Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

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

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Lower Colorado River Multi-Species Conservation Program

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

Prepared by:

Ronald J. Mixan, Joel M. Diamond, PhD., Martin D. Piorkowski, and Daniel P. Sturla
Arizona Game and Fish Department, Wildlife Contracts Branch
5000 West Carefree Highway
Phoenix, Arizona 85086

Lower Colorado River
Multi-Species Conservation Program
Bureau of Reclamation
Lower Colorado Region
Boulder City, Nevada
http://www.lcrmscp.gov

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ACRONYMS AND ABBREVIATIONS

ACP	Agua Caliente Park
AGUAF	Agua Fria National Monument
AHAV	‘Ahakhav Tribal Preserve
AIC	Akaike’s information criterion
AIC_c	Akaike’s information criterion corrected for small sample size
ANOVA	analysis of variance
BWRCP	Bill Williams River Cliff Pond
BWRNWR	Bill Williams River National Wildlife Refuge
CDAM	Cienega Dam
cm	centimeter(s)
CNR	control non-roost
CR	control roost
CVCA	Cibola Valley Conservation Area
DBH	diameter at breast height
DCRR	Date Creek Ranch
ft	foot/feet
g	gram(s)
GIS	geographic information system
HNWR	Havasu National Wildlife Refuge
HRPR	Hassayampa River Preserve
in	inch(es)
INWR	Imperial National Wildlife Refuge
km	kilometer(s)
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
m	meter(s)
NASS	National Agricultural Statistics Service
NDVI	Normalized Difference Vegetation Index
PVER	Palo Verde Ecological Reserve
Reclamation	Bureau of Reclamation
SCT	Santa Cruz River Tumacacori Site
SE	standard error
SI	shape index
SPP	San Pedro River Preserve
THL	Three Links Farm
TNR	treatment non-roost
TR	treatment roost
USGS	U.S. Geological Survey
WCCR	West Clear Creek
YUME	Yuma East Wetlands

Symbols

°C	degrees Celsius
<	less than
≤	less than or equal to
>	greater than
%	percent
±	plus or minus

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Attachments

Attachment

1 Summary Results of ANOVA, Fisher's LSDs, and Associated p-Values for Western Red Bat Roosts (n = 52)

2 Summary Results of ANOVA, Fisher's LSDs, and Associated p-Values for Western Yellow Bat Roosts (n = 31)

3 Meso- and Macro-Occupancy Modeling Results

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EXECUTIVE SUMMARY

The roosting ecology of western red bats (*Lasiurus blossevillii*) and western yellow bats (*Lasiurus xanthinus*) on the lower Colorado River (LCR) is poorly understood. 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 a warm season migratory species on the LCR. The roosting habitat of these two species is poorly understood on the river, and this study focused on defining the roosting habitat affinities of these two species at three scales (micro, meso, and macro). We compared western red and western yellow bat roosting affinities across site conditions (native or restoration sites), gender, and age. At the micro-scale, western red and western yellow bats were associated with roost tree characteristics. At the meso- and macro-scales we attempted occupancy modeling to assess trends in habitat use; however, the sample size was insufficient to confirm these trends. This study demonstrates that western red bats utilize Bureau of Reclamation restoration sites similarly to non-restoration sites as roosting habitat. This study also indicates that western yellow bats use non-restoration and restoration habitats as foraging areas and not roosting resources. These findings indicate that restoration efforts on the LCR should focus on creating roosting habitat for western red bats and foraging habitat for western yellow bats to benefit these species. We recommend that restoration sites include cottonwood-willow woodland with areas that have 20 feet on center spacing to maximize the likelihood of western red bat roost utilization based on red bat roosts occurring in larger trees.

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 2009 (Calvert and Neiswenter 2012). Western red bats have primarily been observed adjacent to permanent water sources in cottonwood, oak, and sycamore (*Platanus occidentalis*) communities (Adams 2003; Findley et al. 1975). The diet of western red bats consists primarily of moths (Order Lepidoptera) captured 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. Incidentally, all known winter captures have been males.

Similar to western red bats, western yellow bats are believed to be a 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, along the Muddy River, 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 had not been recorded on the LCR prior to 1996, but this recent expansion has been confirmed (Adams 2003; A. Calvert 2011, 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 roosting habitat of these two species is poorly understood in the Southwest, and studies should focus on defining their habitat affinities. Identifying the habitat needs of tree-roosting bats is necessary to develop conservation strategies at the landscape level particularly because bats may be sensitive to changes in forest age, structure, and distribution (Thomas and West 1989; Limpert et al. 2007). Studies of tree-roosting bats have focused primarily on roost tree selection variables and avoided addressing habitat affinities at larger spatial scales. Thus, the micro-habitat for some tree-roosting bat species has been defined, while the larger matrix of habitat use has yet to be addressed. Because riparian restoration resulting in greater structural diversity of a habitat may be beneficial for many bat species (Fenton 1997; Williams et al. 2006), it is important to evaluate bat habitat use affinities at multiple scales.

Recently, the Bureau of Reclamation (Reclamation) has undertaken large-scale habitat restoration along the LCR. These restoration sites have the potential of providing roosting habitat for both western red and western yellow bats. The purpose of this project is to characterize species habitat for Reclamation to inform implementation of conservation measures identified within the Lower Colorado River Multi-Species Conservation Program (LCR MSCP); specifically, this project addresses the need for more specific information on habitat use of western red and western yellow bats. The following LCR MSCP conservation measures were addressed and aided through this project:

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

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

Measure to be addressed by future project/management actions:

WRBA2: Create 765 acres of western red bat roosting habitat

In order to help address these conservation measures, we designed a treatment versus control study to evaluate the roosting affinities of these bat species at three scales: micro, meso, and macro. This three-tiered approach provided managers with estimates of roost selection at the tree, patch and landscape scales. By using this multi-scale approach, we can better provide recommendations for habitat creation at the tree, patch, and landscape scales. We used mist netting and standard radio very high frequency telemetry techniques to locate roost sites of western red and western yellow bats. We used the located roosting sites to describe micro-, meso-, and macro-habitat use affinities for these two species. These data were used to evaluate the potential distribution of western red and western yellow bat roosting habitat currently within the LCR MSCP project area. Finally, we prepared recommendations for maintaining and creating roosting habitat for western red and western yellow bats at the tree, patch, and landscape scales based upon the results of the study. We divided this study into four discrete objectives:

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

2. Describe roost site characteristics used by western red and western yellow bats within the LCR MSCP project area and control sites

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

4. Based upon the information gathered in objectives 1–3, provide recommendations for maintaining and creating roosting habitat for western red and western yellow bats within the LCR MSCP project area

METHODS

Study Sites

In collaboration with Reclamation biologists, we selected 18 total sampling locations: 7 treatment sites on the LCR and 11 control sites – 2 in the Bill Williams River drainage adjacent to the LCR, 2 along the San Pedro River drainage, and 1 each along Date Creek, West Clear Creek, Cienega Creek, the Hassyampa River, the Agua Fria River, the Santa Cruz River, and Agua Caliente Park (ACP) (figure 1). We selected treatment and control sites to identify if these species were present in greater magnitude at either site type. It is important to note that this observational study was restricted to comparing existing treatment (Reclamation restoration sites) and control sites (non-restoration sites). Thus, the differences between the control and treatment may be due to site location and not site status as a control or treatment. These two site types were selected to test the hypothesis that western red and western yellow bat roosting habitat characteristics were ecologically similar between control and treatment sites. We measured roosting habitat in restored and control sites to identify differences that might inform recommendations for habitat management in restored areas.

Seven sites within the LCR were selected as treatment plots. LCR plots are composed of irrigated densely planted, even-aged stands of cottonwood and willow species with little or no understory adjacent to but outside the river channel. The treatment plots included the ‘Ahakhav Tribal Preserve (AHAV), Cibola Valley Conservation Area (CVCA), Havasu National Wildlife Refuge (HNWR), Beal Lake, Imperial National Wildlife Refuge (INWR), Palo Verde Ecological Reserve (PVER), and Yuma East Wetlands (YUME). We sampled at the INWR during our 2011 surveys and once during the cold season of 2012 but determined that YUME more closely resembled the vegetation community of our other treatment plots because of the age of the plantings and the size of the restoration area. Therefore, we replaced the INWR with YUME beginning with the warm season surveys in 2012. Likewise, we replaced the HNWR with Beal Lake starting with the 2013 cold season. We also believed replacing these sites would increase the chance of capturing the target species, thereby increasing the sample size of roosts, which would aid in completing objectives 1 and 2.

