distribution maps.

Bibliography of Amphibian Disease
www.jcu.edu.au/school/phtm/PHTM/frogs/bibliog.htm
Compiled by Prof. Rick Spear of James Cook University on a website funded by the National Heritage Trust and the Australian Dept. of Environment and Heritage.

California Reptiles and Amphibians
www.californiaherps.com/index.html
An illustrated online atlas of California reptiles and amphibians designed to promote public awareness and appreciation for these creatures and their habitat.

Center for North American Herpetology
www.cnah.org/
This site is the academic portal to North American herpetology and makes the latest news, scholarship and information on amphibians, reptiles, turtles and crocodilians available.

FrogWeb
frogweb.nbii.gov/
This website is maintained by the U.S. Geological Survey and includes information on issues affecting North American amphibians, on specific species, and what you can do.

Livingunderworld.org
www.livingunderworld.org/
This ongoing, educational web project is dedicated to the preservation of wild and captive amphibians and making accurate amphibian information readily available.

The Mountain Yellow-legged Frog Website
www.mylfrog.info/
This site created by Dr. Roland Knapp, Research Biologist provides the latest news and information regarding the Sierra Nevada and southern mountain yellow-legged frogs.

National Amphibian Atlas
igsaceeswb00.er.usgs.gov:8080/mapserver/naa/
Hosted by the US Geological Survey and funded by the U.S. Fish and Wildlife Service and others, this website contains detailed species distribution maps of amphibians.

Sierra Nature Notes
www.yosemite.org/naturenotes/
The online journal of Natural History News in the Sierra Nevada includes periodic updates on the status of Sierra frogs and toads.

Sierra Nevada Ecosystem Project (SNEP)
www.ceres.ca.gov/snep/pubs/
The final report to Congress in 1996 includes a whole section on amphibians, their natural history and threats to their continued existence.

Organizations Working in the Sierra

Jumping Frogs Research Institute (JFRI)
www.jumpingfrog.org
The mission of the JFRI is to restore and protect native amphibian populations in the Sierra Nevada. To achieve this, JFRI advocates for creating and maintaining healthy amphibian habitat while working with public agencies to ensure amphibian interests are protected.

Defenders of Wildlife

www.defenders.org/index.php

Defenders of Wildlife is a national, nonprofit membership organization dedicated to the protection of all native animals and plants in their natural communities.

Pacific Rivers Council

www.pacrivers.org/

The mission of the Pacific Rivers Council is to protect and restore rivers, their watersheds and native aquatic species.

Declining Amphibian Populations Task Force, California/Nevada Working Group

ice.ucdavis.edu/CANVDecliningAmphibians/index.html

The Declining Amphibian Populations Task Force (DAPTF) operates through a network of Working Groups. The California/Nevada Working Group seeks to understand and reverse amphibian population declines in CA and NV and ensure the existence of all amphibian species.

California Hydropower Reform Coalition

www.hydroreform.org/california

The California Hydropower Reform Coalition, founded in 1997, is a coalition of national, statewide and local river conservation and recreation organizations that work to protect, enhance, and restore California rivers impacted by federally-regulated hydropower dams.

Center for Biological Diversity

www.biologicaldiversity.org/species/amphibians/index.html

The mission of the Center is to work to secure a future for all species nearing extinction through science, law and creative media. They have campaigns targeting the California red-legged frog, the Yosemite toad and the Sierra Nevada mountain yellow-legged frog.

California Association of Resource Conservation Districts

www.carcd.org/

This website includes a directory of all Resource Conservation Districts (RCDs) in California, including the Sierra. Some RCDs are involved in habitat restoration and grazing management that affects Sierra frogs and toads.

Agencies Working on Frogs in the Sierra

California Department of Fish and Game

www.dfg.ca.gov/

The Department of Fish and Game maintains native fish, wildlife, plant species and natural communities for their intrinsic and ecological value and their benefits to people. For more info on their fish removal program, contact Curtis Milliron, Senior Biologist, cmilliro@dfg.ca.gov.

Sierra Nevada Aquatic Research Laboratory (SNARL)

vesr.ucnrs.org/index.html

Administered by UC Santa Barbara, SNARL provides protected wildlands and on-site experimental and support facilities for conducting studies of natural systems over central, eastern California and western Nevada.

Sierra Nevada Aquatic Ecology Group (Pacific Southwest Research Station, U.S. Forest Service)

www.fs.fed.us/psw/programs/snrc/aquatic/index.html

This research group is studying native amphibians, reptiles and fish in the wilderness areas of the High Sierra. For more on their current research and publications check out their website.

U.S Fish and Wildlife Service

www.fws.gov/cno/

The mission of the U.S. Fish & Wildlife Service is working with others to conserve, protect and enhance fish, wildlife and plants and their habitats for the benefit of the American people.

Organizations Outside the Sierra Nevada

The Amphibian Ark

www.amphibianark.org

The mission of the Amphibian Ark is to work in partnership to ensure the global survival of amphibians with a focus on those that cannot be safeguarded by nature.

Amphibian Conservation Alliance

www.frogs.org/index.asp

The mission of this nonprofit educational organization

is to protect amphibians through a full range of scientific, educational and advocacy programs.

Californians for Alternatives to Toxics (CATs)

www.alternatives2toxics.org
CATs mission is to enable the public to gain control over pesticides and other toxic chemicals within the environment of California in ways that will benefit people around the world. CATs has a Reptile, Amphibian and Pesticide Database on their website.

Partners in Amphibian and Reptile Conservation (PARC)

www.parcplace.org
Partners in Amphibian and Reptile Conservation (PARC) is an inclusive partnership dedicated to the conservation of the herpetofauna--reptiles and amphibians--and their habitats.

Save A Frog

saveafrog.org/index.html
A collaborative effort of the Atlanta Botanical Garden and Zoo Atlanta, Saveafrog.org is focused on taking action against amphibian extinction while promoting education and research.

Save the Frogs!

www.savethefrogs.com/index.html
The mission of Save the Frogs! is to be a primary contributor to scientific research, policy-making and legal defense; a major source of amphibian conservation grants; and the principal source of amphibian information and education available to the public.

The World Conservation Union, Amphibian Specialist Group

www.amphibians.org/
This group strives to conserve biological diversity by encouraging and supporting programs to conserve amphibians and their habitat worldwide. The group is a global network of partners who develop funding, capacity and share technology to achieve amphibian conservation goals.

Monitoring/Survey Programs

North American Reporting Center for Amphibian Malformations (NARCAM)

frogweb.nbii.gov/narcam/index.html
Use this site to report any malformed amphibians you have seen using their online submission form or learning more about malformations already reported.

