Priority Drought-related Conservation Actions in 2016 for Listed Amphibians in Sequoia and Kings Canyon National Parks

Final Report for Contract D1580003

Submitted from the National Park Service to the California Department of Fish and Wildlife, Wildlife Branch, Nongame Wildlife Program

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Introduction

Amphibians are among the most vulnerable taxa to extended drought conditions in California because of their reliance on aquatic habitats. Species that breed in shallow, ephemeral waters and those that rely on the presence of surface water for all life stages are particularly at risk. Three such species are the mountain yellow-legged frog (*Rana muscosa*) (Federal and State Endangered) and the Sierra Nevada yellow-legged frog (*Rana sierrae)* (Federal Endangered, State Threatened), collectively mountain yellow-legged frog or "MYLF", and the Yosemite toad (*Anaxyrus canorus*) (Federal Threatened, State Species of Special Concern) populations in Sequoia and Kings Canyon National Parks (SEKI) (Figure 1). Due to the widespread presence of nonnative trout, there are many MYLF populations in SEKI that are relegated to small and/or shallow habitats. These are waterbodies that are generally less than 1 hectare (2.5 acres) in surface area and/or less than 2-3 meters in maximum depth. Tributaries are generally non-existent, ephemeral, or low-flow perennial. These habitats are vulnerable to substantial or complete drying during droughts. In addition, Yosemite toads occupy meadows that are extremely vulnerable to drought impacts. The objectives of this project were to use California Department of Fish and Wildlife (CDFW) funds in 2016 to travel to and survey all recently extant (as of 2013) populations MYLF and Yosemite toad populations infected with chytridiomycosis (Bd), an infectious amphibian fungal disease. These sites are hereafter referred to as Bd positive. Additionally in 2016, funding from US Fish and Wildlife Service (FWS) was used by National Park Service (NPS) and University of California Santa Barbara (UCSB) crews to survey all recently extant (as of 2013) MYLF populations that at the date of last survey were not known to be exposed to Bd, based on swabs collected. These sites will hereafter be referred to as Bd naïve. (The UCSB crews were led by Dr. Roland Knapp.) Since Bd positive and Bd naïve sites are interspersed across the parks, combining funds from CDFW and FWS to support one NPS crew that could survey both types of populations allowed us to survey all recently extant sites in one season – a substantial efficiency of scale.

SEKI has approximately 35 high elevation lake basins in which MYLFs were recently extant, with a large range of population abundance from low to high depending on the basin. Within these basins, 100-125 waterbodies are occupied, with a large range of sizes. Approximately 60 waterbodies are less than 1 hectare in surface area, and 40 of these are less than 0.25 hectare. In addition, approximately 50 of the occupied waterbodies are 3 meters or less in maximum depth. Therefore, roughly half of the occupied waterbodies are highly vulnerable to drought impacts. Further, the few occupied basins that do not have any small or shallow occupied waterbodies are vulnerable to population reductions due to habitat shrinkage. Given the endangered status of MYLFs, all remaining extant populations are critically important for conservation (see MYLF Conservation Strategy; FWS in publication). Survey efforts are needed to determine the status of populations and their habitats.

SEKI has approximately 16 recently extant Yosemite toad population areas. All populations are likely infected with Bd and appear to have lower abundance compared to historical records (FWS 2013, FWS 2014, Brown et al. 2015, USGS unpublished data). Drought stress on their meadow habitat has the potential to extirpate populations. Survey efforts are needed to determine the status of populations and their habitats.