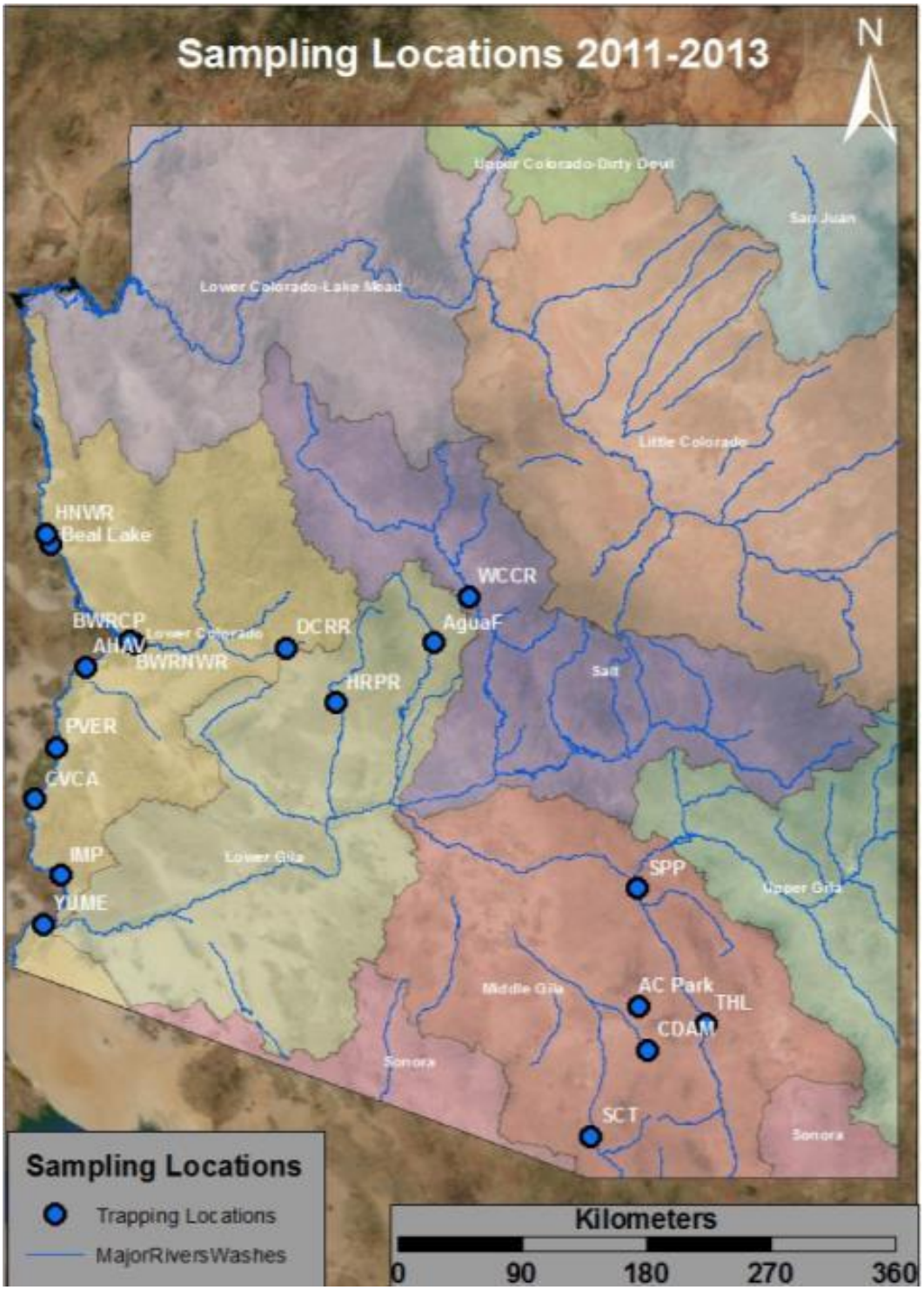

Figure 1.—Sampling site locations, 2011–13.

The control sites were selected off the LCR to accommodate for long-term ecological changes due to river channelization and tamarisk introduction limiting areas of non-restoration habitat on the LCR. We selected control sites off the LCR because little cottonwood-willow habitat exists outside of the restoration areas. We selected four control sites that are characterized by a cottonwood canopy and mixed native and non-native understory. The control sites included the Bill Williams River National Wildlife Refuge (BWRNWR), San Pedro River Preserve (SPP), Three Links Farm (THL), and the Santa Cruz River Tumacacori Site (SCT). Our sites along the San Pedro and Santa Cruz Rivers in southern Arizona harbored a potentially greater diversity of bat species. All control sites were similar in that they had a cottonwood-willow dominated overstory. They differed in streamflow. The BWRNWR had streamflow year round, while the SCT, SPP, and THL were sporadically dry. All control site rivers were similar in width when bank full. We replaced ACP with the SCT starting with the 2012 surveys because the vegetation community more closely resembled our other control plots in overstory and understory plant species assemblages. The hydrology at the SCT also more closely resembled our other control sites. ACP is fed by a warm water spring, while the SCT is located in a riparian corridor. After the conclusion of trapping efforts in 2012, we recommended increasing the number of control sites to augment our captures. Therefore, we added five new control sites for the 2013 warm season trapping session: Bill Williams River Cliff Pond (BWRCP), Date Creek Ranch (DCRR), West Clear Creek (WCCR), Cienega Dam (CDAM), the Hassayampa River Preserve (HRPR), and the Agua Fria National Monument (AGUAF).

Each sampling plot was centered on the Reclamation-recommended netting location. These netting locations were positioned in what biologists assessed to be flyways. In many of the locations, a mist net was strung across an open path between two patches of trees or along an edge of a patch of trees to capture foraging bats. We also placed nets over open water sources to capture bats foraging for hydration. Sample cells extended 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).

Objective 1: Locate roost sites of western red and western yellow bats within the LCR MSCP project area and in control sites

In order to locate roost sites of western red and western yellow bats within the sample cells, we focused on mist net and radio tracking methodologies. We broke our sampling periods into warm season and cold season in order to delineate western red bat use in the warm season from use in the cold season. We sampled for three consecutive years (2011, 2012, and 2013). Within the 18 sampling plots, we attempted to track a total of 20 western red and 20 western yellow bats during the warm season sampling period and 10 western red bats during the cold season.

We used 3.8- x 3.8-centimeter (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 deployed at sunset and remained open for 4 hours. Captured western red and western yellow bats were fitted with very high frequency radio transmitters. We only attached transmitters to bats weighing at least 10 grams (g) and did not attach transmitters to pregnant and/or lactating females. The transmitters weigh 0.37 g, less than 5 percent (%) of a 10-g bat's body weight, and were glued onto their backs using surgical adhesive (OSTO-BOND), which begins to degrade and drop off the bats within approximately 21 days, which coincidentally is also the battery lifespan in the transmitter. We tracked bats to day-roost locations using triangulation methodologies.

We had a total of 21 pooled (warm and cold season combined) sampling events from 2011 to 2013. During each survey year, we sampled the treatment and control plots twice during the cold season or until a single red bat was captured. For the warm season sampling, we visited each site every three weeks from May through the end of July. This sampling design assumed that bats captured between January and March and May through July were resident individuals and not migrating bats utilizing these roosting resources for only a short period of time.

We calculated the distance a bat traveled between discrete roosting locations using ArcGIS (version 10.1; Environmental Systems research Institute, Inc., Redlands, California) to determine the maximum, minimum, and mean distance traveled. For each sample site, we calculated a Shannon-Wiener diversity index (Spellerberg and Fedor 2003) as adapted from its original equation (Shannon 1948) and using the *ln* function, where *Pi* is the proportion of each species at a sampling location. This diversity index provided an estimate of species diversity and evenness across sample sites. We calculated this index to provide a rough estimate of the overall habitat suitability for bats as a taxa. We calculated a separate Shannon-Wiener diversity index for the combined seasons within 2011, 2012, and 2013. While a diversity index is not directly related to the objectives of the project, it was calculated in order to better understand the potential differences in bat diversity between treatment and control sites.

