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Trends in Amphibian Occupancy in the US: Data from the Amphibian Research and Monitoring Initiative

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The monitoring component of the Amphibian Research and Monitoring Initiative (ARMI) is a US network of independent research projects that each include a temporal element. Each project has its own methods and objectives but all use statistically unbiased analytical methods to estimate either the probability of site occupancy by amphibians or abundance of amphibians at the sites. As of 2011, ARMI had accumulated 635 estimates of occupancy for 118 time series where a time series is a temporal sequence of occupancy estimates for a species at a monitoring area. Each of these estimates applies to a defined range of inference that typically covers 10s to 100s of potential amphibian habitat units. Each project requires multiple surveys of a subset of units within the range of inference so that the probability of detecting a species that is present can be incorporated into an estimate of occupancy. ARMI has 39 monitoring areas across the U.S that produce occupancy estimates for 50 species of amphibian. Time series range from 2 to 9 years. In aggregate, these data represent the most comprehensive and quantitative data on amphibian trends across the US. Overall, ARMI estimates that the probability of site occupancy for the amphibians monitored has declined 4.5% (95% CI = 1.2 – 8.0) annually since 2002. he individual trends are variable but 61.8% (73 of 118 time series) show a declining trend. The species and places monitored were chosen for various reasons related to local objectives so are not necessarily representative of other species and places. In some cases, species were chosen for study because of concern for their conservation status but, overall, there does not seem to be a bias towards selecting species that are threatened. Instead, ARMI projects often monitor a suite of species that occur in a particular habitat. We note that ARMI began after some of the severe declines in the US are thought to have occurred. While the primary objective of ARMI is not to provide broad trend information, ARMI data are a unique resource in the ongoing global assessment of amphibian decline.

Lessons learned from 13 years of recovery with the critically endangered mountain-yellow legged frog (Rana muscosa) in southern California

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The once abundant mountain yellow-legged frog (Rana muscosa) has declined from 99% of its former range in southern California since the late 1960‘s. It is currently listed as endangered by both the US Fish and Wildlife Service and the state of California. The mountain yellow-legged frog is a high elevation species that requires at least two years to complete metamorphosis. The US Geological Survey has been monitoring the remaining populations and involved with restoration for this species since 2000. The San Diego Zoo Institute for Conservation Research has been conducting captive husbandry and restoration since 2006 and were the first to successfully breed this species in captivity in 2010. Captively bred animals were released in 2010 and 2011 in an attempt to reestablish a single site. The nascent nature of the captive breeding program has presented us with challenges in our reestablishment effort.

Small sample sizes, low post-release detectability, and unavailability of frogs from multiple life stages has limited our ability to develop a standardized reintroduction methodology for the species. We will discuss some of the challenges and successes of managing anuran reintroductions during the nascent stages of captive breeding programs.

Environmental monitoring of the amphibian chytrid fungus (Batrachochytrium dendrobatidis) in the southeastern United States: Any evidence of disease-related population declines?

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Pathogens and infectious diseases are of significant concern in biological conservation. In many parts of the world population declines and extinctions of amphibians have been attributed to the pathogenic amphibian chytrid fungus, Batrachochytrium dendrobatidis (Bd), which causes chytridiomycosis. Considerable effort has focused on detecting Bd in its amphibian host but, until recently, little was known about the temporal and spatial distribution of this pathogen in the environment. Herein we report the results of concurrent host and environmental sampling of Bd on public lands in the southeastern United States. Between April 2008 and April 2010 we swabbed 1206 amphibians and filtered water (315 samples) from 71 sites. Sites included isolated wetlands, streams, and caves from nine national parks and wildlife refuges extending from the (Southern) Appalachian Mountains to the Florida Keys. Additionally, a wide variety of frogs (20 species), as well as salamanders (21 species), was sampled. Results from quantitative polymerase chain reaction (qPCR) of swabs and filters showed Bd to be common and widespread throughout the region. Batrachochytrium dendrobatidis was detected in each state and in seven of nine US Department of Interior lands sampled. In most cases these were the first 41records of Bd on the properties sampled and are only the second and third records for Florida and Alabama respectively. Our results illustrate a lack of detection of Bd on amphibians does not imply an absence of this pathogen in the environment. Discordance between water and biological samples underscores the need to conduct both environmental and biological sampling to elucidate the distribution of this pathogen in the environment and its potential to infect amphibians. Contrary to the pattern of declines and extinctions observed in Mesoamerica and Australia, Bd is quite ubiquitous in the southeastern US without noticeable changes to amphibian populations. However, mortality events associated with other know amphibian pathogens (e.g. ranavirus and the perkinsus like organism) were observed during the course of this study.

Nine years of monitoring the endangered Arroyo toad in an occupancy framework: Findings, program evaluation, and feedback loop to management.

Brehme, Cheryl (U.S. Geological Survey); Miller, David; Fisher, Robert (U.S. Geological Survey, Canada)

Since 2003, we have monitored the endangered arroyo toad (Anaxyrus californicus) across 87 km of habitat in three watersheds on Marine Corps Base Camp Pendleton (MCBCP), California. The multi-year species occupancy design originated as part of the Amphibian Research and Monitoring Initiative (ARMI) within the USGS and incorporates imperfect detection of the species. In this program, we monitor the presence of arroyo toad breeding populations by documenting the presence of eggs and larvae. Multiyear occupancy models show that arroyo toad population dynamics differ according to hydrology. Population dynamics within ephemeral systems are highly variable and driven by stochastic processes (i.e. amount of rainfall), while those in perennial systems are more stable and likely driven by deterministic processes (i.e. predation, competition, habitat alteration). In the perennial systems, detection of toad larvae is consistently negatively associated with the presence of non-native aquatic species, including bullfrogs, predatory fish, and crayfish. Species interaction models show that after drought years, these non-natives are temporarily extirpated from ephemeral systems, and are slower than arroyo toads in 81recolonizing suitable habitat. However, without drying, the non-native predators have zero probability of extinction. We currently have a monitoring and management feedback loop with MCBCP, who are actively working to control non-native aquatics in this system.

In a recent program review, we used simulated data to evaluate the effectiveness of current and alternate sampling scenarios to detect changes in the distribution of breeding arroyo toads. Using model comparison techniques, we assessed the power to pick the ―true‖ model vs. competing models of decline or no decline.

All designs had relatively high power to detect a 20% decline in occupancy over a 6-year period and were able to distinguish between differing patterns of decline simulated for ephemeral and perennial watersheds.

