THE PHYSIOLOGICAL ECOLOGY OF BATS IN SEQUOIA AND KINGS CANYON NATIONAL PARKS, INFORMED BY FIRE MANAGEMENT
FINAL REPORT

Research Grant #: 146

2021

I. PROJECT SUMMARY

Climate change has caused an increase in the frequency, intensity, and severity of wildfires globally, particularly in California. However, research on the effects of fire on mammals is lacking. Because small insectivorous bats are ecosystem indicators, they are useful model organisms to understand how wildfires affect vertebrate communities. In 2020, Sequoia and Kings Canyon National Parks experienced a severe wildfire that spanned 18,984 acres. We tracked eight California myotis (*Myotis californicus*) to roost sites from a variety of post-burn severities (none, low, moderate and severe) in the summer from June-August 2021. We also determined their physiological response to habitats affected by fire by assessing the skin temperature of nine *M. californicus*, indicating how fire affects their energy expenditure. *M. californicus* showed preference for Black Oak (*Quercus kelloggii*) trees in low severity burn sites, although roosts in all burn severities were used. *M. californicus* utilized low elevation foothill sites in addition to moderate-high elevation sites including roost trees in Sequoia groves. Additionally, *M. californicus* expressed short torpor bouts in the coolest part of the morning, prior to sunrise, demonstrating that not only do the species use and express torpor, but they do so in burnt habitats in summer. This information is particularly useful as it is the first documented evidence of *M. californicus* utilizing deciduous roost trees, and indicates resilience in fire-affected habitats in California partially due to the use of energy-saving physiological strategies.

II. Research questions

- **Proposed Research Questions:**
- What are the effects of fire-managed areas on heterothermic mammals?
    - How do fire regimes affect habitat use by insectivorous bats?
    - How do fire and vegetation structure affect energetic expression of insectivorous bats?
    - Which roost types are preferred by insectivorous bats for use in summer?

- **Revised Research Questions:**
- What are the effects of wildfire on heterothermic mammals?
    - How does wildfire affect roost selection of *Myotis californicus*?
    - How do fire and vegetation structure affect energetic expression of *Californicus myotis*?
    - Which roost types and species are preferred by *Myotis californicus* for use in summer?

III. Differences between proposed work and executed project

There were a few differences in the proposed project and the actual project that occurred. We proposed using a small bat species (California myotis; *Myotis californicus)* as well as a larger bat species (Big brown bat; *Eptesicus fuscus*). Based on 1) capture success and 2) to increase sample size, we ultimately decided to only use *M. californicus*. We also proposed monitoring bat responses from three different elevational ranges to reveal the effects of fire on bats from varying ecotones in the park: 1) foothill woodland habitat (low elevation), 2) upper chaparral shrubland (low-mid elevation), 3) river canyon (mid-elevation), and 4) montane and sequoia forests (mid-high elevation). However, we chose to only assess low-moderate elevation habitat to increase sample size and because a severe wildfire affected the South Fork area of Sequoia National Park in 2020. The importance of monitoring bat response to wildfire was deemed essential, therefore we ultimately chose to focus our efforts on post-wildfire response. We also proposed to use both control and burn sites, however due to bats' ability to fly far distances, we were unable to focus efforts in specific burn severities. Instead, we captured bats in one central location and determined the burn severity of their roost sites, which was variable (sometimes resulting in severely burn areas, unburnt areas, and low and moderately burn areas). Lastly, we also proposed to complete the project in the summer of 2020, but due to COVID-19 restrictions the project was moved to summer of 2021.