Objective 2: Describe roost site characteristics used by western red and western yellow bats within the LCR MSCP project area and control sites

Once located, we described the roosting tree, roosting patch, and roosting landscape characteristics used by western red and western yellow bats. 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. We measured appropriate roost tree characteristics of the four nearest trees to the roost tree. These characteristics included tree height, diameter at 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 of the roosting bat 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 vertically 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). 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. The live crown ratio was an ocular estimate of the percent of live foliage. In addition to recording these data at the location of a roost, this methodology supplied the covariates for habitat models created with objective 3. We measured the same variables for the four trees nearest the roost tree to provide a basis for tree-specific comparisons. We selected variables in part based on a study of tree selection for eastern red bats (Limpert et al. 2007).

Objective 3: Evaluate the current distribution of western red and western yellow bats in relation to determinate habitat affinities within the LCR MSCP project area and control sites

In order to evaluate the roosting affinities of western red and western yellow bats, we used three analysis scales: micro (roosting tree), meso (roosting patch), and macro (roosting landscape).

Micro-Scale (Roosting Tree)

The micro-scale was designed to evaluate the roosting tree specific habitat affinities. We broke trees up into one of four categories: treatment roost (TR), treatment non-roost (TNR), control roost (CR) and control non-roost (CNR). We used the tree characteristics collected under objective 2 to compare western red and western yellow bat roosting and non-roosting habitat in the treatment and control. We used a one-way analysis of variance (ANOVA) to compare the tree characteristics in the control sites and the treatment sites. Specifically, we compared the four categories described above (TR, TNR, CR, and CNR). We also compared roost characteristics for gender (male, female, and non-roost) and age (adult, subadult, and non-roost). Generally, males are thought to be less selective of roosts and, thus, less likely to display differences between the roost and non-roost trees. We included non-roost in these analyses to identify not only if roost use differed across gender but also if the genders both displayed differences between the roost and non-roost trees. These tests allowed us to analyze if genders differed in roost selectivity. We also included non-roost in the age comparison to analyze if adults and subadults differed in their roost selectivity. We analyzed these data using fixed-effect ANOVA and Fisher's LSDs ($\alpha = 0.05$) to test for significant differences in tree characteristics (table 1)

among the four treatment (TR, TNR, CR, and CNR), three gender (male, female, and non-roost), and three age (adult, subadult, and non-roost) levels. We used separate models for each set of comparisons for each species.

Table 1.—Summary and description of tree-based variables compared across treatment blocks, three gender blocks, and three age blocks

Height	Roost tree and nearest neighbor tree height (m)
DBH	Diameter of roost and nearest neighbor tree (cm)
Height of live crown base	Height of live crown base for roost and nearest neighbor trees (m)
Width of crown at base	Width of roost and nearest neighbor trees at ground level (m)
Width of crown at 2 m	Width of roost and nearest neighbor trees at 2 m from ground level (m)
Width of crown at 4 m	Width of roost and nearest neighbor trees at 4 m from ground level (m)
Width of crown at 6 m	Width of roost and nearest neighbor trees at 6 m from ground level (m)
Width of crown at 8 m	Width of roost and nearest neighbor trees at 8 m from ground level (m)
Percent dead crown	Percentage of dead foliage in the crown of roost and nearest neighbor trees
Number of apical meristems	Number of apical meristems in the roost and nearest neighbor trees
Roost height	Height of bat roost in the roost tree (m)
Temperature N aspect	Temperature of the northern aspect of the roost and nearest neighbor trees a the roost height (degrees Celsius [°C])
Temperature E aspect	Temperature of the eastern aspect of the roost and nearest neighbor trees a the roost height (°C)
Temperature S aspect	Temperature of the southern aspect of the roost and nearest neighbor trees a the roost height (°C)
Temperature W aspect	Temperature of the western aspect of the roost and nearest neighbor trees a the roost height (°C)
Vegetation closure at 3 m	Class of vegetation closure at 3 m from base of roost tree (Classes 1 to 7: Class 1 = 0% closure, and Class 7 = 100% closure)
Vegetation closure at 6 m	Class of vegetation closure at 6 m from base of roost tree (Classes 1 to 7: Class 1 = 0% closure, and Class 7 = 100% closure)
Vegetation closure at 9 m	Class of vegetation closure at 9 m from base of roost tree (Classes 1 to 7: Class 1 = 0% closure, and Class 7 = 100% closure)

Meso-Scale (Roosting Patch)

We used the presence or absence of a western red or western yellow bat to develop a geographic information system (GIS) (ArcGIS 10.1) based occupancy model. Each sample site was classified as a dependent variable in order to extract and model the relationship of corresponding spatial covariates from delineated patches. We calculated the area and perimeter of one patch for each treatment and control site using traditional photo interpretation methods of current 1-m ESRI aerial imagery (Spencer 1978). Patches were created by outlining areas of cottonwood-willow plantings within treatment plots for 1.3 km up- and downstream from each mist netting location. We selected 1.3 km because this is the mean distance western red bats moved between roost locations. We calculated the perimeter and area and a shape index (SI) of each patch (figure 2). The SI is a measure of deviation of the perimeter of a patch from the perimeter of a circular patch of equal area (SI = perimeter/[2√(π x area)]). A circle patch has a SI of 1, and the index value increases as the shape becomes more irregular (Shake et al. 2012).

Area: 658,204 m^2 SI: 1.24 | Area: 677,563 m^2 SI: 1.1 | Area: 132,743 m^2 SI: 3.53 | Area: 1,243,949 m^2 SI: 1.51

Figure 2.—Patch size polygons for four sampling locations: AHAV, CVCA, AGUAF, and SPP.

We assigned metrics to each patch from a U.S. Geological Survey (USGS) dataset reflecting vegetation cover (EVC) and vegetation height (EVH) (USGS 2013a). Metrics from similar USGS datasets identifying developed lands (DEV), low woody coverage (LW) (trees and shrubs with canopy coverage of < 50%), high woody coverage (HW) (trees and shrubs with canopy coverage of > 50%), low woody height (LowHT) (shrubs of height < 3 m and trees with height of < 5 m), and high woody height (HighHT) (shrubs of height > 3 m and trees of height > 10 m) were also assigned to each patch.

Meso-scale analysis was based on evaluating the characteristics of the roosting patch within the control and treatment. We created separate models for western red and western yellow bats using the methodology described below. Patches were divided into two categories: treatment and control. We then compared the characteristics of the treatment and control sites using presence/absence based occupancy modeling. We categorized a patch as occupied (presence) if at least 1 individual of the target species was located roosting within the patch during each of the 21 sampling periods. Three treatment sites and six control sites were consistently occupied.

To estimate occupancy (ψ) and detection (p) probabilities, we calculated a series of multi-season occupancy models in PRESENCE 6.1 to identify what landscape attributes influence roosting affinity of western red and western yellow bats (Hines 2006). Two sets of models were run for each species – one for control sites (n = 11) and one for treatment sites (n = 7). We ranked these models according to their Akaike's information criterion (AIC) (Akaike 1973) corrected for small sample size (AIC_c) (Burnham and Anderson 1998). We calculated AIC_c difference (ΔAIC_c) and Akaike weight (w_i) (Buckland et al. 1997) for each model to assess model uncertainty and the likelihood of each candidate model given the data. Models with ΔAIC_c or quasi-AIC ($\Delta QAIC_c$) (corrected for small sample size) ≤ 2 were considered to be well supported by the data, and the model with the lowest AIC value was identified as the best fit model (Burnham and Anderson 1998). We used these models to compare western red and western yellow bat roosting affinities in the control and treatment sample sites. The small sample size precluded any further analysis of model fit.

Macro-Scale (Roosting Landscape)

In order to evaluate macro-scale roost selection drivers, a set of 10 x 5 km sampling polygons were generated in a GIS around each sample point. These polygons extended 2.5 km on either side of the point as well as 5 km up- and downstream. We created a dataset from remotely sensed imagery reflecting major vegetation components of each sample polygon. For development, we used 6 Landsat 4 Thematic Mapper (TM) scenes that were collected June 6, 2011, and covered most of southern Arizona and eastern California. This time temporal window was selected as riparian vegetation has high vigor and vigor of cultivated crops is in a general state of decline (National Oceanic and Atmospheric Administration 2014). This temporal window is also cloud free, allowing for analysis of the entire scene. Scenes were imported into Erdas Imagine (version 2013) where they were processed. Processing of the bands included stacking each scene's spectral bands 1–6 and mosaicking them to form one comprehensive scene. This combined scene was subset to sampling polygons. A Normalized Difference Vegetation Index (NDVI) was created for each separate sampling plot of the subset image through the combination of band 4 [infrared (0.64–0.67 millimeters] and band 3 [red (0.53–0.59 millimeters)] (table 2).