Variation in salinity tolerance of larval amphibians: implications for community composition in coastal wetlands

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Amphibians in freshwater coastal wetlands bordering the Gulf of Mexico periodically experience acute exposure to salinity from hurricane-related overwash events, as well as chronic exposure associated with rising sea levels. In a comparative experimental approach, we tested the hypothesis that seven species of amphibians vary in their tolerance to changes in salinity. In a laboratory study, we exposed larval Hyla cinerea (Green Treefrog), H. squirella (Squirrel Treefrog), Lithobates catesbeianus (American Bullfrog), L. sphenocephalus (Southern Leopard Frog), Anaxyrus terrestris (Southern Toad), and 86Gastrophryne carolinensis (Eastern Narrow-mouthed Toad) from an inland population in Gainesville, Florida and Osteopilus septentrionalis (Cuban Treefrog) tadpoles from Picayune Strand State Forest, Collier County, Florida, USA to acute salinity for three days. For each species, we exposed tadpoles to 0.2 (control), 5, 10, 12, 14, and 16ppt with 30 replicated trials of each treatment. In all species tested, tadpoles reared in the control and 5 ppt treatments had 96.7 – 100% survival, yet no individual survived in the 14 or 16 ppt treatments. Survival varied among species in the intermediate treatments (salinities of 10 and 12 ppt). At 10 ppt, survival in native species ranged from 46.7 to 80%, except for Narrow-mouthed Toad tadpoles, of which none survived at salinities of > 10 ppt. In contrast, survival was 100% for the invasive, nonindigenous Cuban Treefrog at this salinity. At 12 ppt, survival in all native species was 0% except for the Green Treefrog, of which only 3.3% survived. Survival of Cuban Treefrogs remained relatively high (75.9%) at this salinity. Our results illustrate that the non-native Cuban Treefrog has a higher salinity tolerance than do native species, which may contribute to its invasion potential. Moreover, species commonly associated with coastal freshwater wetlands differ in their salinity tolerances, suggesting that salt water intrusion due to storm surges and sea level rise may affect the species composition of these ecosystems.

Can life history traits predict captive performance of endangered amphibians? A meta-analysis to inform decision making in ex-situ conservation programs

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Ex-situ conservation is often advocated as the last resort for amphibian species that face high risks of extinction or threats that cannot be easily resolved by in-situ conservation alone (such as chytridiomycosis). Captive breeding programs can be complex, as they need to account for demographic and genetic dynamics, management of captive and wild populations, quarantine and captive husbandry requirements as well as the eventual release strategy and the establishment of self-sustaining wild populations. This range of challenges implies several key decision nodes which need to be resolved, mostly before a program can even start. Structured decision making, which allows definition of problems and evaluation of alternative actions and trade-offs, can help in addressing such complexity. When selecting a species for ex-situ conservation, uncertainty may regard the suitability of the species for captive breeding (for example its survival and productivity in captivity), as well as the time and costs needed to build sufficient expertise and to achieve the desired target. If these aspects can be at least in part predicted by available information, for example life history traits of species, it is possible to use this knowledge to develop quantitative models that aim to predict possible consequences of given courses of action. In our presentation, we describe a metaanalysis of several captive breeding programs for amphibians worldwide: using hierarchical modelling, we assess how life history traits (generation time, longevity, and fecundity) can be used to predict various measures of

performance in captivity (population growth rate, recruitment and survival). This information can then be used to evaluate how captive breeding programs can assist conservation of the target species.

Batrachochytrium dendrobatidis in the boreal environment

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Amphibians are among the most vulnerable taxa due to synergistic effects of habitat loss, disease, and climate change. The amphibian chytrid fungus, Batrachochytrium dendrobatidis (Bd), causes an infectious disease, chytridiomycosis, that is associated with mass mortalities of many amphibian species and local extinctions in disturbed and pristine landscapes in both temperate and tropical regions. The boreal' is the largest ecoregion on the planet, yet largely because of its remoteness, it is one of the least sampled for Bd. Our research investigates the distribution of Bd in the boreal environment and the relationship between water quality, Bd detection, and Bd density in both amphibians and their aquatic habitats. In spring/summer 2009–2011, we examined Bd occurrence in water samples from 29 amphibian breeding sites in Alaska (USA) across a latitudinal range from approximately 60 to 67 degrees north. These latitudes were chosen to represent the northern-most latitude of Bd that had been reported in the literature up until 2009 (60 degrees) and the known northern-most extent of the wood frog (Lithobates sylvatic us) in Alaska (67 degrees). In 2009 and 2011 we collected skin swabs from amphibians to assess Bd occurrences on animals at these sites. Water quality parameters measured were water temperature, pH, specific conductance, and turbidity. We used qPCR for Bd quantification, and analyzed the results using an occupancy approach with the program PRESENCE 4.1, with AIC as a measure of parsimony for model selection. We found Bd at 38% of sites and as far north as 67 degrees latitude, at very low densities (max. = 8.96 zoospore equivalents per liter of water filtered). All detections except for one occurred in spring. Climate change scenarios are expected to interact with both the wood frog and Bd distributions in Alaska. Our inventories are hoped to provide baseline data for boreal Bd monitoring and a baseline for testing the Red Queen Hypothesis, which explains the evolutionary arms race between host and pathogen, using Bd and wood frogs as a model case study.

Spatial and temporal patterns of Batrachochytrium dendrobatidis occupancy in amphibian habitats

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The chytrid fungus Batrachochytrium dendrobatidis (Bd) is an aquatic pathogen to amphibians implicated as one of the causal agents for global amphibian declines across a spectrum of habitats ranging from heavily degraded to intact wilderness. Bd was first described in 1999, and has been detected in museum specimens dating back to at least 1902. Bd research has focused primarily on the ecology of the pathogen in infected amphibians. Our research seeks to describe Bd ecology in the aquatic environment outside of the amphibian host, evaluate spatial and temporal patterns of detection and density, and investigate the relationship between Bd occupancy and potential covariates including water quality. In spring/summer 2007–10, we collected Bd samples by filtering water from amphibian breeding sites at 36 sites in the United States and measured temperature, pH, and specific conductance at a subset (19 sites). We also intensively monitored one site in Oregon, collecting monthly Bd samples and water quality measurements from 2007 to 2011. DNA was extracted from filters and Bd was quantified using qPCR following established methods. Occupancy modeling was performed using the program PRESENCE, we used AIC as a measure of parsimony for model selection. Bd was detected at 47% of sites sampled (17 of 36 total sites, and 9 of 19 subset with water quality measurements); however, individual site estimates of occupancy ranged from 0.07 to 0.83. Bd occupancy was conditional on pH and detection was conditional on pH and volume filtered. At the intensively monitored site, Bd was detected at least once in every month over 4 years of monitoring. Density reached a peak in spring of every year and a second smaller peak was observed in December in two of the four years. Our findings

contribute to the understanding of the ecology of Bd in the aquatic environment, which will be critical for amphibian conservation. The patterns observed at these sites have informed hypotheses we will test across a broader landscape in the next year.

Trends in amphibian populations in U.S. national parks on the continental divide

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The U.S. Geological Survey's Amphibian Research and Monitoring Initiative (ARMI) conducts long-termmonitoring of amphibian populations in a hierarchical manner with varying levels of effort and spatial coverage. At the middle level of this hierarchy, study areas are often national parks or national wildlife refuges with a defined area of inference, and samples are selected using a probabilistic design. Occupancy and associated vital rates are used to evaluate status and trends. ARMI's Rocky Mountain Region and the National Park Service's Greater Yellowstone Inventory and Monitoring Network conduct monitoring at this scale along a transect composed of the national parks in 3 regions on the Continental Divide, including Glacier National Park in the north, Yellowstone and Grand Teton national parks in the middle, and Rocky Mountain National Park in the south. The transect covers 8° of latitude and the parks differ in size, climate, vegetation, and amounts of human influence. Beginning in 2005, we selected random samples of small drainages (catchments) in each park. . We hypothesized that catchments, which contained an average of 8 wetlands with suitable breeding habitat for amphibians, better represent functional populations and may be less influenced by stochastic variation. Each wetland in a catchment was surveyed at least twice each year for presence of breeding populations, and presence/non-detection of each species was aggregated among the wetlands in each catchment. We found strong differences in occupancy among species and between regions. Occupancy was lowest in Rocky Mountain National Park and highest in Glacier National Park, and of the species broadly distributed in each park, the boreal toad was least abundant in all regions. Initial analyses will evaluate the evidence for declines of each species in each region. These data constitute a good baseline for evaluating future changes to amphibian populations in the Rocky Mountains. Given existing and potential threats from the amphibian chytrid fungus and potential threats to amphibian habitat from climate change, continued monitoring of amphibian populations will provide park managers with information needed to fulfill statutory mandates to maintain biological diversity.

