Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Distribution and Roost Site Habitat Requirements of Western Yellow (*Lasiurus xanthinus*) and Western Red (*Lasiurus blossevillii*) Bats

2012 Summary Findings

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

September 2013

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Lower Colorado River Multi-Species Conservation Program

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2012 Summary Findings

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Lower Colorado River
Multi-Species Conservation Program
Bureau of Reclamation
Lower Colorado Region
Boulder City, Nevada
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ACRONYMS AND ABBREVIATIONS

ACP	Agua Caliente Park
AHAV	‘Ahakhav Tribal Preserve
BWRNWR	Bill Williams River National Wildlife Refuge
cm	centimeter(s)
CNWR	Cibola National Wildlife Refuge
CVCA	Cibola Valley Conservation Area
DBH	diameter breast height
g	gram(s)
HNWR	Havasu National Wildlife Refuge
INWR	Imperial National Wildlife Refuge
km	kilometer(s)
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
m	meter(s)
PVER	Palo Verde Ecological Reserve
Reclamation	Bureau of Reclamation
SCT	Santa Cruz River Tumacacori Site
SPP	San Pedro River Preserve
THL	Three Links San Pedro River
YUM	Yuma East Wetlands

Symbols

°C	degrees Celsius
%	percent

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Attachment

1 Capture and Roost Locations for Western Yellow and Red Bats
2 Photos to be Included for Future Presentation

ABSTRACT

The roosting ecology of western red bats (*Lasiurus blossevillii*) and western yellow bats (*Lasiurus xanthinus*) is poorly understood in the southwestern United States and on the lower Colorado River (LCR) specifically. Western red bats were not recorded on the LCR until after 1996 when a combination of biological contractors and a Bureau of Reclamation (Reclamation) biologist began observing the species there. Similar to western red bats, western yellow bats are believed to be a warm season migratory species in the Southwest. Western yellow bats have also recently been detected in increasing densities on the LCR. Both the western yellow and western red bat are covered species under the Lower Colorado Multi-Species Conservation Program (LCR MSCP). The LCR MSCP is a coordinated, comprehensive, long-term, multi-agency effort with goals including conserving habitat, working toward the recovery of threatened and endangered species, and reducing the likelihood of additional species being listed (Reclamation 2004).

The second year of this project was directed at identifying roosting habitat use by these two species. We radio tracked 10 western red bats and 10 western yellow bats to day roosting habitat on the LCR and other riparian areas to determine the characteristics associated with individual tree roosts. The first 2 years of data collection have provided us with patterns that will be more fully explored after the third and final year of data collection. For western red bats, these patterns indicate roost selection based on a tree patch or roosting neighborhood. In contrast, western yellow bats appear to select roosts for the characteristics of individual trees. It is important to note that we are in the early stages of data analysis and that these patterns must be clarified with more robust analyses.

INTRODUCTION

The roosting ecology of western red bats (*Lasiurus blossevillii*) and western yellow bats (*Lasiurus xanthinus*) is poorly understood (Adams 2003). Western red bats were not recorded on the lower Colorado River (LCR) until 1996 (Calvert and Neiswenter 2012). Western red bats have primarily been observed adjacent to permanent water sources in cottonwood, oak, and sycamore communities (Adams 2003; Findley et al. 1975). The diet of western red bats consists primarily of Lepidoptera it captures in flight at or near the canopy (Harvey et al. 1999). The ecology of the closely related eastern red bat (*Lasiurus borealis*) indicates that bats select roosts in mature deciduous riparian forests adjacent to open water and wetlands (Limpert et al. 2007). Whether western red bats respond to the same habitat types is unknown. Western red bats were thought to be migratory throughout the Southwest, but recent winter captures indicate the presence of a wintering population on the LCR.

Similar to western red bats, western yellow bats are believed to be warm season migratory species in the Southwest (Adams 2003). Western yellow bats occurred historically throughout southern Arizona, extending as far north as Phoenix. However, recent observations of western yellow bats north of Phoenix indicate that the range of this species is expanding northward (Hoffmeister 1986). This expansion of the western yellow bat range in the Southwest has been attributed to the introduction of palm trees along riparian corridors (Adams 2003). Western yellow bats have been detected as far north as Moapa, Nevada, adjacent to the impounded Colorado River at Lake Mead (Williams et al. 2006). This northern range expansion parallels the distribution of exotic palms (Williams et al. 2006). Western yellow bats have not been recorded on the LCR prior to 1996; but this recent expansion has been confirmed (Adams 2003; A. Calvert, personal communication.). The distribution of the species may also be associated with that of Yucca plants in the southwestern United States (Higginbotham et al. 2000). Regardless of these associations, western yellow bats appear to exist in low densities throughout their range.

The purpose of this project is to implement conservation measures identified within the Lower Colorado River Multi-Species Conservation Program (LCR MSCP), specifically:

- MRM1: Conduct surveys and research to better identify covered and evaluation species habitat requirements

- WRBA1: Conduct surveys to determine species distribution of the western red bat

- WRBA2: Create 765 acres of western red bat roosting habitat

- WYBA1: Conduct surveys to determine species distribution of the western yellow bat

- WYBA3: Create 765 acres of western yellow bat roosting habitat

These conservation measures will be accomplished through the use of capture surveys and standard radio very high frequency telemetry techniques to locate roost sites of western red and yellow bats. We will then describe the roost site characteristics used by western red and yellow bats within the LCR MSCP project area (as well as additional compatible riparian habitats outside the project area). These data will be used to evaluate the potential distribution of western red and yellow bat roosting habitat currently within the LCR MSCP project area. Finally, we will develop management guidelines for maintaining and creating roosting habitat for western red and yellow bats at the roost and stand level scales. These guidelines can be used by restoration project managers to create roosting habitat for these two covered species.

OBJECTIVES

To meet the project purpose as it pertains to western yellow and western red bat habitat management, we are addressing the following objectives:

1. Locate roost sites of western yellow and western red bats within the LCR MSCP project area

2. Describe roost site characteristics used by western yellow and western red bats within the LCR MSCP project area and compatible riparian habitats

3. Evaluate the current distribution of western yellow and western red bats in relation to determinate habitat associations currently within the LCR MSCP project area

4. Develop management guidelines for maintaining and creating roosting habitat for western yellow and western red bats within the LCR MSCP project area

METHODS

In collaboration with Bureau of Reclamation (Reclamation) biologists, we selected 10 total sampling locations: 6 within the LCR, 1 in the Bill Williams River drainage adjacent to the LCR, 2 along the San Pedro River drainage, and 1 along the Santa Cruz River in southern Arizona. The six sites within the LCR

were selected as treatment plots. LCR plots are mitigated land-use areas composed of densely planted even-aged stands of cottonwood and willow species with little or no understory. Treatment plots include the ‘Ahakhav Tribal Preserve (AHAV), Cibola Valley Conservation Area (CVCA), Havasu National Wildlife Refuge (HNWR), Imperial National Wildlife Refuge (INWR), Palo Verde Ecological Reserve (PVER), and Yuma East Wetlands (YUM). We sampled at INWR in our 2011 surveys and once during the cold season this year, but determined that YUM more closely resembled the vegetation community of our other treatment plots. Therefore, we replaced INWR with YUM for the warm season surveys. Control sites were selected off of the LCR to accommodate for long-term ecological changes due to river channelization and tamarisk introduction limiting areas of non-manipulated habitat on the LCR. We selected four control sites that were characterized by a cottonwood canopy and mixed native and non-native understory. The control sites included Bill Williams River National Wildlife Refuge (BWRNWR), San Pedro River Preserve (SPP), Three Links San Pedro River (THL), and the Santa Cruz River Tumacacori Site (SCT). We replaced Agua Caliente Park (ACP) with SCT for the 2012 surveys because the vegetation community more closely resembled our other control plots. Each sampling plot was centered on the Reclamation recommended netting location. Sample cells extend for 10 kilometers (km) in each direction along the riparian corridor and 5 km in each direction perpendicular to the riparian corridor. We allocated these cell sizes to correspond to the riparian obligate nature and daily range of western red bats (Adams 2003).

In order to locate roost sites of western yellow and western red bats within the sample cells, we focused on mist net and radio tracking methodologies. Within the 10 sampling plots, we attempted to capture a total of 10 red and 10 yellow bats during the second warm season sampling year and five western red bats during the cold season. We used 3.8-centimeter (cm) x 3.8-cm mesh size, 7.5-meter (m) high mist net sets within foraging and traveling corridors. Where possible, we also set nets across and adjacent to available water sources (e.g., small pools and narrow river channels). Nets were set 1/2 hour before sunset and remained open for 4 hours. Captured western yellow and western red bats were fitted with very high frequency radio transmitters. We only attached transmitters to bats weighing at least 10.5 grams (g) and did not attach transmitters to pregnant and/or lactating females. The transmitters weigh 0.37 g, less than 3 percent (%) of the bat’s body weight, and are glued onto their backs using surgical adhesive. The transmitters fall off the bats within approximately 21 days. We tracked bats to day roost locations using triangulation methodologies.

Once located, we described roost site characteristics used by western red and yellow bats within the sample cells. We mapped the location of all captured red and yellow bats and their roost sites. At each identified roost site, we collected both patch and tree roost site characteristics. To maintain consistency with other LCR MSCP researchers (e.g., flycatcher and cuckoo biologists), we used

LCR MSCP vegetation monitoring field methods (D. Bangle, unpublished) protocol. In addition to the LCR MSCP methods, we measured appropriate roost tree characteristics of the four nearest trees to the roost tree. These characteristics included tree height, diameter breast height (DBH), base height of the canopy, foliar width (i.e., crown width), temperature, roost tree species, number of live branches, live crown ratio, foliage condition, bat roost height, and distance the roosting bat is from the tree trunk. Tree heights, base height of canopy, and bat roost height were estimated with a Lecia Disto D330 laser distance meter and a stationary robel pole. Foliar width was estimated by stationing two robel poles at opposing canopy edges at 2, 4, 6, and 8 m. We then used the marked distances on the robel poles to measure canopy width. Temperature was recorded with a hand-held radiometer (Raytek MT4 Mini infrared thermometer) at 2, 4, 6, and 8 m. Live crown ratio was an ocular estimate of the percent of live foliage. The number of live branches was the number of live stems greater than 10 cm DBH branching from 0–2 m from the tree base. In addition to recording these data at the location of a roost, this methodology supplied the covariates for habitat models created with objective No. 3 (Evaluate current distribution of western yellow and western red bats in relation to determinate habitat associations currently within the LCR MSCP project area.). We measured the same variables for the four trees nearest the roost tree to provide a basis for tree-specific comparisons. We performed a simple frequency analysis across a subset of variables to provide an initial estimate of roost tree characteristics. We also compared roost tree characteristics with those of the four adjacent trees to estimate variables associated with bat use. We used a series of two-tailed student t-tests at a significance level of $\alpha = 0.05$. These methods were focused on summarizing this year's roost site data and not as a full model of bat distribution on the LCR and control sites.

