Declining Amphibian Populations Task Force (DAPTF)
California-Nevada Working Group
January 12-14, 2006
Arcata, California

ABSTRACTS

BECKER, DAWNE
California Department of Fish & Game, Eastern Sierra and Inland Deserts Region, Bishop, CA, dbecker@dfg.ca.gov

Dilemmas in Amphibian Management: Disease and Translocation, a Group Discussion

Researchers and managers working on draft conservation strategies for Sierra Nevada amphibians focused on many issues, including identification of threats, feasibility of conducting restoration projects, the potential need for translocations, and genetics. Conservative management actions were recommended to avoid genetic manipulations, but at the time, disease was not suspected as having such a large role with regard to restoration and management. We now know otherwise. The focus will be on generating a group discussion on amphibian relocations and their value—in the presence of disease—to ascertain whether or not managers should continue *Rana muscosa* (RaMu)-specific restoration/translocation projects in areas where the nearest Ramu populations have been infected with chytridiomycosis. Although other researchers and agencies are facing the same dilemma, a regional California Department of Fish & Game project was the impetus for this discussion. While most of our past and ongoing restoration projects have occurred where an adjacent RaMu population would benefit without active translocation, we now have a newly-fishless water with no adjacent RaMu. We are awaiting the verdict, but suspect that disease has infected the only RaMu populations within the same basin. Do we continue with translocations, possibly extending the range of the disease? Do we discontinue translocations, but wait for further knowledge that may guide us appropriately? Will the public, and just as importantly, USFWS, support restoration projects that result in fishless waters without nearby frog populations and without immediate plans for translocation? Will disease persist if infected tadpoles are transferred into new waters? Initial results by Vredenberg's group (see poster), indicate that non-infected tadpoles transplanted into fishless waters formerly occupied by frogs, but extirpated by disease, have survived without contracting chytrid. Do we have other options that may benefit both amphibians and science? We're testing for Chytrid (and using methods that reduce the likelihood of us spreading it), but irido- and rana-viruses are present in the Sierra Nevada. How do we deal with this, and perhaps other undetected hitchhikers? While assuming that there is not just one "right" answer, it would be much appreciated to hear the combined professional opinions of the group.

BINGHAM, ROBERT E.
Department of Integrative Biology, University of California, Berkeley, CA, rbingham@berkeley.edu

Phylogeography of *Hydromantes shastae*: Implications for Management

The utility of phylogeographic analyses in conservation and management has increased dramatically with the development of molecular and analytic methods. When different molecular markers and statistical approaches yield congruent results, we are able to properly characterize distinct evolutionary lineages and identify divergent populations for management. One application of

phylogeography to management is to identify species with restricted ranges and high levels of genetic divergence between lineages, indicating significant isolation. The Shasta Salamander, *Hydromantes shastae*, is a geographically restricted plethodontid species exhibiting remarkable evolutionary diversification at small spatial scales. New and previously collected tissue samples from throughout the known range of the species were sequenced for the mitochondrial cytochrome b and 16S genes. Bayesian phylogenetic analyses showed statistically supported clades with large divergences between lineages. In two different pairwise comparisons, samples two miles apart were 4.5% divergent in the cytochrome b gene, indicating remarkably high levels of genetic differentiation. Unpublished allozyme data were previously collected for a subset of these populations, and have now been analyzed using multidimensional scaling and population structure software. With relatively high estimates of Nei's genetic distance and fixed allozyme differences, the nuclear data strongly support significant isolation and diversification at small spatial scales. Analyses of both mitochondrial and nuclear markers show *Hydromantes shastae* to be strongly structured across its restricted range, and highlight several divergent populations and lineages that should be of high priority in management actions aimed at preserving evolutionary history and potential in this unique species.

BOIANO, DANNY
Sequoia and Kings Canyon National Parks, Three Rivers, CA, danny_boiano@nps.gov

Update on the Mountain Yellow-legged Frog Restoration Project in Sequoia and Kings Canyon National Parks

In 2001 Sequoia and Kings Canyon National Parks began mechanically removing introduced trout from six lakes and several tributary streams to restore habitat for native aquatic fauna, with an emphasis on improving the status of mountain yellow-legged frog (*Rana muscosa*) populations. By the end of 2005 we have eradicated trout from all six lakes and all but two of the tributary streams. In these two streams we eliminated spawning and should eradicate the few remaining trout, if any, in 2006. We also began restoring five additional lakes in 2004 and 2005 and made substantial progress toward trout eradication in all five sites. To date we have removed more than 18,000 trout. Of particular interest is that trout eradication by non-chemical means appears feasible in lakes as large as 11 acres in surface area and 14 meters in maximum depth, and stream sections totaling more than a kilometer in length.

Concurrent monitoring of frog populations shows significant increases in *R. muscosa* abundance in seven treatment lakes and persistence of small *R. muscosa* populations in the four newest treatment lakes, which are predicted to increase significantly in 2006. Noteworthy developments include: 1) *R. muscosa* eggs and larvae were detected for the first time in one isolated treatment lake; 2) *R. muscosa* adults were detected for the first time in another treatment lake located about a kilometer downstream from the source population; and 3) chytridiomycosis appears to be spreading through one of the restoration basins, but has yet to be detected in any treatment lakes. Recent observations that *R. muscosa* individuals infected with chytridiomycosis have survived and reproduced in larger, deeper lakes (versus smaller, shallower lakes) further support the importance of removing trout from large waterbodies.

BOURQUE, RYAN M.
Humboldt State University, Department of Biological Sciences, Arcata, CA, rmb32@humboldt.edu

A New Alternative Method for Restraining Frogs

Amphibian biologists use several different methods for individually marking adult anurans including toe clipping, PIT tags, visible implant elastomer, and radio transmitters. Employing such techniques requires maintaining control of study animals, which often entails field assistance or the use of anesthetics. Here, I will present an alternative method for restraining anurans that can be used in place of these conventional methods. This device, known as the "Ranid Restrainer", is inexpensive, durable, waterproof, easy to use and decontaminate, lightweight, and restrains frogs safely and quickly. After two years of field-testing, I have found this device to be an invaluable tool, especially when working alone, for marking small to medium sized ranid frogs.

BROWN, CHRIS W.[1]*, DONN A. HOLMES[1], BLAKE R. HOSSACK[2], ROBERT N. FISHER[1]
[1]USGS Western Ecological Research Center, San Diego Field Station, cwbrown@usgs.gov; [2]USGS Northern Rocky Mountain Science Center, Missoula Field Station

Combining Field Protocols, Integrated Database Design and Data Reduction to Improve Data Integrity Among Partners in ARMI

The US Geological Survey's ARMI (Amphibian Research and Monitoring Initiative) program is using several methods and tools to study the health, status and trends of the Nation's amphibian populations in conjunction with National, state and local partners. Successful research and monitoring involving many partners relies on thorough and accurate data. We are building distributable applications that will enable partners to collect and manage data for their own analysis as well as integrating the data at regional and National levels. Software and hardware will be bundled so that data collection and management can be done easily, securely and at minimal cost while having greater data integrity. To do this, we have examined existing field protocols and statistics applications to develop a dynamic database that can function to support the many different individual projects and regions within the program. We have taken into consideration many different levels of technological support and network connectivity among the many regions and partners throughout the Nation. PDA (personal digital assistant) field data collection forms have been developed to meet individual project needs and to synchronize data with the ARMI database structure, linking the data to desktop forms and queries that enable the project managers to reduce the data for their own data analysis, as well as incorporate the data in the National database while still maintaining appropriate control and security. By using these bundled applications, project leaders can effectively manage field crews with current technology to enable accurate and complete data collection, without the need for a large investment into startup or information technology support.