Table 2.—Formula for normalized difference vegetation index (NDVI)

NDVI = [(Band 4 - Band 3) / (Band 4 + Band 3)]

In healthy vegetation, band 3 is absorbed by chlorophyll and band 4 is reflected by the plant's mesophyll tissue. The ratio of the two bands' inverse reflectance creates vegetation indices that isolate vegetation from non-vegetation (Cambell 2008). This method is commonly used to classify, measure, and monitor change of vegetation on large spatial scales (De Fries et al. 1995).

An unsupervised classification was performed on each NDVI to create 20 classes of like values. These classes were individually reviewed and compared to high resolution 1-m imagery to assign each class to one of four vegetation classes: riparian, agriculture, open water, and non-suitable. Anomalies in this dataset were eliminated by fitting it to a refinement mask created with USGS land cover data (USGS 2013b) data (table 3). The resulting vegetation classes were combined in ArcGIS 10.1 to create a vegetation dataset assigned to each sample polygon.

Table 3.—Classification of refinement mask

Riparian	Non-suitable
Recently disturbed forest	Developed – upland deciduous forest
Herbaceous wetland	Developed – upland evergreen forest
Shrub height 1–3 m	Developed– upland mixed forest
Shrub height > 3 m	Developed – upland herbaceous
Forest height 0–5 m	Developed – upland shrubland
Forest height 5–10 m	Developed – medium intensity
Forest height 10–25 m	Developed – high intensity
Agriculture	Developed – roads
National Agricultural Statistics Service (NASS) – orchard	Barren
NASS – row crop – close grown crop	Quarries – strip mines – gravel pits
NASS – row crop	Sparse vegetation height
NASS – close grown crop	Herb height 0–0.5 m
Water	Herb height 0.5–1.0 m
Open water	Herb height > 1.0 m
	Shrub height 0–0.5 m
	Shrub height 0.5–1.0 m

We assigned metrics of datasets reflecting vegetation cover (EVC) and vegetation height (EVH) to each plot (USGS 2013a). Additional metrics reflecting developed lands (DEV) (lands designated as "developed"), low woody coverage (LW) (trees and shrubs with canopy coverage of < 50%), high woody coverage (HW) (trees and shrubs with canopy coverage of > 50%), low woody height (LowHT) (shrubs of height < 3 m and trees with height of < 5 m), and high woody height (HighHT) (shrubs of height > 3 m and trees of height > 10 m) were also assigned to each plot (USGS 2013a).

We used program PRESENCE 6.1 to calculate occupancy and trends associated with the above site-specific vegetation structure and its influence on occupancy. We created two discrete multi-season occupancy models for each of the two target species. The first model consisted of occupancy for only the control sites, and the second model consisted of only the treatment sites. These two models allowed us to compare western red and western yellow bat roosting affinities in the control and treatment sample sites.

RESULTS

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

We had a total survey effort of 173 netting nights – 90 for the control and 83 for the treatment sites (tables 4 and 5). We netted 23 western red bats and 6 western yellow bats in the control sites and 32 and 48 western red and western yellow bats, respectively, in the treatment sites. We captured a total of 55 western red bats from 2011–13, and of those 55, 30 were deemed suitable for transmitter attachment. We were able to track 23 individuals to at least one roosting location. We documented 97 roosting nights and 52 discrete roosts for western red bats. We captured 47 western red bats in the warm season (25 transmitters deployed) and 8 in the cold season (5 transmitters deployed). We captured a total of 54 western yellow bats from 2011–13, deployed 32 transmitters, and identified roosts for 22 individual bats. We captured all western yellow bats during the warm season. We observed 71 western yellow bat roosting nights and located 31 discrete roosting locations (table 4).

We recorded 35 movements between discrete roosting trees among the western red bats we captured. Of the 23 total western red bats tracked to a roost, six used only a single roost, the remaining 17 used at least two discrete roosting trees. The longest western red bat movement between roosting sites was an adult male at the PVER during the cold season. This bat moved 11.23 km between roosts on two separate occasions. In contrast, we observed a subadult male western red bat at the CVCA that moved only 6 m between tree roosts. The mean distance moved

Table 4.—Western red (LABL) and western yellow (LAXA) bat capture and roost summary information 2011–13

	LABL 2011	LABL 2012	LABL 2013	Totals	LAXA 2011	LAXA 2012	LAXA 2013	Totals
Captures	9	25	21	55	10	19	25	54
Transmitter	8	10	12	30	10	10	12	32
Bat with ID roost	6	6	11	23	7	5	10	22
Total roost locations	12	15	25	52	11	5	15	31
Detections	23	28	46	97	20	14	37	71

Table 5.—Western red (LABL) and western yellow (LAXA) bat capture summary by sampling site 2011–13

Site	Type	LABL	LAXA	Trap nights
ACP	Control	0	2	1
AGUAF	Control	2	0	5
BWRNWR	Control	1	0	18
BWRCP	Control	0	0	5
CDAM	Control	0	2	6
DCRR	Control	4	0	5
HRPR	Control	0	1	5
SPP	Control	3	0	17
SCT	Control	6	1	12
THL	Control	3	0	11
WCCR	Control	4	0	5
AHAV	Treatment	2	10	18
Beal Lake	Treatment	0	0	7
CVCA	Treatment	17	11	16
HNWR	Treatment	0	1	10
INWR	Treatment	0	0	6
PVER	Treatment	13	22	15
YUME	Treatment	0	4	11
	Total control	23	6	90
	Total treatment	32	48	83
	Totals	**55**	**54**	**173**

between western red bat roosts was 0.99 km, with a median distance of 0.081 km. This mean distance estimate was driven by cold season male western red bat movements.

We removed these long-distance cold season movements and recalculated our mean distance between western red bat roosts to 0.12 km, with a median distance of 0.078 km. The distance traveled between roosts differed by gender and age. We documented six roost movements for female western red bats: the maximum movement was 0.19 km, the minimum was 0.031 km, the mean was 0.11 km, and the median was 0.084 km. For male western red bats, we detected 29 movements between roosts, with a maximum of 11.23 km, a minimum of 6 m, a mean of 1.12 km, and a median of 0.081 km. The mean for male movements was driven by four long-distance cold season movements. Once we removed these four events our mean distance between roosts declined to 0.12 km, and our median dropped to 0.078 km.

We documented 22 roost movements for adults and 13 for subadults. Adult western red bats moved a maximum of 11.23 km, a minimum of 7 m, a mean of 1.51 km (0.12 km with the cold season movements excluded), and a median of 0.081 km. Subadult western red bats moved a maximum of 0.19 km, a minimum of 6 m, a mean of 0.12 km, and a median of 0.083 km. Roost movements also differed between the control and treatment sites. Western red bats moved between roosts a total of 24 times in the treatment sites. The maximum movement between roosts in the treatment sites was 11.23 km, the minimum was 6 m, the mean was 1.41 km (0.14 km with the cold season movements excluded), and the median was 0.12 km. We documented 11 roosting movements at the control sites, with a maximum movement of 0.19 km. a minimum of 31 m, a mean of 86 m, and a median of 0.078 km.

We documented six western yellow bats that moved between tree roosts. The maximum movement between roosts was 5.17 km, and the minimum was 3 m. Western yellow bats moved a mean of 1.16 km between roosts, with a median of 0.093 km. We did not compare movements between the control and treatment for western yellow bats because of the small sample size (n = 6) and lack of roosts within the treatment sites.

We calculated a diversity index for each site across year and sampling period. We found control locations to have a higher diversity index than our treatment locations, with both remaining similar over the 3-year sampling period. We observed the highest diversity for a cold season treatment plot at the AHAV during the 2011 sampling period and the highest diversity at a warm season treatment plot at the INWR during 2011. We recorded the highest yearly diversity at the AHAV during the 2012 sampling period (table 6). We observed the greatest diversity for a cold season control plot at both the BWRNWR (2012) and THL (2013). We detected the greatest warm season and yearly diversity for a control plot at the BWRNWR during the 2011 sampling period (table 7).