IV. Introduction/Background

Between 15 - 37% of animal species are predicted to become extinct due to climate change (Thomas et al., 2004). Importantly, historical patterns of fire are changing due to an amalgamation of these climatic and anthropogenic effects. The effects of fire on animals is heavily dependent on the ecosystem, frequency of fire, fire severity and season in which the fire occurs (Bendell 1974). Due to the vastly differing responses of mammals to fire, it is thus essential to investigate species separately and understand how differing climatic conditions, fire intensity, fire frequency and type of fire (wild or prescribed) affect survivorship both in the short-and long-term. How small mammals deal with these changes to past fire regimes remains surprisingly unknown, although the key to some mammals' survival may lie with their ability to employ torpor, an energy-conserving strategy whereby metabolic and heart rate, as well as body temperature, reach minimal levels to expend only a fraction of the energy that is used during activity (Ruf and Geiser, 2015). These mammals are termed "heterothermic endotherms" and could be in a better position to survive extreme variability in temperature and habitat degradation than "homeothermic endotherms", or animals that expend large amounts energy to maintain a consistent body temperature.

Insectivorous bats are heterotherms, and importantly are considered indicators of ecosystem health due to their ability to occupy a wide variety of habitats as well as differing thermal niches (Medellín et al., 2000; Stawski et al., 2014). Therefore, investigating how insectivorous bats respond to habitat variability in an area that has not only long been susceptible to wildfires, but has been managed for fires through fire suppression, gives insight to population persistence not only for bats but for a wide variety of other small mammals. The ability to express torpor may have been essential for extant microbats and other mammals not only in terms of saving energy on a short-term scale, but also in response to catastrophic events which have resulted in the extinction of some homeothermic mammalian populations (Lovegrove et al., 2014). An ecological disturbance such as wildfire may initiate torpor use due to a decrease in consumable energy and changes in ambient temperature due to alterations in buffered microclimates (Alencar et al., 2015). Thus, bats may use torpor to manage the constraints associated with food and water shortage, or alternatively exploit post-fire habitats (Doty et al., 2016).

Bats have been shown to use forests with a continuum of vegetation structures, using habitat with sun-exposed roosts for differing physiological requirements (Johnson and Lacki 2014). Fires can further clear vegetative clutter and allow for less maneuverable bat species with high wing aspect ratios to access the area (Inkster-Draper et al., 2013). Indeed, bat activity significantly decreases with clutter (Law and Chidel, 2002). Bat species with high wing-loading are more active in areas that are more frequently burnt (Armitage and Ober 2012) likely due to a decrease in vegetative clutter.

Importantly, very little work has specifically focused on summer bat habitat use and energy expenditure. Although bats commonly use torpor in summer, even during heat waves (Bondarenco et al., 2014), most bodies of work on insectivorous bats are biased towards winter, when bats often hibernate (e.g. Thomas et al., 1990). Torpor in heterothermic mammals is typically associated with a low ambient temperature or decreased food or water availability (Ruf and Geiser, 2015). However, in recent years new data on free-ranging animals have emerged to reveal that torpor is used for a variety of reasons and not only when animals are energetically stressed (Geiser and Brigham, 2012) and may be expressed at mild or warm ambient temperatures (Levin et al., 2012).

In August 2020, a lightning-caused wildfire was initiated in the Sierra Nevada range in Central California. The fire, later deemed the SQF complex, spanned 174,178 acres and encompassed regions of Sequoia National Forest, the Giant Sequoia National Monument, Inyo National forest, land managed by the Bureau of Land Management, state land, private land, and Sequoia National Park (18,984 acres). This wide-ranging and severe wildfire continues to be managed. Therefore, determining how bats physiologically cope with, or even exploit, warmer temperatures in the unique wildfire-affected landscape of Sequoia and Kings Canyon National Parks is essential and gives important insight to how, and if, small mammals are capable of dealing with forests altered by fire, and inform future studies focused on global warming.

V. METHODS

The study took place in the South Fork region of Sequoia and Kings Canyon National Parks from June-August 2021. We investigated the response of adult California myotis (*Myotis californicus*) (n=18; mass=4.5 ± 0.3 g) to differing fire severities of habitat affected by the SQF Complex fire. Bats were captured with mist nets and harp traps placed across paths, forest edges, and across the South Fork River in a central location at the South Fork Campground. Fire severity surrounding the campground was classified from 1 (not burnt) to 4 (severely burnt) according to the Rapid Assessment of Vegetation Condition after Wildfire (RAVG) data. All fire severities were present in the proximity of the capture location, and thus, bats had opportunity to choose preferred roosting habitat over a range of vegetation complexities.