BURKHOLDER, LAURA L.*, and LOWELL V. DILLER
Green Diamond Resource Company, Korbel, CA, lburkholder@greendiamond.com

Population Parameters of Coastal Tailed Frogs in Northwestern California

Several studies have estimated the abundance of tailed frog (*Ascaphus* spp.) larvae within streams, but there has been no attempt to directly estimate the abundance of immature and adult frogs. We conducted a mark-recapture study of post-metamorphic coastal tailed frogs (*A. truei*) on a total of six streams from 2002-04 and used an open population model in Program MARK to estimate capture

probabilities and population size within stream reaches. In 2003 probability of capture appeared to be constant over time (0.06 ± 0.01) and did not differ by age, sex, or creek. In 2004, capture probabilities for both creeks indicated a quadratic time trend depending on age (adults: mean = 0.11 ± 0.02, immatures: 0.13 ± 0.01). Captures were only adequate to estimate population size for two creeks during summer surveys from 2003 to 2004. Summer population estimates of females in both creeks indicated that there were on average 1.82 and 1.25 females per linear meter of stream in 2003 and 2004, respectively. Extrapolated to entire stream length with potential habitat, these estimates suggest potential total population sizes of 40,947 and 5,811 frogs for each creek. Our data indicated that tailed frogs have the potential to be a major biological component of headwater streams, but low capture probabilities limited our ability to estimate abundance for all streams. Because abundance estimates are important for management of this species, future studies should focus on methods that may increase capture probabilities in creeks with low population densities of frogs.

CREED, CLAYTON
US Fish & Wildlife Service, Ventura, CA, creed_clayton@fws.gov

The Endangered Arroyo Toad: How is It Doing

The arroyo toad was listed as endangered under the Federal Endangered Species Act in 1994 because research showed it had been extirpated from approximately 75% of previously occupied habitat. Although a number of drainages containing arroyo toads had been identified at that time, only eight were thought to contain viable populations. Since it was listed, a few previously undetected arroyo toad populations have been located and a number of threats to the species have been addressed. However, other populations appear to have been extirpated or turned out to be misidentified toads of another species. About one half of the approximately 30 currently known arroyo toad populations appear relatively secure in the near term. Many areas occupied by the arroyo toad are protected to a large degree; however, there are also areas vulnerable to expanding human pressures where some level of habitat degradation continues to occur.

D'AMORE, ANTONIA
Dept. of Ecology and Evolution, University of California, Santa Cruz, CA, damore@biology.ucsc.edu

(Meta)population Dynamics of a Threatened Native Amphibian, *Rana draytonii*

Building off of work done with the Elkhorn Slough National Estuarine Research Reserve (ESNERR), I am working with two different populations of the California Red-legged Frog, *Rana draytonii*. One population is located at ESNERR, spread throughout 5 different ponds. The other is on privately owned land with the frogs inhabiting 15 different ponds. I am currently conducting a mark/recapture study using PIT tags in order to estimate interannual survivorship and transition rates between the different ponds. I intend to use this data to build a simple metapopulation model that will describe their movement. In addition to this work, I am radio-tracking a sub-set of the frogs to look at their upland habitat usage and to obtain detailed information about their dispersal routes between ponds. This will potentially allow me to incorporate the effects of matrix habitat type into the model.

Another part of my research focuses on indirect interactions between *Rana draytonii* and its invasive competitor and predator, *Rana catesbeiana*, the American Bullfrog. I focus specifically on changes in microhabitat usage within the ponds, and in breeding behavior.

DEVER, JENNIFER A.
Biology Department., University of San Francisco, San Francisco, CA, jadever@usfca.edu

The Effect of Habitat Quality on Genetic Diversity in a Riparian Frog Species (*Rana boylii*)

Amphibian populations are declining at an alarming rate. Therefore gathering data on existing populations is critical for their proper management. One species that is of concern is the foothill yellow-legged frog (*Rana boylii*), a river-dwelling amphibian whose historic range has been reduced over 66%. A population existing along the Eel River in northern California was surveyed. This river runs through an area that includes both near-pristine and impacted habitat. For this study, sampling from both regions was conducted. Using molecular markers, the level of genetic variability amongst individuals collected from 13 different tributaries branching off the Eel River was completed. Results indicate that habitat quality has an impact on genetic diversity in this species. Such information is extremely useful for conservation management purposes.

DILLER, LOWELL V.*, and LAURA L. BURKHOLDER
Green Diamond Resource Company, Korbel, CA, ldiller@greendiamond.com

Challenges of Monitoring Headwater Amphibians: Searching for a Pattern Among the Warts

As part of developing an aquatic habitat conservation plan on private timberlands, we attempted to use obligate headwater amphibian species to monitor potential impacts of timber harvest. Since 1997, we have been monitoring populations of southern torrent salamanders (*Rhyacotriton variegatus*) and coastal tailed frogs (*Ascaphus truei*). The goal was to compare changes in populations of these amphibians by employing a paired sub-basin design using randomly selected streams in sub-basins with (treatment) and without (control) timber harvest. The initial problem was to find a sufficient number of suitable streams with particular difficulty locating suitable control streams. To date, 30 and 18 monitoring reaches have been established for torrent salamanders and tailed frogs, respectively. Estimating relative abundance of torrent salamanders has proved problematic, because the process of searching for animals appears to have lasting negative impacts on their habitat. The solution may be a “lighter-touch” survey approach and only attempting to determine presence/absence of salamanders. Estimating larval populations of tailed frogs has been successful, but high annual variation made interpreting the results problematic. In hopes of understanding this phenomenon, we began a mark-recapture study of post-metamorphic tailed frogs in 2002. The adults appear to be less variable compared to the larval populations, but it requires substantial effort to obtain a useful estimate through mark-recapture. The options are to have a large research budget that would allow an integrated approach to monitor both larvae and adult frogs or extend the larval monitoring to a longer interval (>10 years).

DRENNAN, JOSEPH E*, RONALD JACKMAN, KARLA R. MARLOW, and KEVIN D. WISEMAN.
Garcia and Associates (GANDA), San Francisco, CA, jed@garciaandassociates.com

Climatic and Water Flow Triggers Associated With Breeding and Movement in a Foothill Yellow-legged Frog (*Rana boylii*) Population on the North Fork Feather River, California

We conducted visual encounter surveys and radio telemetry of *R. boylii* within six tributaries and associated breeding sites of the regulated North Fork Feather River (NFFR; Butte Co., California) in 2004-2005. Local environmental data (tributary/river temperature, tributary/river flow, air temperature, precipitation) was collected from data loggers, a local weatherstation, and hydroelectric gages. Using

chin and flank patterns to identify individuals, we collected movement data on 476 individual frogs including 47 individuals that were captured both years. Frogs showed high site fidelity within tributaries to the NFFR, which act as refugia for frogs during the non-breeding season. Initial movements to the NFFR were triggered by day length, and male frogs left tributaries earlier than females and stayed longer at breeding sites. Females moved at more than twice the rate of males (♀= 58.1 m/day) and covered distances up to 1,899 m in ≤ 6 days for a maximum movement rate of 316.5 m/day. Once at the river, frogs initiated breeding when mainstem water temperatures were ≥10 °C and mainstem flow was ≤ 55% of baseflow, on a descending hydrograph. Length of stay by females at river breeding sites was determined by flow level and sex ratio. While males commonly utilized mainstem breeding sites adjacent to the confluence of "home" tributaries, several males made considerable river movements to breeding sites adjacent to other tributaries.

