Focal Resource: MOUNTAIN & SIERRA NEVADA YELLOW-LEGGED FROGS

Taxonomy and Related Information

Mountain yellow-legged frog (*Rana muscosa)*; Sierra Nevada yellow-legged frog (*Rana sierra)*; occur across Sierra Nevada mountains.

General Overview of Process

EcoAdapt, in collaboration with the U.S. Forest Service and California Landscape Conservation Cooperative (CA LCC), convened a 2.5-day workshop entitled *A Vulnerability Assessment Workshop for Focal Resources of the Sierra Nevada* on March 5-7, 2013 in Sacramento, California. Over 30 participants representing federal and state agencies, non-governmental organizations, universities, and others participated in the workshop[1]. The following document represents the vulnerability assessment results for **MOUNTAIN & SIERRA NEVADA YELLOW-LEGGED FROGS**, which is comprised of evaluations and comments from a participant breakout group during this workshop, peer-review comments following the workshop from at least one additional expert in the subject area, and relevant references from the literature. The aim of this synthesis is to expand understanding of resource vulnerability to changing climate conditions, and to provide a basis for developing appropriate adaptation responses. The resulting document is an initial evaluation of vulnerability based on existing information and expert input. Users are encouraged to refer to the Template for Assessing Climate Change Impacts and Management Options (TACCIMO, http://www.taccimo.sgcp.ncsu.edu/) website for the most current peer-reviewed literature on a particular resource. This synthesis is a living document that can be revised and expanded upon as new information becomes available.

Geographic Scope

The project centers on the Sierra Nevada region of California, from foothills to crests, encompassing ten national forests and two national parks. Three geographic sub-regions were identified: north, central, and south. The north sub-region includes Modoc, Lassen, and Plumas National Forests; the central sub-region includes Tahoe, Eldorado, and Stanislaus National Forests, the Lake Tahoe Basin Management Unit, and Yosemite National Park; and the south sub-region includes Humboldt-Toiyabe, Sierra, Sequoia, and Inyo National Forests, and Kings Canyon/Sequoia National Park.

Key Definitions

Vulnerability: Susceptibility of a resource to the adverse effects of climate change; a function of its sensitivity to climate and non-climate stressors, its exposure to those stressors, and its ability to cope with impacts with minimal disruption[2].

Sensitivity: A measure of whether and how a species or system is likely to be affected by a given change in climate or factors driven by climate.

[1] For a list of participant agencies, organizations, and universities please refer to the final report *A Climate Change Vulnerability Assessment for Focal Resources of the Sierra Nevada* available online at: http://ecoadapt.org/programs/adaptation-consultations/calcc.

[2] Glick, P., B.A. Stein, and N.A. Edelson, editors. 2011. Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment. National Wildlife Federation, Washington, D.C.

Adaptive Capacity: The degree to which a species or system can change or respond to address climate impacts.

Exposure: The magnitude of the change in climate or climate driven factors that the species or system will likely experience.

Methodology

The vulnerability assessment comprises three vulnerability components (i.e., sensitivity, adaptive capacity, and exposure), averaged rankings for those components, and confidence scores for those rankings (see tables below). The sensitivity, adaptive capacity, and exposure components each include multiple finer resolution elements that were addressed individually. For example, sensitivity elements include: whether the species is a generalist or specialist; physiological sensitivity to temperature, precipitation, and other factors (e.g., pH, salinity); dependence on sensitive habitats; species' life history; sensitivity of species' ecological relationships (e.g., predator/prey, competition, forage); sensitivity to disturbance regimes (e.g., wind, drought, flooding); and sensitivity to non-climate stressors (e.g., grazing, recreation, infrastructure). Adaptive capacity elements include: dispersal ability and barriers to dispersal, phenotypic plasticity (e.g., can the species express different behaviors in response to environmental variation), species' potential to adapt evolutionarily to climate change, species' intraspecific/life history diversity (e.g., variations in age at maturity, reproductive or nursery habitat use, etc.), and species' value and management potential. To assess exposure, participants were asked to identify the climate and climate-driven changes most relevant to consider for the species and to evaluate exposure to those changes for each of the three Sierra Nevada geographic sub-regions. Climate change projections were provided to participants to facilitate this evaluation[3]. For more information on each of these elements of sensitivity, adaptive capacity, and exposure, including how and why they were selected, please refer to the final methodology report *A Climate Change Vulnerability Assessment for Focal Resources of the Sierra Nevada*[4].