Frogwatch USA (National Wildlife Federation and USGS)

www.nwf.org/frogwatchUSA/
Frogwatch USA is a frog and toad monitoring program run by the National Wildlife Federation and the U.S. Geological Survey that gives people the opportunity to help scientists conserve amphibians. Anyone can volunteer- go to their website to find out more.

USGS Amphibian Research and Monitoring Initiative

armi.usgs.gov/index.asp
A national program of amphibian monitoring, research, and conservation, this initiative is run by the U.S. Geological Survey.

Researchers Addressing Sierra Amphibian Issues

Amy Lind

Research Wildlife Biologist & Herpetologist
US Forest Service, Sierra Nevada Research Center
www.fs.fed.us/psw/programs/snrc/staff/lind/
Email: alind@fs.fed.us
Primary research interests include: amphibians and reptiles ecology, conservation and restoration; freshwater pond and stream ecology and hydrology; effects of resource management activities.

Roland Knapp

Research Biologist
vesr.ucnrs.org/
Sierra Nevada Aquatic Research Laboratory
vesr.ucnrs.org/pages/knapp/index.html
Email: knapp@lifesci.ucsb.edu
Primary research interests include: the effects

of introduced fish on lake ecosystems; the role of disease in recent amphibian declines; and the taxonomy of lake-dwelling fauna.

Carlos Davidson

Director and Associate Professor of the Environmental Studies Program
San Francisco State University.
bss.sfsu.edu/cdavidson/
Email: carlosd@sfsu.edu
Primary research interests include: the causes of amphibian population declines; political and economic aspects of society's relationship to the natural world.

David F. Bradford

Research Ecologist
US Environmental Protection Agency
epa.gov/esd/land-sci/staff/bradford.htm
Email: bradford.david@epamail.epa.gov
Primary research interests include: interactions between landscape patterns, habitat characteristics and animal distributions, particularly amphibians; causes for amphibian population declines; faunal indicators of ecosystem condition.

Kathleen Mathews

Research Fisheries Biologist
U.S. Forest Service
www.fs.fed.us/psw/programs/snrc/staff/matthews/
Email: kmatthews@fs.fed.us
Primary interests include: effect of management activities (cattle grazing, fish stocking, etc.) on the native aquatic organisms of wilderness streams and lakes.

Karen Pope

Wildlife Biologist
U.S. Forest Service
www.fs.fed.us/psw/programs/
TimberManagement/staff/kpope/
Email: kpope@fs.fed.us
Primary research interests include: conservation and ecology of northern California amphibians; interactions between amphibians and non-native trout and the disease chytrid.

Vance Vredenburg

Assistant Professor, Department of Biology
San Francisco State University.
socrates.berkeley.edu/~vancev/ or web.me.com/vancevredenburg/
Email: vancev@sfsu.edu
Primary research interests include: ecology of emerging infectious disease; introduced species effects on aquatic-terrestrial food web linkages; climate change effects on estuarine food webs.

Bibliography

"Agriculture Linked to Frog Sexual Abnormalities." Science Daily, 5 July 2008. News online. Accessed online 12 August 2008. Available from http://www.sciencedaily.com/releases/2008/07/080703160749.htm.

Amphibian Ark. "Keeping Threatened Amphibian Species Afloat." Amphibian Ark. Database online. Updated 13 August 2008; accessed 14 August 2008. Available from http://www.amphibianark.org.

---."Amphibians as Indicators." Database online. Updated 13 August 2008; accessed 14 August 2008. Available from http://www.amphibianark.org/indicators.htm.

"Amphibian Skin Agent May Battle Multi-drug Resistant Bacteria." ScienceDaily, 23 January 2008. News online. Updated 15 August 2008; Accessed 15 August 2008. Available from http://www.sciencedaily.com/releases/2008/01/080122102502.htm.

Black, Richard. "Bacteria Could Stop Frog Killer." BBC News, 6 June 2008. News online. Accessed online 11August 2008. Available from http://news.bbc.co.uk/2/hi/science/nature/7438205.stm.

Borchardt, John K. "Why we should care if the mountain yellow-legged frog becomes extinct." USA Weekend Magazine, 30 September 2007. Available online from http://www.usaweekend.com/07_issues/070930/070930science.html.

"Breakdown Products of Widely Used Pesticides Are Acutely Lethal To Amphibians, Study Finds." Science Daily, 25 June 2007. Accessed online 12 August 2008. Available from http://www.sciencedaily.com/releases/2007/06/070623213748.htm.

Buggs, Robert L. and Peter C. Trenhan. "Agriculture Affects Amphibians (Part 2): Pesticides,Fungi, Algae, Higher Plants, Fauna, Management Recommendations." Sustainable AgricultureNewsletter (Summer 2003). Accessed 20 August 2007. Available from http://www.sarep.ucdavis.edu/newsltr/v15n2/sa-7.htm.

Cal-Pac Society for Range Management Symposium. "Livestock Grazing and Yosemite Toads."Grazing for Biological Conservation. 23 June 2006. Accessed online 20 August 2008. Available from http://cesantaclara.ucdavis.edu/files/36781.pdf.

CaliforniaHerps. "California Reptiles and Amphibians" California Frogs and Toads. Database Online. Accessed 20 July 2008. Available from http://www.californiaherps.com/info/findfrogs.html

Casper, Gary and Russ Hendricks. "American bullfrog." Amphibian Declines: The Conservation Status of United States Species. Edited by Michael Lanoo. University of California Press, 2005. Quoted in "American bullfrog." Amphibiaweb. Database online. Accessed 2 September 2008. Available from http://amphibiaweb.org/.

Choi, Charles Q. "Can the 'Amphibian Ark' Save Frogs From Pollution/Extinction?" Scientific American Magazine, 19 June 2008. Magazine online. Accessed 2 September 2008. Available from http://www.sciam.com/article.cfm?id=amphibian-ark.

"Climate Change Drives Widespread Amphibian Extinctions; Warmer Temperatures Enhance Growth Conditions of Fatal Fungus." Science Daily, 12 January 2006. Accessed online 12 August 2008. Available from http://www.sciencedaily.com/releases /2006/01060112035218.htm.

Cohen, Janet. Sierra Climate Change Toolkit. 2nd ed. South Lake Tahoe: Sierra Nevada Alliance, 2008.

Cone, Marla. “A New Alarm Sounds for Amphibians.” Los Angeles Times, 25 January 2006, A-14. News online. Accessed 2 September 2008. Available from http://articles.latimes.com/2006/jan/25/nation/na-frogs25.

Conlon, J.M.; M. Patel; T. Pál et al. “Isolation of peptides of the brevinin-1 family with potent candidacidal activity from the skin secretions of the frog Rana boylii.” Journal of Peptide Research 62 no. 5 (August 2003):207-13.