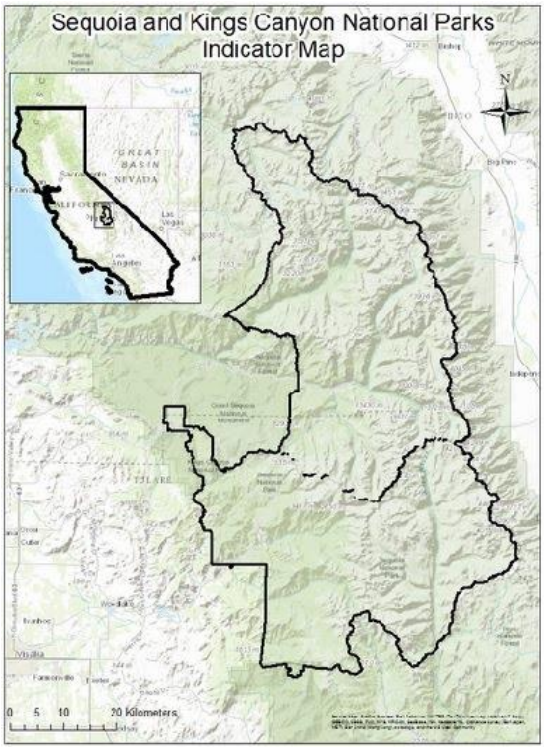

Figure 1: Map of Sequoia and Kings Canyon National Parks in California

Methods

MYLF Surveys

During the 2016 field season (7/2016 through 9/2016) staff from SEKI traveled to and surveyed waterbodies that had recent extant MYLF populations (Figure 2; and Figure 5 in Appendix). Each waterbody was surveyed at least once, during which the number of MYLFs of each life stage was documented. The primary tool for monitoring frog populations is a non-invasive method known as a visual encounter survey (VES), which counts all individuals encountered along a lakeshore or stream section, and records each individual by their life stage (adult, subadult, larvae/tadpole, or egg mass). Temperature is recorded in each waterbody using a handheld thermometer, reaching from the shoreline as far as possible and taking the measurement approximately 0.5 meters below the surface. Data on wetted perimeter drawdowns in MYLF waterbodies were not collected due to a miscommunication with the field crew. Photo points of waterbody drawdown surrounding the outlet were supposed to have been established and condition noted as "full, drawn-down or dry," but it was not done and the project manager did not know until after the surveys were completed for the season. These data will be collected during the next round of parkwide monitoring surveys, which have a goal of being conducted on 3-5 year intervals. Thus, the next parkwide survey is targeted for 2019, 2020, and/or 2021.

Yosemite Toad Surveys

During the 2016 field season (7/2016 through 8/2016) NPS crews traveled to and surveyed waterbodies that had recently extant Yosemite Toad populations with the primary goal of determining population presence and estimating relative abundance using VES, and assessing habitat to gauge vulnerability to substantial or complete drying (Figure 2). The survey protocol is the same as for MYLFs, plus all surveyed habitat was assessed. Crews recorded qualitative site descriptions and quantitative data on the following parameters: Habitat Type (meadow, lake, and stream), Water Present (y/n), Perennial (y/n) with explanation, % Water, and % Flow. Based on conclusions drawn by Dodge and

Vredenburg (FWS 2013) and results of surveys by USGS in 2010-2013 (USGS unpublished data) in which populations appeared less abundant than the 1980s and 1990s, all populations are likely infected with Bd.