Table 6.—Shannon-Wiener diversity index treatment sites

Treatment locations							
	AHAV	**Beal Lake**	**CVCA**	**HNWR**	**INWR**	**PVER**	**YUME**
2011 cold season	1.33	N/A	0	0	1.29	0.69	N/A
2011 warm season	1.63	N/A	1.16	1.21	1.83	0.8	N/A
2012 cold season	1.09	N/A	0.56	N/A	0.35	0.69	N/A
2012 warm season	1.82	N/A	1.64	1.15	N/A	1.14	0.45
2013 cold season	1.16	1.1	N/A	N/A	N/A	N/A	N/A
2013 warm season	1.71	1.46	1.56	N/A	N/A	1.05	0.51
2011 combined	1.87	N/A	1.31	1.43	1.57	1.15	N/A
2012 combined	1.99	N/A	1.7	1.15	0.35	1.23	0.45
2013 combined	1.70	1.48	1.56	N/A	N/A	1.05	0.51

Table 7.—Shannon-Wiener diversity index control sites

Control locations										
	ACP	**AGUAF**	**BWRNWR**	**BWRCP**	**CDAM**	**HRPR**	**SCT**	**SPP**	**THL**	**WCCR**
2011 cold season	N/A	N/A	1.41	N/A	N/A	N/A	N/A	N/A	0.59	N/A
2011 warm season	1.1	N/A	1.91	N/A	N/A	N/A	N/A	1.84	1.6	N/A
2012 cold season	N/A	N/A	1.48	N/A	N/A	N/A	N/A	0.69	0	N/A
2012 warm season	N/A	N/A	1.79	N/A	N/A	N/A	1.5	1.31	1.43	N/A
2013 cold season	N/A	N/A	1.47	N/A	N/A	N/A	1.1	1.33	1.48	N/A
2013 warm season	N/A	1.65	1.61	1.89	1.73	1.2	1.8	1.87	N/A	1.79
2011 combined	1.1	N/A	2.09	N/A	N/A	N/A	N/A	1.84	1.62	N/A
2012 combined	N/A	N/A	1.83	N/A	N/A	N/A	1.5	1.47	1.45	N/A
2013 combined	N/A	1.65	1.83	1.89	1.73	1.2	1.81	1.9	1.48	1.79

Objective 2: Describe roost site characteristics used by western red and western yellow bats within the LCR MSCP project area and control sites

Western red bats and western yellow bats were observed roosting in a number of tree species. Of the 52 discrete roosts located for western red bats, 44 were in Fremont cottonwood (*Populus fremontii*). Two western red bats were observed

in Goodding's willow (*Salix gooddingii*), sycamore, and Mexican fan palm (*Washingtonia robusta*). We detected one western red bat roosting in an athel tree (*Tamarix aphylla*) and a netleaf hackberry (*Celtis reticulata*) each. While we collected a large number of variables associated with the roosting trees, we only provide descriptions of those roost variables that have significant relationships in objective 3. The output for all 98 statistical tests, including those non-significant variables, is presented in attachments 1 and 2. We compiled a detailed description of the roost use of every western red and western yellow bat captured during the course of this study in attachment 3.

Western red bats had statistically significant relationships across the control and treatment for three variables: tree height, DBH of trees, and bat roosting height (table 8). It should be noted that overall tree heights at restoration sites were more homogenous than at the control sites due to these areas being planted at the same time. Variations in tree height did occur between phases at the restoration sites. The control sites contained trees in various states of age and maturity. The results will be represented in metric units, with standard English in parentheses. The mean height for the control roost (CR) trees was 16.08 m (52.8 feet [ft]). The CNR trees had a mean height of 10.15 m (33.3 ft), while the TR and the TNR had a mean tree height of 14.17 m (46.5 ft) and 14.37 m (47.1 ft), respectively (figure 3). The mean tree DBH for western red bat roosts was 67.23 cm (26.5 inches [in]), 30.15 cm (11.9 in), 38.81 cm (15.3 in), and 29.08 cm (11.4 in) in the CR, CNR, TR and TNR, respectively (figure 4). The mean bat roosting height for the CR was 9.6 m (31.5 ft), while the roosting height for the TR was 4.4 m (14.4 ft) (figure 5). Western red bats also had a statistically significant relationship across gender. Males were found roosting in trees with a mean DBH of 70.04 cm (27.6 in), while females were observed in trees with a DBH mean of 39.30 cm (15.5 in) (figure 6). The comparison of males and females was based on roost detections and did not allow equal sampling of genders across a similar range of tree DBH; thus, the findings were based on the roosts sampled and not a random stratified sampling. Western red bat age classes also varied across tree height and DBH. Adults roosted in trees with a mean height of 13.82 m (45.3 ft), while subadults roosted in trees with a mean height of 18.42 m (60.4 ft) (figure 7). Western red bat adults roosted in trees with a mean DBH of 48.11 cm (18.9 in), while subadults roosted in trees with a mean DBH of 84.62 cm (33.3 in) (figure 8).

We detected 93% (29) of western yellow bats roosting in Mexican fan palms. The remaining two western yellow bat roosts were in date palms (*Phoenix dactylifera*). While it was not tested in this study, anecdotal observations indicate that Mexican fan palms had a much higher availability than date palms, and this trend is likely responsible for the roost use described above. Western yellow bats had a statistically significant relationship only with tree height (see figure 10). Mean tree height was 9.80 (32.2 ft), 5.83 (19.1 ft), 14.70 (48.2 ft) and 9.77 m (32.1 ft) for the CR, CNR, TR, and TNR, respectively.

Table 8.—Maximum, minimum, mean, and median tree and roost heights and DBH for western red bat roosts at control and treatment sites

Control roosts (n = 19)	Maximum	Minimum	Mean (SE)[1]	Median
Tree height (m)	23.6	7.6	16.08 (1.11)	16.7
Tree DBH (cm)	194	23.2	67.23 (10.08)	50.4
Roost height (m)	19.9	5	9.61 (1.31)	9.75
Treatment roosts (n = 33)	**Maximum**	**Minimum**	**Mean (SE)**	**Median**
Tree height (m)	22	6.9	14.17 (0.67)	13.3
Tree DBH (cm)	214	4.9	38.81 (6.35)	28.7
Roost height (m)	11.7	2	4.47 (1.73)	4

[1] SE = standard error.

Objective 3: Evaluate the current distribution of western red and western yellow bats in relation to determinate habitat affinities within the LCR MSCP project area and control sites

Micro-Scale (Roosting Tree)

Western red bat habitat use varied across the control and treatment sites at the micro-scale (roosting tree). The height of western red bat roosting trees (CR) in the control plots was statistically ($F = 7.51$; $p = 0.0136$) greater than the non-roosting trees (CNR) (figure 3). In contrast, roosting trees in the treatment plots (TR) did not statistically differ from the adjacent non-roosting trees (TNR) (figure 3). Tree DBH also varied across treatments and roosting condition (figure 4). The DBH of western red bat roosting trees in the control (CR) was ($F = 5.04$; $p = 0.0307$) larger than the non-roosts in both the control (CNR) and treatment TNR sites (figure 4). The DBH of the roosting trees in the treatment site did not statistically differ from either the non-roosts (CNR and TNR) or the control (CR) roosting trees. The height of the bat roosting location on the roost trees differed significantly ($p < 0.0001$) between the control and the treatment sites. Western red bats roosted significantly higher in the control sites than the treatment sites (figure 5). Western red bat roosting trees also varied across gender and age class. The DBH of roosting trees varied between western red bat genders (figure 6). Male western red bats roosted in trees with statistically ($F = 4.83$; $p = 0.0376$) larger DBH than did females. The DBH of female western red bat roosting trees did not statistically differ from non-roosts (figure 6). The height of the roosting tree varied ($F = 5.79$; $p = 0.0242$) across red bat age classes (figure 7). Subadult western red bats roosted in higher trees than did adults. The DBH of roosting trees also varied ($F = 6.74$; $p = 0.0162$) across age classes (figure 8).

