Frogs to Forest Refugia:

Designing Climate-Resilient Habitat for At-Risk Species in the Southern Sierra Nevada Forest

Co-PIs: Claudia Mengelt, USFWS; Nicole Athearn, NPS; Toni Lyn Morelli, USGS

Project Partners:

Andrea Adams, UCSB; Sarah Kupferberg, Independent Researcher; Laura Patterson, CDFW; Mary Grim, USFWS; Brian Halstaed, USGS; Holly Edinger, FS; Sarah Sawyer, FS; Kat Powelson, FWS; Hugh Safford, FS; Christy Brigham, NPS;

Abstract

Incorporating considerations about climate change impacts into habitat restoration and at-risk species conservation continues to be difficult for managers for several reasons: 1) Currently, stressors such as catastrophic fires, drought, and invasive species have a bigger impact on the demographics and persistence of relatively short-lived, at-risk species. 2) Most agencies' missions and funding allocations are not aligned with managing for decadal scales.

This project aims to advance our knowledge base for bridging the gap between managing for the current mandates and priorities and long-term climatic changes. We will develop an on-the-ground demonstration project for a climate refugium that can increase resilience to current stressors as well as for future climatic changes to the long-term means and the extremes. Thus, the project will develop new adaptation science and resource management approaches through the co-production model and by designing a climate refugium for several at-risk species that considers current and future habitat needs. Furthermore, we will demonstrate how to integrate immediate research and conservation needs with longer-term climate adaptation research needs and develop a decision-making approach that can guide within-year planning, 5-year strategic planning, and decadal-scale scenario-based planning.

Project Outcomes:

1) Spatial and statistical design for habitat conservation and restoration that maximizes short-term conservation needs and long-term climate resilience.
2) An Adaptive Management design that leverages existing research and monitoring capacity to enhance populations of at-risk aquatic species, birds, and small mammals.
3) A project proposal for a long-term climate adaptation research and implementation project that leverages federally funded research results and funding with private and state funds to restore aquatic ecosystems and forested habitat to maximize climate resilience and enhance the adaptive capacity of existing wildlife populations.
4) Novel approach and understanding for maintaining at-risk species populations in the Southern Sierra Nevada

Background

Climate change adaptation research has made major advances over the last decade. For example, much is known about the impacts of climate change; many novel adaptation planning approaches have been developed (Glick et al. 2009, Morelli et al. 2016, etc.); decision tools have become ubiquitous; and many novel adaptation options have been proposed. Over the next decades, research is needed to demonstrate how these adaptation planning schemes can translate to adaptation implementation on the ground. It is critical that the implementation of adaptation actions is accompanied by statistically rigorous observations to draw causal inferences about the effectiveness of those actions intended to yield climate resilience.

This project proposes to integrate the latest advances in research on climate change impacts on the Sierra Nevada forested and aquatic ecosystems (Albano et al. 2018, Broderick et al. 2019, Howard et al. 2019) with novel advances in climate refugia planning and structured decision-making (Morelli et al. 2016) to A) design a conservation/climate adaptation plan that yields important near-term benefits for multiple at-risk species; and B) result in long-term climate resilience. This conservation/adaptation plan will be paired with a statistically rigorous observation and evaluation design to ensure that conservation scientists and adaptation practitioners can learn from the implementation (NAS 2016).

Management Goals: The overarching goal for the implementation of the conservation design is to maintain ecosystem function and native species, where feasible, in the face of uncertainty about how climatic changes will reorganize ecosystems. The near-term conservation plan will meet the immediate needs of natural resource managers (FWS, FS, NPS, BLM) to support efforts that maintain or enhance populations of species that are endangered, threatened or considered at-risk of needing CESA or ESA protection. The long-term planning will help ensure that current management actions are not maladaptive and are consistent with long-term projections of species persistence within the project's geography.

Why the Southern Sierra Nevada?

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 (Diffenbaugh et al, 2014). 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 (Boistrame et al. 2017, Roche et al. 2018).