All bats captured during the initial netting effort were assessed for body mass, forearm length, sex, reproductive status, age, wing damage, and parasite load. This information will be later used to catalogue species in the park associated with different habitat types. Targeted bats were fitted with temperature-sensitive radio transmitters with individual transmitter frequencies (0.57 g, LB-2T, and 0.40 g, BD-2XT, Holohil Systems Inc., Carp, ON, Canada) to assess skin temperature and torpor patterns over a period of up to two weeks. Due to the difficulty of implanting internal transmitters and to increase transmitter range, external transmitters were used. Skin temperature of small heterothermic mammals is usually <2.0 °C cooler than core body temperature (Barclay et al. 1996) and thus a reliable measurement of torpor patterns in species with large body temperature fluctuations like bats.

The morning following release, targeted bats were radio-tracked to their roost location every day, and roost and habitat characteristics recorded (tree species, slope, aspect, roost type, DBH, height of roost tree, % bark on tree, % exfoliating bark, sun exposure level (1-3), decay stage, crown class, elevation, and basal area). We also used the point-quarter method to choose four “random” trees; the nearest tree in each cardinal direction (N, S, E, and W); these trees were also assessed for the above characteristics. The random trees will later be used to determine if bats actively selected for specific characteristics within a habitat. The locations of the bats were also recorded with a GPS unit (GPSMap 66; Garmin, Olathe, KS) and associated with a corresponding fire severity in ArcGIS Pro v. 2.9 using a map generated with RAVG data provided by Sequoia National Park (Fig. 1) to determine if bats selected roost locations in their habitat based on the severity of the burn.

