## **From Frog to Forest Conservation: Identifying Climate-Refugia for At-Risk Species in the Southern Sierra Nevada Forest**

**Poster – AGU 2020**

Claudia Mengelt1, Kat Powelson1, Toni Lyn Morelli2, Nicole Athearn3, Carolyn Enquist4, Cathleen Balantic2, Andrea Adams5, Mary Grim1, Chelsea Tanner6

**Abstract**

Incorporating climate change impacts into habitat restoration and species conservation remains challenging for natural resource managers for many reasons, including:

1) To date, stressors such as urbanization, agriculture, catastrophic fires, drought, and invasive species have the largest impact on the demographics and persistence of relatively short-lived, at-risk species;

2) Research synthesis and adaptation planning often ends with identifying actions to be implemented without the funds or authority to implement; and

3) Most agencies’ statutory requirements, missions, and funding allocations are not aligned with climate change adaptation/mitigation or managing for decadal scales.

Efforts to bridge the gap between managing for the current priorities and long-term climatic changes are needed. To accomplish this, short-term conservation efforts can be combined with climate adaptation frameworks such as climate refugia design to increase resilience to current stressors and future climatic changes. This work interfaces with on-going regional and national research to operationalize climate change refugia conservation into state and federal management actions by assembling scientists and decision-makers in a collaborative conservation planning and implementation effort.

Several species in the Southern Sierra Nevada are at-risk, such as Foothill-Yellow-Legged Frog or Western Pond Turtle require some immediate actions to protect the remaining populations. At the same time, climate change impacts such as heat stress, declining snowpack, and catastrophic fires pose an additional risk to their long-term persistence in these forests. To address these multiple management needs and objectives, this project incorporates the latest science and practice of decision-analysis with novel conservation science. Here we present preliminary results of this collaborative approach. We will describe a pathway to overcoming the knowledge-to-action barrier and how we will move from a design a climate-refugia to achieve these multiple spatial and temporal management objectives.

**Background**

This project aims to incorporate the latest science in decision-analysis, conservation biology, and climate change adaptation to design and implement a network of climate-refugia for two [at-risk species](http://www.fws.gov/at-risk/pdf/at-risk-species-conservation-pacific-southwest.pdf): Foothill Yellow Legged Frog and Western Pond Turtle. This project aims to overcome two major barriers to climate adaptation:

1. Knowledge-to-action barrier, and
2. Managing today's crisis instead of adapting to future climatic changes

***Study Site***



Figure 1. Map of Tuolumne and Merced Watersheds (HUC 08) and observations of this project's two focal species (foothill yellow-legged frog and western pond turtle). Data source: 1 [California Natural Diversity Database](https://wildlife.ca.gov/Data/CNDDB) - locations are obscured, 2 [NRCS Watershed Boundary Dataset](https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/water/watersheds/dataset), 3 [Jepson Ecoregions](https://ucjeps.berkeley.edu/eflora/geography.html)

Southern Sierra Nevada snowpack is projected to decrease significantly under projected climate change, and precipitation is likely to arrive in the form of rain instead of snow. As a result, peak run-off will be earlier in the season with a direct impact on aquatic species that have phenology linked to the timing of the peak run-off. Downstream, the San Joaquin Valley and San Francisco depend on the Southern Sierra for water storage and water delivery during the dry and hot summers. Considering the summer temperature increases projected for the central valley, the future water deficit in the summer will likely increase significantly [[1]](https://www.pnas.org/content/112/13/3931.short). Therefore, managing mountain ecosystems to maximize water retention on the landscape and groundwater recharge will be an important climate adaptation opportunity in the face of the projected loss of snowpack in the Southern Sierra Nevada Mountains.

Maintaining drought and fire-resilient forests in the Sierra Nevada mountains and foothills will be challenging due to multiple stressors. When landscape-scale disturbances deviate from the historic disturbance regime to which an ecosystem has adapted, the landscape loses biodiversity and, in the worst case, becomes invaded by non-native species. Hydrological and temperature changes associated with climate change combined with past fire-suppression have changed the fire-disturbance regime in the Sierra Nevada forests. There is broad consensus that restoring the natural fire regime and returning to a heterogenous forest with thinner stand density will improve ecosystem function and increase water retention on the landscape [[2]](https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2018WR024098)[[3]](https://onlinelibrary.wiley.com/doi/abs/10.1002/eco.1978).