Reducing the risk of high-severity fires and increasing water storage capacity of the landscape also benefit the many native wildlife and plant species that have adapted to a heterogeneous forest and depend on a patchy landscape to meet their habitat requirements. For example, California Spotted Owls depend on dense tree canopies and understory for nesting and rearing of juveniles but benefit from nearby open meadows for foraging (Blakesley et al. 2005). In contrast, Barred Owls have been invading the North Pacific Forest as a result of habitat alteration due to logging and fire suppression. This created a denser and more homogenous forest structure, to which Barred Owls tend to be better adapted. Barred Owls are more generalists and tend to be more aggressive, thus, displacing the native spotted owls. Similarly, invasive American bullfrogs (*Lithobates catesbeianus*, hereafter bullfrogs) have been implicated in the decline of native Ranid species across western North America (Kats & Ferrer 2003, Casper & Hendricks 2005). Specifically, Foothill yellow-legged frog (*Rana boylii*, hereafter FYLF) populations have experienced declines across the Southern Sierra Nevada (Hayes et al. 2016). This species has been recommended for listing under the California Endangered Species Act. Protecting the species' clade in the S. Sierra Nevada is especially vital because it contains high levels of genetic diversity and is distinct from the remaining four clades (Hayes et al. 2016, McCartney-Melstead et al. 2018). Factors implicated in declines include altered hydrology (dams), introduced predators (such as bullfrogs), disease (*Batrachochytrium dendrobatidis*), climate change, sediment flows post-fire, and contaminants. To ensure persistence of FYLF populations, it is critical that we develop an understanding of the effectiveness, feasibility, and cost of implementing conservation projects that increase the survival and resilience of FYLF populations especially on the Southern (warm) edge of their range.

The area in and around the Yosemite and Sequoia NPs serve as ideal natural laboratories to study the impacts of climate change and the effectiveness of various forest treatments and restoration designs. Biologists in Yosemite NP, Sequoia NP, and surrounding Forest Service land have been monitoring many wildlife and plant species for decades. Such datasets enable the detection of climatic trends. Specifically, songbirds have been monitored along an elevational gradient for many decades, which has contributed to a national assessment of decadal bird population trends (Rosenberg et al. 2019). In addition, the Illilouette basin in Yosemite NP and the "Let Burn Zone" in Sequoia NP have experienced a natural wildfire regime since the early '70s when natural wildfire programs were established in the parks (van Wagtendonk 2007). These locations thus become ideal control sites for forest and wildlife restoration and conservation experiments.

Proposed Work Plan:

1) Conduct a meta-analysis to identify the most suitable habitat for FYLF (funded by USFWS and to be completed by fall 2020) and other important aquatic species under current conditions and projected climate change (data from Howard et al. 2017 could be leveraged for this analysis)
2) Leverage on-going research identifying the most suitable habitat for fisher and spotted owl in the same geography to develop high-priority habitat restoration and conservation goals in the Merced and Tuolumne watersheds
3) Conduct a meta-analysis and write a summary report of best management practices to reduce fire risk and its potential impacts on habitat quality for these at-risk species in the near- and long-term
4) Conduct a Structured-Decision-Making workshop employing expert elicitation to identify priority habitat for conservation and restoration that is suitable for climate refugia for several at-risk or listed species (including amphibians, fish, birds, mammals, and plants) in the Tuolumne and Merced watersheds
5) Complete geospatial analysis and design of adaptation/restoration experiments to A) increase the likelihood of the at-risk/listed species to persist under current stressors; and B) increase the likelihood of the at-risk/listed species to persist under several, different future climate and ecological outcome scenarios. This work will be translated into proposals for restoration grants to the state of California and various funders of on-the-ground restoration (a working-group to develop an on-the-ground pilot project for the SWAP implementation is being formed in January 2020; CDFW will lead with FWS the development of such an implementation project).

Proposed Timeline:

TIMEFRAME	TASKS	CONTRIBUTES TO PROJECT OUTCOME
QUARTER 1	Literature review to determine habitat requirements for target species and conceptual model for conservation and restoration for short-term needs	1) Spatial design for habitat conservation
QUARTER 1	Gather available data for spatial analysis of habitat and climate resilience	
QUARTER 1	Structure Decision Making (SDM) prototyping with project leaders	2) Adaptive Management Design
QUARTER 1	Identify project partners to participate in the SDM workshop	2) Adaptive Management Design; and 3) Project Proposal
QUARTER 2 – QUARTER 4	Determine habitat availability for target species and conceptual model for conservation and restoration for climate adaptation	1) Spatial design for habitat conservation
QUARTER 4	Structured Decision-Making workshop (can be held remotely if shelter-in-place is needed)	2) Adaptive Management Design and 3) Restoration Project Proposal
QUARTER 4	Develop monitoring design to identify management benefits	2) Adaptive Management Design and 3) Restoration Project Proposal
QUARTER 5	Gather additional information and finalize the analysis for the spatial design to maximize multi-objective conservation benefits	1) Spatial design for habitat conservation 2) Adaptive Management Design and 3) Restoration Project Proposal
QUARTER 5-8	Work toward publication and long-term funding model for the restoration project	4) Novel approach