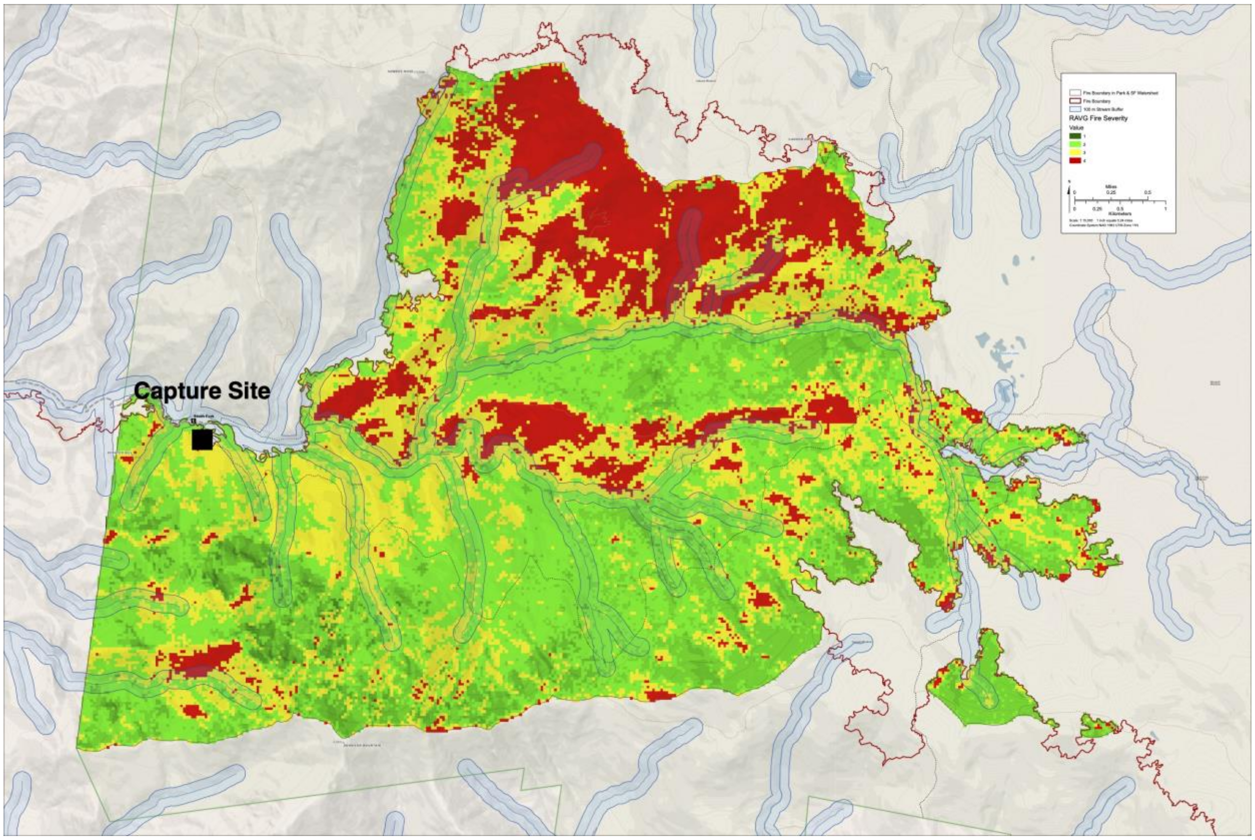

Fig. 1*. Rapid Assessment of Vegetation Following Fire Severity with bat capture location. Dark green represents unburnt habitat (level 1), light green represents low severity burn (level 2), yellow represents moderate severity burn (level 3), and red high severity burn (level 4).*

Skin temperature of bats were recorded continually in 10-min intervals using a datalogger (University of New England, Armidale, AU) set within strong reception of bat location to collect information on torpor and activity patterns. The position of the bats and reception of transmitter signal by the receiver/logger were assessed every day when possible, and, if necessary, the receiver/logger was moved to ensure data collection. Data were loaded onto a laptop computer approximately every 3–5 days.

Ambient temperature was measured with temperature data loggers (±0.5 °C, iButton thermochron DS1921G, Maxim Integrated Products, Inc., Sunnyvale, CA, USA) in the shade 1 m above the ground. A total of eight data loggers were used in the study, allocating two loggers for each burn severity (1-4).

We will use Generalized Linear Models in the program R (R Core Team, 2019) to determine differences in torpor patterns of bats amongst the different fire severities. Torpor variables assessed in the GLM will include torpor bout duration, minimum skin temperature during each torpor bout, maximum temperature reached during passive rewarming bouts in the daytime, and number of torpor bouts per day. Using equations adjusted to accommodate Daily Energy Expenditure (DEE) calculations for each species of bat, we will subsequently be able to assess which roosts provide the most energetically beneficial environment. Specifically, those bats which express the lowest DEE will be considered to use the least amount of energy.

To estimate the effects of fire on vegetation and roost selection, we will also use GLMs in R. We will randomly select 200 points within a 5-mile radius from the capture site, which contains ample representation of all RAVG burn severities, using the sample stratified function in the raster package in R (Hijmans, 2020). We will subsequently create a GLM model to assess whether burn severity differs between roost points and random points. To estimate the effects of roost vs. random tree characteristics we will use GLMMs with a binomial distribution in package glmmTMB (Brooks et al., 2017) to compare characteristics of roost trees relative to available surrounding trees. Because tree species are independent of each other, we will also employ a Pearson's chi-squared test (Zar, 2010). to test if roost tree and random tree distribution was equitable.

VI. Results

Because our data have not yet been statistically analyzed, the following results will be descriptive in nature.

We placed radiotransmitters on a total of 19 *M. californicus* (14F, 5M). However, we were not able to locate or collect physiological data for 6 individuals (Table 1). We were able to locate 21 roosts from 8 individual *M. californicus*, and ascertained physiological data from 9 individuals (Table 1). We were able to **both** track 5 individuals to roost sites **and** collect physiological data. The majority of tagged bats were postlactating females (Table 1).