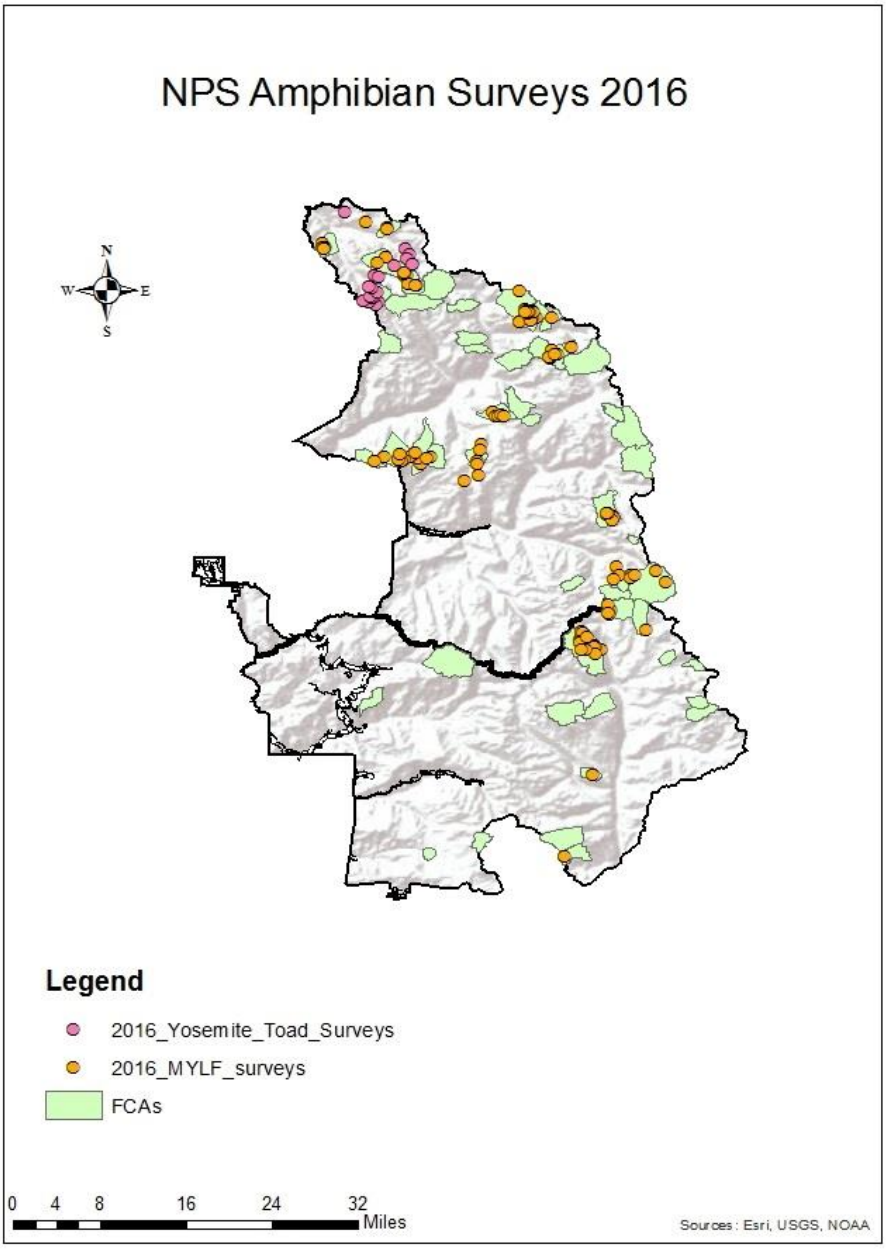

Figure 2: Map of VES locations for MYLF and Yosemite toad conducted by NPS crews for CDFW Contract D1580003. The green polygons are frog conservation areas (FCAs) selected for inclusion in the MYLF Conservation Strategy (FWS 2018). MYLF populations are extant in FCAs with orange survey dots and are extirpated in FCAs with no survey dots - areas where we hope to eventually re-establish populations.

Results

In the 2016 field season SEKI field technicians visited a total of 30 lake basins and conducted VES in 134 waterbodies with recently extant MYLF and Yosemite toad populations in SEKI (Tables 1 and 2). Habitat data were collected for all Yosemite toad populations. Some MYLF populations were surveyed multiple times due to personnel availability. The sites that were surveyed multiple times are located in Basins where NPS crews are conducting physical removal of non-native fish. Protocol for crew members at these sites is to conduct VES twice per season in all waterbodies if time allows. The adult and tadpole totals in Table 1 included only the highest results if repeat surveys were conducted.

MYLF Results

Table 1 summarizes the results of the MYLF VES. A total of 108 waterbodies known to have Bd positive MYLF populations were visited and surveyed in 2016. SEKI crews observed MYLFs in 72 waterbodies, documenting a 33% decline in populations since a 2009-2013 survey effort. On a basin scale, 48% of basins had no declines in occupied sites, 20% had minor declines (<40% decrease in occupied sites), 20% had major declines (≥40% decrease in occupied sites), and 12% had complete declines (basin-scale extirpation) (Figure 2). The basins where no change in occupied sites was observed were Bullfrog Lakes, Coyote, Darwin Bench, Dusy, Glacier Divide, Gorge of Despair, McGee Lakes, Palisade Creek, Sixty Lake, Sky Parlor Meadow, Swamp Lakes, Tyndall Creek, and Upper Evolution. Captive reared frogs were reintroduced to Tyndall in 2016, which influenced the status of that basin's population. The basins where a minor decline of occupied MYLF sites was observed were Amphitheater, Glacier Lakes, Granite Pass, LeConte Divide and South Milestone. The basins where a major decline of occupied MYLF sites was observed were Barrett, Horseshoe Lake, Milestone, Slide Creek, and Upper Kern. Basins where no MYLF were observed, preliminarily indicating a 100% decline, were Glacier Creek, Lewis Lake, and West Kennedy.

Table 1: SEKI MYLF populations surveyed by NPS crews in 2016

Basin Name	Species	#Historical Populations Surveyed	#Populations Found	Total Frogs (Subadults + Adults)	Total Tadpoles
Amphitheater[C]	*R. sierrae*	9	7	89	2950
Barrett Lakes[A]	*R. sierrae*	17	7	35	1485
Bullfrog Lakes	*R. muscosa*	2	2	240	679
Coyote	*R. muscosa*	1	1	53	76
Darwin Bench	*R. sierrae*	2	2	9	8
Dusy	*R. sierrae*	1	1	5	42
Glacier Creek	*R. muscosa*	1	0	0	0
Glacier Divide	*R. muscosa*	1	1	7	0
Glacier Lakes	*R. muscosa*	2	1	6	6
Gorge of Despair	*R. muscosa*	1	1	2	6
Granite Pass	*R. muscosa*	4	3	49	41
Horseshoe Lakes	*R. muscosa*	5	3	3	119
LeConte Divide	*R. sierrae*	6	5	22	544
Lewis Lake	*R. muscosa*	1	0	0	0
McGee Lakes	*R. sierrae*	2	2	184	935
Milestone	*R. muscosa*	10	5	14	414
Palisade Creek	*R. sierrae*	1	1	228	1,040
Sixty Lake[C]	*R. muscosa*	7	7	35	225
Sky Parlor Meadow	*R. muscosa*	1	1	0	34
Slide Lakes	*R. muscosa*	4	1	0	0
South Milestone	*R. muscosa*	7	4	43	336
Swamp Lakes	*R. muscosa*	10	10	351	4,026
Tyndall Creek[B]	*R. muscosa*	1	1	123	9[B]
Upper Evolution	*R. sierrae*	6	6	82	21796
Upper Kern	*R. muscosa*	4	2	1	7
West Kennedy	*R. muscosa*	2	0	0	0