Translocated Invasive Burmese Pythons Demonstrate Remarkable Movement and Navigational Abilities

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Animals must navigate in order to obtain resources within their environment. The navigational strategies that individuals employ in both familiar and novel environments have important implications for their ability to use their environment. A variety of navigational strategies have been documented in reptiles, most of them based on some form of path integration, which requires the memory of an outward path to return ―home‖. True navigation, the ability to travel directly towards a goal after displacement to an unfamiliar location without using familiar routes, has rarely been documented in reptiles, primarily in sea turtles. Evidence for true navigation is typically found in long-distance migrants such as birds, marine fish, and monarch butterflies. We conducted a study to examine the ability of invasive Burmese pythons (Python molurus bivittatus) to navigate ―home‖ when displaced considerable distances from their point of capture. We translocated 6 adult Burmese pythons 20-35 km from their capture locations. Within 3-8 months, all snakes exhibited directed, long-distance movements towards their original capture locations (rho=0.96, P<0.0001).

Most snakes resumed less-directed movement patterns when they arrived close to their original capture locations. Our results indicate that invasive Burmese pythons exhibit true homing and navigational abilities when displaced long distances from their home range. Such abilities may reduce risk associated with the exploration of new areas outside their home range and may have important implications for expansion of the geographic range of invasive python in south Florida.

Does Translocation Influence Physiological Stress in the Agassiz's Desert Tortoise?

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Wildlife translocation is increasingly used to mitigate disturbances to animals or habitat due to human activities, yet little is known about the extent to which translocating animals causes stress. To understand the relationship between physiological stress and translocation, we conducted a multi-year study (2007-2009) using a population of Agassiz‘s desert tortoises (Gopherus agassizii) near Fort Irwin, California. Blood samples were collected from adult tortoises in three treatment groups (resident, translocated, and control) for one year prior to and two years after translocation to determine if this activity caused a measurable physiological stress response, and the time frame over which animals adjust to translocation. Samples were analyzed by radioimmunoassay for plasma total corticosterone (CORT), a glucocorticoid hormone commonly associated with stress responses in reptiles. CORT values were analyzed in relation to potential covariates (e.g. animal sex, date, activity, treatment, handling time, air temperature, movement, precipitation, and annual plant production) among seasons and years. On a broad scale, we measured lower CORT in years of low annual forage and precipitation and higher concentrations in years with more abundant forage and precipitation. However, when attempting to tie this to the areas inhabited by individual tortoises, estimated annual biomass production, precipitation, and movement did not significantly explain CORT concentrations. CORT values in males were higher than in females, and values for both varied monthly throughout the activity season and among years. We found that translocation of desert tortoises did not result in elevated stress levels. Rather variations in CORT concentration were best explained by the year and sex of the animal. From these results, we conclude that translocation does not elicit a physiological stress response in desert tortoises.

Desert Tortoise Use of Burned Habitat

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Wildfires burned more than 36,000 acres of critical habitat for the desert tortoise (Gopherus agassizii) in southern Nevada in 2005. In the Mojave Desert, the proliferation of introduced annual grasses, particularly red brome (Bromus madritensis ssp. rubens) and Mediterranean grass (Schimus barbatus and S. arabicus), has increased fire frequency and fire size, resulting in long-term habitat alteration across portions of the landscape. Direct effects of fire on desert tortoises include mortality due to acute heat exposure, and potential loss of food and cover. Indirect effects include long-term changes in vegetation composition and structure, and these are hypothesized to affect the quality of desert tortoise habitat. To investigate the indirect effects of wildfire on tortoises, we compared movement patterns, home range size, microhabitat use, behavior, and survival for desert tortoises located in, and adjacent to, burned habitat. Annual plant production in burned habitat was higher than in unburned habitats and primarily consisted of invasive annual grasses. As expected, burned habitat had notably lower perennial plant cover throughout the study. To evaluate how the shifts in vegetation affect habitat use, animal activity, and behavior, tortoises were monitored using radio telemetry. Approximately 45% of observed home ranges in the post-fire environment contained burned habitat, and numerous observations (n=11,407) corroborated tortoise use of both habitat types (48.7% burned, 51.3% unburned). We found that tortoises moved further into burned habitat with each successive year following the fire. Foraging behavior was most often observed in burned habitat and ―resting‖ was the most frequent

behavior observed in unburned habitat. Tortoises were more likely to use burrows for shelter in burned habitat,
while vegetation was used as a shade resource more often in unburned areas. This study demonstrates the continued use of severely fire-altered habitat by desert tortoises, with evidence of increasing recolonization of the area over time, suggesting that burned habitat should continue to be managed for desert tortoises.

Amphibian population trends in Yosemite National Park: What do we know from long-term monitoring?

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In 2000, the U.S. Geological Survey implemented the Amphibian Monitoring and Research Initiative (ARMI) which is designed to provide data on amphibian population trends on federal lands throughout the U.S. We implemented the ARMI program at Yosemite National Park, California (USA) using two different approaches. One was a focused mark-recapture study of Rana sierrae at a single meadow complex, and the other was a statistically-based design that used double surveys at 175 sites across 14 watershed units to evaluate population trends in three anuran species (R. sierrae, Pseudacris regilla, Bufo canorus) throughout the 3,081 km^2 park. We tagged 757 individual R. sierrae from 2003 to 2011 and used mark-recapture data based on 2,431 captures to model population trends related to precipitation, sex, and year. The R. sierrae population fluctuated from 45 to 115 frogs over the nine years of our study, but there was no clear up or downward trend. We conclude that this R. sierrae population at Yosemite NP is stable over a relatively long period of time, even in the presence of Bd. The watershed research was initiated in 2004 and continues as an ongoing program. We use double survey protocol at each site (pond, lake or meadow) to assess detectability for each species for each year. Detectability for the three anurans is high, ranging from approximately 0.70 - 0.90. We have analyzed presence data along with 15 site and survey covariates to evaluate population trends for each of the three study species. There are different population trends for different species, and different trends in the two major river drainages within the park. While population trends for Bufo and Rana are somewhat inconsistent, Pseudacris populations are declining within each of the major drainages.