Table 1. Measured and observed characteristics of radio-tagged *M. californicus* : Reproductive Status (Post=Postlactating, NR=Not Reproductive;R=Reproductive); Age (A=Adult); Forearm Length; Ear Length, Presence of Keel, Mass, Wing Damage (0-3, 0 being no damage 3 being severe damage), whethr the individual was tracked to at least one roost site, and whether skin temperature data were ascertained.

	Frequency	Sex	Reproroductive Status	Age	Forearm Length (mm)	Ear Length (mm)	Keel Present	Mass (g)	Wing Damage	Tracked to Roost?	Physiological Data?
1	150.905	F	Post	A	33.4	10	Y	4.7	0	Y	Y
2	150.865	F	Post	A	33.3	11.6	Y	4.4	0	N	Y
3	148.071	M	NR	A	32.6	10.7	Y	4.4	0	N	Y
4	148.172	M	NR	A	31.7	11.5	Y	4.3	0	Y	Y
5	148.275	M	NR	A	31.6	10.3	Y	4.3	0	N	N
6	148.385	F	Post	A	32.4	10.5	Y	4.7	0	N	Y
7	148.487	F	Post	A	33.4	10.3	Y	4.5	1	Y	Y
8	148.588a*	M	NR	A	32.6	11.9	Y	4.4	0	Y	Y
9	148.588b*	F	Post	A	32.2	11.7	Y	4.9	0	N	Y
10	148.682	F	Post	A	33.9	10.3	Y	4.4	0	N	Y
11	148.786	F	Post	A	33.9	11.1	Y	4.8	0	Y	Y
12	148.884	F	Post	A	32.8	10.4	Y	4.3	0	N	N
13	151.058	F	Post	A	33.5	10.7	Y	4.5	0	Y	N
14	148.983	F	Post	A	33.3	10.2	Y	5.2	0	N	N
15	151.138	M	R	A	32.2	10.4	Y	4.3	0	N	N
16	151260	F	Post	A	33.6	10.6	Y	4.9	0	N	N
17	151.418	F	Post	A	34.2	10.5	Y	4.4	0	Y	N
18	151540	F	Post	A	32.7	10.7	Y	4.7	0	Y	N
19	151580	F	Post	A	33.9	10.6	Y	4.3	0	N	N

* Transmitter fell off 148.588a, was retrieved in field, and re-used for 148.588b.

Bats displayed a high proclivity to roost in California black oak and Canyon live oak trees (Table 2). Notably, most of the roost trees were live, maintained a high percent of bark, were moderately exposed to the sun, and were generally either unburnt or burnt only to the base or midpoint of the tree. Bats typically roosted underneath exfoliating bark of the tree. *M. californicus* also preferred roosts in moderate to high canopy coverage that were typically in the codominant crown class (Table 2).

Bats also exhibited a strong preference for habitats that were only minorly burnt. The area where bats most commonly roosted was in a mosaic burn site, surrounded to the north and east by moderately and severely burnt areas. Notably, bats used all classifications of the RAVG data. These data are not yet available as not all roosts have been entered into ArcGIS.

Table 2. Characteristics of roost trees used by *M. californicus* include Elevation (m); ALRH=White alder (*Alnus rhombifolia*), CADE=Incense cedars (*Calocedrus* spp.), QUKE=California black oak (*Quercus kelloggii*), UMCA=California bay (*Umbellularia californica*), QUCH=Canyon live oak (*Quercus chyrysolepis*), ABCO=White fir (*Abies concolor*); Slope:F=Flat, G=Gentle, M=Moderate, S=Steep; Aspect; Roost Type: CR=Crevice, EB=Exfoliating bark, CA=Cavity, UK=Unknown; DBH (cm); Tree height (m); Roost height (m); Sun Exposure: 1=None, 2=Half, 3=Full; % Bark on Tree; % Exfoliating Bark on Tree; Decay Stage: Stage 1=Live, Stage 2=Declining, Stage 3=dead, Stage 4=Loose Bark, Stage 5=Clean, Stage 6=Broken, Stage 7=Decomposed, Stage 8=Down Material, Stage 9=Stump; Burn Scale: UA=Unburnt Alive, UD=Unburnt Dead, BBMi=Bark Burnt to Midpoint of Tree, BBMa=Bark Burnt to Base of Tree, % Canopy Cover; Stand Basal Area (feet squared/acre); Crown Class: D=Dominant, C=Codominant, I=Intermediate, S=Suppressed. a "." Entry indicates missing data.