Damschroder, James. “Yellow-legged Frogs in Peril, Plan Could Help.” Union Democrat, June 16, 2008. News online. Accessed on 14 August 2008. Available from http://www.uniondemocrat.com /news/results.cfm?story_no=26845.

Davidson, Carlos; C. Shaffer; and M. R. Jennings. “Declines of the California red-legged frog: climate, UV-B, habitat and pesticides hypotheses.” Ecological Applications 11 (2001):464-479.

---. H. Bradley Shaffer; and Mark R. Jennings. “Spatial Test of the Pesticide Drift, Habitat Destruction, UV-B, and Climate-Change Hypotheses for California Amphibian Declines.” Conservation Biology 16, no. 6. (2002): 1588-1601.

---. “Declining Downwind: Amphibian Population Declines in California and Historical Pesticide Use.” Ecological Applications 14, no. 6 (2004): 1892-1902.

---. Gary Fellers.“Yosemite Toad.” Amphibian Declines: The Conservation Status of United States Species. Edited by Michael Lanoo. University of California Press, 2005. Quoted in “Yosemite toad.” Amphibiaweb. Database online. Accessed 2 September 2008. Available from http://amphibiaweb.org/.

---. M. Benard; H. B. Shaffer; J. Parker; C. O’Leary; J. M. Conlo; and L. A. Rollins-Smith. “Effects of chytrid infection and carbaryl exposure on survival, growth and antimicrobial peptide defenses in foothill yellow-legged frogs (Rana boylii).” Environmental Science and Technology 41 (2007):1771-1776.

---. R. Knapp. “Multiple stressors and amphibian declines: dual impacts of pesticides and fish on yellow-legged frogs.” Ecological Applications 17 (2007):587-597.

---. Kerri Stanley; and Staci Simonich. Pesticide Residues in Frogs and Amphibian declines in the California Cascades and Sierra Nevada. Final Research Report to the State Water Resources Control Board. SWRCB Grant Agreement No: 03-265-556-0, 2008.

Declining Amphibians Populations Task Force. California/Nevada Working Group. Database online.Updated 4 March 2008; accessed 20 August 2008. Available from http://ice.ucdavis.edu/CANVDecliningAmphibians/index.html.

DiDonato, Joseph. “Endangered Amphibian Research within Grazed Grasslands.” Keeping Landscapes Working 4, Issue 1 (Winter 2007): 4-5.

Dudley, Tom. “Exotic Species in Aquatic Ecosystems.” Pacific Research Institute. Accessed online 20 August 2008. Available from http://io.uwinnipeg.ca/~simmons/ysesp/exotic3.htm.

“Dying Frogs Sign of a Biodiversity Crisis.” Science Daily, 12 August 2008. News online. Accessed online 15 August 2008. Available from http://www.sciencedaily.com/releases/2008/08/080812135654.htm.

Fellers, Gary M. “California red-legged frog.” Amphibian Declines: The Conservation Status of United States Species. Edited by Michael Lanoo. University of California Press, 2005. Quoted in “California red-legged frog.” Amphibiaweb. Database online. Accessed 2 September 2008. Available from http://amphibiaweb.org/.

---.“Foothill yellow-legged frog.” Amphibian Declines: The Conservation Status of United States Species. Edited by Michael Lanoo. University of California Press, 2005. Quoted in “Foothill yellow-legged frog.” Amphibiaweb. Database online. Accessed 2 September 2008. Available from http://amphibiaweb.org/.

Frog Decline Reversal Project, Inc. “Why Care about Frogs?” Database online. Updated 9 May 2008. Accessed 15 August 2008. Available from http://www.fdrproject.org.au/pages/whycare.htm.

“Frog Skin Chemicals Block HIV in Lab Study” Environmental News Service, 30 September 2005. News online. Accessed 20 July 2008. Available from http://www.ens-newswire.com/ens/sep2005/2005-09-30-02.asp.

Global Amphibian Assessment (GAA). “Summary of Key Findings.” Database online. Updated May 2006; accessed 30 July 2008. Available from http://www.globalamphibian.org/summary.htm.

Graber, Sarah. “Foothill yellow-legged frog.” Edited by Kellie Whittaker. AmphibiaWeb. Berkeley, California. Database online. Updated 14 December 2007. Accessed 2 September 2008. Available from http://amphibiaweb.org/.

Hayes, Dr. Tyrone. Interview by KQED. Pesticides. KQED Public Media for Northern California, May 2008. Available online from: http://amphibiaweb.org/declines/ChemCon.html.

Hickey, Ellen; Joan Clayburgh and Shannon Raborn. Planning for the Future: A Sierra Nevada Land Use Index. South Lake Tahoe: Sierra Nevada Alliance, 2005.

Hiles, Sara Shipley. “Slipping Away: Frogs, salamanders and other amphibians are sliding into oblivion.” Defenders Magazine, Spring 2008. Magazine online. Accessed 15 August 2008. Available from http://www.defenders.org/newsroom/defenders_magazine/spring_2008/slipping_away.php.

Hollis, Robert. “Frog Discovery May Jump-Start Shift in Attitude.” Los Angeles Times, 20 January 2008, B5.

International Union for Conservation of Nature and Natural Resources (IUCN). Amphibian Conservation Action Plan. Gland, Switzerland: World Conservation Union, 2007. Available from http://www.amphibianark.org/pdf/ACAP.pdf.

“Introduced Species.” Amphibiaweb. Database Online. Updated 14 May 2008; accessed 18 July 2008 Available from http://amphibiaweb.org/declines/IntroSp.html.

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

---. “Status of Amphibians.” Sierra Nevada Ecosystem Project: Final Report to Congress. vol. II Assessments and Scientific basis for management options. Davis: University of California, Center for Water and Wildland Resources, 1996.

Knapp, Roland A.; Daniel M. Boiano; and Vance T. Vredenburg. “Removal of Non-native Fish Results in Population Expansion of a Declining Amphibian (Mountain Yellow-legged Frog, Rana muscosa).” Biological Conservation 135 no. 1 (February 2007): 11-20. Author manuscript available from: http://www.pubmedcentral.nih.gov/picrender.fcgi?artid=1839007&blobtype=pdf.

---.“Natural History- Ecosystem Role.” In the Mountain Yellow-Legged Frog Site. Article online. Updated 24 May 2008. Accessed 15 August 2008. Available from http://www.mylfrog.info/naturalhistory/ecosystem.html.

---.“Natural History- Distribution.” In the Mountain Yellow-Legged Frog Site. Article online. Updated 24 May 2008. Accessed 15 August 2008. Available from http://www.mylfrog.info/naturalhistory/ecosystem.html.