A. Data from one lake missing, B. More tadpoles found in earlier surveys done by UCSB crews, C. Multiple surveys conducted for several populations

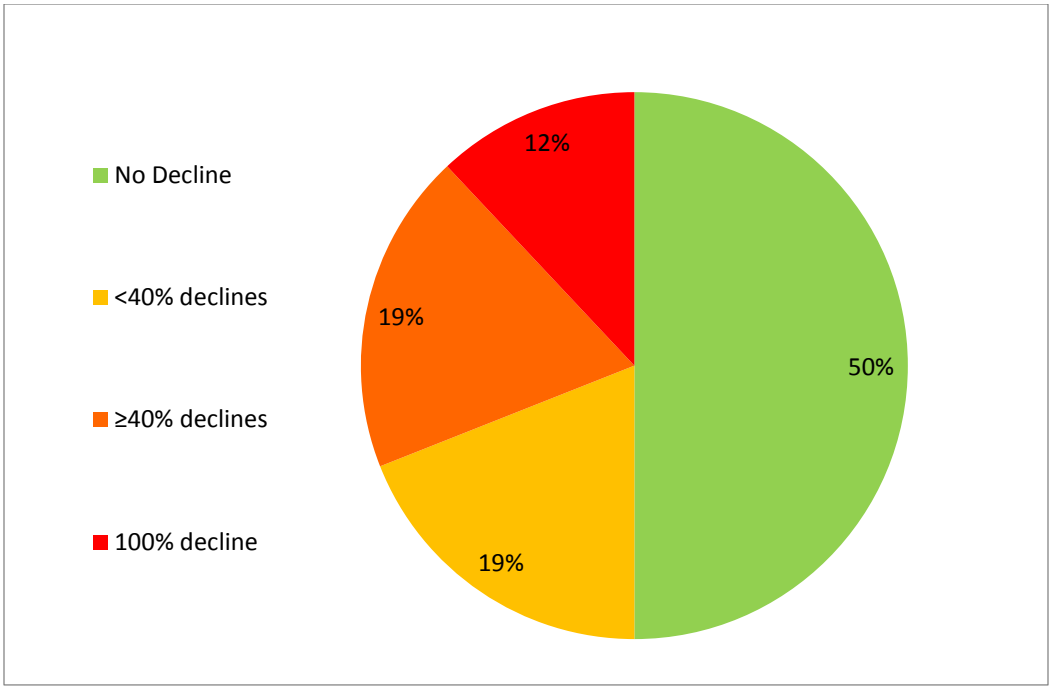

Figure 2: SEKI basin scale MYLF population trends from 2009-2016.

Yosemite Toad Results

Table 2 summarizes the results of the Yosemite toad VES. A total of 19 populations were visited and surveyed in 2016. SEKI crews observed Yosemite toads in 15 of the population sites (primarily meadows), documenting a 21% decline in populations since 2009-2013. On a basin scale, 57% of basins had no decline in occupied Yosemite toad sites, 14% had minor declines, and 29% had complete declines (Figure 3). The basins where no change in occupied Yosemite toad population sites was observed were Davis, Glacier Divide, Martha, and North Martha. A minor decline in occupied Yosemite toad population sites was observed at Sapphire. No Yosemite toads were observed in Evolution and McGee, preliminarily indicating a 100% decline.

Table 2: SEKI Yosemite toad surveys conducted by NPS crews in 2016

Basin Name	Species	#Historical Populations	#Populations Found	Total Frogs (Subadults + Adults)	Total Tadpoles	Water Source	Comments
Davis	*A. canorus*	2	2	3	3030	Ephemeral	
Evolution	*A. canorus*	2	0	0	0	Partial Perennial	
Glacier Divide	*A. canorus*	1	1	3	0	Ephemeral	
Martha	*A. canorus*	4	4	24	8794	Ephemeral	210 tadpoles desiccated
McGee	*A. canorus*	1	0	0	0	Ephemeral	
North Martha	*A. canorus*	6	6	76	76	Ephemeral	4055 tadpoles desiccated
Sapphire	*A. canorus*	3	2	64	64	Partial Perennial	15 dead tadpoles, 11 unhealthy tadpoles