Tree ID	Bat Frequency	Elevation (m)	Tree Species	Slope	Aspect	Roost Type	DBH (cm)	Tree Height (m)	Roost Height (m)	Sun Exposure	% Bark on Tree	% Exfoliating bark	Decay Stage	Burn Scale	% Canopy Cover	Stand Basal Area (ft2/acre)	Crown Class
R148172.04072021	148.172	3586	ALRH	F	NNE	CR	39.5	51.54	8.38	2	99	1	1	UA	78.16	25	C
R148487.11072021	148.487	4747	CADE	G	E	EB	43.9	16.92	.	3	85	30	3	BBMi	30	100	D
R148588.17072021	148.588	3681	QUKE	M	WNW	EB	29.2	12.80	7.16	2	95	3	1	BBMi	84.92	25	C
R148588.18072021	148.588	3740	QUKE	G	WNW	EB	14.2	7.62	5.03	2	65	15	4	BBMi	91.68	115	I
R148588.19072021	148.588	3691	QUKE	M	N	EB	30	10.67	4.57	2	90	2	1	BBMi	74	110	C
R148588.21072021	148.588	3586	UMCA	F	N	EB	31.5	15.24	3.05	2	95	5	1	UA	79.2	105	C
R148588.22072021	148.588	3586	QUCH	G	WNW	EB	35	16.15	6.10	2	95	10	1	UA	77.9	105	C
R148588.23072021	148.588	3586	QUCH	G	WNW	EB	40	16.15	4.57	2	95	10	1	UA	77.9	105	C
R148786.19072021	148.786	5440	QUKE	M	NW	EB	94.6	22.10	14.17	2	85	5	2	BBMa	45	125	C
R148786.20072021	148.786	5003	ABCO	M	NE	UK	79.9	37.80	.	3	98	6	3	BBMi	10	140	D
R150905.29062021	150.905	3675	QUKE	M	NNE	EB	40	15.24	8.23	2	95	3	1	BBMi	90.64	25	C
R150905.30062021	150.905	.	QUCH	G	NNW	EB	75	28.96	8.53	2	95	10	1	UA	96.88	.	.
R151058.02082021	151.058	5161	QUKE	M	N	CA	29.1	12.80	7.77	2	90	7	1	BBMi	78	135	C
R151058.27072021	151.058	5230	QUCH	M	N	EB	82.5	33.53	.	2	99	6	3	BBMa	15	135	C
R151058.31072021	151.058	5171	QUCH	M	NE	UK	20.3	14.33	.	2	95	4	1	BBMi	12	140	C
R151418.04082021	151.418	3665	QUCH	G	W	EB	48.5	14.63	3.20	2	97	10	1	UA	79.75	35	C
R151418.05082021	151.418	3740	ALRH	G	SSW	EB	30.7	6.10	2.13	1	70	35	1	UA	90	50	S
R151418.06082021	151.418	3691	ALRH	G	SSW	EB	39.1	12.95	3.81	3	75	45	4	UD	62.3	55	C
R151418.07082021	151.418	3799	QUCH	M	SW	UK	38.1	11.28	3.05	3	75	18	1	UA	20	45	C
R151540.06082021	151540	4219	QUCH	S	E	EB	.	.	9.91	2	95	15	3	BBMi	.	.	I
R151540.07082021	151540	3999	CADE	G	NW	UK	72.5	34.59	.	3	92	10	3	BBMi	35	70	D

Although physiological data still need to be analyzed, preliminary findings show that most *M. californicus* expressed short, shallow bouts of torpor from approximately 5:00 – 8:00 am, coinciding with the coolest part of the morning.