***Foothill Yellow Legged Frog and Western Pond Turtle Ecology and Threats***

**Ecology:**

* Foothill yellow-legged frog is primarily stream dwelling and an obligate stream breeding species that occurs from sea level to 1940 meters elevation. Foothill yellow-legged frogs can occur in streams associated with a wide variety of vegetation types including valley-foothill hardwood, valley-foothill hardwood-conifer, valley-foothill riparian, ponderosa pine, mixed conifer, mixed chaparral, and wet meadows [[4]](https://www.fs.fed.us/psw/publications/documents/psw_gtr248/psw_gtr248.pdf)
* Western pond turtles use both aquatic and terrestrial habitats. They utilize lotic and lentic habitats, and are more abundant in habitats with basking sites [[5]](https://bioone.org/journals/journal-of-herpetology/volume-43/issue-3/08-033R2.1/Variation-in-Body-Size-Growth-and-Population-Structure-of-span/10.1670/08-033R2.1.short). Western pond turtles require terrestrial habitat for nesting, overwintering, dispersal, and aestivation.

**Threats:**

* Both of these species have experience reductions in population size and local extirpations, at varying intensities across their ranges. Both are affected by multiple interconnected stressors, which can make it challenging to identify the most efficient and effective management solutions.
* Non-native species: predation and competition by non-native species including American bullfrogs (Rana catesbeiana), smallmouth bass (Micropterus dolomieui), crayfish (e.g, Procambarus species) and largemouth bass (Micropterus salmoides)
* Habitat loss: Both species have experienced habitat loss, degradation, and fragmentation as a result of land use change, drought, and wildfire.
* Disease: Batrachochytrium dendrobatidis (Bd) is a fungal pathogen thought to be one of the main factors leading to the extirpation of foothill yellow-legged frogs on the Southern California Coast [[6]](https://onlinelibrary.wiley.com/doi/full/10.1002/ece3.3468). The effect of Bd in the Southern Sierras is not well understood.
* Altered hydrology: FYLF life history and habitat needs are closely tied to the timing and velocity of stream flows.  As a result, changes in stream hydrology can have direct and indirect negative impacts on FYLF populations.

**Knowledge-to-Action Barrier**

Much has been written about the efficacy and limitations of knowledge transfer to decision-making and action-taking [[7]](https://www.sciencedirect.com/science/article/pii/S0006320720307564)[[8]](https://esajournals.onlinelibrary.wiley.com/doi/10.1002/fee.1733)[[9]](https://www.pnas.org/content/107/51/22026) etc. Natural scientists and resource managers have greatly advanced the sophistication of approaches to incorporating science into decision-making based in decision-analysis and other social sciences [[10]](https://onlinelibrary.wiley.com/doi/book/10.1002/9781444398557) [[11]](https://pubmed.ncbi.nlm.nih.gov/23574343/). Despite these advances in improving science application to decision-making and conservation or adaptation planning, moving from planning to action-taking faces substantial barriers and many planning documents remain just plans [[7]](https://www.sciencedirect.com/science/article/pii/S0006320720307564).



Figure 2. From Wright et al. 2020 [[7]](https://www.sciencedirect.com/science/article/pii/S0006320720307564) Analysis of 12 case studies that used structured decision making were assessed success across multiple stages from identifying leadership to identifying optimal actions all the way to implementation and the final desired outcome related to biological integrity. It is noteworthy that few of these case studies resulted in achieving their state objectives, let alone achieving the desired biological integrity. Often, these case studies were not successful in securing funding for implementation.

Building on the lessons learned from the case studies in Wright et al. [[7]](https://www.sciencedirect.com/science/article/pii/S0006320720307564), this project aims to overcome these barriers by aligning funds and partners for implementation as an integral part of the planning process.

**A Pathway from Planning to Action**

*Problem Framing* - The initial decision problem will most likely be framed as the design of a cost-effective strategy to guide where and what actions to take to maximize population persistence and viability in the Tuolumne or Merced watershed. This particular decision-problem however is linked to additional decisions to be analyzed:

Linked Decision 1: Where do we want to implement the optimal actions identified as part of the first decision-problem to maximize  persistence in the face of current stressors?

Linked Decision 2:  Where do we want to optimize future actions to maximize adaptive capacity and persistence in the face of anticipate climate change impacts?

Linked Decision 3: Within the presumed climate refugia, what actions need to be optimized now to increase the likelihood of persistence in the future?

*Objective* – One of the most fundamental objective is presumed to be to maximize persistence of Rana boylii and Western Pond Turtle in the Tuolumne or Merced watershed in the short-term and long-term while minimizing cost.