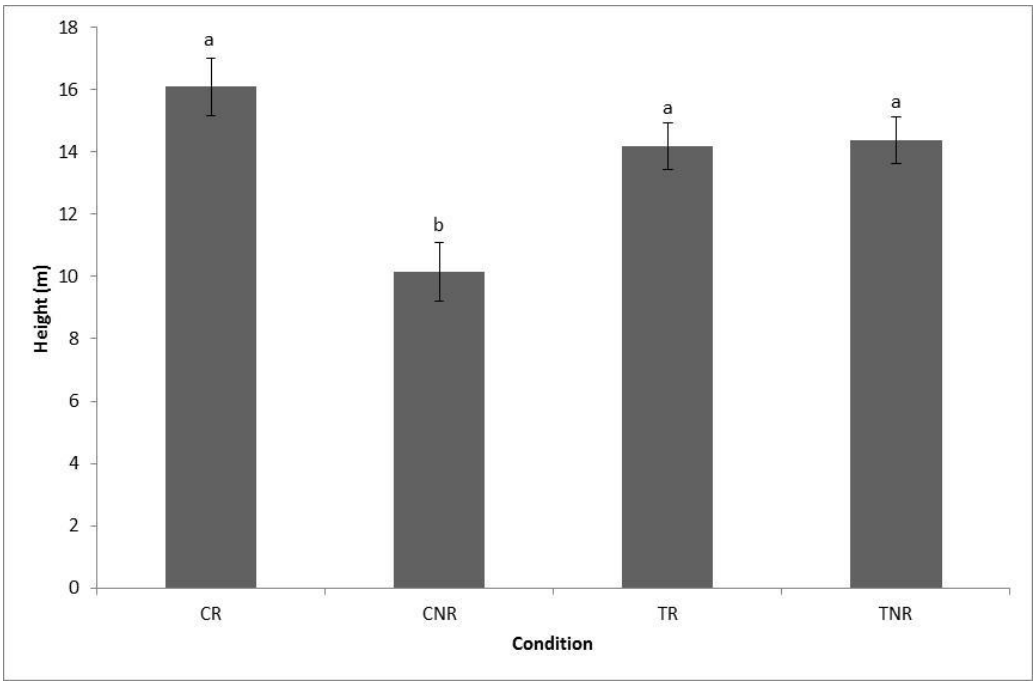

Figure 3.—Mean and standard error of total tree height for western red bat roosts across four conditions: control site roost tree (CR), control site non-roost tree (CNR), treatment site roost tree (TR), and treatment site non-roost tree (TNR). Letters indicate statistical significance based on Fisher's LSD (F = 7.51; p = 0.0136).

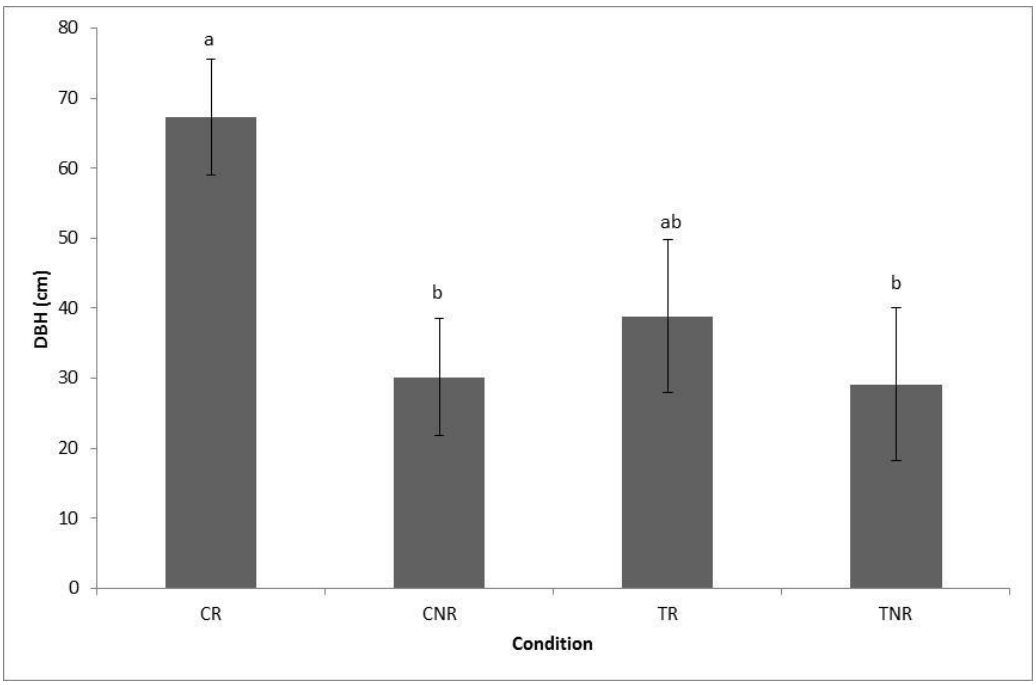

Figure 4.—Mean and standard error for DBH of western red bat roosts across four conditions: control site roost tree (CR), control site non-roost tree (CNR), treatment site roost tree (TR), and treatment site non-roost tree (TNR). Letters indicate statistical significance (F = 5.04; p = 0.0307).

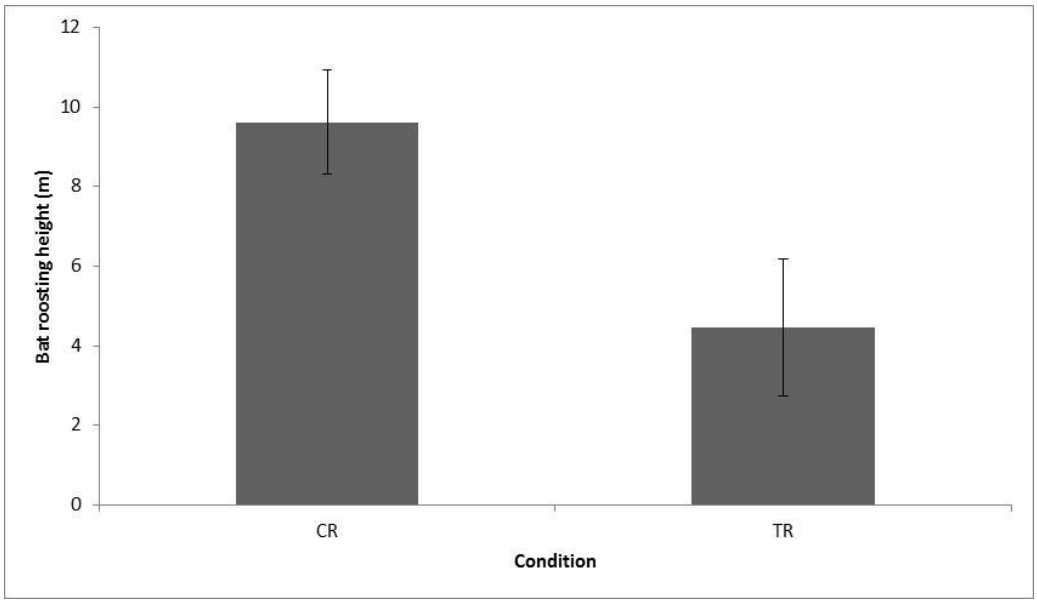

Figure 5.—Mean and standard error bat roosting height between control (CR) and treatment (TR) roosting trees (t = 7.29, p = 0.0003).

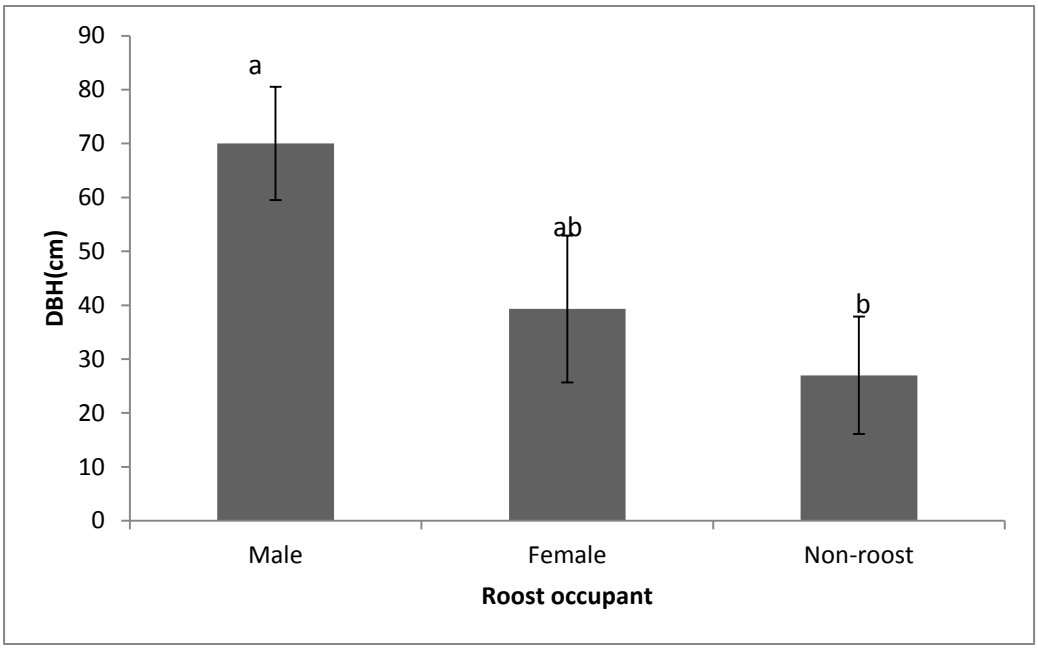

Figure 6.—Mean and standard error for DBH across three roost occupant types: male occupant, female occupant, and non-roost.
Letters indicate statistical significance (F = 4.83; p = 0.0376).