Although other species may have been present, we cannot accurately identify species that were not captured in in mist nets. Therefore, species diversity analyses are limited to captured bats only. For each sampling location, we calculated the Shannon-Wiener Diversity Index (Spellerberg and Fedor 2003) as adapted from its original equation (Shannon 1948) and used the *ln* function in which P*i* is the proportion of each species at a sampling location.

$$H' = -\sum_{i=1}^{n} Pi(\ln(Pi))$$

We reanalyzed data from 2011, which used a $\log_{10}$ function for the Shannon-Wiener Diversity Index (Diamond 2011), and recalculate the data using the *ln* function for direct comparison of data between 2011 and 2012. We analyzed both seasons (i.e., cold versus warm) (table 1) in 2012 separately and compared the indices with analyses from 2011. Additionally, we calculated a separate Shannon-Wiener Diversity Index for the combined seasons within 2011 and 2012.

Table 1.—2012 sampling locations by date across the cold (February 6 – March 1) and warm season (May 21 – July 2) for western red (*Lasiurus blossevillii*) and western yellow (*Lasiurus xanthinus*) bats

Sampling locations	Acronym	Cold season sampling dates	Warm season sampling dates
‘Ahakhav Tribal Preserve	AHAV	February 9, 27, and 28	May 24, June 21, and July 19
Bill Williams National Wildlife Refuge	BNWR	February 14, 29, and March 1	May 30, June 26, and July 24
Cibola Valley Conservation Area	CVCA	February 7	May 22, June 19, and July 17
Havasu National Wildlife Refuge	HNWR	February 13	May 29, June 25, and July 23
Imperial National Wildlife Refuge	INWR	February 6	N/A
Palo Verde Ecological Reserve	PVER	February 8	May 23, June 20, and July 18
San Pedro River Preserve	SPP	February 22	June 11, July 2, and July 30
Santa Cruz River Tumacacori Site	SCT	February 15	June 7, June 27, and July 25
Three Links San Pedro River	THL	February 21	June 13 and July 26
Yuma East Wetlands	YUM	N/A	May 21, June 18, and July 16

RESULTS

We mist netted western red and yellow bats for a total of 39 sample nights (see table 1). We sampled BWRNWR and AHAV three times each during the cold season in an effort to spread our winter sample across sites after we had captured western red bats at CVCA, PVER, and SPP. We sampled all other sites once during the cold season. During the warm season, we sampled eight sites on three occasions, while THL was sampled twice due to monsoon thunderstorms prohibiting our efforts on two occasions. Western red and/or yellow bats were captured at four Reclamation treatment sites (AHAV, CVCA, PVER, and YUM) and three control sites (SPP, THL, and SCT). We detected 14 bat species at control sites and 11 species at treatment sites. During the cold season, we detected seven bat species at control sites and five species at treatment sites.

In 2012, the cold season sampling locations (N = 9) were visited between February 6 – March 1 and the warm season locations (N = 9) between May 21 – July 30 (see table 1). Sixteen bat species were recorded during 39 sampling nights. We categorized each species as to whether or not they were present during the cold season, warm season, or both (table 2). Two sampling locations did not have bats present during the cold season (HNWR and SCT), and all locations had bats present during the warm season.

Table 2.—Bat species diversity at each study site in the cold season, warm season, and both (Light grey represents bat species captured only during the cold season; medium grey represents species captured only during the warm season; black represents species captured in both the cold and warm seasons.)

		Treatment sites					Control sites		
	AHAV	CVCA	HNWR	INWR	PVER	BNWR	SPP	THL	ACP
Townsend's big-eared bat									
Western red bat									
Western yellow bat									
California leaf-nosed bat									
California myotis									
Pallid bat									
Canyon bat									
Mexican free-tailed bat									
Big brown bat									
Yuma myotis									
Arizona myotis									
Cave myotis									
Pocketed free-tailed bat									
Silver-haired bat									
Mexican long-tongued bat									
Western small-footed bat									
Southwestern myotis									
Number of Bats (Cold Season)	7	1	1	31	2	13	0	11	N/A
Number of Bats (Warm Season)	43	59	12	25	21	67	31	113	6
Number of Species (Cold Season)	5	1	1	4	2	5	0	2	N/A
Number of species (Warm Season)	7	7	4	7	4	10	9	11	3
Shannon-Wiener diversity index (Cold Season)	4.71	N/A	N/A	3.63	2.00	4.12	N/A	1.79	N/A
Shannon-Wiener diversity index (Warm Season)	4.56	2.60	3.13	6.33	2.71	7.19	6.74	4.81	1.09
Shannon-Wiener diversity index (Combined Warm and Cold Season)	5.23	3.15	3.26	6.08	3.76	5.60	6.74	4.79	3.00

The Shannon-Wiener Diversity Index shows that species diversity was higher during the warm season and at control sampling locations (table 3 and figure 1).

Table 3.—Bat species diversity using the Shannon-Wiener Diversity Index by season within year and by year with combined seasons for 2011 and 2012

	Treatment locations						Control locations				
	AHAV	CVCA	HNWR	INWR	PVER	YUM	BNWR	ACP	SPP	THL	SCT
2011 cold season	1.33	0.00	0.00	1.29	0.69	N/A	1.41	N/A	N/A	0.59	N/A
2011 warm season	1.63	1.16	1.21	1.83	0.80	N/A	1.91	1.10	1.84	1.60	N/A
2012 cold season	1.09	0.56	N/A	0.35	0.69	N/A	1.48	N/A	0.69	0.00	N/A
2012 warm season	1.82	1.64	1.15	N/A	1.14	0.45	1.79	N/A	1.31	1.43	1.50
2011 combined	1.87	1.31	1.43	1.57	1.15	N/A	2.09	1.10	1.84	1.62	N/A
2012 combined	1.99	1.70	1.15	0.35	1.23	0.45	1.83	N/A	1.47	1.45	1.50

Note: All Shannon-Wiener Diversity Indices were calculated using the following equation: $H' = -\sum_{i=1}^{n} Pi(\ln(Pi))$. Data from 2011 were recalculated from a log_{10} function to a *ln* function.

SUMMARY OF SAMPLING SITES

‘Ahakhav Tribal Preserve

At the AHAV control site, we detected one western red bat, captured five western yellow bats, and tracked three individuals. The single western red bat was detected in the cold season, and the western yellow bats were captured in the warm season. We located roosts for two of the three western yellow bats that had transmitters attached (see attachment 1 for all capture and roost locations).

- The western red bat detected at AHAV in the cold season escaped our net before we could record any biological data.

- We captured one male western yellow bat at AHAV on May 24. We fitted the bat with a transmitter and tracked it for a week. We detected the bat twice at the same roost, an old Mexican fan palm (*Washingtonia robusta)* just outside of Parker, Arizona.

- We captured another male western yellow bat and fitted him with a transmitter on June 21 and were able to follow him that night until the signal was lost heading south. This bat was not detected again.

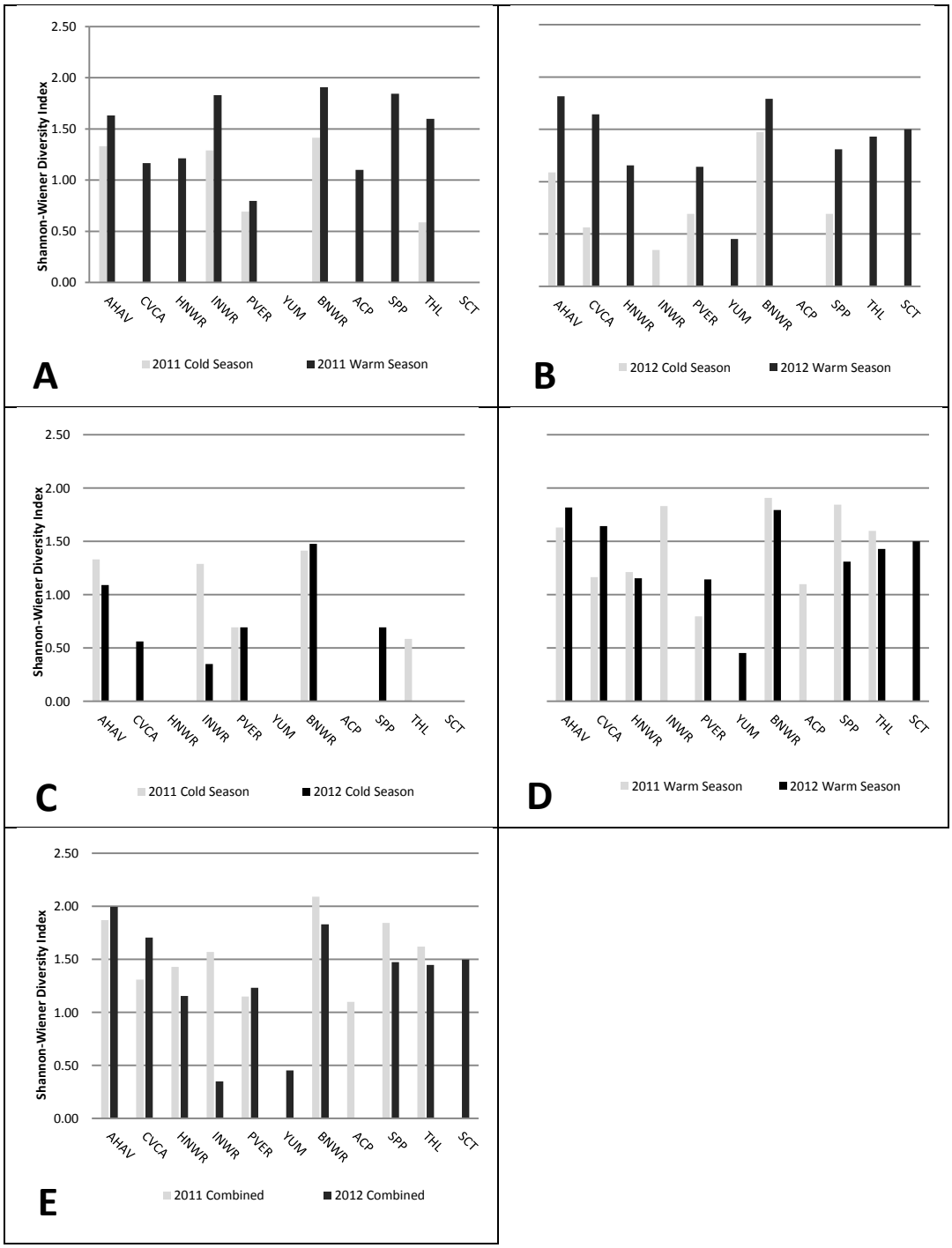

Figure 1.—Comparison of the Shannon-Wiener Diversity Index by season in 2011 (A), 2012 (B), 2011 and 2012 cold seasons (C), 2011 and 2012 warm seasons (D), and combined by year (E).