Proposed Budget: (overhead rate 22%)*

	Year 1	Year 2	Year 1	Tasks
FWS			**Leveraged Support**	
GIS and biotechnical support GS-7	$47,137	$47,137		Inventory of existing monitoring data; Literature Review; GIS analysis for at-risk species in preparation of the SDM workshop; data management
Project Management GS-14			$13,000	Coordinate between individual projects and project staff; Facilitate the SDM workshop; Coordinate the development of the proposal for on-the-ground restoration
GIS support GS-11			$5,000	Supervision of the GIS technician and GIS product development
Feasibility Study for FYLF conservation			$80,000	Project funded to assess restoration opportunities in the Tuolumne and Merced Watersheds
Project Management and Facilitation	$40,000			Support all aspect of the project in and around Park lands
Biological Consultant/Biostatistician	$20,000	$80,000		Development of statistical design for conservation experiment; support for grant-writing
Project consultation and interagency coordination GS-12 & GS-14			$10,000	Support in facilitating the SDM workshop; support in coordination across agencies and project partners
Total:	**$107,137**	**$127,000**	**$108,000**	
Overhead:	**$23,570**	**$27,970**		
Total Requested:	**$130,707**	**$154,970**		

*https://www.fws.gov/policy/e4264fw1.html (FWS overhead rates)

Literature cited:

Adams, A.J., et al. 2017. Extreme drought, host density, sex, and bullfrogs influence fungal pathogen infection in a declining lotic amphibian. Ecosphere 8:e01740.

Adams, M.J. and C.A. Pearl. 2007. Problems and opportunities managing invasive bullfrogs: is there any hope? Pgs 679-693 *in* Gherardi, F. ed. Biological invaders in inland waters: Profiles, distribution, and threats. Springer.

Blakesley, J.A.; Noon, B.R.; Anderson, D.R. 2005. Site occupancy, apparent survival, and reproduction of California spotted owls in relation to forest stand characteristics. Journal of Wildlife Management. 69: 1554–1654.

Casper, G.S. and R. Hendricks. 2005. *Rana catesbeiana* Shaw 1802: American bullfrog. Pgs. 540-546 *in* Lannoo, M.J., ed. Amphibian declines: the conservation status of United States species. University of California Press, Berkeley.

Diffenbaugh N S, Swain D L and Touma D 2015 Anthropogenic warming has increased drought risk in California Proc. Natl Acad. Sci. 112 3931–6

Goldberg, C.S., et al. 2016. Critical considerations for the application of environmental DNA methods to detect aquatic species. Methods in Ecology and Evolution 7:1299-1307.

Hayes, M.P. and M.R. Jennings. 1986 Decline of Ranid frog species in western North America: are bullfrogs (*Rana catesbeiana*) responsible? Journal of Herpetology 20:490–509.

Hayes, M., C. Wheeler, A. Lind, G. Green, and D. Macfarlane. 2016. Foothill Yellow-Legged Frog Conservation Assessment in California. United States Department of Agriculture.

Howard J.K., Kurt A. Fesenmyer, Theodore E. Grantham, Joshua H. Viers, Peter R. Ode, Peter B. Moyle, Sarah J. Kupferburg, Joseph L. Furnish, Andrew Rehn, Joseph Slusark, Raphael D. Mazor, Nicholas R. Santos, Ryan A. Peek, and Amber N. Wright. 2018 A freshwater conservation blueprint for California: prioritizing watersheds for freshwater biodiversity. Freshwater Science 2018 37:2, 417-431.

Kamoroff, C., N. Daniele, R. Grasso, R. Rising, T. Espinoza, and C. S. Goldberg. In review. Effective removal of the American bullfrog (*Lithobates catesbeianus*) on a landscape level: long term monitoring and removal efforts in Yosemite Valley, Yosemite National Park. Biological Invasions.

Kats, L.B. and R.P. Ferrer. 2003. Alien predators and amphibian declines: review of two decades of science and the transition to conservation. Diversity and Distributions 9:99-110.

McCartney-Melstad, E., M. Gidiş, and H.B. Shaffer. 2018. Population genomic data reveal extreme geographic subdivision and novel conservation actions for the declining foothill yellow-legged frog. Heredity 121:112–125.

Pearl, C.A., M.J. Adams, N. Leuthold and R.B. Bury. 2005. Amphibian occurrence and aquatic invaders in a changing landscape: implications for wetland mitigation in the Willamette Valley, Oregon, USA. Wetlands 25:76–88.

Rosenberg K.V., A.M. Dokter, P.J. Blancher, J.R. Sauer, A.C. Smith, P.A. Smith, J.C. Stanton, A. Panjabi, L. Helft, M. Parr, P.P. Marra. 2019 Decline of the North American avifauna. Science DOI: 10.1126/science.aaw1313