FELLERS, GARY M.
USGS Western Ecological Research Center, Point Reyes National Seashore, Point Reyes, CA, gary_fellers@usgs.gov

An Update on Frogs, Contaminants, and Disease Research

A fungal disease (chytridiomycosis), first described in 1999 and possibly introduced from Africa, has been closely associated with amphibian die-offs in the Sierra Nevada and elsewhere, but it is not clear whether the chytrid fungus is a primary cause of the declines or whether it gets a foothold when amphibian populations are under stress. Chytrid fungus in Yosemite National Park was reported in *Rana muscosa* in 2001 (Fellers et al.). In 2005, I began a detailed study of two watersheds in Yosemite and one at Point Reyes National Seashore to determine the distribution of chytrid fungus in native amphibian tadpoles. In a series of related studies, data from contaminants research suggest that pesticides are playing a significant role in amphibian declines in the Sierra Nevada. Studies comparing contaminants levels in frog and tadpole tissue with concentrations in sediment, air, snow, and water in coastal and mountain regions of California strongly support the view that contaminants are playing a significant role in amphibian declines.

FISHER, ROBERT[1*], ADAM BACKLIN[1], CYNTHIA HITCHCOCK[1], STACIE HATHAWAY[1], and RUSSELL SMITH[2]
[1]USGS Western Ecological Research Center, San Diego Field Station, rfisher@usgs.gov; [2]Los Angeles Zoo, Los Angeles, CA.

Update on the *Rana draytonii* and *Rana muscosa* Situations in Southern California

Both remaining native ranid species in southern California have suffered precipitous declines over the past 35 years. The remaining populations are unstable and continue to be impacted by disease, fires, floods, debris flows, and invasive species. We will review the status of these species based on our field data from 2005 and make some recommendations about future prospects of these populations. Adaptive management is immediately needed at most populations if they are to stabilize and increase. Additionally, extirpated populations need to be re-established if these species are going to persist in the region.

GARWOOD, JUSTIN M.*, KAREN L. POPE, HARTWELL H. WELSH, Jr.
USFS-PSW, Redwood Sciences Laboratory, Arcata, CA, jg18@humboldt.edu

Indirect Effects of Introduced Trout on Native Amphibians in Northern California by Expansion of an Opportunistic Predator: Does the Hyperpredation Hypothesis Apply?

Through the introduction of exotic trout, thousands of undisturbed high-elevation aquatic habitats of the west have been ecologically transformed. Although direct effects of these fish introductions have been well documented, less research has addressed possible community-level effects within these ecosystems. Exotic species, such as nonnative trout, can provide a supplemental food source to native predators, which can allow the predators to increase in abundance, possibly magnifying their effect on native prey species. We studied the diet and distribution of two native garter snakes (*Thamnophis atratus*) and (*T. sirtalis*) relative to their natural amphibian prey and nonnative trout distributions in a high-elevation basin within the Trinity Alps Wilderness, CA from 2003-2005. Aquatic garter snakes (n=38) foraged on nonnative fish 56% of the time and amphibians 44%, whereas common garter snakes (n=38) diets were comprised entirely of amphibians. Aquatic garter snakes (n=113) were narrowly distributed, with 88% captured within 50 m of fish presence and maintained high abundances at sites containing fish. Common garter snakes had a much wider distribution and lower site abundances than aquatic garter snakes. Only 16% of the common garter snake (n=156) captures were within 50 m of nonnative fish. These results suggest that aquatic garter snakes have adapted to a subsidized nonnative food source, thereby probably increasing their densities above a naturally occurring level. Aquatic garter snakes affinity toward fish prey also suggests they could have expanded their range by following fish distributions after the onset of fish stocking occurred. Since amphibians are an important component of aquatic garter snakes diet, they could be overexploiting amphibians in areas where high densities of fish allow them to maintain unnaturally large population sizes.

GIBBONS, WHIT
University of Georgia, Savannah River Ecology Laboratory, Aiken, SC, gibbons@srel.edu

Long-term Amphibian Studies, DAPTF, and PARC: A Natural Alliance

Research opportunities at the University of Georgia's Savannah River Ecology Laboratory (SREL) from 1951-2006 have provided an almost unprecedented situation for developing long-term ecological studies on amphibians. More than a half century of data collection has led to findings and interpretations about distribution and abundance patterns that would not have been possible with shorter-term projects. The findings have implications to ecology and behavior of herpetofauna that are directly related to conservation issues of interest to both DAPTF and PARC and that are necessary to address questions related to the proper environmental management of wetland systems and their importance to regional amphibian biodiversity. Data from more than one million amphibians of more than 40 species reveal the importance of research continuity and funding in determining patterns and processes critical for making accurate scientific predictions and judicious land management decisions. Ecological interpretations based on short-term studies and short-sighted economic goals can lead to erroneous and costly conclusions that result in imprudent management decisions that could have been avoided if consistent study and longer-term information had been available.

GOLDSTEIN, JEFFREY[1]*, KARIN HOFF[2], STANLEY HILLYARD[3]
[1]Department of Biological Sciences, University of Nevada, Las Vegas, NV, Goldstj1@unlv.nevada.edu; [2]Dept. of Biology, University of Nevada, Reno; [3]University of Nevada School of Dental Medicine, Las Vegas, NV

Thermal Sensitivity of Growth, Development and Temperature Selection of the Relict Leopard Frog (*Rana onca*)

The Relict Leopard frog (*Rana onca*) is a rare species that has been petitioned for endangered status under the Federal ESA. *Rana onca* was believed to have gone extinct sometime after 1950, but was rediscovered in the early 1990s. Currently there are five populations located near the Overton arm of Lake Mead or near Black Canyon on the Colorado River including thermally influenced springs with water temperatures in excess of 35^{O}C at some sites. It is not known whether *R. onca* tadpoles acclimate to, or are adversely affected by, the high temperatures. Our experiments were designed to determine the effects of rearing temperature on size at metamorphosis, rate of development, and temperature preferences. We found some evidence of temperature acclimation in both oxygen consumption and temperature selection. We also found a very clearly defined optimal temperature for growth and development. We will discuss the implications of temperature optima and acclimation for tadpole and adult survivorship.

GRASSO, ROBERT L.[1]*, RONALD M. COLEMAN[1], and CARLOS DAVIDSON[2]
[1]California State University, Sacramento, CA, rgrasso@lycos.com; [2]San Francisco State University, San Francisco, CA.