- We netted two subadult females and one male western yellow bat the night of July 19. We placed a transmitter on the male and were able to track him for a week. On the night of July 19, the bat was monitored foraging along a canal adjacent to the trap site until approximately midnight. The bat was observed day roosting in a Mexican fan palm in the vicinity of the tribal government buildings near the trap site on July 20, 23, and 25, suggesting that the bat is a warm season resident along the LCR. The two subadult females were not fitted with transmitters in order to spread our sample across sites.

Cibola Valley Conservation Area

We captured seven western red bats and four western yellow bats at CVCA. Three of the western red bats were captured during the cold season. The rest of our captures occurred during the warm season. We placed transmitters on three western red bats (detecting roost sites for two) and two western yellow bats (detecting a roost site for one).

- At CVCA during the cold season, we captured three male western red bats within the first hour. We fitted the first male captured with a transmitter and were able to follow him for 14 days, detecting the bat seven times. The initial capture of this bat occurred on February 7, and the last signal we detected was on February 21. Of those seven detections, we were able to find six different day roosts, all of which were in the foliage of Fremont cottonwoods (*Populus fremontii*). The bat roosted in the treatment site as well as the Cibola National Wildlife Refuge (CNWR). All six roosting sites were within 5 km of the capture site, suggesting that this bat is a cold season resident on the LCR. The other two western red bats were not fitted with transmitters in order to spread our winter sample across sites.

- We captured one western red and one western yellow bat on May 22. We fitted the female captured with a transmitter; unfortunately, we were unable to locate her signal, and thus, we could not identify any roost locations. We later located this dropped transmitter from an aerial survey within the patch. The western yellow bat was fitted with a transmitter, but the signal was lost heading west, and no roost locations were found.

- The female western red bat we captured on June 19 was not fitted with a transmitter because she was lactating.

- On the night of July 17, we netted three western yellow and two western red bats. We fitted transmitters on a subadult male western red bat and subadult male western yellow bat. We detected the western red bat five times at three roosts over the course of a week. All three roosts were located within the treatment plot and were within 400 m of each other. On five separate occasions, we tracked the western yellow bat to a group of Mexican fan palms near a private residence approximately 6 km from the trapping site. We did not attach transmitters to the other three bats we captured in order to spread our sample across sites or because they did not meet minimum weight requirements.

Palo Verde Ecological Reserve

We captured nine western red bats and eight western yellow bats at PVER. One western red bat was captured during the cold season, with the rest of our captures occurring during the warm season. We attached five transmitters to western red bats and four transmitters to western yellow bats.

- We captured and tracked a male western red bat at PVER for 21 days (from February 8 to March 1), detecting it in a day roosting location nine times. The bat used two Fremont cottonwood roosts less than 100 m apart. The bat was detected seven out of the nine times in a large clump of dead foliage approximately 1.5 m from the ground.

- Two male western red bats were on caught on May 23 and fitted with transmitters. We were able to follow these bats for most of the night, but eventually the signal faded and was lost moving south along the river. A male western yellow bat was also fitted with a transmitter on May 23. We tracked this bat for a portion of the night until the signal grew weak and finally disappeared. Two pregnant western red bats captured on May 23 were not fitted with transmitters, and another western yellow bat escaped while being removed from the net.

- We captured three western red and two western yellow bats on the night of June 20. We tracked one male western red bat to the same Fremont cottonwood on three occasions over the course of 2 weeks. This day roost was located within the treatment plot where the bat was trapped. We also fitted a transmitter to a post-lactating female western yellow bat on June 20. We detected this bat two times over the course of 2 weeks at a private residence roosting in a Mexican fan palm in Blythe, Arizona. A male western yellow bat was caught on June 20. This bat was tracked through the night, but the signal was lost heading south. We also captured a male adult and subadult western red bat on June 20, but did not attach transmitters because of low weight (subadult 9 g) and in order to spread our sample across sites.

- On July 18, we captured four western yellow bats and one western red bat. We attached a transmitter to the female subadult western red bat and tracked it until late in the night. The bat seemed to be foraging in and around the patch, but when we returned the next morning, the signal was lost. This bat was a subadult and may have dispersed to another part of the river. We also attached a transmitter to a male subadult western yellow bat. We tracked this bat south from the trapping site to a Mexican fan palm approximately 250 m north of Interstate 10. We obtained two locations on this bat day roosting in the Mexican fan palm. We did not attach transmitters to the other three western yellow bats in order to spread our sample across sites.

Yuma East

We observed two western yellow bats at YUM during the warm season and did not sample this site during the cold season.

- We captured an adult female on May 21 and did not attach a transmitter because the bat was pregnant.

- On July 16, we captured an adult male and deployed a transmitter. That night, we tracked this bat foraging over the Yuma Palms shopping center. At approximately 0330, this bat headed southwest and was lost. We conducted an extensive search the next day, but did not locate the bat. On July 18, we again detected this bat foraging over the Yuma Palms shopping center. This time the bat headed east at approximately 0330 before doubling back and heading in the same direction as the night of July 16. We did not detect this bat again.

San Pedro River Preserve

We detected one western red bat at the SPP control site during the cold season and zero during the warm season.

- We captured the male western red bat on February 22 at SPP and later detected the bat three times at two different day roosts. Both roosts consisted of a standing live Fremont cottonwood with a dead Fremont cottonwood leaning against the roost tree. The bat was roosting within the dead foliage where the live standing roost tree and the dead tree met. The two day roosts are within 200 m of one another.

Three Links Ranch

We detected three western red bats at the THL control site during the warm season and zero during the cold season.

- We captured three western red bats on July 26. We did not attach transmitters to two male subadults because of low weight (8.5 and 10 g). We did attach a transmitter to a post-lactating female. We detected this bat only once, roosting in a Fremont cottonwood near the trapping site. During searches along the San Pedro on July 30 and 31, we did not detect it again.

Santa Cruz River Tumacacori

We detected four western red bats at SCT during the warm season and zero during the cold season. Unfortunately, due to pregnancy and weight restrictions, we could not place transmitters on these bats. On June 7 and June 27, we captured lactating females, and on July 25, we captured two subadults. One escaped in the process of conducting measurements, and the other was not fitted with a transmitter due to weight limitations (9 g). The detection of these bats suggests a breeding population of western red bats along the Santa Cruz River in southern Arizona.

We did not capture either western red or yellow bats at INWR or HNWR (treatment sites) or at BWRNWR (control site). We captured western red bats in February, May, June, and July. Western yellow bats were detected in May, June, and July.

ROOST CHARACTERISTICS

Western Yellow Bat

We captured a total of 19 western yellow bats and radio tagged 10 during 2012. Bats were captured at four of the Reclamation treatment sites (AHAV, CVCA, PVER, and YUM) and zero control sites. All western yellow bat captures occurred during the warm season. We were able to identify roosts for five of these individuals. All of these bats selected only one roost each; therefore, they had a mean of one roost per bat. We collected roosting locations for these bats a mean of 2.8 times with a minimum of 2 and a maximum of 5 observations. Western yellow bats were detected at five separate roosts, all of which were in palm trees. The mean roost tree height was 12.5 m and ranged from 7.5 to 15.8 m. The roost trees varied in DBH from 40.4 to 206.5 cm with a mean of 88.56 cm. The live crown for roost trees had a mean value of 7.5 m from the

ground and ranged from 4 to 11m. All roosting locations were consistently below the live crown within the dead palm frond skirt. The percent of dead crown varied between 50% and 55% with a mean value of 51% dead crown. Bat roosting height above the ground had a mean value of 6 m and varied between 4 and 9 m. Crown width mean was 2.9 m wide and ranged from 0.5 to 4.6 m. Temperatures on the surface of the roosting trees averaged 41.2 degrees Celsius (°C) and varied from 25.4 to 50.4 °C. A comparison of roosting tree characteristics to those of adjacent trees indicates patterns of roost use. Neighboring trees had a mean height of 11.3 m and were not significantly different ($p = 0.564$) from roost trees (figure 2). Adjacent trees had a mean DBH of 58.3 cm and were not significantly different ($p = 0.368$) from roost trees (figure 3). The height of the start of the live crown in neighboring trees was 7.2 m and did not differ significantly ($p = 0.816$) from roost trees (figure 4). Crown width did not differ significantly ($p = 0.737$) between adjacent trees (3.4 m) and roost trees (figure 5). Crown width of adjacent trees was skewed toward a higher mean because of a large Aleppo Pine (*Pinus halepensis*) that was deemed to be a neighboring tree. Adjacent trees had a percent of dead crown mean value of 34.38% and differed significantly with roost trees ($p = 0.048$), which had a larger proportion of dead crown (figure 6).