Reassessment of the distribution and conservation priorities of Fijian iguanas based on recent field work

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The enigmatic monotypic iguanid genus Brachylophus was known monotypically from the south Pacific for 170 years before there was suggestion of diversification in the genus. Over the last 40 years several species were described and currently the iguanids from the south Pacific are now represented by two genera and a total of five species, although two of the species are extinct. Recent published analysis of a molecular and morphological dataset indicated that there were three clear species units within the Brachylophus populations sampled, but many island populations were not represented in that study. The living three endemic species of Brachylophus iguanas described from Fiji have been listed under CITES, the US Endangered Species Act, and IUCN Red List for a very long time. Additionally one invasive iguana species (Iguana iguana) has become a threat in northern Fiji, on islands occupied by native iguanas. Work has been initiated to control and/or eradicate that invasive from Fiji. For much of the last decade conservation actions have generally focused on only one of these three species (vitiensis), and the other two species (bulabula, fasciatus) remained poorly known. Field research on over 40 islands over the last two years has greatly

increased our knowledge base for these other two species and now conservation priorities can be discussed. This research has also shown that additional undescribed species of iguanas still persist in Fiji and their descriptions are now a priority so that they are properly recognized and conserved. We also found that many islands are now unsuitable for iguanas and the populations are restricted to a smaller list then we expected. Additionally, significant new gaps in knowledge of the distribution of all of these iguanas have been identified and are targeted for future studies. This program is a model of how an international governmental collaboration, with an in country NGO has made great knowledge strides over a relatively short period of time, with limited resources on a priority taxa for conservation.

Detection of stream-breeding amphibians using environmental DNA

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Detection of aquatic vertebrates using environmental DNA (eDNA) in water samples is a promising new method for documenting the presence of native and invasive species. This method had been recently proven effective in wetland and canal systems, but it was unknown whether eDNA would be detectable from vertebrates in fast-moving streams. To test the efficacy of this method for detecting stream vertebrates, we designed molecular (PCR) assays for two low-density, lotic amphibians (Idaho Giant Salamanders, Dicamptodon aterrimus; Rocky Mountain Tailed Frogs, Ascaphus montanus) in northcentral Idaho. In the field, we first filtered 5 -10 L of stream water from five streams over two seasons and estimated density for the target species using kick-sampling. After protocol testing and development, we successfully detected both species from these filter samples in streams with densities as low as 0.01 and 0.10 individuals per m 2 for salamanders and frogs, respectively. Detection probability was lower for
Rocky Mountain Tailed Frogs in spring than in early fall and was unrelated to field-measured densities. We found gains in efficiency of eDNA over field methods to be 20x for Idaho Giant Salamanders and 11x for Rocky Mountain Tailed Frogs. In follow-up work, we found that sampling 1 L of stream water led to far lower detection probabilities than sampling 5 L. Additionally, we found that our original conventional PCR methods occasionally produced spurious results that were indistinguishable from the real product for both species. We therefore converted our protocols to apply quantitative PCR, which uses a probe that provides additional specificity. Along with other collaborators at the University of Idaho, we are continuing to develop multi-species eDNA tests and methodology for monitoring amphibians and fishes across systems. More work is required to test the limitations of eDNA applications; however, this technique has the potential to be a highly sensitive and cost-efficient tool for the detection and monitoring of both native and invasive species across aquatic systems.

Using Monitoring Data to make Decisions about Amphibian Conservation

Grant, Evan (USGS - ARMI)

Concern for natural resources, especially in protected areas like National Parks in the United States, have resulted in a general call for monitoring data on the status of animal populations at broad scales. More rarely are these monitoring programs designed to directly inform resource management decisions. In contrast to many natural resource monitoring programs, explicit in the goals of the ARMI program is to provide information useful to improve US protected areas management. The development of a monitoring program is a key step in assessing the current status of species‘ occurrences and distributions, examining population trends over time, and identifying suitable targets for management to halt or reverse declining trends. One monitoring program detected declining trends in occupancy of a community of wetland breeding amphibian populations in one US National Park. This triggered a need to identify suitable management actions to halt or reverse the decline. I demonstrate how monitoring data may be used in a formal decision analysis through the following steps: 1) Collect monitoring data; 2) Fit model to data, including estimation of trend and covariate effects; 3) Identify management alternatives; 4) Identify optimal management strategies.

Evaluating Amphibian Response to Missouri River Flooding Using Novel Occupancy Modeling

Grant, Tyler (Iowa State University); David, Otis; Rolf, Koford (Iowa Cooperative Fish and Wildlife Research Unit, Ames, IA, United States)

Restoration of the Missouri River ecosystem has been ongoing since the Water Resources Development Act of 1986. We began in 2009 an assessment of the ecological functionality of mitigation properties in Iowa using the anuran community as ecological indicators. In 2011, the Missouri River experienced record flooding. Annual runoff was 75 km3, substantially more than the next highest estimated runoff of 61.7 km3 in 1881. The mitigation properties were inundated with >4 meters of water for over a month in July and August. Some breeding ponds were >1 kilometer away from the flood boundary. The 2011 flood offered a unique opportunity to assess the response and resiliency of anuran species to extensive flooding at 125 sample sites distributed along a 19 km floodplain corridor. We used a novel occupancy model that relaxed the closure assumption to demonstrate that anuran species rapidly colonized new shallow wetlands as the river stage rose. The probability of occupancy at sites with 30 cm of water was nearly 100% for Pseudacris maculata, Lithobates pipiens, and L. blairi, but decreased to 0% with increasing depths. Phenologically, L. pipiens, Anaxyrus woodhousii, Hyla versicolor/chrysocelis, and P. maculata began metamorphosing at dates comparable to 2010. Conversely, L. blairi, L. catesbeianus, and Acris blanchardi metmorphosed 3-5 weeks later than in 2010. These three species breed later than other species and flooding likely hindered reproduction. L. pipiens and A. woodhousii appeared to have successful reproduction despite the flooding, judging from the number of observed metamorphs at 81 post-flood survey points. H. versicolor/chrysocelis complex and P. maculata produced a moderate number of tadpoles. L. blairi and A. blanchardi produced few metamorphs. The data indicate that species that breed later in the season metamorphosed later and in smaller numbers. We will present data from the spring and summer of 2012 to document longer-term response of these species to the flooding, including rates of recolonization of flooded areas. The resiliency of these species and the habitat on which they depend may prove important under future climate change scenarios which predict more climate extremes. We suggest that a elevational gradient of habitats is necessary to provide useable habitat over a wide range of potential river stages

Hierarchical case-control logistic regression reveals multiple patterns in giant gartersnake habitat selection

Halstead, Brian (U.S. Geological Survey); Valcarcel, Patricia (Oregon State University, Canada); Wylie, Glenn; Coates, Peter; Casazza, Michael (U.S. Geological Survey, Canada)

The giant gartersnake (Thamnophis gigas) is listed as threatened by the U.S. Fish and Wildlife Service and the State of California because of extensive habitat loss within its restricted range. Little is known, however, about how the giant gartersnake selects habitat at small spatial scales. We examined microhabitat selection of the giant gartersnake to help guide habitat restoration and management efforts for this rare species. We used a case-control design, whereby we recorded the percent cover of several habitat types (open water, emergent vegetation, submerged vegetation, bare ground, litter (dead vegetation), and terrestrial vegetation) and vegetation categories (aquatic = hardstem bulrush (tule; Schoenoplectus acutus), cattail (Typha spp.), duckweed (Lemna spp.), water primrose (Ludwigia peploides), mosquitofern (Azolla spp.), algae, and rice (Oryza sativa); terrestrial = grasses (Poaceae), weedy dicots, rushes (Juncaceae), and woody shrubs and vines) within a 0.5 m radius of an individual snake‘s location and at a paired random point within 50 m of the individual‘s location during the active season (April – September, 2009 and 2010). We used Bayesian hierarchical paired logistic regression to estimate the odds of use based upon microhabitat conditions. Emergent vegetation, terrestrial vegetation, litter, and submerged vegetation were positively selected. Bare ground and open water were neither positively nor negatively selected. Rice was negatively selected by the population, but individuals were highly variable in their selection of rice habitat. Only one aquatic plant, hardstem bulrush, was positively selected. Water primrose, duckweed, and cattails were neither positively nor negatively selected. Mosquitofern, algae, and rice were all negatively selected. Rushes were the only positively selected terrestrial vegetation; all other terrestrial vegetation was used in proportion to its availability. Hierarchical case-control logistic regression provided inference to the population, quantified variability among individuals in the selection of microhabitats, and allowed an examination of selection by individual snakes in a single analysis. Our results suggest that restoration and management activities that

promote abundant cover of aquatic and terrestrial vegetation and litter, while maintaining microhabitat heterogeneity, will likely improve habitat conditions for the giant gartersnake. Restoration of native tule marsh habitat, in particular, will likely benefit giant gartersnake populations.