---.“Threats-Disease.” In the Mountain Yellow-Legged Frog Site. Article online. Updated 24 May 2008. Accessed 15 August 2008. Available from http://www.mylfrog.info/threats/disease.html.

Kupferberg, S.J. “Bullfrog (Rana catesbeiana) Invasion of a California river: the role of larval competition.” Ecology 78 (1997):1736–1751.

Lawler S.P.; Dritz D.; Strange T.; Holyoak M. “Effects of Introduced Mosquitofish and Bullfrogs on the Threatened California Red-legged Frog.” Conservation Biology, 13, No. 3 (June 1999): 613-622.

Lind, Amy; Hartwell Welsh Jr.; and Randolph Wilson. “The effects of a Dam on Breeding Habitat and Egg Survival of the Foothill Yellow-legged Frog (Rana boylii) in Northwestern California.” Herpetological Review 27 no. 2 (1996): 62-67.

Lombardi, Linda. “Frogs Are Coal-mine Canaries of Environment.” Lubbock Online. 29 February 2008. News online. Available from http://www.lubbockonline.com/stories/022908/liv_252294572.shtml

Mount, Jeff; Amy Lind; Sarah Yarnell and Sarah Kupferberg. “Pulsed-flow effects on foothill yellow-legged frog: Integration of empirical, experimental and hydrodynamic modeling approaches: First Year Progress Report to CA Energy Comission.” Davis: University of California, Center for Watershed Sciences, 2008.

Morgan, Jess A.T.; Vance T. Vredenburg; Lara J. Rachowicz; Roland A. Knapp; et al. “Population Genetics of the Frog-killing Fungus Batrachochytrium dendrobatidis..” Proceedings of the National Academy of Science of the United States of America (PNAS) 104 no. 3421 (August 2007). Journal online. Accessed online 31 July 2008. Available from http://www.pnas.org/content/104/34/13845.full.pdf+html.

National Park Service. U.S. Department of the Interior. Restoration of Sierra Nevada Yellow-legged Frogs: Experimental Fish Removal. Yosemite National Park. June 23 - July 25, 2008.

Natural Resource Conservation Service (NRCS). “Farm Pond Ecosystems.” Fish and Wildlife Habitat Management Leaflet 29 (February 2006): 1-12. Journal online. Accessed 31 July 2008. Available from http://policy.nrcs.usda.gov/media/pdf/tn_b_40_a.pdf.

“New Report Details Historic Mass Extinction of Amphibians; Humans Worsen Spread of Deadly Emerging Infectious Disease.” Science Daily, 12 August 2008. Accessed online 12 August 2008. Available from http://www.sciencedaily.com/releases/2008/08/080811195627.htm.

Pearl, Christopher and Michael Adams. “Cascade frog.” Amphibian Declines: The Conservation Status of United States Species. Edited by Michael Lanoo. University of California Press, 2005. Quoted in “Cascades frog.” Amphibiaweb. Database online. Accessed 2 September 2008. Available from http://amphibiaweb.org/.

Perlman, David. “Exploring an Amphibian Epidemic: UC team Believes Deadly Fungus May be Killing Frogs, Toads, Salamanders in Sierra.” San Francisco Chronicle, 7 August 2008.

“Poison from Frog Skin Leads to a Painkiller.” New York Times, 2 January 1996. Updated 15 August 2008; accessed online 15 August 2008. Available from http://query.nytimes.com/gst/fullpage.html?res=9801E7D71E31F931A35752C0A96E958260&sec=health&spon=&partner=permalink&exprod=permalink

“Pollution Drives Frog Deformities By Ramping Up Infections.” Science Daily, 25 September 2007. News online. Accessed online 12 August 2008. Available from http://www.sciencedaily.com/releases/2007/09/070925130649.htm.

Ray, Casey. “Following the Frogs.” Sierra Nature Notes 2 (November 2002). Journal online. Accessed online 12 August 2008. Available from http://www.yosemite.org/naturenotes/FollowingFrogs.htm.

Reading, C.J. “Linking global warming to amphibian declines through its effects on female body condition and survivorship.” Global Change and Conservation Ecology (21 September 2006). Journal online. Accessed 5 August 2008. Available from http://cat.inist.fr/?aModele=afficheN&cpsidt=18474689.

Romansic, John. “Cascades frog.” Edited by Vance Vredenburg. AmphibiaWeb. Berkeley, California. Database online. Updated 5 April 2004; Accessed 2 September 2008. Available from http://amphibiaweb.org/.

---. Yair Chaver. “Yosemite Toad.” Edited by Kellie Whittaker. AmphibiaWeb. Berkeley, California. Database online. Updated 8 August 2008; Accessed 2 September 2008. Available from http://amphibiaweb.org/.

The Sierra Fund. Mining’s Toxic Legacy: An Initiative to Address the Mining Toxins in the Sierra Nevada. Sacramento: Sutter Printing, 2008.

Skerratt, Lee Francis; Lee Berger; et al. “Spread of Chytridiomycosis Has Caused the Rapid Global Decline and Extinction of Frogs.” EcoHealth Journal Consortium (2007). Journal online. Accessed online 12 August 2008. Available from http://www.jcu.edu.au/school/phtm/PHTM/frogs/papers/skerratt-2007.pdf.

Sopory, Ambika. “American bullfrog.” Edited by David Wake and Kevin Gin. AmphibiaWeb. Berkeley, California. Database online. Updated 5 April 2004; Accessed 2 September 2008. Available from http://amphibiaweb.org/.

Stuart, Simon N. “Status and Trends of Amphibian Declines and Extinctions Worldwide.” American Association for the Advancement of Science 306 (December 2004): 1782-1786. Magazine online. Available from http://www.sciencemag.org.

Symonds, Katie. “Ranchers Restore Amphibian-friendly Ponds.” Endangered Species Bulletin 33 no. 1 (Spring 2008). Accessed online 3 August 2008. Available from http://www.carangeland.org/Files%20to%20Link /News/2008/08-07USFWS%20-%20Ranchers%20Restore%20Ponds.pdf.

Tunstall, Tate and Gary Fellers. “California red-legged frog.” Edited by Vance Vredenburg. AmphibiaWeb. Berkeley, California. Database online. Updated 3 February 2008; Accessed 2 September 2008. Available from http://amphibiaweb.org/.

University of California- Cooperative Extension. “Grazing for Biological Conservation.” Keeping Landscapes Working Vol. 4, Issue 1 (Winter 2007) 1- 7.

US Department of Agriculture, Forest Service (USDA Forest Service). “Determining the Effects of Livestock Grazing on Yosemite Toads (Bufo canorus) and Their Habitat: An Adaptive Management Study.” Pacific Southwest Research Station: Sierra Nevada Research Center. Accessed online 13 August 2008. Available from http://www.fs.fed.us/psw/programs/snrc/bio_diversity/aquatic_anthropogenic_ sub1/yosemite_toad.shtml.