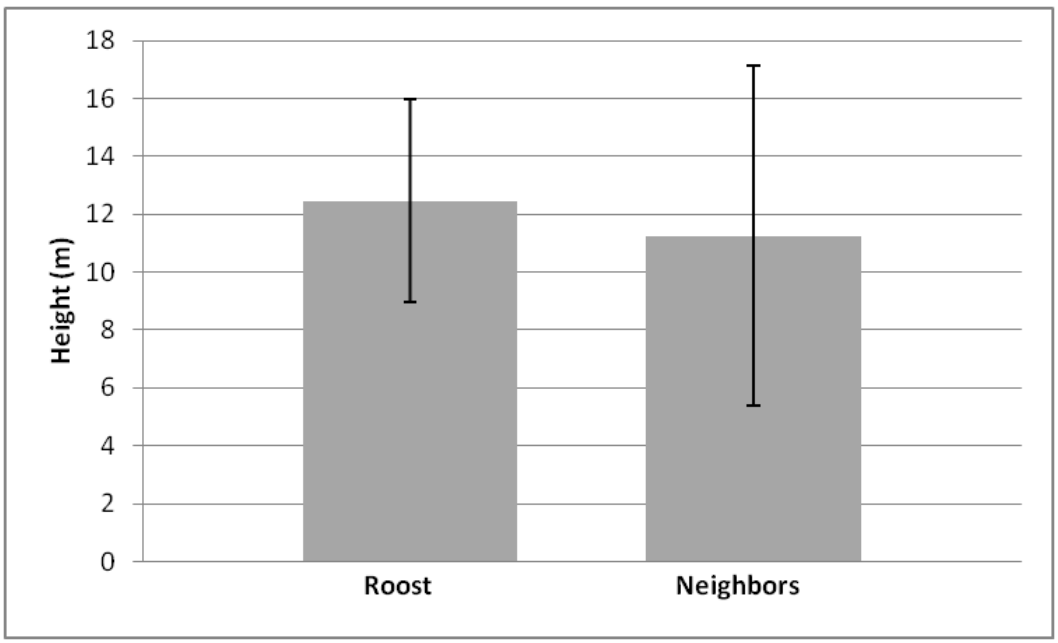

Figure 2.—Comparison of mean and standard deviation of tree height between the roosting tree and the four adjacent neighbor trees (p = 0.564).

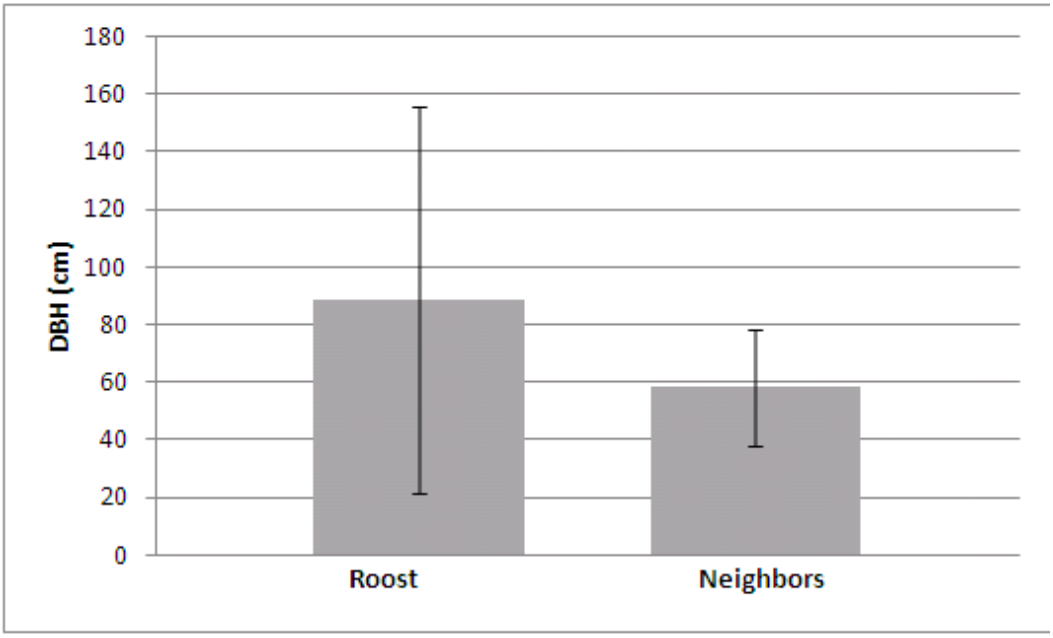

Figure 3.—Comparison of mean and standard deviation of DBH between the roosting tree and the four adjacent neighbor trees (p = 0.368).

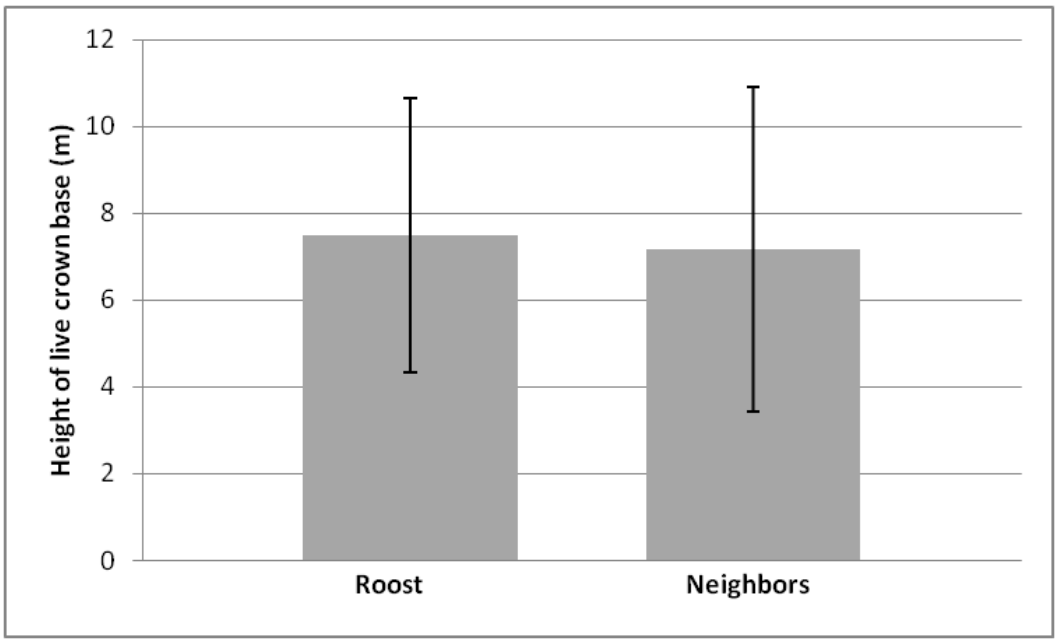

Figure 4.—Comparison of mean and standard deviation of height of the base of the live crown between the roosting tree and the four adjacent neighbor trees (p = 0.816).

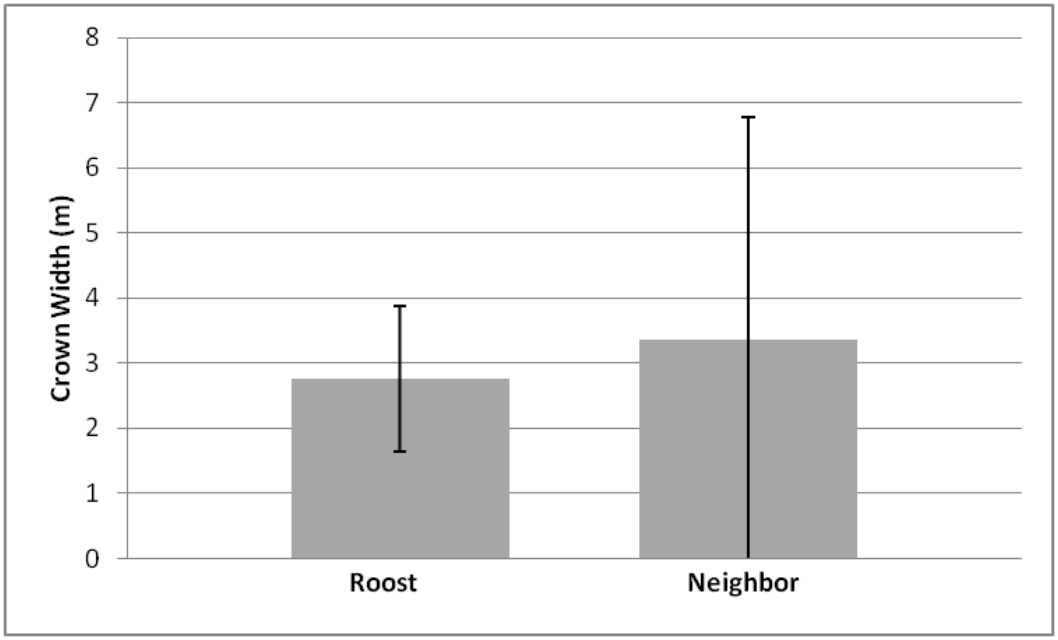

Figure 5.—Comparison of mean and standard deviation of the crown width between the roosting tree and the four adjacent neighbor trees (p = 0.737).

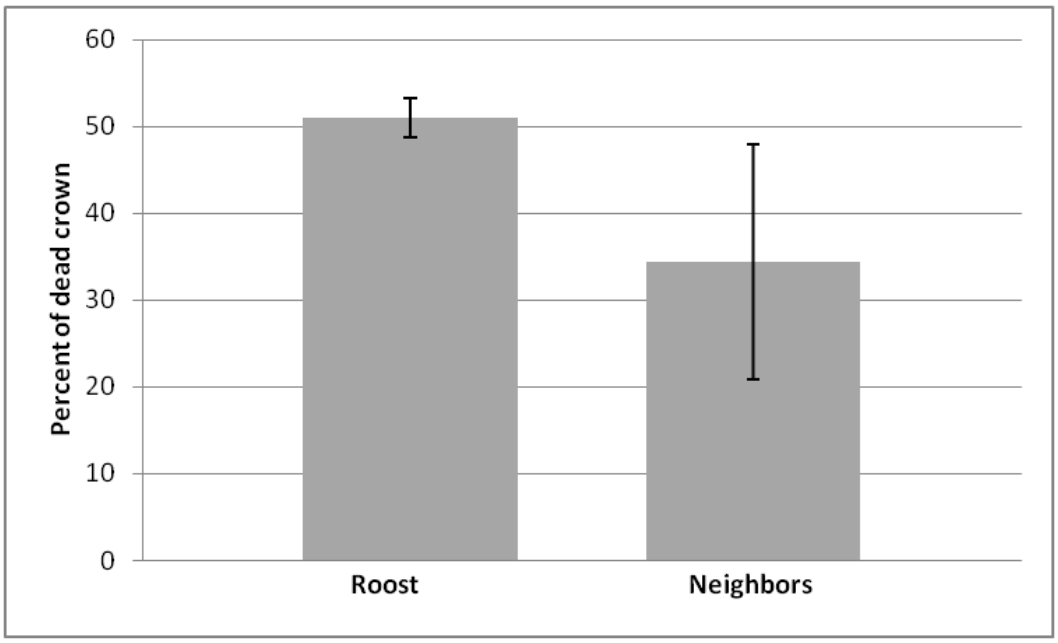

Figure 6.—Comparison of mean and standard deviation of the percent of dead crown between the roosting tree and the four adjacent neighbor trees (p = 0.048).