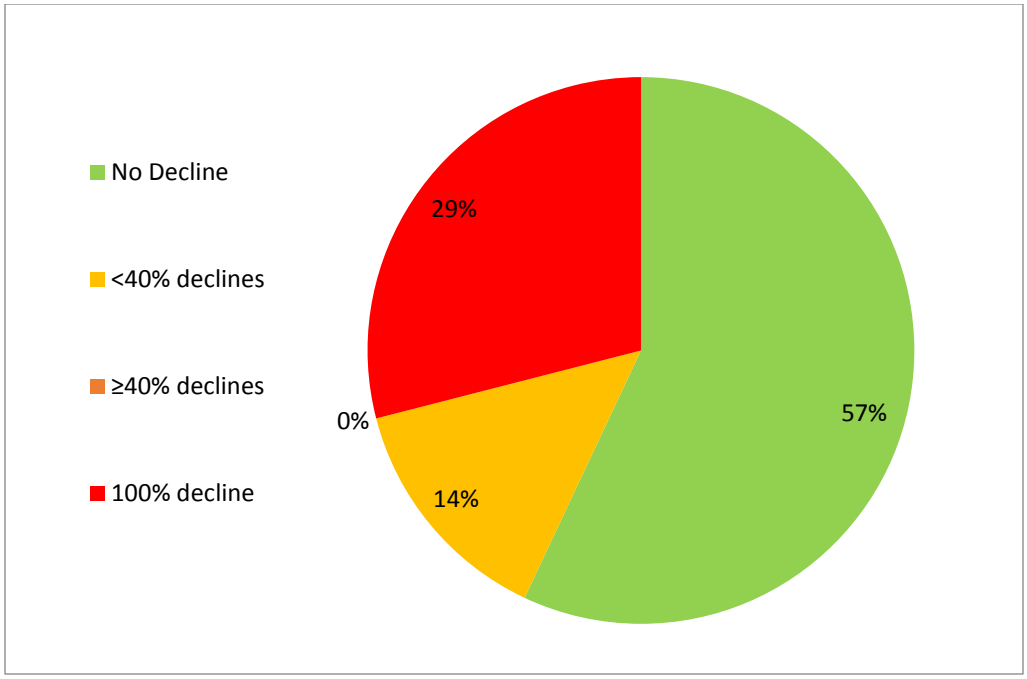

Figure 3: SEKI basin scale Yosemite toad population trends from 2009-2016.

For the Yosemite toad surveys, more extensive data on survey habitat were collected by the NPS surveyors (Table 3). Surveyors observed that 2 population sites were perennial, 8 sites had adequate water, 2 sites were starting to dry, and 6 sites were mostly dry (Figure 4). Habitat data were not collected at DL1. Water level status was determined by the qualitative site description notes recorded by surveyors. These notes ranged from a few sentences to a few paragraphs depending on the complexity of the habitat, and included observations on site water levels.

Table 3: SEKI habitat data for Yosemite Toad surveys in 2016

Basin ID	Site ID	Date	Habitat Type	% Water	% Flow	Water Source	Water Level Status
Davis	DL1	7/19/2016	no data	no data	no data	no data	no data
Davis	DL2	7/19/2016	Meadow	75%	30%	ephemeral	adequate
Evolution	EV1	7/28/2016	Meadow	15%	0%	ephemeral	mostly dry
Evolution	EV2	7/28/2016	Meadow	40%	85%	perennial	perennial
Glacier Divide	GLA	8/2/2016	Meadow	15%	35%	ephemeral	mostly dry
Martha	MAR1	7/17/2016	Meadow	10%	80%	ephemeral	adequate
Martha	MAR2	7/17/2016	Meadow	20%	70%	ephemeral	adequate
Martha	MAR3	7/17/2016	Meadow	50%	20%	ephemeral	adequate
Martha	MAR4	7/17/2016	Meadow	30%	30%	ephemeral	slightly dry
McGee	MCG	8/1/2016	Meadow	10%	65%	ephemeral	mostly dry
North Martha	NM1	7/18/2016	Meadow	70%	15%	ephemeral	adequate
North Martha	NM2	7/18/2016	Meadow	60%	10%	ephemeral	adequate
North Martha	NM3	7/18/2016	Meadow	20%	0%	ephemeral	mostly dry
North Martha	NM4	7/20/2016	Meadow	40%	25%	ephemeral	slightly dry
North Martha	NM5	7/19/2016	Meadow	30%	75%	ephemeral	adequate
North Martha	NM6	7/19/2016	Meadow	30%	25%	ephemeral	adequate
Sapphire	SAP1	7/29/2016	Other	60%	5%	perennial	perennial
Sapphire	SAP2	7/29/2016	Meadow	25%	40%	ephemeral	mostly dry
Sapphire	SAP3	7/29/2016	Meadow	2%	0%	ephemeral	mostly dry