Vollrath, Kristen and Erika Sheetenhelm eds. “Chemical Contaminants.” Amphibiaweb. Berkeley, California. Database Online. Updated 14 May 2008; Accessed 18 July 2008. Available from http://www.amphibiaweb.org/declines/ChemCon.html.

Vredenburg, Vance T. “Reversing Introduced Species Effects: Experimental Removal of Introduced Fish Leads to Rapid Recovery of a Declining Frog.” PNAS 101 no. 20 (18 May 2004). Journal online. Accessed online 12 August 2008. Available from http://www.pnas.org/cgi/doi/10.1073/pnas.0402321101.

---.Gary Fellers and Carlos Davison. “Southern mountain yellow-legged frog.” Amphibian Declines: The Conservation Status of United States Species. Edited by Michael Lanoo. University of California Press, 2005. Quoted in “Southern mountain yellow-legged frog.” Amphibiaweb. Database online. Accessed 2 September 2008. Available from http://amphibiaweb.org/.

---.R. Bingham, R. Knapp, et. al. “Concordant molecular and phenotypic data delineate new taxonomy and conservation priorities for the endangered mountain yellow-legged frog.” Journal of Zoology 271 (2007): 361-374.

---.“Sierra Nevada mountain yellow-legged frog.” Edited by Kellie Whittaker. AmphibiaWeb. Berkeley, California. Database online. Updated 15 December 2007; Accessed 2 September 2008. Available from http://amphibiaweb.org/.

---.Robert Drewes; Tyrone Hayes; and Karen Swaim. Interview by KQED. Disappearing Frogs. KQED Public Media for Northern California, May 2008. Available online from: http://amphibiaweb.org/declines/declines.html.

---. “Climate Change.” M. McDonald and T. Sayre eds. Amphibiaweb. Database Online. Updated 14 May 2008; accessed 18 July 2008. Available from http://www.amphibiaweb.org/declines/ClimateChange.html.

---.“Southern mountain yellow-legged frog.” Edited by Kellie Whittaker. AmphibiaWeb. Berkeley, California. Database online. Updated 17 June 2008. Accessed 2 September 2008. Available from http://amphibiaweb.org/.

Wake, David B. and Vance T. Vredenburg. “Are We in the Midst of the Sixth Mass Extinction? A View from the World of Amphibians.” PNAS 105 (12 August 2008). Journal online. Accessed online 12 August 2008. Available from http://www.pnas.org/cgi/doi/10.1073/pnas.0801921105.

---“Climate Change Implicated in Amphibian and Lizard Declines.” PNAS 104 n. 20 (15 May 2007). Journal online. Accessed online 15 August 2008. Available from http://www.pnas.org/content/104/20/8201.full.pdf+html

Weldon, Ché; Louis H. du Preez; et. al. “Origin of the Amphibian Chytrid Fungus.” Emerging Infectious Diseases 10 no. 12 (December 2004). Journal online. Accessed online 12 August 2008. Available from www.cdc.gov/eid.

Wilkinson, John, ed. “Habitat Destruction, Alteration and Fragmentation.” Amphibiaweb. Database Online. Updated 14 May 2008; accessed 18 July 2008. Available from http://www.amphibiaweb.org/declines/HabFrag.html.

Endnotes

[1] Global Amphibian Assessment (GAA). "Summary of Key Findings." Database online. Updated May 2006; accessed 30 July 2008. Available from www.globalamphibian.org/summary.htm.

[2] Hiles, Sara Shipley. "Slipping Away: Frogs, salamanders and other amphibians are sliding into oblivion." *Defenders Magazine*, Spring 2008. Magazine online. Accessed 15 August 2008. Available from www.defenders.org/newsroom/defenders_magazine/spring_2008/slipping_away.php.

[3] Jennings, M.R. and M.P. Hayes. *Amphibian and reptile species of special concern in California*. Rancho Cordova, California: California Department of Fish and Game, Inland Fisheries Division, Final report, 1994.

[4] National Park Service U.S. Department of the Interior. *Restoration of Sierra Nevada Yellow-legged Frogs:Experimental Fish Removal*. Yosemite National Park. June 23 - July 25, 2008.

[5] Hiles, "Slipping Away."

[6] Knapp, Roland Knapp. "Natural History- Ecosystem Role" In the *Mountain Yellow-Legged Frog Site*. Article online. Updated 24 May 2008. Accessed 15 August 2008. Available from www.mylfrog.info/naturalhistory/ecosystem.html.

[7] Borchardt, John K. "Why we should care if the mountain yellow-legged frog becomes extinct." *USA Weekend Magazine,* 30 September 2007. Available online from www.usaweekend.com/07_issues/070930/070930science.html.

[8] Frog Decline Reversal Project, Inc. "Why Care about Frogs?" Database online. Updated 9 May 2008. Accessed 15 August 2008. Available from www.fdrproject.org.au/pages/whycare.htm.; Amphibian Ark. "Amphibians as Indicators." Database online. Updated 13 August 2008; accessed 14 August 2008. Available from www.amphibianark.org/indicators.htm.; Amphibian Conservation Summit. "Declaration." Washington DC, 17-19 September 2005. Database online. Available from www.globalamphibians.org/acap_5fsummit_5fdeclaration.pdf.

[9] Lombardi, Linda. "Frogs Are Coal-mine Canaries of Environment." *Lubbock Online*. 29 February 2008. Database online. Available from www.lubbockonline.com/stories/022908/liv_252294572.shtml.

[10] Vredenburg, Vance. Robert Drewes; Tyrone Hayes; and Karen Swaim. Interview by KQED. *Disappearing Frogs*. KQED Public Media for Northern California, May 2008. Available online from: amphibiaweb.org/declines/declines.html.

[11] GAA, "Summary."; "Frog Skin Chemicals Block HIV in Lab Study." *Environmental News Service*. Newswire online. Accessed 20 July 2008. Available from www.ens-newswire.com/ens/sep2005/2005-09-30-02.asp.; "New Report Details Historic Mass Extinction of Amphibians; Humans Worsen Spread of Deadly Emerging Infectious Disease." *Science Daily* 12 August 2008. Accessed online 12 August 2008. Available from www.sciencedaily.com/releases/2008/08/080811195627.htm.

[12] Hayes, Dr. Tyrone. Interview by KQED. *Pesticides*. KQED Public Media for Northern California, May 2008. Available online from: amphibiaweb.org/declines/ChemCon.html.

[13] *Ibid*.

[14] *Ibid*.

[15] *Ibid*.

[16] *Ibid*.