Western Red Bat

We captured a total of 25 western red bats and fitted 10 with transmitters during 2012. We detected western red bats at three Reclamation treatment sites (AHAV, CVCA, and PVER) and three control sites (SPP, THL, and SCT). We captured and tracked three western red bats during the cold season and seven during the warm season. We were able to identify roosts for six of these individuals. We observed western red bats utilizing a total of 15 separate roosts. All 15 of these roosts were in Fremont cottonwood trees. We observed western red bats at a mean of 2.8 roosts per bat with a minimum of 1 and a maximum of 6. We collected roosting locations for these bats a mean of 5.4 times with a minimum of 3 and maximum of 9 observations. We observed western red bats roosting in cottonwoods with a mean height of 13.4 m and ranged from 6.9 to 19.1 m. The mean DBH for roost trees was 44.6 cm and varied from 4.9 to 214 cm. The live crown began at a mean height of 3.5 m from the ground and ranged from 1 to 9 m. A mean of 20.1% of the live crown was dead in the roost trees, and it varied from 1 to 45%. The foliar width of the roost tree had a mean of 3.4 m and ranged from 0.75 to 7.5 m. We recorded mean temperature from the roosting trees at 21.6 °C, and it varied from 12 to 32.4 °C. Comparisons between roost tree and nearest neighbor trees' characteristics indicated highly variable roost use patterns. Neighboring tree height (13.04 m) was not significantly different ($p = 0.666$) from roost tree height (figure 7). We found DBH was also not significantly ($p = 0.214$) different between neighboring (24.6 cm) and roost trees (figure 8). The height of the base of the live crown for neighboring trees (4 m) was not significantly different ($p = 0.354$) from the roost tree (figure 9). We found that the live crown width did differ significantly ($p = 0.037$) between roost and neighboring (2.8 m) trees, with roost trees having a larger proportion of live crown width (figure 10). Percent of dead crown also did not differ significantly ($p = 0.330$) between adjacent and roost trees (figure 11).

DISCUSSION

Our findings indicate patterns of western yellow and western red bat habitat use. Data have been re-evaluated as suggested previously (Diamond 2011), and patterns should be interpreted with caution until all data are finalized and collected in 2013.

During the warm season we used a transmitter with a longer battery life, which lasted up to 21 days compared to 14 days. This increased battery life led to the transmitters having a weaker signal, which made it more difficult to locate the bats. As a result, we lost many of the bats we fitted with transmitters during the first round of warm season trapping. As a result, we focused much time and

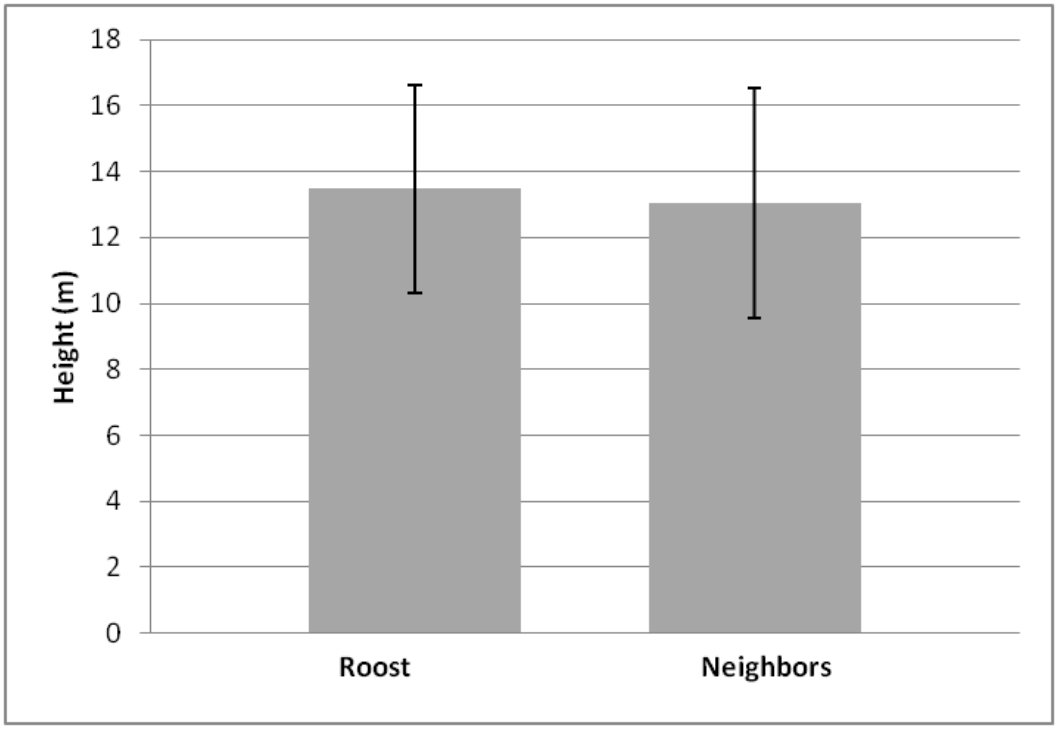

Figure 7.—Comparison of mean and standard deviation of tree height between the roosting tree and the four adjacent neighbor trees (p = 0.666).

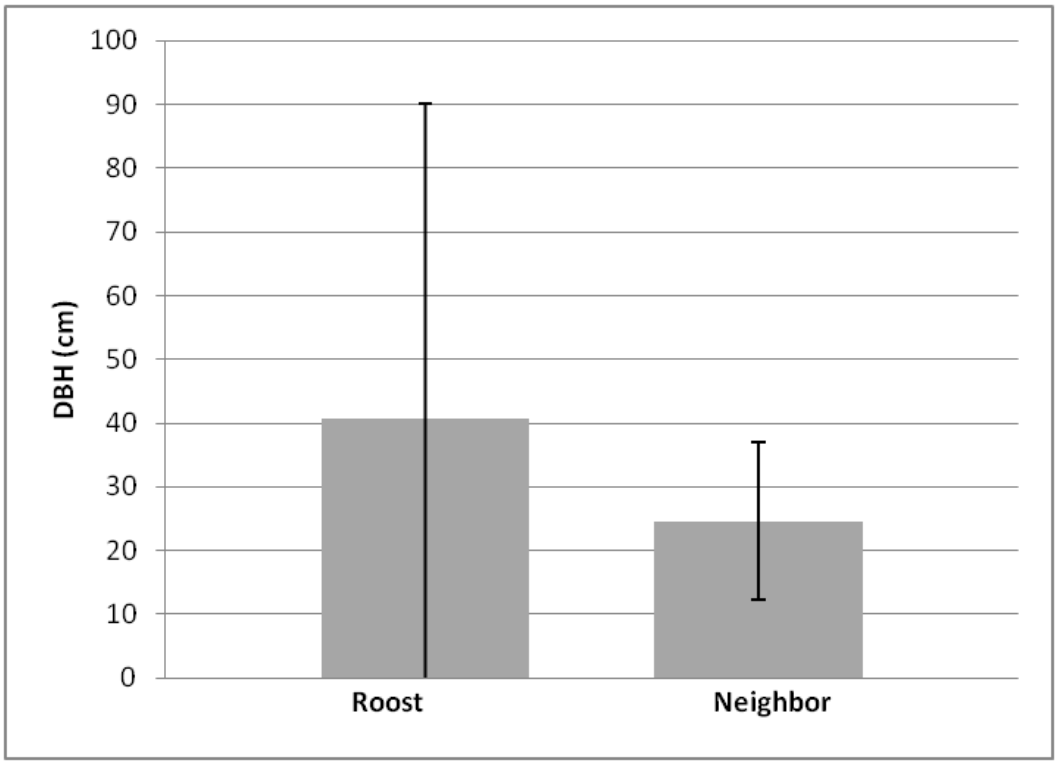

Figure 8.—Comparison of mean and standard deviation of DBH between the roosting tree and the four adjacent neighbor trees (p = 0.214).

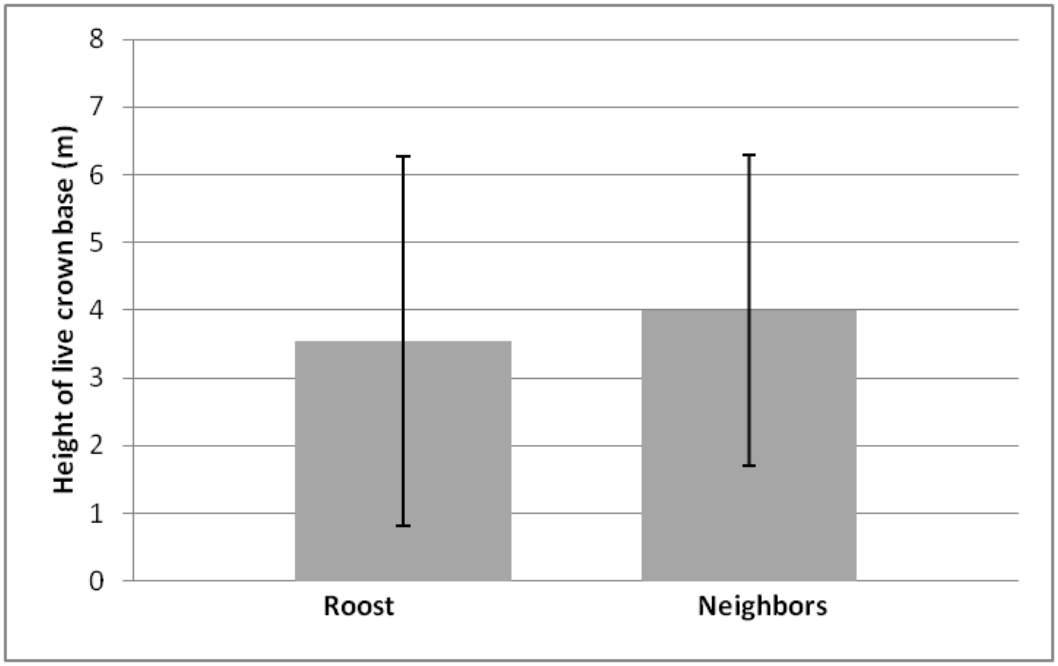

Figure 9.—Comparison of mean and standard deviation of height of the base of the live crown between the roosting tree and the four adjacent neighbor trees (p = 0.354).