Palatability and Antipredator Response of Yosemite Toads (*Bufo canorus*) to Nonnative Brook Trout (*Salvelinus fontinalis*) in the Sierra Nevada Mountains of California

Alien or introduced predators such as fish will often compete, displace or prey upon native amphibians. Amphibians that have evolved in fishless habitats often lack the necessary chemical defenses and behavioral responses to avoid predation and are thus unable to resist or co-occur with introduced predators due to the lack of a shared history. Toads, however, possess noxious chemicals that may be adequate to deter non-native predators which may allow co-occurrence with alien predators, even when the same introduced predator has already been implicated in the decline of other amphibian species. Yosemite toads have experienced population declines throughout their range in which trout have been widely introduced, but it is not clear whether trout are responsible for the decline through direct predation of larval life stages. Through a series of no-choice palatability trials, antipredator response experiments and choice experiments I determined the level of threat brook trout pose to larval Yosemite toad life stages. Firstly, brook trout found all early life stages of Yosemite toads to be unpalatable and unlikely rely on these stages as a primary food source in aquatic montane environments. Secondly, Yosemite toad tadpoles did not respond to chemical cues of brook trout. Thirdly, even though Yosemite toads were sampled by trout the toads did not suffer any ill effects.

HARRIS, SEAN M.[1]*, JEF R. JAEGER[1], CHAL L. CROSS[2], and DAVID F. BRADFORD[3]
[1]Department of Biological Sciences, University of Nevada, Las Vegas, NV, smharris@unlv.nevada.edu; [2]Environmental and Occupational Health Program, University of Nevada, Las Vegas, NV; [3]US Environmental Protection Agency, Landscape Ecology Branch, Las Vegas, NV

Habitat Selection by the Relict Leopard Frog (*Rana onca*): Assessing Effects of Vegetation Encroachment

In recent years, two populations of the extremely rare relict leopard frog (*Rana onca*) have gone extinct. These population extinctions occurred concomitantly with the encroachment of native emergent vegetation into pools in which frogs were usually observed. These observations implicate a causal effect between vegetation encroachment and relict leopard frog population declines. In order to determine if adult *R. onca* prefer more vegetatively open habitats, we conducted a radio-telemetry study at Blue Point Spring within the Lake Mead National Recreation Area. A total of 809 radio telemetry observations were made on 34 frogs from April 2 through December 7, 2004. Habitat was assessed at two scales, macrohabitat (within one-meter segments down the length of the stream) and microhabitat (within 25 cm^2 areas centered on each frog observation). Polytomous Logistic Regression (PLR) was used with both macro- and microhabitat data to compare habitat characteristics between "low-use" and "high-use" areas. A more traditional multiple analysis of variance (MANOVA) approach was also used at the macrohabitat scale to compare used segments to unused segments of the stream. Analyses supported the hypothesis that adult *R. onca* select for areas with less vegetative cover (particularly for areas with less *Eleocharis*, *Scirpus*, and *Typha*). There is also some support that these frogs select for wider portions of the stream and for a higher percentage of that stream to be shallower water (less than 13 cm). We interpret these results to reflect selection of habitats mostly during the warmer periods of the year, and that much of these patterns may be driven by selection of foraging sites.

HEMINGWAY, VALENTINE A. [1,2]*, ANTONIA D'AMORE[1,2], and KERSTIN WASSON[1]
[1]Elkhorn Slough National Estuarine Research Reserve, Watsonville, CA, hemingway@biology.ucsc.edu; [2]Univ. of California Santa Cruz, Dept. of Ecology and Evolutionary Biology, Santa Cruz, CA.

Interannual Changes in the Distribution of Amphibians and Associated Threats in the Elkhorn Slough Region

The California red-legged frog, *Rana draytonii*, has been extirpated from 70% of its former range, and its population is estimated to have decreased by 90%. Protected under the Endangered Species Act, the US Fish and Wildlife Service authored a Draft Recovery Plan in 2002, designating the Central Coast as its strongest Recovery Unit. Elkhorn Slough National Estuarine Research Reserve falls within this recovery unit, and it is home to one of the remaining populations of the frog. However, since 2002 the California red-legged frog population has experienced a precipitous decline at the Reserve. This has sparked our research into the underlying causes of this decline and our assessment of the populations surrounding the Reserve. To this end, we identified 45 freshwater sites in the Elkhorn Slough region and determined the presence or absence for each of five amphibian species in each of these sites, including California red-legged frogs (*Rana draytonii*), Pacific treefrogs (*Pseudacris regalia*), American bullfrogs (*Rana catesbeiana*), Western toads (*Bufo boreas*), and Santa Cruz long-toed salamanders (*Ambystoma macrodactylum croceum*). For each we also collected data on physical characteristics and vegetation, searched for threats such as invasive bullfrogs and predatory fish, looked for signs of disease outbreaks such as malformations and die-off events, and checked water quality. We have used a variety of statistical tools and GIS to analyze these first two years of data. Through our analyses, we have found

some interesting trends that we will continue to investigate through our regional monitoring program and intensive research investigations.

HOGAN, JENNIFER
California Department of Water Resources, Sacramento, CA, jhogan@water.ca.gov

Lessons Learned ..... While Doing Maintenance Activities Where There Are California Red-legged Frogs

Maintenance activities within the Department of Water Resources Delta Field Division's ponds and drainages have provided some opportunities and challenges for DWR Environmental Scientists. Regulatory agencies, handling techniques, habitat determination, and survey results have all provided us with a chance for further understanding. Learning to deal effectively with the regulatory agencies was the first challenge. Handling California red-legged frogs and tadpoles in a safe and reliable manner provided another learning opportunity. Learning to determine red-legged frog habitat also proved to be interesting, since we discovered these frogs in areas where we initially did not expect them to be. The most exciting lesson learned, though, is that the work we are doing in these drainages appears to be good for the frogs. DWR is now entering its fourth year of these maintenance activities. We will undoubtedly learn more lessons as we continue our work. Hopefully, we will also continue to benefit this threatened frog.

HOLMES, JEFF[1]*, PRIYA NANJAPPA-MITCHELL[2], and ERNIE GARCIA[3]
[1]Partners in Amphibian and Reptile Conservation (PARC), co-chair, Southeastern PARC, and Conservation Southeast, Inc., conservationsoutheast@comcast.net; [2]PARC State Agencies Coordinator, Gurnee, IL; [3]PARC Federal Agencies Coordinator, US Fish and Wildlife Service, Weaverville, CA.

Aligning Northwest Herp Conservation Issues, Actions, and Funding: What's broken? How do we fix it? Where's the money?

Partners in Amphibian and Reptile Conservation (PARC) has developed a successful, multi-entity adaptive management model and organizational structure. PARC is deploying this model throughout its regional working groups. The model emphasizes communication and complementarity between technical working groups. This model is designed to optimize applied conservation biology and minimize resource expenditures that do not meaningfully impact wild populations and their habitats. In this model, partners affiliate themselves with one or more technical working groups based on their individual skills and interests. The model then provides a vehicle for the coordinated flow of knowledge, funding, and other resources between "Information Gathering" working groups (Research, Inventory/Monitoring) and "Implementation" working groups (Management, Education/Outreach, Policy/Trade) in order to maximize the net conservation impact of every penny and every drop of sweat.