Robust Estimation of Giant Gartersnake Density in Linear Habitats using Spatial Capture-markrecapture Models

Halstead, Brian (U.S. Geological Survey); Wylie, Glenn; Coates, Peter; Casazza, Michael (U.S. Geological Survey, Canada)

The estimation of animal densities is essential for comparing abundances among habitat types or locations. Estimating the effective sampled area, however, can be a difficult task. Spatial capture-markrecapture (CMR) models (Royle and Young, 2008) offer a highly effective solution to this problem by estimating the latent activity center location of both captured and unobserved individuals. Estimation of density then proceeds by calculating the number of individual activity centers that occur within the sampled area. For organisms that occur in linear habitats, expression of density as a function of distance, rather than area, is often appropriate. We used a simplification of the Royle and Young (2008) model to calculate robust linear densities of the giant gartersnake (Thamnophis gigas) from spatially referenced captures on trap transects in a canal system. Closed CMR models indicated a positive effect of water temperature on capture probability of the giant gartersnake at our site, so in addition to spatial effects, we included effects of water temperature in our spatial CMR model. We captured 23 individuals 37 times in traps from 2 June – 8 July 2011. Our estimate of abundance from model-averaged closed CMR models was 44 (95% CI = 28 – 75) individuals. The corresponding density of the giant gartersnake in the sampled canal was 43 (28 – 68) individuals/km. Spatial CMR models are an effective solution to calculating herpetofaunal densities in a number of sampling situations, and can be easily modified to calculate densities in linear habitats.

A telemetry-based method for measuring animal activity

Lardner, Bjorn (Colorado State University); Savidge, Julie (Colorado State University, Fort Collins, CO, United States); Reed, Robert; Rodda, Gordon (U.S. Geological Survey, Fort Collins, CO, United States)

Radio transmitters for animal telemetry can be built to incorporate a mercury switch that causes the signal to change from a fast pulse rate to a slow pulse rate depending on how the transmitter is oriented. But the lack of signal change is not evidence that the animal did not move, because not all movements cause the switch to tip. We tried to increase the reliability of information on activity in juvenile Brown Treesnakes (Boiga irregularis) by analyzing, with the sound analysis program Avisoft SAS Lab Pro, not just pulse rate but also the signal amplitude received and recorded (with a <$100 digital recorder) at a fixed station. We exploited the fact that the transmitter‘s antenna orientation relative to the receiving antenna affects the strength of the signal received. Also the structure and density of vegetation between the transmittered animal and the receiver will cause variation in received signal amplitude when an animal travels through a heterogeneous habitat. There are commercially available data loggers that automate collection of this type of data, but they can be quite expensive – especially if more than one logger is required (as when multiple animals located far from each other are simultaneously tracked). Our solution is comparably cheap, but more labor intensive. However, we believe our method can extract more data, or data of better quality, than can commercial logging stations, because we have the ability to tailor the signal detection settings afterwards. Doing so, we can optimize the delicate tradeoff between failing to detect transmitter signals (signal discrimination threshold set too high) versus registering excessive background radio frequency noise (threshold set too low). We describe field recording obstacles that we experienced; provide pros and cons of different software analysis workflows; show how pulse rate data compare to amplitude data; and visualize how weather station data can be aligned with activity diagrams. We note that those who work on very small animals, requiring the most lightweight possible transmitters (e.g. 0.35 407g), might be able to use amplitude data alone to avoid the additional weight (0.4 – 0.5 g) inflicted by inclusion of a position-sensitive switch with the transmitter.

Detection rates of geckos in visual encounter surveys: Turning confounding variables into useful knowledge

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Visual encounter surveys without capture-mark-recapture are prone to generate population size indices suffering from an unknown bias because survey conditions differ in time and space. Knowledge of variables that cause such variation, and the size of their effects, can be used to guide the collection of relevant survey covariates, correct survey data, or anticipate situations where bias might be unacceptably large. Adjusting for these _nuisance' variables can simultaneously help shed light on the ecology of the target species. We used negative binomial regression to evaluate confounding variables for a data set where 220-meter long transects were surveyed at night, on 9,475 occasions, for invasive Brown Treesnakes (Boiga irregularis) and – as a by-product – their gecko prey (primarily Hemidactylus frenatus and Lepidodactylus lugubris). Searchers differed substantially in gecko detection rates with the most extreme pairwise comparisons differing by a factor of six. Detection rates with the worst and the best Headlamp differed by a factor of at least two. More geckos were seen during wet weather conditions, but the effect size was small. Strong winds had a negative effect on sightings, and the wind effect is potentially as large as those of searchers or headlamps. The moon phase caused 14% more gecko sightings when contrasting a detection-rate peak (waning and new moon) to a detection-rate dip (a few nights prior to full moon). The latter result was obtained when simultaneously adjusting for whether or not the moon was above the horizon at the time of the focal transect survey, which had an additive effect corresponding to 11%. Fitting a sine function to data suggested that the gecko population size was 24% higher at the end of the wet season than at the end of the dry season. There was also strong support for more long-term population fluctuations. The various factors influencing gecko counts are likely to play a role in nocturnal surveys of many cryptic species. While some factors can be addressed well with measured covariates, others will be difficult to eliminate as a significant source of error in long-term monitoring programs.

Spatial, temporal and taxonomic variation in patterns of population decline in Appalachian Plethodontid salamanders

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Highton (2005) documented widespread population declines in 28 species of Plethodon in the eastern US by the 1980's, a pattern typical of infectious disease or climate change. Between June–October 2011, We resurveyed 67 of Highton's sites, including 192 populations of 14 species of Plethodon over an area of 767 km. Our goal was to compare current species presence and abundance to historic surveys, and to determine whether Batrachochytrium dendrobatidis (Bd) was present. At each site we sampled 3, 50 x 3m plots and captured all salamanders found under cover objects. We identified each capture to species, sex, and age class; swabbed each animal for Bd; and measured snout-to-vent length (SVL), mass and body temperature. We captured a total of 1,870 salamanders (μ= 8.6/site; range = 0–75) of 14 species, swabbed 1,400 animals at 62 sites, and analyzed 612 swabs. To determine whether Bd was present historically, we swabbed museum specimens collected at 5 sites. Using results from contemporary field 426 surveys and historic data collected from those same sites between 1957–96, we compared patterns of occupancy among decades using multi-season dynamic occupancy models that account for incomplete detection. We did not find one or more species at 71% (44/62) of sites and on average we found 1.02 species missing per site (range = 0–3). Species groups varied in the amount of population loss: glutinosus were absent at 51%