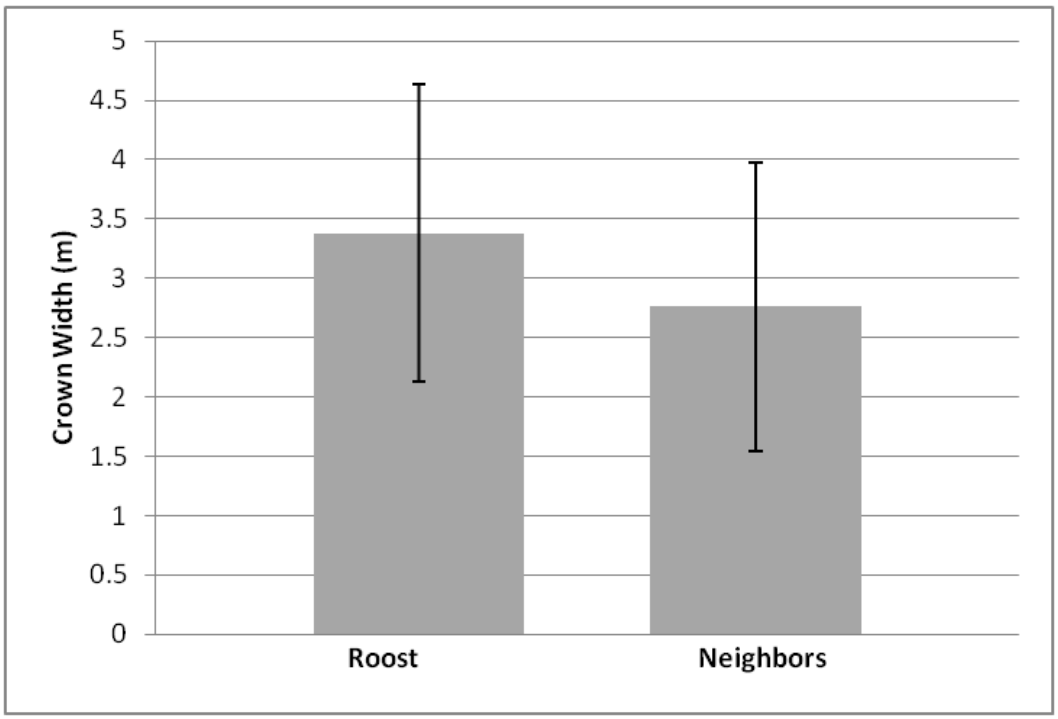

Figure 10.—Comparison of mean and standard deviation of the crown width between the roosting tree and the four adjacent neighbor trees (p = 0.037).

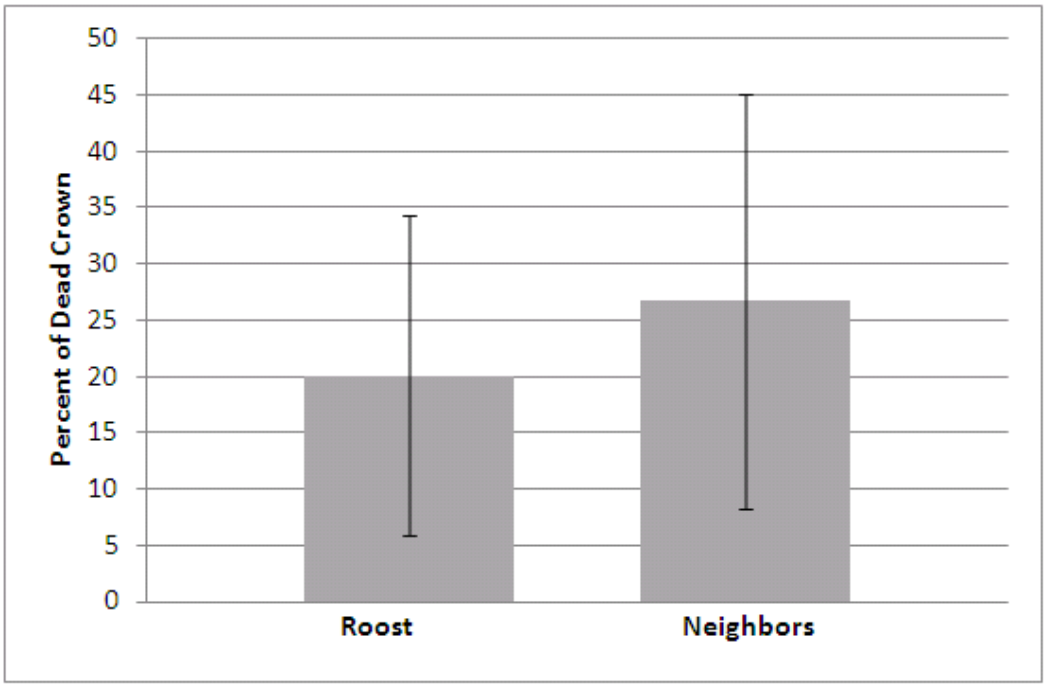

Figure 11.—Comparison of mean and standard deviation of the percent of dead crown between the roosting tree and the four adjacent neighbor trees (p = 0.330).

effort in locating missing signals, extensively searching up and down the LCR and adjacent habitat for days at a time. We also conducted telemetry from a fixed wing aircraft in an effort to locate missing signals. This issue was remedied by acquiring transmitters with a stronger signal before the second round of warm season trapping.

In 2012, we calculated the Shannon-Wiener Diversity Index using a more common approach involving the *ln* function, whereas 2011 data were computed using a $\log_{10}$ function. By re-evaluating 2011 data using the same approach, we were able to make comparisons between 2011 and 2012 data. Comparing treatment locations with control locations (see figure 1) may indicate the potential of maximum community diversity (using the Shannon-Wiener Diversity Index) at an approximate value of 1.5 for these habitat types. This may be indicative of an ecologically functional system that treatment sites can be compared to in order to measure successful restoration efforts. However, caution is advised depending on the objectives of specific restoration efforts.

We have witnessed a trend across sampling years 2011 and 2012 with treatment sites increasing in combined (warm season + cold season) species diversity. AHAV, CVCA, and PVER showed increases from 2011 to 2012, while HNWR was the only treatment site to demonstrate a drop in species diversity. It may be important to note that HNWR is the smallest in size of these treatment sites. We left YUM and INWR out of this comparison because they were not sampled

during all seasons across years. Across the same temporal scale, we observed a decrease in combined species diversity at control sites (BWNWR, SPP, and THL) that were sampled throughout all seasons. We left ACP and SCT out of this comparison because they were not sampled during all seasons across years.

By using the Shannon-Wiener Diversity Index, we will be able to make more statistically accurate inferences to species diversity across sites, years, and conditions (e.g., cold versus warm season). At this point, interpretations can only be made from the trends provided in the results, but without statistical significance. A third year of data will allow us to determine diversity index confidence intervals for each site, year, and condition and more accurately compare treatment to control sites. This may be useful when comparing the biological function or health of an existing natural habitat (control sites) to that of our treatment sites where some level of restoration has been implemented.

At this early stage in the project, these patterns should be evaluated with a high degree of caution and should be re-evaluated as additional data are collected during the last field season (2013). Our preliminary analyses of these data were focused on a single spatial scale – that of the individual roost tree. This fine spatial scale may not account for roost selection by western red bats. Our 2011 analysis found western red bat roost trees were not significantly different from adjacent trees, indicating a larger spatial response to roosting sites. This pattern of patch level selection of tree roosts was also noted with eastern red bats (Higginbotham et al. 2000). In 2011, we found that crown width was not significantly different between roost and neighboring trees. However, our 2012 analysis revealed crown width to be significantly different between roost and neighboring trees (roost trees having a larger width), indicating a possible relationship between canopy structure and bat use. We believe it is likely that western red bats are responding to patch scale habitat characteristics rather than tree-specific characteristics.

In contrast, western yellow bats appear to be associated with specific roost tree characteristics. Our 2011 analysis found yellow bat roosts had a significantly higher live crown base and percent dead crown. As we noted in our 2011 analysis, roost trees with a high live crown base and a high percentage of dead crown indicate the presence of a wide and deep dead palm frond skirt. These palm skirts likely provide a suitable microclimate that is not found in those palms lacking a large dead frond skirt. The 2012 analysis revealed yellow bat tree roosts with a significantly larger proportion of dead crown but not a significantly higher live crown base, suggesting that percent dead crown may be a more accurate indicator of yellow bat roosting sites. We believe that western yellow bats are likely using the treatment plots solely as foraging habitat and not for roosting. Yellow bats appear to be selecting a specific tree with a large dead palm frond skirt for roosting.

It is important to mention that the majority of western red and yellow bats in 2011 were captured at treatment plots, and 36 of 44 captures in 2012 also occurred at treatment plots. Treatment plots are providing species a larger, more intact patch of cottonwood-willow habitat than occurs elsewhere along the LCR or at the control plots. During 2012, the majority of western red bat roosts were located within treatment plots (10 of 15 with 2 roost locations occurring at nearby CNWR), and all yellow bats were captured within treatment plots. However, no yellow bat roosts were located within treatment plots across 2011 and 2012 sampling. This pattern gives further support to our interpretation that red bats are likely selecting roost locations based on patch or canopy characteristics, and yellow bats are utilizing treatment plots as foraging grounds. Our tree-scale analysis will be used as the basis for scaling up to patch and landscape level analysis after the final year of data collection and defining these emerging patterns further. Due to small sample sizes, we will require additional data to analyze the relationship between distances from capture location to roosting site. We will use our tree roost, patch, and landscape scales to analyze these distance relationships once additional specimens have been collected.