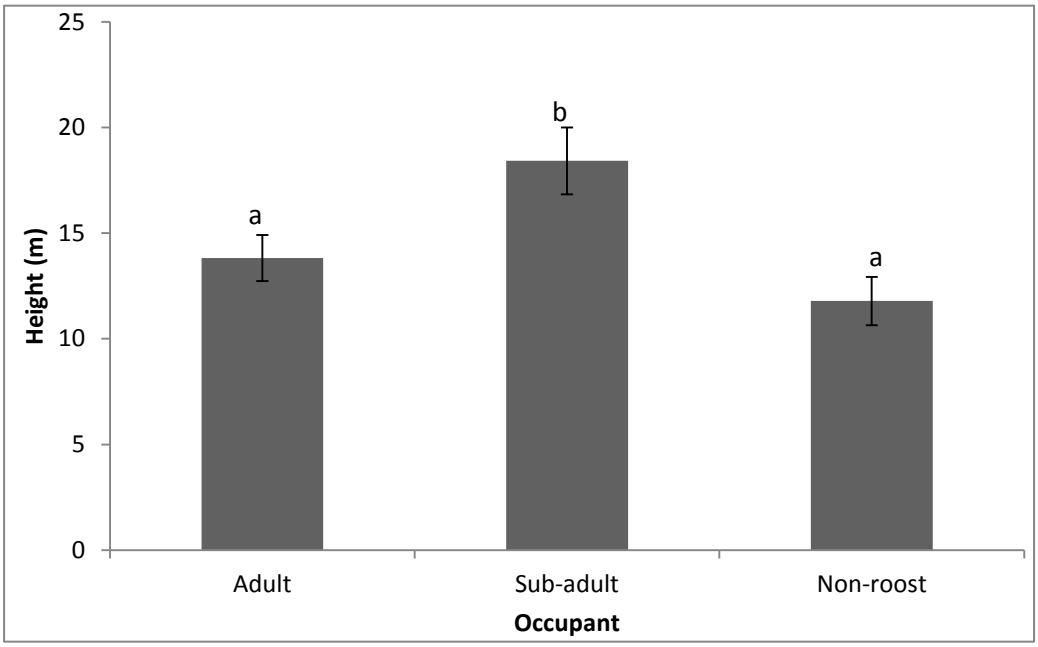

Figure 7.—Mean and standard error for tree height across three roost occupant types: adult occupant, subadult occupant, and non-roost.
Letters indicate statistical significance (F = 5.79; p = 0.0242).

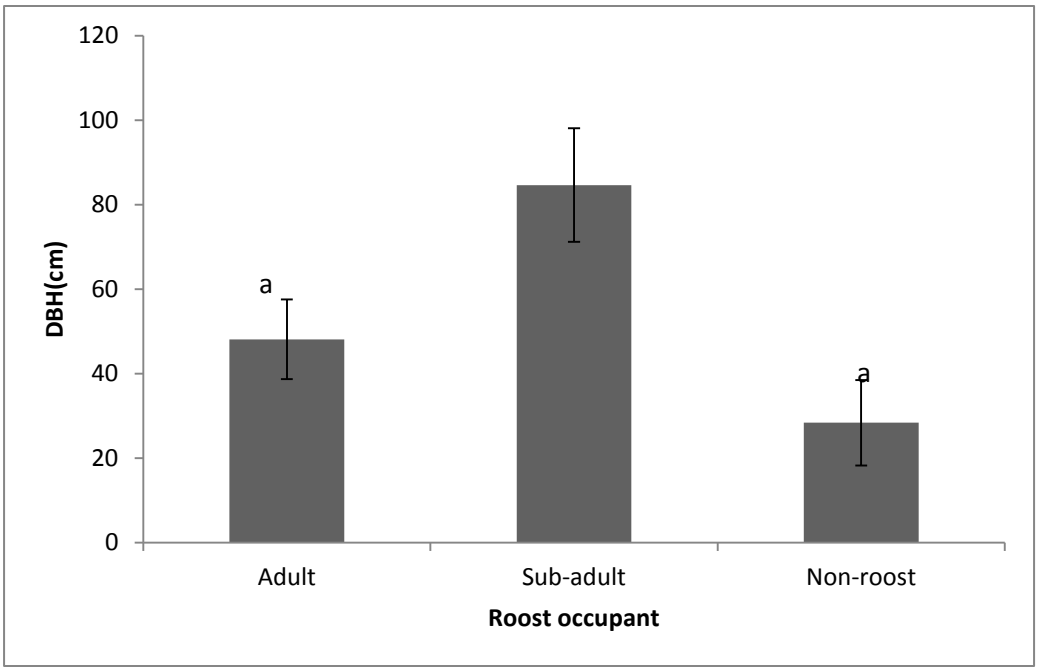

Figure 8.—Mean and standard error for DBH across three roost occupant types: adult occupant, subadult occupant, and non-roost.
Letters indicate statistical significance (F = 6.74; p = 0.0162).

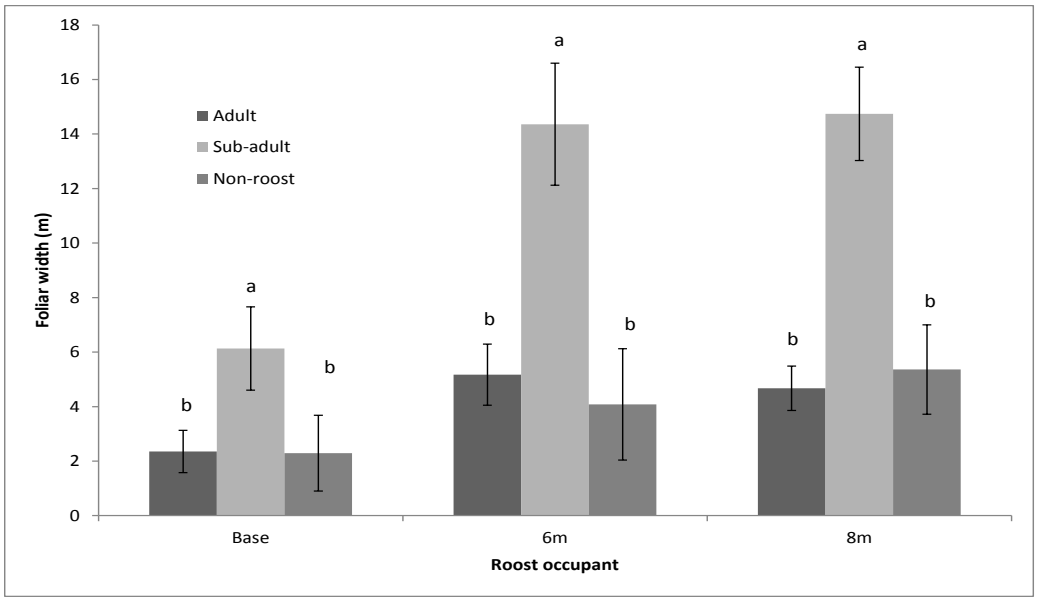

Figure 9.—Mean and standard error for foliar width at the base, 6 m, and 8 m across three roost occupant types: adult occupant, subadult occupant, and non-roost.
Letters indicate statistical significance within foliar width categories. Base (F = 4.59; p = 0.0424), 6 m (F = 7.61; p = 0.0116), and 8 m (F = 9.62; p = 0.00074).

Subadults roosted in trees with larger DBH than adults. The foliar width of the subadult roosting tree was wider at the base (F = 4.59; p = 0.0424), 6 m (F = 7.61; p = 0.0116), and 8 m (F = 9.62; p = 0.00074) (see figure 9).