(31/63) of historic sites, welleri from 50% (3/6), cinereus from 24% (14/59), and jordani from 6% (2/35). We found a significant decrease in occupancy for the genus across all sites (goodness-of-fit test; z = -3.552; p = 0.0004), with significantly greater decreases at higher elevations and lower latitudes (z = -6.03; p < 0.0001). Occupancy was initially 95% in 1950–1970,dropped to 84% in 1980 and declined to 74% since 1990. We detected low levels of infection (2–20 ZSE; μ = 7.25) by Bd in 4 individuals (0.7% prevalence) from Catoctin N.P., MD. qPCR of 258 museum specimens of cinereus and glutinosus species groups from Pisgah N.F. (1970-87) were negative, as were 184 from Shenandoah N.P. (1957-65). Analyses of museum specimens continue, to determine whether Bd was more prevalent historically. Our results support predictions of species loss from higher elevations in the southern Appalachians as explained by projected changes in regional climate (Milanovich et al. 2009). Future studies need to evaluate mechanisms of climate change on populations.

Climatic variation predictably affects clutch phenology in Agassiz's Desert Tortoise (Gopherus agassizii)

Lovich, Jeff (U.S. Geological Survey); Agha, Mickey; Liszewski, Meaghan (U.S. Geological Survey, Flagstaff, AZ, United States)

Phenology is the study of the timing and environmental causes both biotic and abiotic of biological events and life cycles. We studied clutch phenology of an Agassiz‘s Desert Tortoise (Gopherus agassizii) population at a wind energy generation facility near Palm Springs, California for seven field seasons from 1997-2011, and at Joshua Tree National Park in 1998. Using radiotelemetry and X-radiography we quantified variation in the following phenophases based on the number of calendar days since 1 January: appearance and disappearance of first and second clutches, and interclutch intervals between first and second clutches. Third clutches were only observed in five of seven years, produced by seven different females, none of which produced more than one triple clutch during the entire period of study, so they were not included in some statistical analyses. During the course of the study, shelled eggs were visible from as early as 11 April to as late as 28 July, and the total length of time that eggs were visible differed statistically among years. Appearance of first clutches in cool years was later than in warm years. After controlling for maternal effects, we observed statistically significant interannual variation in all phenophases except for interclutch intervals. Based on known and inferred oviposition dates in 2011, females dropped their eggs 1-12 days (x = 6.4) after they were last visible in X-radiographs. Using degree day methodology we calculated heat unit accumulation (HUA) during the post-hibernation and nesting season for each year. After setting our biofix to the approximate date of emergence from hibernation (March 1) at a minimum threshold temperature of 17.8o C we calculated HUA to various clutch phenological events. We then used minimum HUA during two time periods to predict the mean date of first clutch appearance in subsequent years, with 1-6 day accuracy. We also tested the broader application of HUA against reproduction data collected at Joshua Tree National Park, and predicted first clutch appearance within one day. HUA, as it relates to clutch phenology, has important management and climate modeling implications for predicting phenophases in the reproductive cycle of the federally threatened Desert Tortoise.

Skipped breeding in common toads

Muths, Erin (US Geological Survey); Scherer, Rick (Colorado State University, Fort Collins, CO, United States); Bosch, Jaime (Museo Nacional de Ciencias Naturales, Madrid, Spain)

Intensive monitoring can yield data that are useful in examining hypothesis-driven questions about particular sites or populations of amphibians. Demographic data collected from apex site monitoring in the western U.S. led to collaboration with Spanish colleagues to compare data from high elevation toad populations at sites on two continents. Breeding is limited by energetic or environmental constraints and in long-lived species it is sometimes prudent to skip breeding opportunities because of current conditions. Environmental conditions may vary considerably across the geographic and elevational range of a species and species whose life history strategies can respond variably to environmental constraints are likely to maintain populations at the

extremes of their ranges. Decisions as to whether or not to breed offer such an opportunity to adjust life history to circumstances. We use capture-recapture data to estimate the probabilities of survival and temporary emigration (i.e., skipped 503 breeding) in a high-elevation population of common toads (Bufo bufo). We compared estimates within species, to existing data on common toads at low elevations, and between toad species that share a common and similarly stressful environment. We found that common toads at high elevations sites tendto have high survival probability and high probability of skipping breeding relative to common toads at low elevations, providing preliminary evidence of variability in this component of the common toad life history strategy.

Experimental translocation of desert tortoises spanning two decades and three states

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The southwestern United States is increasingly being impacted by human activities, fueled both by urban development and associated infrastructure, and more recently with utility‐scale renewable energy development. The Mojave Desert is the focus of much of this development, and is also home to many 517 sensitive species, including Agassiz's desert tortoise (Gopherus agassizii), which is threatened throughout its range. Development disturbances within desert tortoise habitat create a management dilemma, which balances the conservation of the species against the reality of habitat losses. Translocation is frequently proposed as a minimization/mitigation strategy to move individual tortoises to areas away from harm, although translocation has remained controversial due to a paucity of peer reviewed research on the topic, and also negative opinions of many stakeholder groups and the popular press. Beginning in 1997, we initiated a coordinated research program designed to increase our understanding of the conditions under which translocation could be conducted successfully for this species. Our research has spanned nearly the entire range of the tortoise, with field sites extending from St George Utah, to Barstow California, and a variety of habitat types and abiotic conditions. We have progressively asked questions from the survivorship, reproductive behavior, and habitat use and site fidelity of desert tortoises, whether time and treatment in captivity influenced success of translocation, whether tortoises can be translocated to areas outside of typical habitat, and finally whether translocation induces measurable physiological stress. Importantly we have simultaneously studied the responses of resident and control populations of tortoises as well as translocated individuals. Collectively the results of this research indicate that by all near-term measures, that translocation can be conducted successfully. Translocated tortoises have similar survivorship, reproduction, and stress levels as compared to residents and controls, and neither time in captivity, nor pre-release conditions of providing water and forage influence these responses. Importantly, we did find that habitat use, and movements of translocated tortoises differed from resident and control animals, sometimes dramatically, yielding important management considerations for translocations of this species.

Automated Pattern Recognition Program for Leopard Frogs

Pilliod, David (US Geological Survey);

Identification of individual animals is needed for studying population demography and movement patterns and is the basis for mark-recapture analyses. Animals with unique body markings (e.g., coloration or stripes) are easily identified by the human eye from photographs. Photo-matching provides a noninvasive alternative identification method but has been limited to small datasets because of time and effort requirements of manual searches. To improve photo-matching for research purposes, Identifrog software was developed. Identifrog uses a spot-pattern recognition algorithm to identify individual northern leopard frogs (Lithobates pipiens) using images of their dorsal spot pattern. The algorithm consists of multiple reduction steps that reduce false matching images at each step. The system returns the top ten ranked individuals as closest

matches along with a classification of these into _probable' versus _not so probable' categories. The classification serves as an indication whether the query individual was previously captured or not. Identifrog was tested on a dataset of 200 individuals, with a total of 854 images. Identifrog identified 95% of the true matches in the top ten and classified 87% of the true matches as _probable' in the top ten. Depending on the discriminators, the system classified 77-84% of individuals new to the database as _not so probable' matches. Future versions of this software will adapt the spot-pattern recognition algorithms for other spotted animals by either adding or removing reduction steps suitable for animal identification.