[17] Vredenburg, Interview by KQED. *Disappearing Frogs*.

[18] "Poison from Frog Skin Leads to a Painkiller." *New York Times*, 2 January 1996. Updated 15 August 2008; Accessed online 15 August 2008. Available from query.nytimes.com/gst/fullpage.html?res=9801E7D71E31F931A35752C0A96E958260&sec=health&spon=&partner=permalink&exprod=permalink

[19] "Amphibian Skin Agent May Battle Multi-drug Resistant Bacteria." *ScienceDaily*, 23 January 2008. Newswire online. Updated 15 August 2008; Accessed 15 August 2008. Available from www.sciencedaily.com/releases/2008/01/080122102502.htm.

[20] Conlon, J.M.; M. Patel; T. Pál; A. Sonnevend; C. Davidson; P.F. Nielsen; L.A. Rollins-Smith. "Isolation of peptides of the brevinin-1 family with potent candidacidal activity from the skin secretions of the frog Rana boylii." Department of Biochemistry F.H.M.S., United Arab Emirates University. 9 August 2003.

[21] Amphibian Ark, "Amphibians as Indicators," 2008.

[22] "Frog skin chemicals."

[23] Tunstall, Tate and Gary Fellers. "California red-legged frog." *AmphibiaWeb*. Berkeley, California. Database online. Accessed 2 September 2008. Available from amphibiaweb.org/.; Fellers, Gary M. "California red-legged frog." *Amphibian Declines: The Conservation Status of United States Species*. Edited by Michael Lanoo. University of California Press, 2005. Quoted in "California red-legged frog." *Amphibiaweb*. Database online. Updated 3 February 2008; Accessed 2 September 2008. Available from amphibiaweb.org/.

[24] Jenning and Hayes, *Amphibian and Reptile Species*.

[25] Romansic, John. "Cascades frog." Edited by Vance Vredenburg. *AmphibiaWeb*. Berkeley, California. Database online. Updated 5 April 2004; Accessed 2 September 2008. Available from amphibiaweb.org/.; Pearl, Christopher and Michael Adams. "Cascade frog." *Amphibian Declines: The Conservation Status of United States Species*. Edited by Michael Lanoo. University of California Press, 2005. Quoted in "Cascades frog." *Amphibiaweb*. Database online. Accessed 2 September 2008. Available from amphibiaweb.org/.

[26] Jennings and Hayes, *Amphibian and Reptile Species*.

[27] Fellers, Gary. "Foothill yellow-legged frog." *Amphibian Declines: The Conservation Status of United States Species*. Edited by Michael Lanoo. University of California Press, 2005. Quoted in "Foothill yellow-legged frog." *Amphibiaweb*. Database online. Accessed 2 September 2008. Available from amphibiaweb.org/; Graber, Sarah. "Foothill yellow-legged frog." Edited by Kellie Whittaker. *AmphibiaWeb*. Berkeley, California. Database online. Updated 14 December 2007. Accessed 2 September 2008. Available from amphibiaweb.org/.

[28] Gary Fellers and Carlos Davison. "Southern mountain yellow-legged frog." *Amphibian Declines: The Conservation Status of United States Species*. Edited by Michael Lanoo. University of California Press, 2005. Quoted in "Southern mountain yellow-legged frog." *Amphibiaweb*. Database online. Accessed 2 September 2008. Available from amphibiaweb.org/.; Vredenburg, Vance."Southern mountain yellow-legged frog." Edited by Kellie Whittaker. *AmphibiaWeb*. Berkeley, California. Database online. Updated 17 June 2008. Accessed 2 September 2008. Available from amphibiaweb.org/.

[29] Vredenburg, Vance, R. Bingham, R. Knapp, et. al. "Concordant molecular and phenotypic data delineate new taxonomy and conservation priorities for the endangered mountain yellow-legged frog." *Journal of Zoology* 271 (2007): p. 361-374.

[30] Knapp, Roland. "Natural History- Distribution." In the *Mountain Yellow-Legged Frog Site*. Article online. Updated 24 May 2008. Accessed 15 August 2008. Available from www.mylfrog.info/naturalhistory/ecosystem.html.

[31] Vredenburg, Vance. "Sierra Nevada mountain yellow-legged frog." Edited by Kellie Whittaker. *AmphibiaWeb*. Berkeley, California. Database online. Updated 15 December 2007; Accessed 2 September 2008. Available from amphibiaweb.org/.

[32] Davidson, Carlos and Gary Fellers."Yosemite Toad." *Amphibian Declines: The Conservation Status of United States Species*. Edited by Michael Lanoo. University of California Press, 2005. Quoted in "Yosemite toad." *Amphibiaweb*. Database online. Updated 8 August 2008; Accessed 2 September 2008. Available from amphibiaweb.org/.

[33] Skerratt, Lee Francis; Lee Berger; Richard Speare; Scott Cashins; Kieth Raymond McDonald; Andrea Dawn Phillott; Harry Bryan Hines; and Nicole Kenyon. "Spread of Chytridiomycosis Has Caused the Rapid Global Decline and Extinction of Frogs." *EcoHealth Journal Consortium*. 2007. Accessed online 12 August 2008. Available from www.jcu.edu.au/school/phtm/PHTM/frogs/papers/skerratt-2007.pdf. pg. 1.

[34] International Union for Conservation of Nature and Natural Resources (IUCN). *Amphibian Conservation Action Plan*. World Conservation Union, Gland, Switzerland. 2007. www.amphibianark.org/pdf/ACAP.pdf. p.21.

[35] *Ibid*., p. 22.

[36] Weldon, Ché; Louis H. du Preez; Alex D. Hyatt; Reinhold Muller; and Rick Speare. "Origin of the Amphibian Chytrid Fungus." *Emerging Infectious Diseases*. December 2004. Vol. 10, No. 12. Accessed online 12 August 2008. Available from www.cdc.gov/eid. p. 2100.

[37] *Ibid*., 2102-3; Choi, Charles Q. "Can the 'Amphibian Ark' Save Frogs From Pollution/Extinction?" *Scientific American Magazine*. 19 June 2008.

[38] Weldon, "Origin," p. 2103.

[39] Morgan, Jess A.T.; Vance T. Vredenburg; Lara J. Rachowicz; Roland A. Knapp; Mary J. Stice; Tate Tunstall; Rob E. Bingham; John M. Parker; Joyce E. Longcore; Craig Moritz; Cheryl J. Briggs; and John W. Taylor. "Population Genetics of the Frog-killing Fungus Batrachochytrium dendrobatidis." *Proceedings of the National Academy of Science of the United States of America* (PNAS). 21 August 2007. Vol. 104, No. 34. Accessed online 31 July 2008. Available from www.pnas.org/content/104/34/13845.full.pdf+html. p.13845.