During the workshop, participants assigned one of three rankings (High (>70%), Moderate, or Low (<30%)) to each finer resolution element and provided a corresponding confidence score (e.g., High, Moderate, or Low) to the ranking. These individual rankings and confidence scores were then averaged (mean) to generate rankings and confidence scores for each vulnerability component (i.e., sensitivity, adaptive capacity, exposure score) (see table below). Results presented in a range (e.g. from moderate to high) reflect variability assessed by participants. Additional information on ranking and overall scoring can be found in the final methodology report *A Climate Change Vulnerability Assessment for Focal Resources of the Sierra Nevada*[4].

Recommended Citation

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[3] Geos Institute. 2013. *Future Climate, Wildfire, Hydrology, and Vegetation Projections for the Sierra Nevada, California: A climate change synthesis report in support of the Vulnerability Assessment/Adaptation Strategy process.* Ashland, OR. http://ecoadapt.org/programs/adaptation-consultations/calcc.

[4] Kershner, J.M., editor. 2014. *A Climate Change Vulnerability Assessment for Focal Resources of the Sierra Nevada.* Version 1.0. EcoAdapt, Bainbridge Island, WA. http://ecoadapt.org/programs/adaptation-consultations/calcc.

This document is available online at EcoAdapt (http://ecoadapt.org/programs/adaptation-consultations/calcc).

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Overview of Vulnerability Component Evaluations

SENSITIVITY

Sensitivity Factor	Sensitivity Evaluation	Confidence
Generalist/Specialist	**3 Specialist**	**2 Moderate**
Physiology	**3 High**	**3 High**
Habitat	**3 High**	**3 High**
Life History	**1 R-selection**	**3 High**
Ecological Relationships	**3 High**	**2 Moderate**
Disturbance Regimes	**3 High**	**3 High**
Non-Climatic Stressors – Current Impact	**3 High**	**3 High**
Non-Climatic Stressors – Influence Overall Sensitivity to Climate	**2 Moderate**	**1 Low**
Other Sensitivities	**No answer provided by participants**	**No answer provided by participants**

Overall Averaged Confidence (Sensitivity)[5]: Moderate–High

Overall Averaged Ranking (Sensitivity)[6]: Moderate–High

ADAPTIVE CAPACITY & EXPOSURE

These sections were not completed by participants in the time allotted.

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[5] 'Overall averaged confidence' is the mean of the entries provided in the confidence column for sensitivity, adaptive capacity, and exposure, respectively.

[6] 'Overall averaged ranking' is the mean of the perceived rank entries provided in the respective columns.

Sensitivity

1. Generalist/Specialist.

a. Where does species fall on spectrum of generalist to specialist: Specialist
   i. Participant confidence: Moderate

b. Factors that make the species more of a specialist: Phenology dependency

Additional comments: Factors that make the species more of a specialist include dependence on water availability for breeding. Overall, these species are considered specialists because of habitat needs, not because of diet needs.

References: The Sierra Nevada and mountain yellow-legged frogs occupy high-elevation (i.e. 1370 m to 3660 m) (4495 ft to 12008 ft) lakes, seeps and springs, slow-moving streams (Lacan et al. 2008), and meadows. Both species of mountain yellow-legged frog are dependent on perennial water for breeding and prolonged larval development (Lacan et al. 2008).

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2. Physiology.

a. Species physiologically sensitive to one or more factors including: Temperature, precipitation, salinity, pH, dissolved O2, other – disease

b. Sensitivity of species' physiology to one or more factors:
   i. Participant confidence:

Additional comments: The egg and larval stages are extremely sensitive to water quality. Currently there are studies examining the impacts of pollution on frog declines to determine if there is a correlation. Although not a direct impact on frog physiology, the main disease threat (Chytrid fungus) cannot survive in hot temperatures but does well in cold, upper elevations.