Setting the stage for damaging invaders: Do assignations of potential invaders as low risk ignore ecosystem consequences of invasions?

Reed, Robert N. (U.S. Geological Survey); Rodda, Gordon H. (U.S. Geological Survey, Canada); Siers, Shane R.; Savidge, Julie A. (Colorado State University, Canada)

Risk assessments for invasive species typically focus on (1) the probability of a species establishing in a recipient location and (2) the probability that the species will cause ecological or economic impacts. In these risk assessment schemes, organisms that fail to receive high risk ratings for both elements are often rated fairly low in terms of overall risk. However, such schemes assign risk at a species-by-species level, without consideration of potential ecosystem-level consequences of the establishment of seeminglylow risk species. One such consequence could be that a low risk species, once established, aids the establishment or increases the impacts of a second, more damaging species. We illustrate this possibility using data on vertebrates on Guam, where the native avifauna has been largely eliminated by the invasive brown treesnake (Boiga irregularis). Of the remaining vertebrate prey items available to brown treesnakes on Guam, approximately half of the lizards and all of the terrestrial mammals are themselves introduced. Using data from historical surveys, complete removal plots, snake necropsies, and other projects, we demonstrate that current snake densities are largely tied to the availability of exotic vertebrate prey. Exotic prey historically helped sustain snake populations at high levels even while birdpopulations were being depleted on Guam, which facilitated the island-wide extinction of many bird taxa.

Furthermore, the introduction of new prey species to Guam is ongoing and these introductions could bolster snake populations, making snake control more difficult. Apart from rodents, none of the exotic prey species currently consumed by brown treesnakes would be assigned a high risk rating when subjected to most formal risk assessment schemes. Low risk species can thus set the stage for the establishment of high risk species, and by subsidizing the high risk species can increase its ecological impacts and make it more resilient to control efforts. Such considerations are as yet not incorporated in formal risk assessments for potential invaders.

Genetic erosion at the margin of a species' boundary: A case study on the threatened California Red-legged Frog (Rana draytonii)

Richmond, Jonathan (US Geological Survey); Barr, Kelly (US Geological Survey, San Diego, Canada); Backlin, Adam; Fisher, Robert (US Geological Survey, Canada)

Management of marginal populations is particularly challenging due to natural processes that typically affect such populations (i.e. reduced gene flow, smaller size, etc.) as well as _unnatural' process related to urbanization, anthropogenic-induced fires, pesticides, competition with invasive species and others. This clash of phenomena is highlighted in southern California, where recent fires and other disturbances have created new concerns for threatened taxa; however, few studies have studied the genetic consequences of modern disturbances such as fire in this landscape. Using microsatellites and mtDNA sequence data, we studied the geographic structuring and diversity of the threatened California Red-legged Frog (Rana draytonii) at the southern range limit in California, where populations have rapidly extinct since the

1960s. We found that isolated populations at the southernmost sampling sites form distinctive clusters within a larger southern phylogroup, and that genetic diversity and admixture substantially increase in populations that are closer to the species _core' in California's central Coast Ranges. For populations in which the fire history is known, we show although census sizes notably decreased in post-burn sampling, no clear loss of genetic diversity could be directly attributed to any major fires. We used use approximate Bayesian modeling to show that reductions in effective population size predate the fires in all cases. For one population, we traced the bottleneck to a catastrophic dam break in 1928 and provide evidence that reduced effective size was likely due to a founder event, given that remnant dam infrastructure is responsible for creating the current frog habitat in the canyon.

Collaborative conservation successes for native leopard frogs of the southwestern USA

Rosen, Philip (Universityof Arizona); Schwalbe, Cecil (USGS Southwest Biological Science Center, Canada); Caldwell, Dennis (Caldwell Design, Canada); Hall, David (University of Arizona, Canada)

Ranid frog conservation in the American Southwest faces 3 primary biological challenges: (1) eliminating harmful non-native animals; (2) finding warm waters or non-susceptible populations for chytridiomycosis (Bd) resistance; and (3) sustaining landscape scale metapopulations. Dispersal of non-native animals and pathogens puts a premium on landscape-level efforts and thus cooperation with multiple landholders, public and private. Regulatory issues can limit and facilitate efforts, particularly with special-status amphibians. Conflicts and synergies exist with sportfish and other native species. However, most landuse modes can be reconciled with ranid conservation. We focus on 4 case studies from Arizona involving Chiricahua Leopard Frog (Rana [Lithobates] chiricahuensis; CLF; a federally threatened species) that, over two decades, provide successful models and cautionary notes: Case 1 (San Bernardino Valley) demonstrated that private ranches are suitable conservation areas, benefitting ranchers and frogs, while highlighting concerns that discouraged private participation. Case 1 also highlighted difficulties with bullfrog control in complex environments; international boundaries; leopard frog disease and dispersal; and complications with native fish needs. In Case 2 (Altar Valley), a large National Wildlife Refuge facilitated landscape-scale success with CLF recovery, while highlighting bullfrog dispersal from adjoining ranches. Initially contentious public-private and public agency disagreements imposed heavy costs on participants, even as recovery succeeded. Fortuitous funding and perseverance reversed this, yielding total elimination of exotics from valley waters and a robust CLF metapopulation. In Case 3 (EmpireValley), a large National Conservation Area is facilitating landscape-scale recovery implementation for native aquatic vertebrates. Challenges include Bd management; bullfrog removal; increased non-native fish populations on private ranchettes; and permitting and timeliness issues for cooperating conservationists and public agencies. Cooperation of private entities reflects successes in Cases 1 and 2. In Case 4 (Pajarito Mountains), extensive public agency cooperation is facilitating bullfrog eradication across a landscape with large aquatic complexes. This ongoing effort by NGO, university, state, and federal agencies' personnel is enlarging successful recovery zones that facilitate metapopulation function of native frogs and defeat bullfrog metapopulation dynamics. Private assistance has been strong, but sportfish and crayfish challenges remain on public lands. Success throughout the Case 4 region would meet federal criteria for Recovery Unit 1 (of 7) of the Chiricahua Leopard Frog, a first step toward de-listing. Similarly active restoration efforts are occurring in other recovery units.

Amphibian Squeeze: synergistic impacts of climate change and introduced fish on amphibians in the US Pacific Northwest mountains

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Amphibians in the mountains of western North America are ―squeezed‖ between two synergistic anthropogenic threats: rapidly changing climate and introduced fish. Exotic fish (primarily trout) exclude amphibians from many deep, perennial lakes and ponds. However, the shallow fishless ponds and wetlands

on which many populations now rely may be disproportionately vulnerable to climate-induced drying. This situation presents both opportunities and challenges. Fish removals from mountain lakes have been successful in restoring aquatic habitat for amphibians, thus may represent a viable option for building resilience to climate change. However, the intensity of synergistic effects, and hence the effectiveness of fish removals for preventing declines, will vary among landscapes and species based on the amount and quality of fishless habitat and the proportion of habitats that are likely to become unsuitable for amphibians in future climates. Evaluating vulnerability to these factors across broad landscapes requires a new generation of hydrologic modeling approaches specific to wetlands, an understanding of geographic variation in the distribution of existing wetland habitats, and an assessment of life history sensitivity for a range of species. The intention of our talk is to synthesize the magnitude of this problem, and to support this overview with preliminary results from an ongoing interdisciplinary collaborative effort, which suggest that variable infiltration capacity (VIC) climate-hydrologic models can be successfully adapted to link climate models and landscape-specific amphibian species occurrence data, enabling informed vulnerability assessment and climate adaptation planning.