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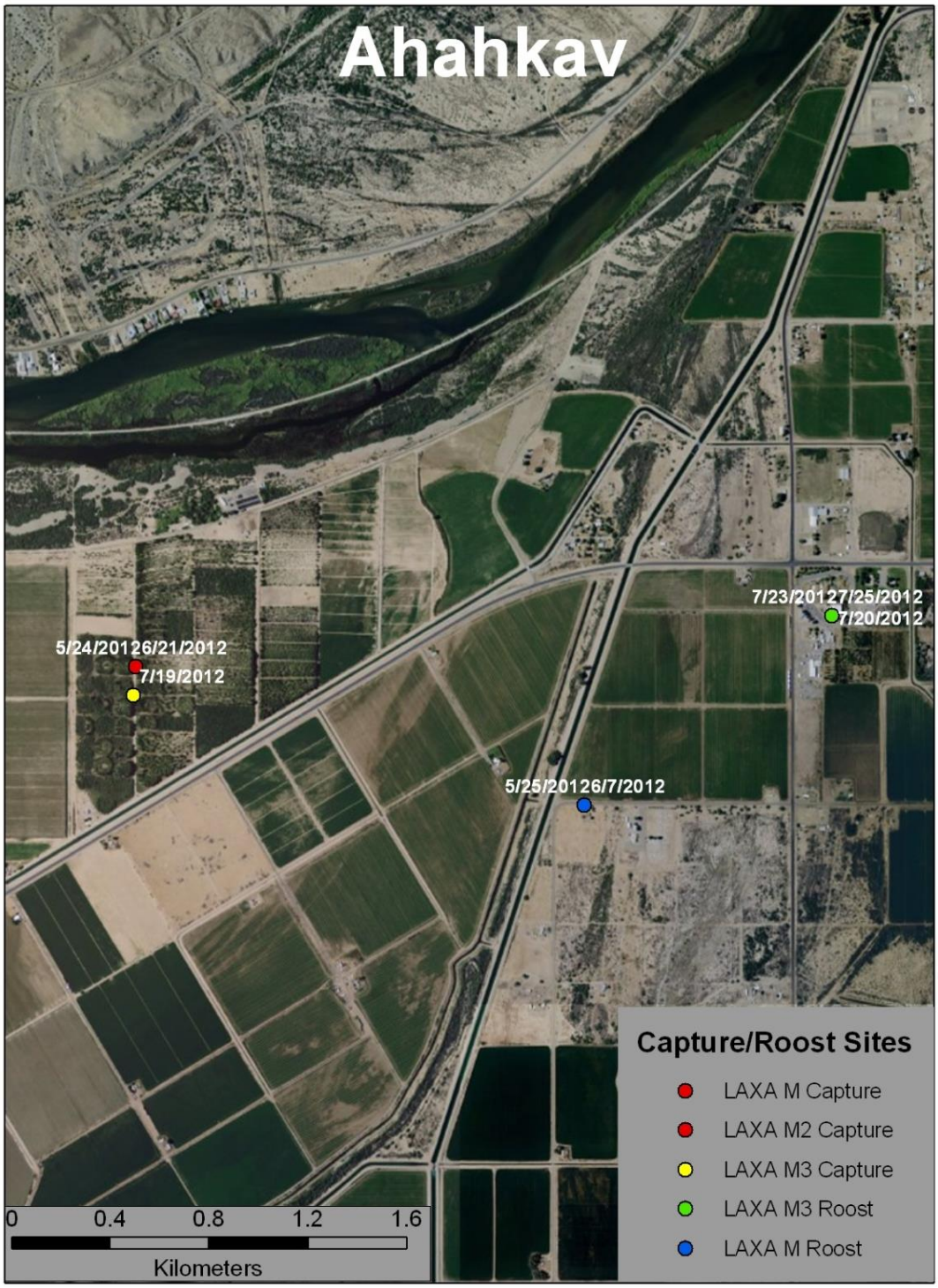
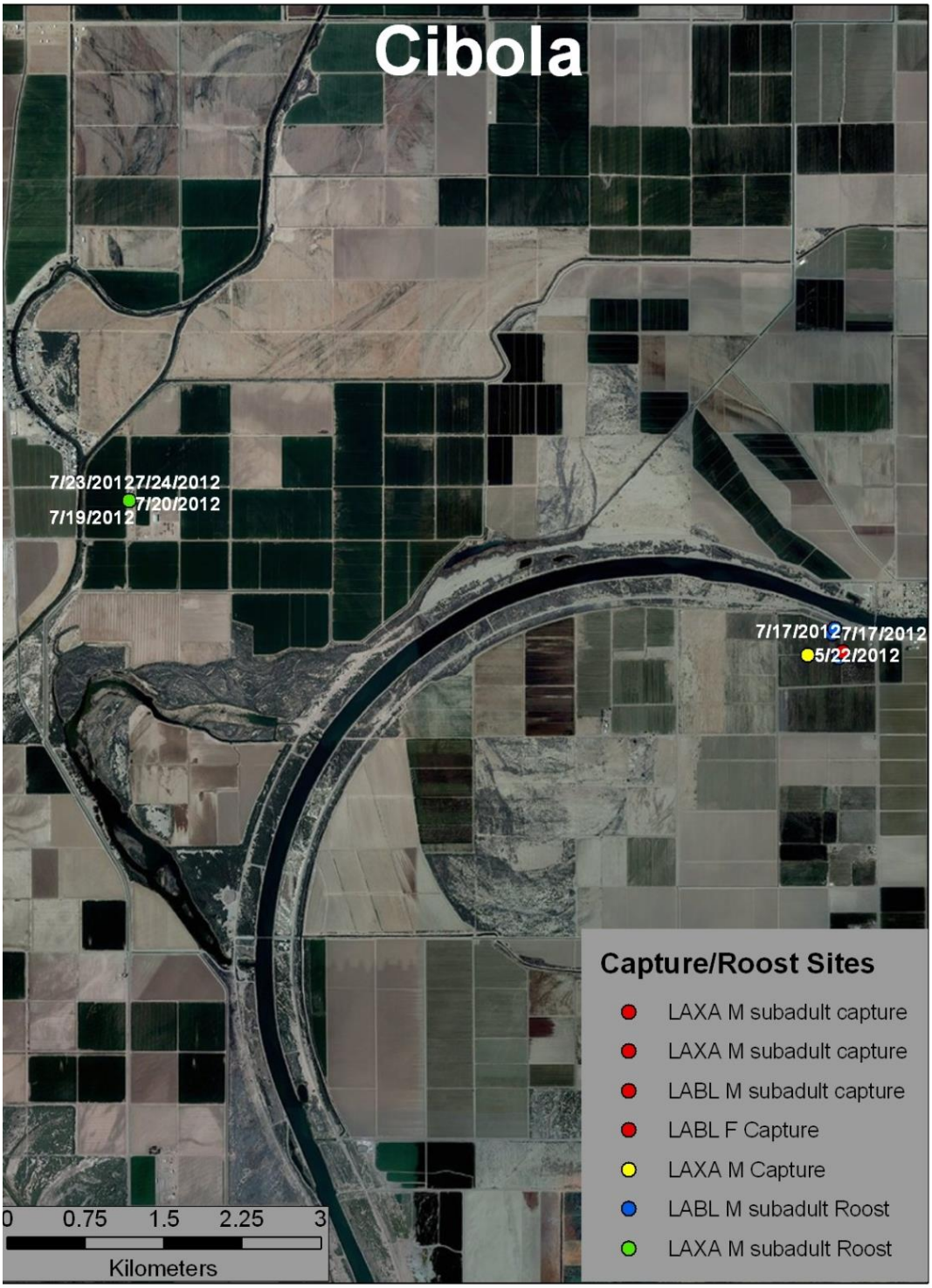
ATTACHMENT 1

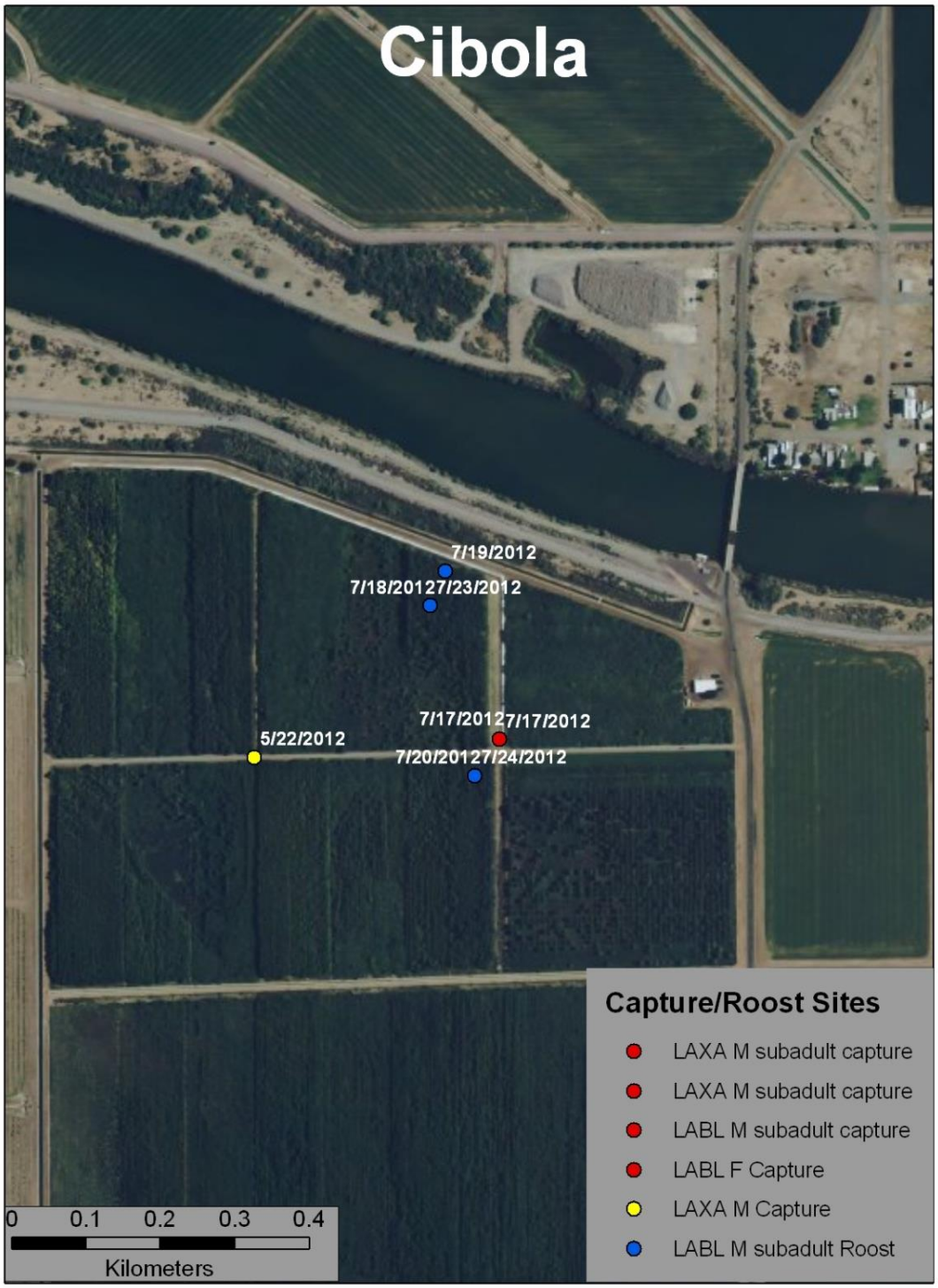
Capture and Roost Locations for Western Yellow and Red Bats



Capture and roost locations at the 'Ahakhav Tribal Preserve (warm season).