References: In addition, warming water temperatures may exert both positive and negative influence on mountain yellow-legged frogs. Stream temperatures have increased in recent decades as air temperatures have increased (Hari et al. 2006, Webb and Nobilis 2007, and Kaushal et al. 2010 cited in Null et al. 2012). Water temperatures influence the biological, physical, and chemical properties of aquatic ecosystems, including dissolved oxygen levels, nutrient cycling, productivity, metabolic rates and life histories (Vannote and Sweeney 1980; Poole and Berman 2001). Warming may benefit mountain yellow-legged frogs if it results in decreased time to metamorphosis, as occurs with some species (e.g. Pacific tree frog) (Paull et al. 2012). Warming may also alter susceptibility to infection and infection rates, although the relationship in North American amphibians is often nonlinear. Warming may increase the ability of a pathogen to penetration the host, but also decrease a tadpole's period of sensitivity (Paull et al. 2012). Furthermore, pathogen outbreaks in foothill yellow-legged frogs in Northern California associated with warm temperatures (e.g. *Lernaea cyprinacea*) may be aided by reduced water levels, resulting in higher densities of larvae and easier transmission of the pathogen (Kupferberg et al. 2009).

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3. Sensitive habitats.

a. Species dependent on sensitive habitats including: Seasonal streams, seeps/springs, alpine/subalpine, other – perennial water

b. Species dependence on one or more sensitive habitat types: High
   i. Participant confidence: High

Additional comments: There is high dependence on perennial water; for example, successful breeding requires perennial water because egg to metamorphosis is 2-3 years.

References: Breeding occurs primarily in smaller lakes, which are more susceptible to drying (Lacan et al. 2008). Highest egg mass counts have been recorded in summers following high snowpack, and snowpack reductions predicted in the northern Sierra Nevada (Safford et al. 2012) may reduce Sierra Nevada yellow-legged frog recruitment success as the frequency of summer drying of small lakes increases (Lacan et al. 2008). Full metamorphosis for the Sierra Nevada population segments requires two to four years (Knapp and Matthews 2000; Lacan et al. 2008), and drying even once in 10 years yielded a significantly lower abundance of metamorphs than lakes and ponds that remained wet (Lacan et al. 2008).

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4. Life history.

a. Species reproductive strategy: R-strategy
    i. Participant confidence: High
b. Species polycyclic, iteroparous, or semelparous: Iteroparous

Additional comments: There is a very low survival rate overall (many different life stages that may not survive).

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5. Ecological relationships.

a. Sensitivity of species' ecological relationships to climate change including: Forage, habitat, hydrology
b. Types of climate and climate-driven changes that affect these ecological relationships including: Temperature, precipitation, pH (changes in water chemistry from runoff and wildfires)
c. Sensitivity of species to other effects of climate change on its ecology: High
    i. Participant confidence: High

Additional comments: Forage may also be sensitive if macroinvertebrate abundance changes.

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6. Disturbance regimes.

a. Disturbance regimes to which the species is sensitive include: Wildfire, drought, flooding, other – long winter, extreme cold
b. Sensitivity of species to one or more disturbance regimes: High
    i. Participant confidence: High

Additional comments: Disturbance regimes include wind (could be an issue for dispersion from water body to water body and/or an issue of desiccation), wildfire (frequency and severity), flooding (severity and timing), drought (frequency, severity, duration), and extreme cold (frequency and severity).

References: In other areas, such as Colorado, extinctions of amphibian species in montane regions are attributed to drought conditions experienced during the mid 1970s (Finch et al. 2012). However, no clear pattern exists regarding effects of wildfire on amphibians, possibly because there are limited studies for most species. Response to fire varies according to life history strategy. According to a meta-analysis conducted by Hossack and Pilliod (2011), of 19 populations in the Western U.S., studied before and after fire, 7 displayed negative response to fire, 5 positive, and 6 displayed no response to fire. Fire effects were greater in forests where fire had been suppressed and in areas that burned with high severity. Species that breed in streams were also vulnerable to post-fire habitat changes, especially in the Southwest, as pools may dry or fill with sediment, and post-fire debris flows may greatly reduce rearing habitat. In contrast to fishes, amphibian re-colonization from adjacent areas is expected to occur slowly (Hossack and Pilliod 2011).