*Conceptual Model* - When considering potential actions to maximize persistence of Rana boylii in the Tuolumne or Merced watersheds, it is helpful to consider a simple conceptual model that illustrates how stressors and management actions might impact the species.



Figure 3: Conceptual Model for Foothill Yellow Legged Frog – This logic model illustrates the mechanistic links between A. habitat quality (light green oval) and threats to the habitat (orange boxes); B. threats (orange boxes) to the population and population’s fecundity, survival, and dispersal (light green boxes); and C. fecundity, survival, dispersal, occupancy and the fundamental objective of maximizing the persistence of the populations in the Tuolumne and Merced watersheds. The blue boxes represent the categories of management actions to either reduce the threats to the habitat and populations or directly benefit the habitat or populations.

*A Menu of Options* - To develop the optimal management strategy, individual management actions presented in the strategy table (Table 1) will be evaluated for conservation benefits and costs as part of the consequence and trade-off analysis that will yield the optimal portfolio of actions in any given stream reach within the Tuolumne or Merced watershed.

Table 1. The menu of options lists the individual management actions for each category of potential management actions such as habitat restoration or direct population management actions. When developing an optimal strategy to maximize the likelihood of persistence of the population, different portfolios of actions are composed from the menu of options.



*Optimizing the portfolio of actions*

Potential portfolio of actions (also referred to as strategy) might be comprised of more or less restoration actions versus population management actions depending on which will perform better against the objectives. To illustrate the optimization process, three hypothetical strategies follow:

Strategy A - Focused on Threat management: Invasive species removal; Decrease threats from altered hydrology (i.e. work with dam operators to mimic natural hydrography)

Strategy B - Habitat Management: Restore channel morphology, increase availability of gravel substrate, increase availability of side channels, restore riparian vegetation, reduce availability of bullfrog habitat

Strategy C (Population Management): in-situ head-starting, disease management, captive rearing

The optimal strategy will be selected based on the maximizing the benefits of all the actions in a given strategy versus the cost. Specifically, each action (xi) part of the strategy would provide benefits to the frog (Bi) and incur costs (Ci). Thus, the optimal strategy would be selected according to the following:

Once the optimal strategy - a combination of the possible actions listed in the strategy table - is identified through expert elicitation during the SDM workshop, project funding is available to initiate at least the first year of implementation and staffing to develop proposals to leverage the already committed funds. The implementation will be accompanied by rigorous monitoring to improve the ability to assess the benefits (bi) of each action and improve the optimization model for the future and adjust the management. This will likely help overcome the first implementation barrier.

**Methods**

To optimize the selection of conservation actions to address present and future threats, this project combines two decision-analytical frameworks: the PrOACT cycle [10] and the the climate-refugia design framework [[12]](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0159909). Both of these frameworks build on an extensive body of research in decision-analysis and adaptation planning. A major benefit from employing structured decision-making is to disentangle the complexity of resource management decision and explicitly incorporate value judgment (why is this a difficult decision? what do we care about?) into an objective cost-benefit analysis of the different management actions (how do we fix it?).



Figure 4. The PrOACT Cycle: Based in the science of decision-analysis, the diagram depicts the steps in the PrOACT [Problem-Objectives-Alternatives-Consequences-Trade-off Analysis] cycle.

Climate-Refugia Design [[12]](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0159909)  for details on the climate refugia conservation approach see the companion poster and [Climate Refugia Network](https://www.climaterefugia.org/)

**Overcoming Barriers to Climate Adaptation**

***From Planning to Implementation:***

**This project aims to achieve implementation and overcome the barriers identified by heading the recommendations in Wright et al [] particularly with regards to funding limitations, the need for leadership, and early, measurable milestones for achievements. Thus, our effort focuses on:**

1) Management Strategy is optimized to fit the currently available budget

2) Planning scope is commensurate with the authority and willingness to implement

3) Optimized strategy is scalable to increase as available funding and partners with authority to implement expands

Developing this decision-framework aims to enable us to prioritize actions to manage current threats to at-risk species while also working toward climate resilience and avoiding the dichotomy between short-term versus long-term planning horizons. It demonstrates how to mainstream climate adaptation into current natural resource policy and management priorities [[13]](https://link.springer.com/article/10.1007/s10113-017-1259-5#Sec12). Furthermore, it combines the prioritization of “what to do” with “where to undertake the priority actions” both to address current and future vulnerabilities.

**Acknowledgement:**

Funding for this research is provided by USFWS, Science Applications Program and USGS' Southwest Climate Adaptation Science Center