Assessing the impact of wildfire on desert tortoise (Gopherus agassizii) thermal biology

Snyder, Sarah (University of Nevada, Reno); Tracy, C. Richard (University of Nevada, Reno, Canada); Nussear, Kenneth; Esque, Todd; DeFalco, Lesley; Drake, Kristina; Modlin, Andrew (U.S. Geological Survey, Canada)

Recently, fires in the Mojave Desert have burned extensive portions of desert tortoise habitat. Changes in vegetative cover and species composition of desert shrubs resulting from fire can be challenging for tortoises as those vegetative elements are necessary to create the thermal heterogeneity used in behavioral thermoregulation by these ectotherms. To assess the impact of wildfire on the thermal environment, we quantified the thermal quality of burned and unburned habitat with respect to the tortoise by developing a habitat quality index using operative temperature models. To determine whether differences in habitat quality affect the thermoregulatory behavior of tortoises, we observed tortoise behavior and measured body temperatures from temperature-sensitive data loggers attached to tortoises residing within and outside of a fire perimeter. This enabled us to discern differences in daily activity time, habitat usage, and body temperature patterns among tortoises in burned and unburned areas. Results suggest burned habitat is of slightly lower thermal quality to tortoises than is unburned habitat, but tortoises readily use both habitat types to thermoregulate effectively. Our study will help to direct conservation efforts in restoring habitat of sufficient quality to maintain viable populations of the desert tortoise.

A Species Distribution Model for the Endangered Arroyo Toad, Anaxyrus californicus, in Southwestern California

Treglia, Michael (Texas A&M University); Fisher, Robert (U.S. Geological Survey, Western Ecological Research Center, Canada)

The arroyo toad, Anaxyrucalifornicus, is a U.S. endangered species, endemic to southern California, U.S.A. and northern Baja California, M.X. The species is generally associated with streams in large, sandy floodplains throughout the region. A number of factorshave caused the species to become endangered including altered flow regimes, invasive predators, and invasive vegetation that alter habitat structure. To better understand large-scale factors that influence the distribution of A. californicus, we developed species distribution models for a portion of its range, in Orange, Riverside, and San Diego Counties of southwestern California. We incorporated landscape variables such as topography, soil type, and land cover, as well as vegetation and climatic data. The distributional data that we used to develop our models were derived from multiple sources including locality information associated with voucher specimens in museum collections, data provided by the U.S. Fish and Wildlife Service, and distribution surveys conducted by the U.S. Geological Survey, Western Ecological Research Center. We used maximum entropy methodology for data that were considered as —presence-only‖ (i.e., no survey data are available to confirm absence of the species from sites), and

regression-based approaches for data that could be considered as ―presence/absence‖ (i.e., specific distribution surveys that could confirm presence as well as absence). These species distribution models can be used to identify potential habitat where A. californicus may exist but has not been surveyed. Additionally, our approaches can be used to help predict changes in the species' distribution under various future scenarios including climate change and regional alterations to land cover. We will continue to develop these models to incorporate the recent history of regional land cover change, and to analyze changes in the distribution of A. californicus. By analyzing influences of regional land cover on the presence of habitat for this endangered species, we hope to develop a more thorough understanding of the steps necessary for its conservation.

Long-term trends in anuran occupancy in the Atchafalaya Basin of Louisiana

Waddle, Hardin (U.S. Geological Survey)

The Atchafalaya River Basin in southern Louisiana is the largest contiguous tract of river bottomland remaining in North America. The U.S. Geological Survey has been monitoring anuran amphibians in the Atchafalaya for the last decade (2002–2012). Monitoring from 2002-2006 consisted of a series of vocalization surveys conducted on rainy nights at 40 sites. Sampling was suspended in 2007 and from 2008-2012 monitoring resumed using both visual encounter surveys and vocalization surveys. Additional sites have been added, but the majority of the 40 original sites are still being surveyed. This long-term dataset provides an excellent opportunity to examine the occupancy dynamics of the 12 species of anurans found in this area. Most of the species declined in site occupancy during the 2002-2006 period when only vocalization surveys were employed. Analysis of the vocalization data from 2008-2012 will reveal if this 5-yr trend was indicative of a long-term decline in occupancy or only the downward phase of a cyclical occupancy pattern in the Atchafalaya. Examination of the visual encounter data from recent surveys will also help determine the value of capture data in estimating occupancy and detecting a trend relative to vocalization surveys alone. Because anurans call for specific purposes and calling is influenced in various ways by environmental conditions, it may be difficult to account for all of the causes of heterogeneity in detection probability using occupancy analysis based solely on vocalization surveys. Combining visual detections may provide a dataset that is more reliable for determining true occupancy dynamics and less disposed to trends than vocalization data only.

Occupancy dynamics in a pair of pond-breeding amphibians: Testing contrasting predictions about the impacts of climate change

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Climate change is anticipated to be one of the major drivers of ecological change of this century. In the last three decades, the average annual temperature in the southeastern U.S. has risen approximately 1.1°C, with the greatest increase occurring in winter. During this time, precipitation has decreased, primarily in winter and spring. Continuation of these trends could negatively impact pond-breeding amphibians, especially those that rely on winter and spring rains to fill seasonal wetlands, trigger breeding, and ensure reproductive success. From 2009 to 2012, we monitored two winter-breeding amphibians (the Ornate Chorus Frog [OCF], Pseudacris ornata, and the Mole Salamander [MS], Ambystoma talpoideum) at St. Marks National Wildlife Refuge, in northwest FL, USA. Life histories differ in these species: MS typically occurs in long-hydroperiod wetlands and exhibits paedomorphosis, whereas OCF preferentially breeds in fishless, ephemeral ponds with short hydroperiods. We predicted that, under a scenario of ongoing drought, estimates of local extinction would increase and occurrence probabilities would decrease for MS if breeding sites dried prematurely. Because OCF has high dispersal, short larval periods, and exploits ephemeral ponds, we predicted that this species would 762 occupy sites at or near historically known breeding sites if inundated long enough for successful larval development. Under these conditions, occupancy for OCF should be stable over time, but could decrease in years of severe drought. We deployed automated recorders to monitor calling activity of

OCF and used traps to capture MS at upland ponds. Overall, approximately 22% and 62% of the ponds we sampled were occupied by MS and OCF, respectively. For MS, model-averaged estimates of occupancy probabilities, corrected for imperfect detection, progressively decreased over time as drought severity increased. Estimates of extinction probabilities for MS increased from 0.0 to 0.699 over the course of our study, whereas estimates of colonization probabilities were low (0.085-0.096) and less variable. These results suggest that the decline in occupancy may have been due to an increase in the probability of extinction rather than a decrease in the probability of colonization. In contrast, estimates of occupancy probabilities for OCF were stable over time, except for one year with breeding failure due to dry ponds. These results demonstrate that species with contrasting life histories may respond differently to perturbations such as drought. Under the current scenario of rapid global ecological change, it is especially important that a species' life history and ecology serve as the foundation for predictions about climate change impacts, as well as for identifying species as —models‖ for studying environmental change.