[40] Knapp, Roland. "Threats-Disease." In the *Mountain Yellow-Legged Frog Site*. Article online. Updated 24 May 2008. Accessed 15 August 2008. Available from www.mylfrog.info/threats/disease.html.

[41] Perlman, David "Exploring an Amphibian Epidemic UC team Believes Deadly Fungus May be Killing Frogs, Toads, Salamanders in Sierra." *San Francisco Chronicle,* 7 August 2008.

[42] Morgan, "Population genetics," p. 13847.

[43] Wake, David B. and Vance T. Vredenburg. "Are We in the Midst of the Sixth Mass Extinction? A View from the World of Amphibians." *Proceedings of the National Academy of Science of the United States of America* (PNAS). 12 August 2008. Vol. 105. Accessed online 12 August 2008. Available from www.pnas.org/cgi/doi/10.1073/pnas.0801921105. p. 11469.

[44] IUCN, *Amphibian Conservation*, p.22.

[45] Knapp, "Threats-Disease."

[46] Wake and Vredenburg, "Are we in the midst," p. 11468.

[47] *Ibid*., p. 11469; Knapp, "Threats-Disease."

[48] "Dying Frogs Sign of a Biodiversity Crisis." *Science Daily,* 12 August 2008. Accessed online 15 August 2008. Available from www.sciencedaily.com/releases/2008/08/080812135654.htm.

[49] Davidson, Carlos and R. Knapp. "Multiple stressors and amphibian declines: dual impacts of pesticides and fish on yellow-legged frogs." *Ecological Applications* 17 (2007): p. 587-597.

[50] Morgan, "Population genetics," p. 13846.

[51] Wake and Vredenburg, "Are we in the midst," p. 11468.

[52] Morgan, "Population genetics," p. 13849.

[53] *Ibid*.

[54] *Ibid*.

[55] IUCN, *Amphibian Conservation,* p. 22.

[56] *Ibid*.

[57] Choi, "Can the Amphibian Ark."

[58] Wake and Vredenburg, "Are we in the midst," p.11466.

[59] IUCN, *Amphibian Conservation,* p. 19; Vredenburg, Interview by KQED, *Disappearing Frogs*.

[60] Black, Richard. "Bacteria Could Stop Frog Killer." *Science/Nature, BBC NEWS*. Accessed online 11August 2008. Available from newsvote.bbc.co.uk/mpapps/pagetools/print/news.bbc.co.uk/2/hi/science/nature/7438.

[61] *Ibid*.

[62] Choi, "Can the Amphibian Ark." ; Amphibiaweb. "Chemical Contaminants." *Amphibiaweb*. Database Online. Updated 14 May 2008; Accessed 18 July 2008. Available from www.amphibiaweb.org/declines/ChemCon.html.

[63] *Ibid*.

[64] *Ibid*.

[65] The Sierra Fund. *Mining's Toxic Legacy: An Initiative to Address the Mining Toxins in the Sierra Nevada*.Sacramento: Sutter Printing, 2008.

[66] Jennings, Mark. "Status of Amphibians." *Sierra Nevada Ecosystem Project: Final Report to Congress*. (SNEP). vol. II Assessments and Scientific basis for management options. Davis: University of California, Center for Water and Wildland Resources, 1996. p.940.

[67] Amphibiaweb, "Chemical Contaminants."

[68] Cone, Marla. "A New Alarm Sounds for Amphibians." *Los Angeles Times,* 25 January 2006, A-14. Available from articles.latimes.com/2006/jan/25/nation/na-frogs25.

[69] *Ibid*.

[70] *Ibid*.

[71] *Ibid*.

[72] Zabik, J.M. and J.N. Seiber. "Atmospheric transport of organophosphate pesticides from California's Central Valley to the Sierra Mountains." *Journal of Environmental Quality* 22 (2007): p. 80-90.

[73] Aston, L.S. and J.N. Seiber. "Fate of summertime airborne organophosphate pesticide residues in the Sierra Nevada mountains." *Journal of Environmental Quality* 26 (1997): p. 1483-1492.

[74] Davidson, Carlos; C. Shaffer; and M. R. Jennings. "Declines of the California red-legged frog: climate, UV-B, habitat and pesticides hypotheses." *Ecological Applications* 11 (2001): p. 464-479.; Davidson, Carlos; H. Bradley Shaffer; and Mark R. Jennings. "Spatial Test of the Pesticide Drift, Habitat Destruction, UV-B, and Climate-Change Hypotheses for California Amphibian Declines." *Conservation Biology* Vol. 16, No. 6. (2002) pg. 1588-1601.

[75] *Ibid*.

[76] Davidson, "Spatial Test."

[77] *Ibid*.

[78] Davidson, Carlos. "Declining Downwind: Amphibian Population Declines in California and Historical Pesticide Use." *Ecological Applications* V. 14, no. 6 (2004): p. 1892-1902.

[79] Davidson, Carlos, Kerri Stanley and Staci Simonich. "Pesticide Residues in Frogs and Amphibian declines in the California Cascades and Sierra Nevada." *Final Research Report to the State Water Resources Control Board*. SWRCB Grant Agreement No: 03-265-556-0, 2008.

[80] *Ibid*.

[81] R. Knapp. "Multiple stressors and amphibian declines: dual impacts of pesticides and fish on yellow-legged frogs." *Ecological Applications* 17 (2007): p. 587-597.; Davidson, "Declines of the California."; Davidson, "Spatial Test."; Davidson,"Declining Downwind."

[82] Amphibiaweb. "Introduced Species." *Amphibiaweb*. Database Online. Updated 14 May 2008; accessed 18 July 2008 Available from amphibiaweb.org/declines/IntroSp.html.

[83] *Ibid*.; National Park Service, "Restoration."

[84] Vredenburg, Vance T. "Reversing Introduced Species Effects: Experimental Removal of Introduced Fish Leads to Rapid Recovery of a Declining Frog." *Proceedings of the National Academy of Science of the United States of America* (PNAS). 18 May 2004. Vol. 101, No. 20. Accessed online 12 August 2008. Available from www.pnas.org/cgi/doi/10.1073/pnas.0402321101.

[85] National Park Service, "Restoration."

[86] Vredenburg, "Reversing Introduced." ;Knapp, Roland A.; Daniel M. Boiano; and Vance T. Vredenburg. "Removal of Non-native Fish Results in Population Expansion of a Declining Amphibian (Mountain Yellow-legged Frog, Rana muscosa)." *Biological Conservation* V. 135 No. 1 (February 2007): p. 11-20.

[87] Vredenburg, "Reversing Introduced," 7649.

[88] Knapp, "Removal of Non-native," section 3.2.