JOHNSON, PAUL G.*, and ROBERT SAULINO
National Park Service, Pinnacles National Monument, Paicines, CA 95043; paul_johnson@nps.gov

Re-introducing the Foothill Yellow-legged Frog to Pinnacles National Monument

The foothill yellow-legged frog (*Rana boylii*) is a declining species that has apparently been extirpated from the entire southern portion of its range. In the first half of the 1900's it was collected from Pinnacles National Monument in the Inner Coast Ranges of Central California, but none have been

observed there for decades. Re-establishing a population of this species on federally protected lands at Pinnacles may be key to its continued survival at the current southern end of its range. In 2005 we began a pilot study to evaluate methods for re-introducing this species to Pinnacles. We translocated newly hatched tadpoles from genetically homogeneous populations within a 50 km radius. We reared tadpoles in predator-free pens in streams at Pinnacles and in identical control pens in streams at the donor sites. Results indicate that the rearing pens were effective in maintaining high larval survival rates, and that habitat conditions at Pinnacles are conducive to foothill yellow-legged frog survival from hatching through the metamorphosis stage. In 2006 we will begin full-scale re-introduction efforts.

KUPFERBERG, SARAH J.[1], and WENDY J. PALEN[2]
[1]Quest Engineering Corp., Point Richmond, CA, skupferberg@pacbell.net; [2]Department of Integrative Biology, University of California, Berkeley, CA

Evaluating the Accuracy of Different Monitoring Designs by Subsampling a 14-Year *R. boylii* Eggmass Census. .

Rana boylii eggmass surveys have been conducted annually on a 5 km reach of the South Fork Eel River (Mendocino Co., CA) since 1992. These detailed spatial and temporal data provide the opportunity to evaluate the consequences of choosing among a variety of sampling strategies for estimating 1) site occupancy, and 2) population trends through time. Such choices are often made by managers of regulated rivers. For the purposes of hydroelectric dam relicensing utilities and regulators are faced with the task of determining species distributions and site occupancy over very long reaches, (up to 50 river miles). Further, they must monitor the status of populations to detect long term trends and decide whether to invoke adaptive management of flow regime. We evaluated the effects of specific spatial and temporal sampling biases which reflect potential real world constraints. For example, over the life of a 30 year dam license, censusing of *R. boylii* may only occur periodically, e.g. once every five years, or selectively at populous breeding sites located in proximity to large tributary confluences. We find that the underlying spatial and temporal pattern in *R. boylii* breeding strongly influences the accuracy of monitoring, because nearly 50% of the population breeds within one riffle-pool sequence of perennial tributary confluences consistently across years. One of the consequences of this pattern is that if surveys and monitoring efforts solely focused on these sites, we would overestimate both the population size and population stability through time. In the absence of *a priori* knowledge about the longitudinal distribution of individuals (e.g. a full reach survey) it would be unlikely to accurately capture the spatial and temporal dynamics of *R. boylii* populations.

LIND, AMY[1]*, ROBERT GRASSO[1], SEAN PARKS[1], PETER STEIN[1], BARBARA ALLEN-DIAZ[2], SUSAN McILROY[2], KEN TATE[3], LESLIE ROCHE[3], WILLIAM FROST[4], and NEIL McDOUGALD[4]
[1]USDA Forest Service, Sierra Nevada Research Center, Davis, CA, alind@fs.fed.us; [2]College of Natural Resources, Univ. of California, Berkeley, CA; [3]Dept. of Plant Science, Univ. of California, Davis, CA; [4]Univ. of California, Cooperative Extension, Division of Agriculture and Natural Resources.

Determining the Effects of Livestock Grazing on Yosemite Toads (*Bufo canorus*) and Their Habitat.

This study is a collaborative effort between the USDA Forest Service, Region 5 (California) and Pacific Southwest Research Station, Sierra Nevada Research Center; and the Universities of California, Davis and Berkeley. Our goal is to better understand the relationships between livestock grazing and Yosemite toad populations and habitats. The study has two complementary components. Phase I will

capitalize on existing data and we will use correlative multivariate analyses to relate toad occupancy at a large number of meadows (n > 50) to a set of environmental variables (both GIS and field-derived) as well as livestock grazing history. Phase II is an experimental study of 20 meadows on the Stanislaus and Sierra National Forests. Four livestock grazing treatments are being implemented in 5 replicate blocks (= grazing allotments): (1) no grazing within the entire meadow, (2) no grazing within breeding areas, (3) grazing to utilization standards throughout the meadow, and (4) historically ungrazed reference meadows. Baseline data were collected in 2005 for 15 meadows; candidate ungrazed meadows were surveyed and final selections will be made in spring 2006. Treatments will be implemented in summer 2006 and meadows will be studied for a minimum of three years. In 2005, we collected data on toad breeding areas, larvae, and metamorphic toads and environmental data at both meadow and local (toad-centric) scales. Environmental data included: meadow topography, plant composition, hydrologic characteristics, water quality, and livestock utilization. We also tested methods for counting tadpoles and marking all life stages of toads. Future analyses will focus on developing toad habitat models and relating toad population status and habitat requirements to livestock utilization levels.

MATTHEWS, KATHLEEN R.[1], KRISHNA V. FELDMAN[1]*, and IGOR LACAN[2]
[1]USDA Forest Service, Pacific Southwest Research Station, Berkeley, CA, kmatthews@fs.fed.us;
[2]University of California, Berkeley, Department of Environmental Science, Policy and Management, Berkeley, CA

Mountain Yellow-legged Frog (*Rana muscosa)* Breeding Dynamics in Dusy Basin, Kings Canyon National Park: How do Variable Snowpack and Lake Water Levels Affect Recruitment?

Our 1997-2005 surveys of mountain yellow-legged frogs in Dusy Basin found that most breeding (>70% of egg masses) occurred in shallow (<3m) lakes prone to late summer drying. Up to 4 years of tadpole recruits can be lost when lakes dry due to their extended tadpole phase. In upper Dusy Basin, more than 60% of egg masses were found in one shallow lake (max depth = 1m) that often undergoes a dramatic decrease in volume during years with low snowpack and precipitation. This breeding lake was totally dry by the end of the summer in 4 of 9 years; presumably, all tadpoles died because there was no connectivity to other water bodies. More breeding may now occur in shallow lakes vulnerable to drying because the largest lake in upper Dusy Basin has fish. Few egg masses were found in this larger, deeper lake (max depth = 10 m) either because frogs no longer breed in this lake or egg masses are quickly eaten by fish and not observed in surveys. Other lakes used for breeding are deeper and did not totally disappear in the low snowpack years. In lower Dusy Basin, over 90% of egg masses are found in one (max depth = 1.5 m) of four adjacent lakes; this lake has not dried up in surveys conducted from 1998-2005. To determine if there is a link between water availability and recruitment into adults, we compared the number of metamorphs in breeding lakes prone to drying with those breeding lakes not prone to drying. The lakes that intermittently dry up show low recruitment of metamorphosed frogs. The exclusion of successful frog breeding from the deepest lakes where recruitment may be more successful is another impact of introduced fish on this declining frog population.

McIVER, WILLIAM R.
U.S. Fish and Wildlife Service, Ventura, California 93003, bill_mciver@fws.gov

Hybridization between Native California tiger salamanders (*Ambystoma californiense*) and Non-native Tiger Salamanders (*Ambystoma tigrinum*): Developing Management Strategies

The California tiger salamander (*Ambystoma californiense*) is federally listed as endangered in Sonoma and Santa Barbara Counties, and threatened in central California. Non-native barred tiger salamanders (*Ambystoma tigrinum mavortium*) were introduced into central California as fishing bait in the mid-1900s. The threat of hybridization with non-native tiger salamanders is particularly severe in the Central Coast Range and Bay Area regions, and, to a lesser extent, the Central Valley region. Hybridization between species may lead to introgression, which occurs when hybrid individuals repeatedly backcross to one or both parental types so that genetic material is transferred between the two species. Natural hybridization can be an important component of evolutionary processes; however, hybridization and introgression can be cause for concern, particularly if they are the result of human activities such as the introduction of non-native taxa. Management strategies regarding hybridization in native California tiger salamanders need to be developed through cooperation between Federal and State agencies, researchers, consultants, and private landowners.