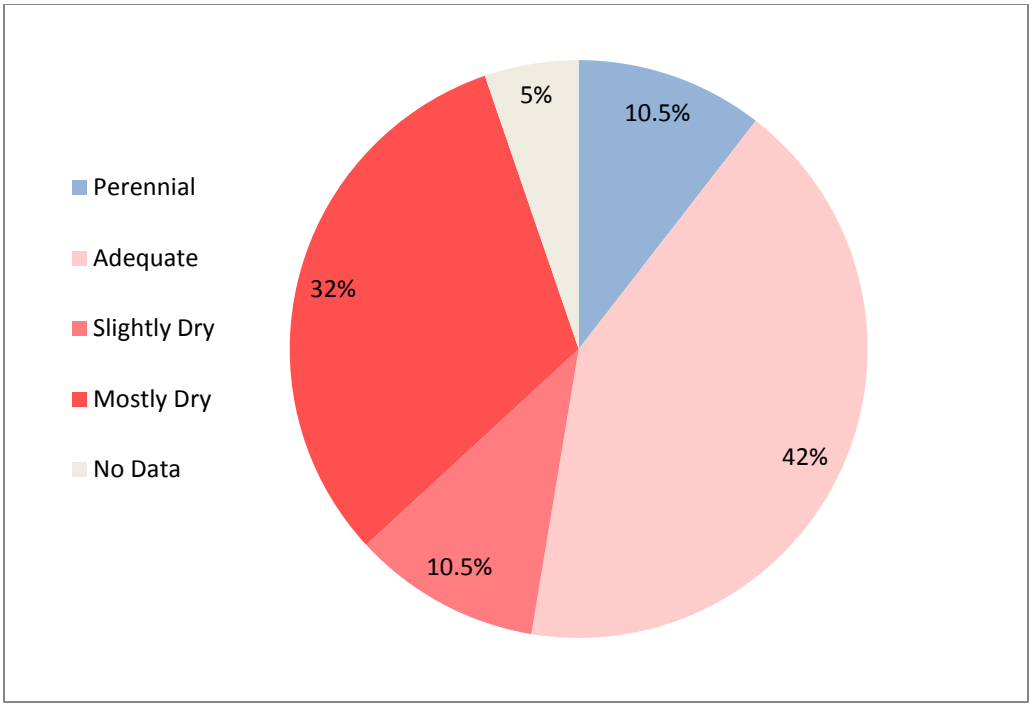

Figure 4: SEKI water level status when NPS field crews conducted Yosemite toad VES in 2016.

Discussion

An inventory of high elevation waterbodies in SEKI was conducted from 1997-2002, led by R. Knapp (UCSB). This effort found 567 waterbodies occupied by MYLFs (Knapp unpublished data). A second round of MYLF surveys, conducted jointly by UCSB and SEKI crews from 2009-2013, visited 492 of the original 567 occupied sites, 182 of which were still occupied. This was a 63% decline in occupied MYLF sites. In the 2016 field season, SEKI crews surveyed 108 waterbodies (this project), and UCSB crews surveyed an additional 62 waterbodies, that were occupied during the 2009-2013 surveys. Including the data from both of these 2016 efforts, 120 of the 170 waterbodies recently occupied by MYLFs were still occupied. These results represent an additional 29% decline in occupied MYLF sites. While this observed rate of decline between the second and third round of surveys was substantially less than the decline observed between the first and second round of surveys, it occurred over a shorter period of time. This indicates that the number of occupied MYLF sites in SEKI is still declining, although the rate may be slowing. Of the 50 sites that were not occupied in the 2016 surveys, we cannot say with certainty as to what may have caused the lack of detections. However, we know all of these sites were Bd positive, and many sites had populations that had exhibited very low abundance for extended periods of time and thus were extremely vulnerable to extirpation. Although no explicit data were collected on the water levels of the 2016 MYLF survey sites, all of these sites are lakes or perennial ponds and had aquatic habitat present that has been typical for each site. Further, observations in SEKI and Yosemite National Park by NPS staff and collaborating researchers at least anecdotally suggest that MYLF populations in permanent aquatic habitat actually benefited from the drought, in the form of several successive longer growing seasons and less-harsh winters that increased survival and growth rates. The drought may have temporarily and slightly reduced aquatic habitat in many sites, but not enough to eliminate habitat, and thus likely was not a major driver for the lower number of detections. However, data on the spread of Bd in SEKI over the past decade show that many MYLFs in numerous waterbodies suffered substantial Bd-caused mortality. For example, Barrett and Milestone had Bd outbreaks beginning around 2003 and have had steady incremental losses of frogs and occupied waterbodies over time, and further losses appear to be ongoing even though much permanent aquatic habitat is present. Additionally, South Milestone appears to have had a Bd outbreak in 2015 that likely caused the decline documented there. It therefore appears that Bd infections, following historic losses from non-native trout, were likely the primary driver of MYLF decline in SEKI over the drought period of the last 4-5 years. The drought may have had a minor impact on MYLF habitat, and in concert with historic losses from non-native trout may have been

responsible for some population declines (see Lacan et al. 2008), but at the park scale drought is unlikely to have been a major driver of the decline in population status observed between the 2009-2013 period and the 2016 survey.