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7. Interacting non-climatic stressors.

   a. Other stressors that make the species more sensitive include: Residential and commercial development, agriculture and aquaculture (fish stocking, grazing), energy production and mining, transportation and service corridors, biological resource use (logging), human intrusions and disturbance, natural system modification, invasive and other problematic species, pollution and poisons
   b. Current degree to which stressors affect the species: High
      i. Participant confidence: High
   c. Degree to which non-climate stressors make species more sensitive: Moderate
      i. Participant confidence: Low

Additional comments: Both frogs are high elevation species and as such, responses above are based in that context.

References: Mountain yellow-legged frogs are sensitive to a number of non-climatic stressors, including high-elevation non-native fish stocking (Bradford 1989; Knapp and Matthews 2000; Null et al. 2012), agrochemical contamination (Davidson et al. 2002, Davidson and Knapp 2007), and fungal infections (Fellers et al. 2001; Wake and Vredenburg 2008), which may compound species sensitivity to climate-driven changes. Rivers on the western slope of the Sierra Nevada above about 2000 m (6562 ft) were mostly fishless prior to stocking, although they are now managed to sustain several native and non-native trout (Viers and Rheinheimer 2011). Studies have found that stocked non-native trout have contributed to the decline of mountain yellow-legged frogs (Bradford 1989; Bradford et al. 1994; Knapp and Matthews 2000) and may severely limit breeding habitat to smaller ponds prone to desiccation (Lacan et al. 2008), compounding possible mortality from desiccation and other climate-driven changes. In addition, it has been suggested that airborne pesticides have contributed to the decline of mountain yellow-legged frog populations (Davidson et al. 2002; Fellers et al. 2004). The long metamorphosis of tadpoles in the Sierra Nevada populations and the fact that adults spend nearly all their time in the water make them especially susceptible to pesticide poisoning (Fellers et al. 2004). Declines of mountain yellow-legged frog were found concentrated in lower elevation sites in California, and were associated with the amount of upwind agricultural land use, suggesting that mountain yellow-legged frogs may be particularly sensitive to agrochemicals (Davidson et al. 2002). Analysis of tissue from other Sierra Nevada frogs indicates that high-elevation frogs accumulate pesticides, and that tissue concentrations can be better indicators of exposure than water and soil concentrations (Smalling et al. 2013). Sub-lethal impacts resulting from pesticides, including reduced resistance to disease, are also likely (Sparling 1994 cited in Fellers et al. 2004; Smalling et al. 2013). In contrast, other studies suggest that pesticides may not contribute to the decline of mountain yellow-legged frogs in the alpine regions of the southern Sierra Nevada, but rather that declines are consistent with a pattern of spread of chytridiomycosis (Bradford et al. 2011). Chytridiomycosis, an emerging infectious disease caused by a fungal pathogen, *Batrachochytrium dendrobatidis*, is having a devastating impact on native frogs of the Sierra Nevada, already weakened by the effects of pollution and introduced predators (Fellers et al. 2001; Wake and Vredenburb 2008; Bradford et al. 2011).

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8. Other sensitivities.

   a. Other critical sensitivities not addressed: No answer provided by participants
      i. Participant confidence: No answer provided by participants
   b. Collective degree these factors increase species' sensitivity to climate change: No answer provided by participants

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9. Overall user perceived ranking.

a. Overall sensitivity of this species to climate change: High
    i. Participant confidence: Moderate

Adaptive Capacity & Exposure

Workshop participants were unable to complete the Adaptive Capacity and Exposure sections of the Vulnerability Assessment for Sierra Nevada and Mountain Yellow-Legged Frogs. Please refer to the vulnerability briefing titled *Sierra Nevada Individual Species Vulnerability Assessment Briefing: Mountain Yellow-Legged Frogs* for an overview of vulnerability findings for these species.

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