MENEKS, MAIJA
U.S. Forest Service, Humboldt-Toiyabe National Forest, mmeneks@fs.fed.us

Columbia Spotted Frog Monitoring, NE Nevada

Three Districts of Humboldt-Toiyabe National Forest in NE Nevada support populations of Columbia spotted frog (Great Basin Population), a Candidate species. Monitoring sites, one per District, were established in 2004 and 2005 to better understand local characteristics of this frog. This monitoring will assist in Forest project design; and monitoring is also a line item in the Nevada Columbia Spotted Frog Conservation Agreement. Monitoring includes PIT tagging and elastomer marking for mark-recapture. Other data taken includes GPS position, gender, snout-vent length, weight, and general observations of animal condition and capture location. Presented are one or two years of data collection, depending upon year of site establishment, including length, weight, distribution, and population estimates.

OLSON, DEANNA H. (Dede)
USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR 97331, dedeolson@fs.fed.us

Amphibian Research and Conservation on US Pacific Northwest Federal Lands.

Advances in amphibian knowledge, management effects and conservation approaches support an adaptive management framework for northwest species and land management practices. A body of work emerging from US Forest Service and Bureau of Land Management studies is providing new science to serve as the foundation of land management decisions. Examples from the portfolio of studies with which I have been involved include: 1) greater understanding of amphibian distributions, population trends, discrete populations, mobility, species interactions and species-habitat associations; 2) effects on amphibians of culverts, riparian grazing, forest thinning, headwater riparian buffers, forest leave islands and edges; and 3) development of effective survey protocols for inventory and monitoring, assessment procedures for risk and uncertainty, and multispecies protection strategies. This suite of topics is not

intended as an exhaustive list of amphibian conservation issues in the northwest, but rather reflects the shifting priorities of amphibian species research and conservation on northwest federal lands through the last ten years. While scientific resiliency is needed to respond to varying issues identified for research, compendia of knowledge syntheses need to iteratively compile emerging information. The capability of research to track issues is largely one of funding and personnel, both showing diminishing trends at present. However, in the northwest, new syntheses are becoming available through a variety of media, including revised field guides with expanded scope, fact sheets, cd-roms, web-available presentations and documents, federal conservation assessments and strategies for special status and sensitive species, and habitat management guides, in addition to the more traditional publication-based literature.

PALEN, WENDY J.
Department of Integrative Biology, University of California, Berkeley, CA, wpalen@berkeley.edu

Landscape-scale Risk Assessment for Current and Future UV-B Exposure of Alpine Amphibians of the Pacific Northwest.

Increasing ultraviolet-B radiation (UV-B, 290-320 nm) as a result of stratospheric ozone depletion has been proposed as a leading explanation for declining amphibian populations for almost ten years. It is not until recently however, that we have begun to examine the likelihood that UV-B could influence amphibians at the large spatial scales relevant to population declines and species conservation. A key limitation to these efforts has been in understanding how results from a variety of single experimental sites relate to the effect of UV-B more generally across many sites. Here I present the results of a series of field experiments testing the importance of UV-B exposure for the hatching success of two species of montane amphibians, *Ambystoma macrodactylum* and *Rana cascadae*, at sites spanning a gradient of UV-B exposure. Using the existing variation in the concentration of UV-B attenuating optical color (dissolved organic matter, DOM) present in the water at different amphibian breeding sites, I find that ambient levels of UV-B only negatively affect amphibian egg survival in the clearest of sites when compared to embryos shielded from UV-B. Secondly, I used the level of UV-B exposure associated with significant mortality from these field experiments to evaluate the relevance of the total dose of UV-B received by embryos surveyed across a large number of montane breeding sites. By combining data on the timing of incubation, measured incident UV-B, optical properties of the water, and the depth distribution and light exposure of embryos at each site I find that 0.4% of *A. macrodactylum* and 0% of *R. cascadae* embryos across a landscape of breeding sites are exposed to doses of UV-B exceeding lethal levels in our field experiments. These results confirm and extend earlier predictions that ambient levels of UV-B are not likely to cause widespread embryonic mortality.

PAPENFUSS, TED
Museum of Vertebrate Zoology, University of California, Berkeley, CA, asiaherp@calmail.berkeley.edu

Amphibian and Reptile Field Work in Afghanistan as an Invited Guest of the Taliban.

The Taliban ruled Afghanistan from 1996 until shortly after September 11, 2001. As part of my research on the amphibians and reptiles of the Middle East, I convinced the Taliban leadership to invite me on a field trip to study amphibians and reptiles. When I arrived in Afghanistan in May 2000 I was met by Aktar Usmani, the number two man in the Taliban leadership, heir designate to the elusive one-eyed Mullah Mohammad Omar, and colleague of Osama Bin Laden. Usmani gave me two of his personal body guards, a driver and a translator and allowed me to travel throughout Taliban ruled Afghanistan. We found many interesting species of amphibians and reptiles, including a species of salamander

(Batrachuperus mustersi) that only lives in a single stream in the Hindu Kush. At the end of my trip, the Taliban Foreign Minister, hoping to improve relations with the US, asked me to organize a Museum of Vertebrate Zoology expedition to Afghanistan for the fall of 2001. This never happened due to the events of September 11.

PEEK, RYAN*, and SAPNA B. KHANDWALA
Stillwater Sciences, Berkeley, CA 94705, ryan@stillwatersci.com

Rana boylii Plasticity and Management Under Dam-controlled Flows in the Northern West-slope Sierra Nevada

Rana boylii (foothill yellow-legged frog) populations are found throughout the foothills of the Sierra Nevada, often occurring downstream of large dams that control flows for much of the year. Renewal of hydroelectric project licenses generally requires studies of project-related effects on surrounding ecosystems, to help inform the design of flow schedules that are consistent with species conservation and management.

Focused studies conducted in support of hydro-relicensing generally occur in two phases and are designed to fill gaps in our understanding of species ecology and potential responses to altered flows. The first phase is focused on local distribution and basic life history timing of *R. boylii*. The second phase focuses on a specific analysis of how the hydroelectric project may potentially affect the species, including habitat connectivity and the effects of regulated flows on breeding habitat. Based on case studies on the South Fork Feather and South Fork American rivers, results of first phase investigations have validated current research on *R. boylii* habitat use and local distribution in similar watersheds. In addition, our observations suggest *R. boylii* can occur in atypical habitats (man-made tunnels over a mile from the main channel, within roadside culverts, and along the banks of reservoirs).

Studies in the second phase, however, are generally more complex and ask more detailed ecological questions. We need an integrated, efficient approach that can maximize our understanding of flow effects on *R. boylii* (within the hydroelectric project relicensing time frame), that furthers both scientific research and overall species management goals.

POPE, KAREN L.[1,2]*, SHARON P. LAWLER[1], AND HART W. WELSH[2]
[1]Ecology Graduate Group & Entomology Dept, UC Davis, kpope@ucdavis.edu; [2]U.S. Forest Service Pacific SW Research Station, Redwood Sciences Laboratory.