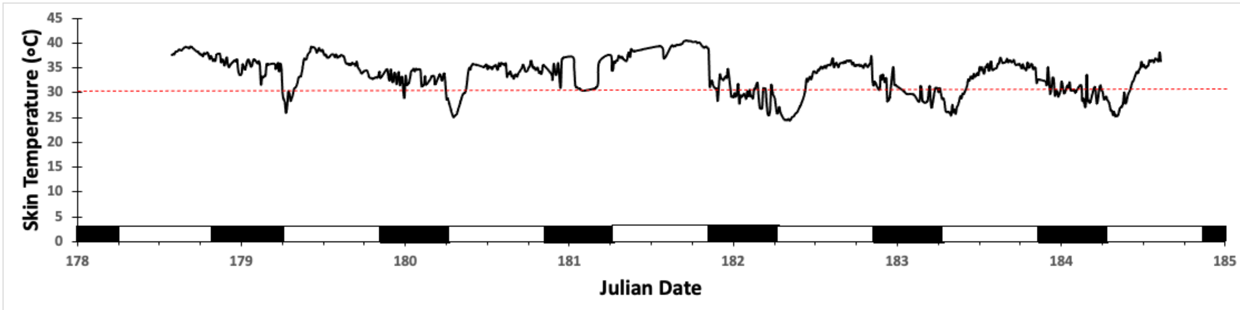

Fig. 2. Example skin temperature of an individual *M. californicus* (individual frequency number = 150.905, female, postlactating). The y-axis describes the skin temperature (°C), while they x-axis shows the Julian date associated with the data. The solid black line represents skin temperature, while the dashed red line indicates the torpor "cutoff" temperature of 30°C (below this temperature the bat is considered to be torpid). The black and white bars indicate night and day.

Figures 3a-3c. show examples of an *M. californicus*, Dr. Anna Doty radiotracking a tagged *M. californicus*, and an *M. californicus* roost tree.

Fig. 3a. A captured *M. californicus*.

Fig. 3b. Radiotracking in Sequoia National Park.

Fig. 3c. An example roost tree (an oak) used by *M. californicus* (bat frequency # 150.905). The red circle indicates the position of the roost on the tree.

VII. DISCUSSION

This study revealed important information about a species that is common throughout the western United States, yet surprisingly little information has been formally published noting their ecology and physiology. Previous research on *M. californicus* demonstrated their proclivity to roost in coniferous trees, such as Ponderosa pine, Douglas fir, Western white pine, and Grand fir (Brigham et al. 1997; Barclay and Brigham, 2001). However, we found that *M. californicus* roosted primarily in deciduous trees such as Black oak and Canyon live oak. When published, this study will demonstrate not only that the species roosts in deciduous trees, but also that *M. californicus* is flexible in roost site selection, demonstrating their ability to capitalize on the common tree species available in their habitat.

Additionally, the previous work investigating roost site selection of the species indicated that *M. californicus* requires large dead coniferous trees that project above the canopy (dominant) in open areas (Brigham et al., 1997). However, our study found the opposite: that *M. californicus* roost in live deciduous trees that are codominant in more cluttered areas. The preference for cluttered areas is evidenced by their selection of roost trees in low-burn sites. Although the species had the option to roost in moderate to severe burn sites, which resulted in less vegetative density and more open areas, these sites were rarely chosen. Recent acoustic research has shown that *M. californicus* is more active in areas less impacted by fire (Blakey et al., 2019), possibly indicating that increasing severity of fire can have a negative impact on roosting and foraging opportunities for the species. The discrepancy between the studies by Brigham et al. (1997) and Barclay and Brigham (2001) may be due to the location of the study sites. Both aforementioned studies were located in British Columbia. Although summer temperatures in parts of British Columbia are comparable to that of our study site, the study sites of Kootenay Lake and Nelson average summer temperatures ~10°C cooler than our study site in Sequoia National Park. Cooler temperatures may influence bats to choose open areas to capitalize on solar exposure in the earlier parts of the day to facilitate rewarming from torpor.