A 21% decline in Yosemite toad populations was observed in 2016. The populations were most recently surveyed from 2010 to 2013. Habitat data (site description, habitat type, water presences, water levels, perennial status, % water and % flow) were collected for the Yosemite toad surveys conducted in the 2016 field season (see Table 3). Approximately 85% of the surveyed sites were ephemeral water sources, and of those, 50% were showing signs of drying, and 38% were mostly dry. Davis Basin experienced no decline in populations, and the water levels were adequate when surveyed. In Evolution Basin, no Yosemite toads were observed. One population site was mostly dry; however, the other population site contained a perennial water source, so drought may not have been the complete cause of the apparent extirpation of the Evolution Basin Yosemite toad populations. Yosemite toads were observed in Glacier Divide Basin, but the habitat was mostly dry and tadpoles may have desiccated before metamorphosing. Martha Basin had adequate water over most of the sites when surveyed; however, desiccated tadpoles were observed in a dry pothole in MAR4. Martha Basin had observable Yosemite toads in all historical population sites. McGee Basin was mostly dry when surveyed and had no Yosemite toads observed in the historical population site. McGee was one of the later surveys (August 1); however, if Yosemite toads had reproduced, tadpoles still should have been present at that time. This indicated that the drought may have had an observable impact on the McGee Basin Yosemite toad population. The North Martha Basin Yosemite toad population sites ranged from adequate water levels to mostly dry. While Yosemite toads were observed in all historical population sites, extensive tadpole desiccation was observed in NM1, NM3, and NM5, and surveyors noticed that more tadpoles were at high risk of desiccation mortality. The data suggest that North Martha Basin Yosemite toad populations had observable drought impacts. Sapphire Basin had one population site with a perennial water source and two sites that were mostly dry. In SAP3, which was mostly dry, there were no Yosemite toads observed, indicating impact from drought. However, in SAP1 surveyors observed tadpoles showing signs of infection (white patches on skin, lethargic behavior), indicating that disease may also be having an impact on Yosemite toad populations.

Conclusions/Recommendations

MYLF

There are currently multiple efforts being undertaken to conserve MYLF populations in Sequoia and Kings Canyon National Parks. Habitat restoration by the NPS to benefit MYLFs in SEKI has been ongoing since 2001. SEKI crews have used physical methods (gillnets and electrofishers) to remove nonnative fish from 7 basins, reducing effects from predation, competition, and population fragmentation. Physical restoration work is ongoing in Amphitheater, Sixty Lake, and Upper Bubbs. McGee Basin is slated to start physical restoration in the 2017 field season. SEKI crews are planning to begin to use piscicide (in 2018) to complete fish eradication in basins that are too large or complex to be fully restored with physical methods. Non-native fish removal will help MYLF populations during drought because it allows the frogs to re-populate the larger and deeper water bodies from which they have historically been extirpated.

SEKI and UCSB crews continue to collaborate to monitor MYLF populations for signs of Bd-caused die-offs. In the 2016 seasons USCB crews and SEKI crews surveyed both Bd positive and negative recently extant populations (Figure 5). Continued monitoring is critical to catching die-offs in action. When die-offs are caught early more conservation interventions are available. In 2015 SEKI coordinated with UCSB researchers to conduct an *in situ* treatment during a die-off. Results are not yet available on the efficacy of the experimental treatment. In August 2016, SEKI coordinated a multi-partner effort to salvage *R. muscosa* from two imperiled populations for captive rearing and immunization at the Oakland and San Francisco zoos, as follows. Field crews from SEKI and UCSB's Sierra Nevada Aquatic Research Laboratory (SNARL) collected a total of 227 late-stage tadpoles and recently metamorphosed froglets, including 77 from Pinchot Basin and 150 from Milestone Basin. These sites had Bd outbreaks circa 2003 and by 2016 the MYLF populations

had steadily declined toward extirpation, prompting FWS to allow SEKI to "salvage" animals before extirpation occurred, for a captive-rearing, immunization and reintroduction effort. This action is consistent with recovery techniques recommended in the MYLF Conservation Strategy (FWS in publication). Collected animals were transported out of the backcountry by helicopter. Salvaged frogs will be reintroduced to their respective wild populations in 2017 and 2018 and will hopefully help increase recruitment in these populations. At the zoos, the collected animals are cleared of Bd using itraconazole, and survival rates are typically high. Prior to reintroduction, frogs are "immunized" by exposing them to Bd for a second time and then cleared of infection. The first intraconazole treatment prevents mortality and the second treatment is hoped to facilitate an adaptive immune response in the frogs.

In July 2016, we successfully coordinated a multi-partner effort (San Francisco Zoo, Oakland Zoo, and FWS) to reintroduce 172 zoo-reared *R. muscosa* back into SEKI. All frogs were collected as late-stage tadpoles in summer 2015, and transported to the Oakland and San Francisco zoos. Animals were grown to adulthood and immunized against disease, and then driven and flown back to their native habitats in SEKI, where they were released. Field crews from SEKI and UCSB released the frogs into three lakes, including 48 frogs to one lake in Sixty Lake Basin, and 42 frogs to one pond and 82 frogs to a second pond near Tyndall Creek. Eighty-six frogs that were too small to be immunized in 2016 were retained at the zoos. These frogs will be immunized and reintroduced to habitats in SEKI during summer 2017. All populations reintroduced in 2016 were monitored using pit tag mark-recapture methods. That monitoring will continue in subsequent years and also include populations reintroduced in 2017.