Effects of Fish Stocking and Fish Removal on Cascades Frogs (*Rana cascadae*) and Other Native Species

We have completed three years of a four-year study testing the effects of introduced trout on the flow of insect and amphibian prey from lakes to predators in uplands. We are studying 4 historically fishless 'reference' basins, and 12 'treatment' basins under three management schemes: trout stocking, suspended stocking, and fish removals. Lakes are at elevations over 1,920 m in the Trinity Alps of California. In summer, 2003 we collected biweekly pre-treatment data at all basins, and in fall we initiated treatments. Sites are being re-sampled in summers 2004-6. We are surveying amphibians, snakes, aquatic insects, bats, and birds. The aquatic fauna did not differ among the three treatments before fish removal, but Cascades frogs, garter snakes and large-bodied insects were more numerous in reference lakes. In 2004 and 2005, recruitment of Cascades frogs, Pacific treefrogs and large aquatic insects improved dramatically in fish removal lakes. Preliminary results will be presented that focus on changes in amphibian populations and distributions across treatments during the first three years of the project.

RACHAWICZ, LARA[1,2]*, and CHERIE BRIGGS[2]
[1]Resources Management and Science, Yosemite National Park, Yosemite, CA, lara_rachowicz@nps.gov;
[2]Dept. of Integrative Biology, Univ. of California, Berkeley, CA.

Effects of Density on *Batrachochytrium dendrobatidis* Transmission in Mountain Yellow-legged Frogs (*Rana muscosa*).

An emerging infectious disease of amphibians, chytridiomycosis, caused by the fungal pathogen *Batrachochytrium dendrobatidis*, recently has been implicated in population declines and possible extinctions throughout the world, including in protected areas. *B. dendrobatidis* zoospores, the infectious stage of the fungus, infect keratinized cells found in the mouthparts of anuran tadpoles and the skin of postmetamorphic individuals. Here, we examined the form of the transmission function of this pathogen in the mountain yellow-legged frog (*Rana muscosa*) by performing laboratory and field experiments. We then used a maximum likelihood approach to determine what form of the transmission function is best supported by the experimental data. We also investigated what impact crowding might have had on transmission. In the laboratory and in some natural environments, we detected a significant positive relationship in the proportion of *R. muscosa* tadpole hosts that became infected after a few weeks of *B. dendrobatidis* exposure with increasing numbers of previously infected *R. muscosa* tadpoles added to their local environment.

ROMANSIC, JOHN*, KRISTIN DIEZ, ELISE HIGASHI, and ANDREW BLAUSTEIN. Department of Zoology, Oregon State University, Corvallis, OR, romansij@science.oregonstate.edu

Separate and Combined Effects of Nitrate and the Pathogenic Water Mold *Saprolegnia* on Survival of Amphibian Larvae

Synergisms between stressors and infectious organisms can have important effects on host organisms. Nitrate pollution is an environmental stressor of global significance. We tested for a synergism between nitrate and *Saprolegnia*, a pathogenic water mold, using larvae of three amphibian species: *Ambystoma gracile* (northwestern salamander), *Hyla regilla* (Pacific treefrog) and *Rana cascadae* (Cascades frog). Each species was tested separately, using a fully factorial experiment with three nitrate addition treatments and two *Saprolegnia* treatments. Nitrate treatments had nominal nitrate concentrations of 0, 5, and 20 mg/L. *Saprolegnia* treatments were three hemp seeds laden with *Saprolegnia* (*Saprolegnia* treatment) and three sterile hemp seeds (control treatment). Each experiment lasted for one week. No significant effects of nitrate addition or *Saprolegnia* were found on survival of *H. regilla*. In contrast, survival of *R. aurora* was affected by an interaction between *Saprolegnia* and nitrate. With no nitrate, survival of *R. aurora* was significantly lower in the *Saprolegnia* treatment compared to the control treatment. However, there were no significant effects of the *Saprolegnia* treatment on survival when nitrate was added. *A. gracile* followed a pattern similar to *R. aurora*, but the difference between the *Saprolegnia* treatment and the control treatment when nitrate was not added was not significant, nor was there a significant nitrate by *Saprolegnia* interaction. Our results suggest that nitrate addition and *Saprolegnia* had less-than-additive effects on *R. aurora* survival. Less-than-additive interactions between stressors and infectious organisms have been described in other systems. Future studies should attempt to determine what controls the nature of interactions between stressors and infectious organisms.

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STEAD, JONATHAN[1]*, HARTWELL WELSH[2], and KAREN POPE[2]
[1]Graduate Group in Ecology, UC Davis, Davis, CA, steadje@yahoo.com; [2]US Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, Arcata, CA.

Critically Low Numbers of Cascades Frog in the Lassen Region

We conducted a cooperative inter-agency investigation into the status of native amphibians and nonnative fishes in lentic habitats at Lassen Volcanic National Park. Census surveys at Lassen Volcanic National Park were conducted during summer 2004, and results of surveys that we conducted in the Thousand Lakes and Caribou Wilderness areas during summer 2002 are also presented here. Visual encounter surveys were conducted to identify presence, species, life stage and relative abundance of amphibians, and timed gill net sets or visual surveys were used to identify fish presence, species, and relative abundance. Habitat data were also collected. We use generalized additive models to examine site attributes associated with amphibian occurrences, including the presence or absence of fish. Herpetofauna detected include the Pacific treefrog (*Hyla regilla*), western toad (*Bufo boreas*), long-toed salamander (*Ambystoma macrodactylum*), Cascades frog (*Rana cascadae*), rough-skinned newt (*Taricha granulosa*), western terrestrial garter snake (*Thamnophis elegans*), and the common garter snake (*T. sirtalis*). Fish species detected include three species of trout (Family: Salmonidae), five minnow species (Family: Cyprinidae), and the Tahoe sucker (*Catostomus tahoensis*). Our models suggest that populations of long-toed salamanders and Pacific treefrogs are less likely to be found in water bodies supporting fish. The Cascades frog was only detected at three sites, and could not be analyzed statistically. We believe that the Cascades frog is in immediate risk of extirpation from the Lassen region. Although fish clearly adversely affect palatable amphibian species, a number of considerations lead us to believe that fish are not the main driver behind the observed regional decline of Cascades frog. Factors outside the scope of this investigation may play an important role in declines observed in the Lassen region.

STEPHENS, MOLLIE*, AND BERNIE MAY
Department of Animal Science, University of California, Davis, CA, mrstephens@ucdavis.edu

Conservation Genetics of the Yosemite

The Yosemite toad (*Bufo canorus*) is an endemic and declining Sierran amphibian. Previous *reports* of population genetic structure in this species were limited to samples in Yosemite and Sequoia Kings Canyon National Parks, a subset of the entire species range. This study examines populations from throughout the entire range using 500 base pairs of mitochondrial DNA control region. Analyses of population genetic structure revealed a paraphyletic *B. canorus* group, relative to its sister taxon, the western toad (*B. boreas*). *B. canorus* exhibits apparent gene flow with *B. boreas* in the northern part of its range, possibly indicative of secondary contact between the two species. Implications for species management will be discussed. Additional work
with nuclear markers will assist in determining whether the observed pattern is unique to mtDNA or reflective of a true pattern of gene flow between species.