Our study also indicated that *M. californicus* will use torpor in the summer. This result is unsurprising as there is recent ample evidence that heterothermic endotherms will employ torpor year-round to reduce the effects of challenging environmental conditions (e.g. Turbill et al., 2003; Johnson and Lacki, 2014). Because of the high temperatures in Sequoia National Park during this time (~37-38°C), the only time bats could use torpor was in the early hours of the morning, which our data supported. Torpor is a useful strategy for bats in summer as their high surface area to volume ratio results in high rates of evaporative water loss (e.g. Cryan and Wolf, 2003), which can partially be compensated for by the use of torpor. Additionally, to our knowledge, our study, when published, will be the first to document evidence that *M. californicus* employs torpor. Although most insectivorous bats are known to frequently use torpor, providing as much data as possible from a range of species is useful to gather baseline data for future work. Future data analysis from this study will also specifically explore the relationship between burn severity and torpor use in the species.

VIII. Relevance to Conservation

This study showed that due to the tendency for *M. californicus* to roost in more cluttered habitat, retention of *S. giganteum* groves is particularly important. *S. giganteum* are considerably more fire resistant than other tree species in Sequoia National Park, and thus provide the vegetative density that is essential for the persistence of *M. californicus*. At least four individuals from the study were found to roost in a Sequoia grove approximately 3.5 miles from the capture site, detailing the "willingness" of the species to fly moderate distances to roost in more densely vegetated habitat. Although *M. californicus* were not found to roost in *S. giganteum* themselves, the trees helped create a preferable environment for the bats. Management to preserve and protect *S. giganteum* is important not only for the structural integrity of the forest, but also for the preservation of insectivorous bats in Sequoia and Kings Canyon National Parks.

IX. Future Work

Future projects in Sequoia National Park and elsewhere in California can be conducted to further explore the relationship between bats and wildfire. There are many directions future work could take; possibilities include assessing the response of a larger bat species (e.g. the big brown bat *Eptesicus fuscus*) to wildfire in a similar area of Sequoia and Kings Canyon National Parks to understand how body size affects response, or determining the physiological strategies of *M. californicus* in completely unburnt landscapes that experience similar climatic conditions to further elucidate how and if fire truly affects roost site selection and physiology. I am particularly interested in exploring the former option as my next fire-focused study. Additionally, studies could focus on how forest density preference affects response in fire-affected areas (e.g. clutter-adapted bats vs. open space-adapted bats), or capture efforts could be conducted entirely in larger Sequoia groves to determine whether bats do occupy *S. giganteum* as roost sites. There is so much more to learn about the response of bats to both wild and prescribed fires in California; because there exist a huge variety of habitats in the state, there are practically endless opportunities to determine how different species respond to fire both in terms of their physiology and roost selection, but also foraging strategies. I look forward to further exploring the unique relationship between bats and fire in California.

X. Deliverables

Some deliverable dates were modified due to COVID-19 restrictions; the research project was planned for completion by August 2020, but was pushed back one year to 2021. Therefore, manuscripts and presentations are now planned for completion in Fall 2022.

Deliverable	Planned Completion Date
CSU Bakersfield student field trip – bat identification	June 2021 - completed
Field tour with National Park Service Resource Management and Science Division at Sequoia and Kings Canyon	March and April 2021-completed
North American Society for Bat Research presentation	Fall 2022
Peer-reviewed manuscript: Habitat and roost selection of bats in Sequoia and Kings Canyon National Parks, informed by wildfire.	Fall 2022
Peer-reviewed manuscripts: Energetic expression of bats in Sequoia and Kings Canyon National Parks, informed by wildfire.	Fall 2022

XI. BUDGET

What	Proposed	Actual
Research Supplies	$23,780	$23,780
Total	$23,780	$23,780
Total to be reimbursed to the League		$0

XII. REFERENCES

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