Continuing to monitor Bd positive MYLF populations in SEKI will allow us to evaluate the efficacy of interventions already taken and help prioritize sites for future interventions.

Yosemite Toad

Basins that still retain all of their historical Yosemite toad populations but showed impacts from drought are the highest priority for drought related intervention. Martha and North Martha Basin fit those criteria. Continued monitoring during drought years will be important to maintaining the population sites in these vulnerable basins. Options for interventions may include local translocations, where tadpoles in drying pools and potholes are relocated to larger bodies of water within the basin. The next level of priority would be Sapphire Basin, which experienced a partial decline in historical Yosemite toad populations. Options for interventions may include local translocations of adults and tadpoles from other sites within the basin. McGee and Evolution Basin would be the next priority for intervention. No Yosemite toads were observed in these basins, making interventions more challenging and demanding more resources. Options for interventions may include developing a captive breeding program in collaboration with zoos and reintroducing captive-reared Yosemite toads to their historical population sites. Lowest priorities are the sites that had no decline in Yosemite toad populations or observable signs of drought impact. Continued monitoring will be important for all basins as the climate continues to change causing unpredictable impacts on these sensitive ecosystems. Long-term monitoring on 3-5 year intervals is a general goal for long term management of SEKI listed MYLF and Yosemite toad populations. Project funds will continue to be sought to support a robust monitoring effort over time. If specific project funds are not able to be secured, then monitoring will occur using other funds as capacity allows.

Citations

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Acknowledgements

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Appendix

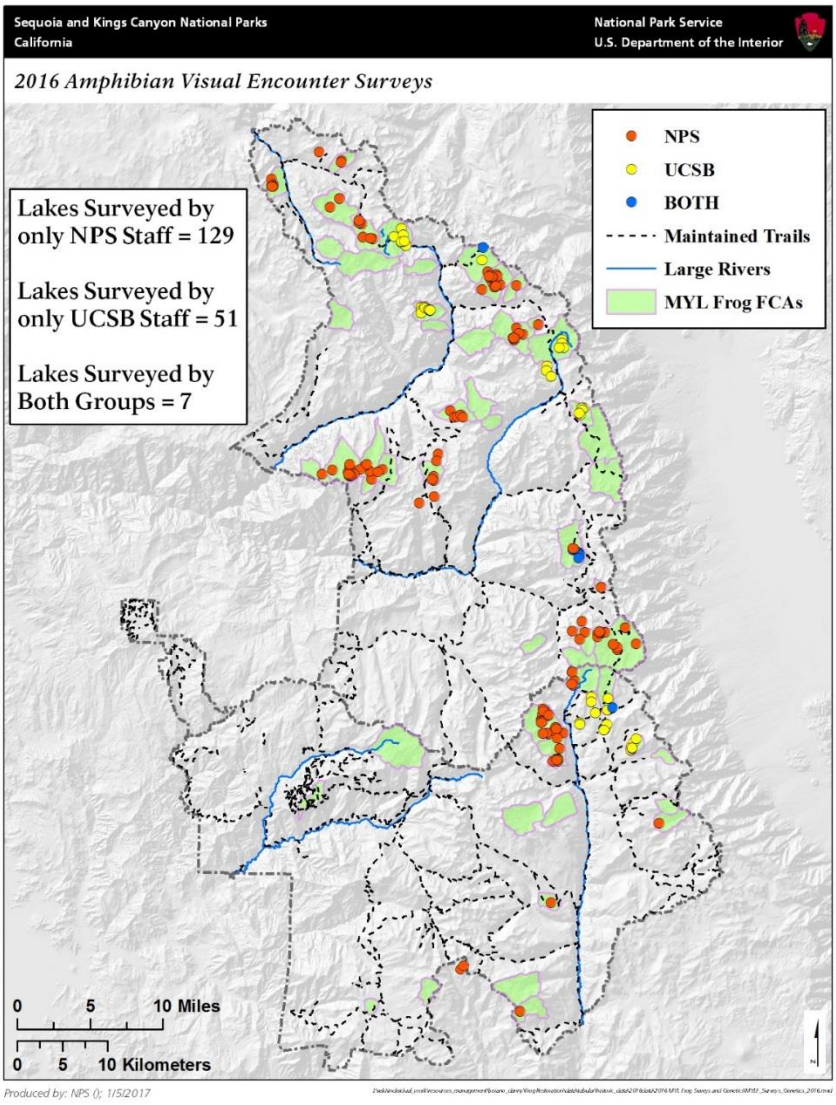

Figure 5: Map of VES locations for MYLF and Yosemite toad conducted by NPS and UCSB field crews. This map shows surveys at both Bd naïve and Bd positive sites. Bd naïve sites were surveyed with a grant from US Fish and Wildlife Service.