VELEZ, CRISTINA E.[1]*, and ROSS D. HALEY[2]
[1]Public Lands Institute, University of Nevada Las Vegas, Las Vegas, NV, Cristina_Velez@partner.nps.gov; [2]National Park Service, Lake Mead National Recreation Area, Boulder City, NV

Status of Relict Leopard Frogs, *Rana onca*, in Arizona and Nevada

The relict leopard frog, *Rana onca,* was considered to be extinct in 1950 but was rediscovered in 1991 at 2 springs within the Lake Mead National Recreation Area. Because such low numbers (<1100) were estimated to exist in the wild, a Conservation Agreement and Strategy (CAS) was initiated for this species in 2002. The CAS was finalized and sent out for signatures by state and federal agencies in November 2005. The main goal of the CAS is the long-term conservation of *R. onca*. Implementation of the plan includes the rearing and translocation of wild stock to new spring locations within their historical range. Since 2003, 977 froglets and 2747 tadpoles have been translocated among 2 springs in Arizona and 3 springs in Nevada. In total, there are currently 6 natural and 5 experimental populations of *R. onca*. This paper reports the status of conservation efforts since 2003, and will include the results of biannual visual encounter surveys at each location.

WELSH, HARTWELL H., JR.
USDA Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, Arcata, CA 95521, hwelsh@fs.fed.us

Amphibian Population Status on Northwest California Landscapes: What is the Role of Anthropogenic Disturbance in Declines of Amphibians in Northern California?

The herpetology group at the Redwood Sciences Lab, with assistance from graduate students in the biology and wildlife departments at Humboldt State University, has been studying the natural history, demography, and landscape ecology of amphibian assemblages in aquatic and terrestrial environments of Northern California for 21 years. A primary focus of our research has been to study the interactions between amphibian biology and human land management practices. In this talk I examine several interrelated themes that have emerged from this work. I discuss both individual species, and species assemblages, whose populations have declined on northern California's landscapes in response to anthropogenic natural resource management. Amphibian populations in this region have declined due to detrimental forestry practices, introductions of non-native predators, and manipulations of the natural flow regimes of north coast rivers. I review specific mechanisms that stress species by exceeding their physiological limits, and/or their fixed, evolved thresholds of ecological niche space, to explain three distinct regional amphibian population decline trajectories. I suggest possible modifications to these anthropogenic disturbance regimes that could help reverse on-going declines while still meeting human needs.

WENGERT, GRETA[1]*, MOURAD GABRIEL[1], JAMES BETTASO[2], BRIAN SHAW[3], and DON ASHTON[2].
[1]MGW Biological, Arcata, CA, greta@mgwbio.com; [2]EartHerp, Manila, CA; [3]Klamath Wildlife Resources, Redding, CA

Summer Home Range and Movements of Female Mountain Yellow-legged Frogs (*Rana muscosa*) in a Northern Sierra Nevada Stream

The mountain yellow-legged frog (*Rana mucosa*) is endemic to the Sierra Nevada Mountains of California and Nevada where they inhabit aquatic habitats at elevations ranging from 1400m to 3700m. To date, no published information on the home range or movement patterns of mountain yellow-legged frogs within streams of the northern Sierra Nevada Mountains exists. This part of a continuing study focuses on the summer movement patterns, home range, and microhabitat associations of mountain yellow-legged frogs within a northern Sierra Nevada stream, with particular attention to movements out of the main stream channel.

Eighteen frogs, seventeen female and one male, were affixed with radio transmitters on July 23-24, 2005. Frogs were tracked through early October. Mean summer home range (July through early October) of frogs was 379 m^2 (±150 m^2 SE) at 50% probability and 2235 m^2 (± 880 m^2) at 95% probability. Total upstream to downstream distance along the creek ranged from 20 m to 245 m for a mean of 69.6 m (±14.6 m SE).

Movements away from the creek were infrequent and small in distance, and more common in the early summer tracking period, possibly because off-creek refugia were more abundant. The ongoing winter tracking session of 21 frogs should more accurately determine off-creek movements since off-creek habitat should be more abundant with the winter precipitation. Results of this study will provide more insight into the conservation needs of this rare species and the importance of riparian buffers in timber harvest within National Forest lands.

WHEELER, CLARA A.*, JUSTIN M. GARWOOD, and HARTWELL H. WELSH, JR.
US Forest Service, Pacific Southwest Research Station, Redwood Sciences Laboratory, Arcata, CA, cawheeler@fs.fed.us

Reproductive Ecology and Breeding Migration Patterns of the Cascade's Frog (*Rana cascadae*) in the Trinity Alps Wilderness, California

Due to dramatic declines across the range of the Cascade's frog (*Rana cascadae*) in California, and recent genetic work suggesting that these frogs are of a distinct population segment, there has been increased interest in the conservation of the species resulting in a number of ongoing research projects. The purpose of our study was to obtain information regarding the species reproductive ecology and breeding migration patterns. We documented egg mass locations, approximate date of breeding activity at each site, and movement to breeding sites based on mark-recapture data within Deep Creek Basin, Trinity Alps Wilderness, CA in 2003 thru 2005. In addition, we monitored male adult arrival time and breeding activity of frogs captured at one of the primary breeding sites within the basin. Breeding sites ranged 1,976 – 2,226 m in elevation with breeding activity occurring from the end of May through July within the basin. Our results indicate that *R. cascadae* are explosive breeders, however, the timing of breeding activity occurs later with increasing elevation ($R2 = 0.49$, $N=30$, $P<0.0001$). Of 213 ponds in the basin (at least 0.15 m deep and 2-m2 surface area), 33 individual ponds were used for reproduction, but only 13 (6%) were used in all 3 years. We observed extensive movements to a breeding site used almost exclusively for reproduction (>1050 m traveled) even when closer breeding sites were available. Our observations suggest that individuals can have high breeding site fidelity. We found a significant

negative correlation between male frog size and arrival time to the breeding area in all years (Pearson, r =-0.40, N=122, P<0.0001).

WISEMAN, KEVIN D.[1]*, KARLA R. MARLOW[1], JOSEPH DRENNAN[1], RONALD JACKMAN[1], and JAMIE BETTASO[2]
[1]Garcia and Associates (GANDA), San Francisco, CA, kwiseman@garciaandassociates.com; [2]U.S. Fish and Wildlife Service, Arcata, CA

Cannibalism in the Foothill Yellow-Legged Frog (*Rana boylii*)

Cannibalism has been reported in 12 of 21 families of frogs including ranids. Dietary studies of *Rana boylii* indicate that these frogs consume a wide variety of invertebrate prey including insects, spiders, and centipedes. Cannibalism, however, has not been documented in this species. Herein, we report two field observations of cannibalism in *R. boylii* from El Dorado and Humboldt Counties, California. In both cases, adult frogs (one adult female and an adult of undetermined sex) preyed upon post-metamorphic juvenile conspecifics during the month of September. In other western ranid species, adult predation upon juvenile conspecifics is the most commonly reported form of cannibalism, and may occur more frequently in nature than previously believed. Post-metamorphic frogs constitute a valuable, seasonally-available resource for adults in the late fall. We hypothesize that cannibalism rates would increase with microhabitat overlap between life stages and in years of high recruitment. Recent studies suggest that cannibalism may play a role in the transmission of disease, and this unique life history trait could have unknown implications for declining ranid populations in the West.

*Indicates speaker in multi-authored presentation.