[89] Knapp, "Removal of Non-native," section 4.2.

[90] For more information to go to: www.dfg.ca.gov/habcon/conproj/big_pine/bp_txt.pdf.

[91] Knapp, "Removal of Non-native," section 4.2.

[92] *Ibid*.

[93] Sopory, Ambika. "American bullfrog." Edited by David Wake and Kevin Gin. *AmphibiaWeb*. Berkeley, California. Database online. Updated 5 April 2004; Accessed 2 September 2008. Available from amphibiaweb.org/.

[94] Casper, Gary and Russ Hendricks. "American bullfrog." *Amphibian Declines: The Conservation Status of United States Species*. Edited by Michael Lanoo. University of California Press, 2005. Quoted in "American bullfrog." Amphibiaweb. Database online. Accessed 2 September 2008. Available from www.amphibiaweb.org.

[95] Kupferberg, S.J. "Bullfrog (Rana catesbeiana) Invasion of a California river: the role of larval competition." *Ecology* 78 (1997):p. 1736–1751..

[96] Lawler S.P.; Dritz D.; Strange T.; Holyoak M. "Effects of Introduced Mosquitofish and Bullfrogs on the Threatened California Red-legged Frog." *Conservation Biology* Vol. 13, No. 3 (June 1999): p. 613-622.

[97] Dudley, Tom. "Exotic Species in Aquatic Ecosystems." *Pacific Research Institute*. Accessed online 20 August 2008. Available from io.uwinnipeg.ca/~simmons/ysesp/exotic3.htm.; Lind, Amy; Hartwell Welsh Jr.; and Randolph Wilson. "The effects of a Dam on Breeding Habitat and Egg Survival of the Foothill Yellow-legged Frog (Rana boylii) in Northwestern California." *Herpetological Review* V. 27 No. 2 (1996): p. 65.

[98] DiDonato, Joseph. "Endangered Amphibian Research within Grazed Grasslands." *Keeping Landscapes Working* Vol. 4, Issue 1 (Winter 2007): p. 5.

[99] For more information, go to web.uvic.ca/bullfrogs/.

[100] Jennings, "Status of Amphibians," p. 939.

[101] Amphibiaweb. "Habitat Destruction, Alteration and Fragmentation." *Amphibiaweb*. Database Online. Updated 14 May 2008; accessed 18 July 2008. Available from www.amphibiaweb.org/declines/HabFrag.html.

[102] Hickey, Ellen; Joan Clayburgh and Shannon Raborn. *Planning for the Future: A Sierra Nevada Land Use Index*. South Lake Tahoe: Sierra Nevada Alliance, 2005. p. 17.

[103] *Ibid*., p. 15; Amphibiaweb "Habitat Destruction."

[104] Hickey, Planning for the Future, p. i.

[105] *Ibid*., p. 10.

[106] Davidson, "Spatial Test," p.1597; Davidson "Declines of the California," p. 475.

[107] Lind "The Effects of a Dam," p. 62.

[108] *Ibid*., 65. Jennings, "Status of Amphibians," p. 939.

[109] *Ibid*.

[110] *Ibid*.

[111] *Ibid*.

[112] *Ibid*.

[113] Lind, "The Effects of a Dam."

[114] *Ibid*, p. 63.

[115] *Ibid*.

[116] *Ibid*., p. 66.

[117] *Ibid*., p. 65.

[118] Mount, Jeff; Amy Lind; Sarah Yarnell and Sarah Kupferberg. "Pulsed-flow effects on foothill yellow legged frog: Integration of empirical, experimental and hydrodynamic modeling approaches: First Year Progress Report to CA Energy Comission." Davis: University of California, Center for Watershed Sciences, 2008.

[119] *Ibid*.

[120] *Ibid*.

[121] Jennings, "Status of Amphibians," p. 938-39.

[122] *Ibid*.

[123] University of California- Cooperative Extension. "Grazing for Biological Conservation." *Keeping Landscapes Working* Vol. 4, Issue 1 (Winter 2007): p.1.

[124] Cal-Pac Society for Range Management Symposium. "Livestock Grazing and Yosemite Toads." *Grazing for Biological Conservation*. 23 June 2006. Accessed online 20 August 2008. Available from cesantaclara.ucdavis.edu/files/36781.pdf. p.1.

[125] *Ibid*.

[126] *Ibid*.

[127] DiDonato, "Endangered Amphibian," 4; Symonds, Katie. "Ranchers Restore Amphibian-friendly Ponds." *Endangered Species Bulletin,* US Fish & Wildlife Service. Spring 2008 Vol. 33, No. 1. Accessed online 3 August 2008. Available from www.carangeland.org/Files%20to%20Link/News/2008/08-07USFWS%20-%20Ranchers%20Restore%20Ponds.pdf. p.3.

[128] Hollis, Robert. "Frog Discovery May Jump-Start Shift in Attitude."*Los Angeles Times,* 20 January 2008, B5.

[129] Symonds, "Ranchers Restore," p. 31.

[130] *Ibid*.

[131] Hollis, "Frog Discovery."; DiDonato, "Endangered Amphibian," p. 4.

[132] Cohen, Janet. *Sierra Climate Change Toolkit*. 2nd ed. South Lake Tahoe: Sierra Nevada Alliance, 2008.p. 12.

[133] Amphibiaweb. "Climate Change." *Amphibiaweb*. Database Online. Updated 14 May 2008; accessed 18 July 2008. www.amphibiaweb.org/declines/ClimateChange.html.

[134] *Ibid*.

[135] Reading, C.J. "Linking global warming to amphibian declines through its effects on female body Condition and survivorship." *Global Change and Conservation Ecology.* Published online: 21 September 2006. Springer-Verlag 2006. Accessed 5 August 2008. Available from cat.inist.fr/?aModele=afficheN&cpsidt=18474689.

[136] *Ibid*.

[137] Amphibiaweb, "Climate Change."; "Climate Change Drives Widespread Amphibian Extinctions; Warmer Temperatures Enhance Growth Conditions of Fatal Fungus." *Science Daily* 12 January 2006. Accessed online 12 August 2008. Available from www.sciencedaily.com/releases /2006/01060112035218.htm.

[138] Lind, "The Effects of a Dam" 65-66; Dudley, "Exotic Species in Aquatic Ecosystems."

[139] Hickey, *Planning for the Future,* 25.

[140] Listing these organizations does not necessarily reflect endorsement of their causes by the Sierra Nevada Alliance.

SIERRA NEVADA ALLIANCE

Keeping light in the range.

P.O. Box 7989
South Lake Tahoe, CA 96158

Phone: 530.542.4546 Ext. 311
Fax: 530-542-4570
info@sierranevadaalliance.org
www.sierranevadaalliance.org