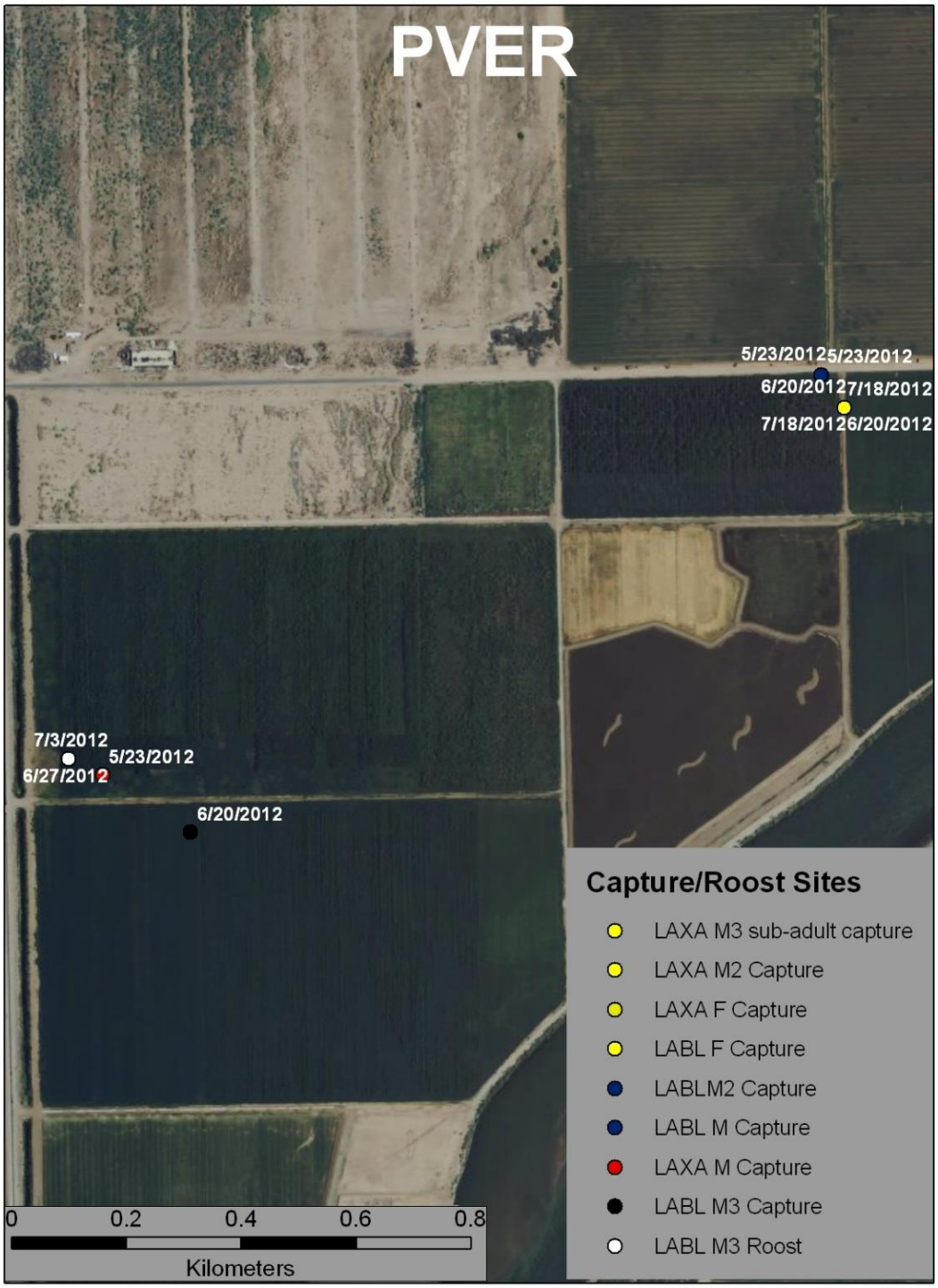


Overview of capture and roost locations at Cibola Valley Conservation Area (warm season).



Closeup of Cibola Valley Conservation Area capture site (warm season).

Roost locations for the subadult male western yellow bat at Cibola National Wildlife Refuge (warm season).

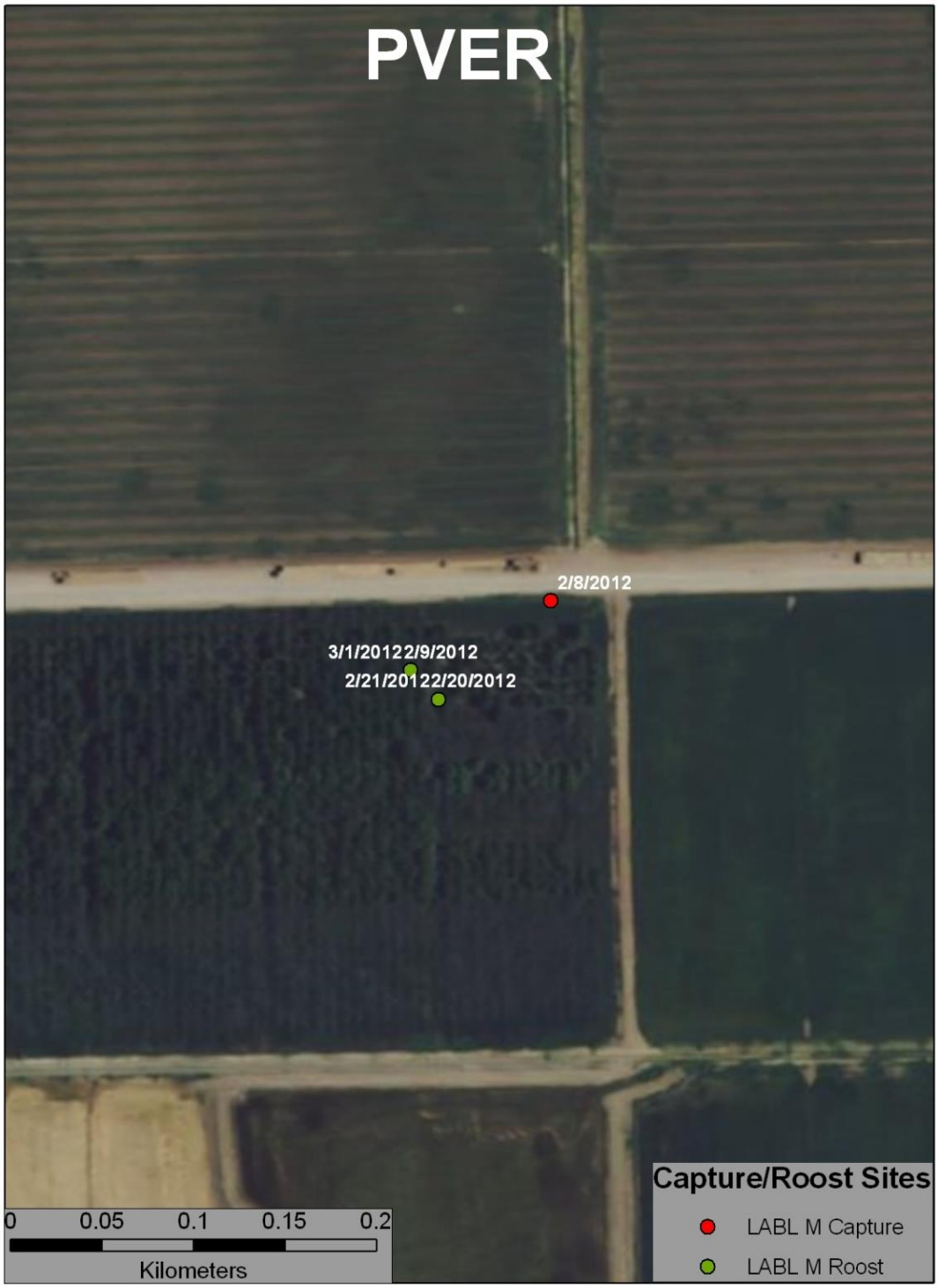


Capture and roost locations at Palo Verde Ecological Reserve (warm season).

Western yellow bats captured at Palo Verde Ecological Reserve roosting in and near Blythe, California (warm season).

Capture and roost locations for western red bat at Three Links San Pedro River (warm season).

Capture and roost locations for western red bat at Cibola Valley Conservation Area (cold season).



Capture and roost locations for western red bat at Palo Verde Ecological Reserve (cold season).

Capture and roost locations for western red bat at San Pedro River Preserve (cold season).

ATTACHMENT 2

Photos to be Included for Future Presentation

Western yellow bat (*Lasiurus xanthinus*) caught at Havasu National Wildlife Refuge fitted with a transmitter.

Male western red bat (*Lasirurs blossevilli*) caught at Cibola Valley Conservation Area with the transmitter attached.

Western red bat *(Lasirurs blossevillii)* caught at Palo Verde Ecological Reserve was found roosting in this Fremont cottonwood.

The Mexican fan palm to the right of the person is where the Arizona myotis (*Myotis lucifugus occultus*) was tracked to and where the maternity colony was discovered. A western yellow bat was observed roosting in the palm to the left of the person.