Western yellow bat habitat use also varied across the treatment and control sites at the micro-scale (roosting tree). Unlike the western red bat that had multiple significant relationships on the micro-scale, the western yellow bat roosting tree varied across the treatment and control sites only on a single variable, tree height. The tree height for western yellow bats captured in the treatment (TR) sites was statistically (F = 3.49; p = 0.0499) greater than only the control non-roosting trees (CNR) (figure 10). Thus, roosting habitat of western yellow bats was statistically equivalent in the treatment and control sites likely confounded by the high variance in the control sites due to the small sample size. Male western yellow bats roosted in trees that had wider crowns at the base (F = 7.64; p = 0.0057) and 2 m (F = 4.68; p = 0.0295). The average crown width at the base for male roosts was 4.7 m ± 1.09, while female roosts averaged 3.5 m ± 0.079. The crown width at 2 m averaged 5.4 m ± 1.045 for male roosts and 3.6 m ± 0.689 for female roosts.

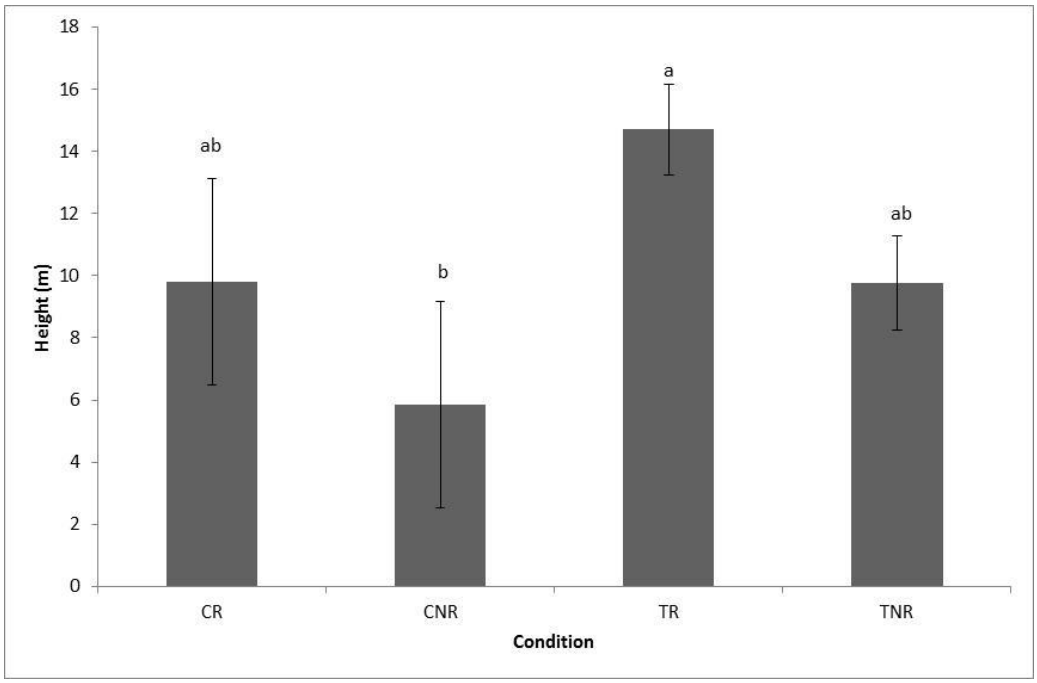

Figure 10.—Mean and standard error for tree height across four conditions for western yellow bats: control site roost tree (CR), control site non-roost tree (CNR), treatment site roost tree (TR), and treatment site non-roost tree (TNR). Letters indicate statistical significance (F = 3.49; p = 0.0499).

Meso-Scale (Roosting Patch)

Because of the complexity of our models and the low sample size, we were unable to ascertain tangible results at the meso- and macro-scales. We present our findings here and have included further results and tables in attachment 3 as an exercise in how these data could be analyzed if the sample size had been larger. We identified three top occupancy models for western red bat treatment sites at the meso-scale that identified a negative association with low tree height, patch treatment area, and riparian habitat as the strongest model drivers. These top models ranked identically, all sharing an Akaike weight (w_i) of 0.32. No single top model out ranked others. As part of the exercise, these three models with $\Delta QAIC_c \leq 2$ were selected for model averaging (Burnham and Anderson 2002). Naïve occupancy ranged between 0.40 and 0.50, with detection constant at 0.39. Modeled occupancy did not perform well, with estimates of 0–1.0; this poor estimate is a result of the small sample size (n = 21), missing observations, (n = 58) and the complexity of the models. These missing observations are attributed to adding a large number of control locations in year three in an attempt to increase sample size.

We identified four top occupancy models for western red bat control sites at the meso-scale that identified negative associations with low tree height and patch

area to perimeter ratio and positive associations with high tree height and patch area as the strongest model drivers. These top models shared similar Akaike weights (w_i) ranging between 0.20 and 0.14. Again, this can be attributed to the small sample size and missing observations due to the addition of control sites in year three. No single top model was superior to others, but tree heights (both low and high) were superior to patch metrics (area and area:perimeter) (Burnham and Anderson 2002). These four models with $\Delta QAIC_c \leq 2$ were selected for model averaging (Burnham and Anderson 2002). Model averaging estimated occupancy rates between 0.43 and 0.80 in year two of surveys. That is to say, if a bat was not detected in year one, then the estimate for year two is 0.43 (colonization). If a bat was detected in year one, then the occupancy estimate for year 2 is 0.80 (already colonized). For year three, occupancy was estimated at 0.58 (colonization) and 0.72 (already colonized). The model constant detection probability was 0.31. Once again, further results and tables can be found in attachment 3. A narrative summary of the roost site locations found at the meso-scale can be found in attachment 4.

Macro-Scale (Roosting Landscape)

We identified three top occupancy models for western red bat treatment sites at the macro-scale that recognized negative associations with the average vegetation height per plot and a positive association with percent composition of agriculture land cover as the strongest model drivers. These top models ranked similarly, all sharing similar Akaike weights (w_i) ranging between 0.24 and 0.19. No single top model out ranked others. Again, this can be attributed to the small sample size and missing observations due to the addition of control sites in year three. These three models with $\Delta QAIC_c \leq 2$ were selected for model averaging (Burnham and Anderson 2002). Model number three was similar to model number one but allowed for detection variation between surveys. Naïve occupancy estimates ranged between 0.40 and 0.60, with detection probability modeled constant at 0.43. Model averaging estimated occupancy for 2010, 2011, and 2012 at 0.00–1.00, 0.00–0.75, and 0.00–0.56, respectively. Further results and tables can be found in attachment 3.

Objective 4: Based upon the information gathered in objectives 1–3 provide recommendations for maintaining and creating roosting habitat for western red and western yellow bats within the LCR MSCP project area

We detected all western red bat roost locations of the bats we captured at treatment sites within the CVCA and PVER and did not observe any at other restoration areas. The vast majority of these roost locations at the CVCA and PVER occurred in the nursery planting and Phase I. We detected only one roost in another phase (PVER Phase II), with all roosts, with the exception of one

(Goodding's willow), occurring in cottonwoods. We observed western red bat roost locations at control sites to be in taller trees with a larger DBH as compared to surrounding non-roost trees. Recommendations can be found within the discussion below.

DISCUSSION

During the course of this study, we were able to detect relationships between western red and western yellow bats and their habitat affinities. This study has increased our understanding of the roosting ecology of western red and western yellow bats in the Southwestern United States. This study used four objectives to facilitate further understanding of the roosting ecology of western red and western yellow bats within the LCR MSCP project area. Specifically, we were able to locate roost sites and describe roost site characteristics of western red and western yellow bats within the LCR MSCP project area and control sites. We also evaluated the current distribution of western red and western yellow bats in relation to determinate habitat affinities within the LCR MSCP project area and control sites. These findings allowed us to develop management recommendations for maintaining and creating roosting habitat for western red and western yellow bats within the LCR MSCP project area.

The first objective of this study was to locate roost sites of western red and western yellow bats within the LCR MSCP project area and in control sites. We were able to locate roosting locations for 23 western red bats and 22 western yellow bats. Our initial study design was based on locating roosts for 30 western red bats (10 in the cold season and 20 in the warm) and 20 western yellow bats. While we were able to capture a total of 55 western red bats, 22 of these individuals were either too small, pregnant, or lactating females, and transmitters were not attached. We also tried to limit our sampling at each site to keep from oversampling in one location. Of the 30 western red bats with transmitters, we located roosting sites for all but 7. These seven individuals either shed the transmitters or were lost during tracking. Unfortunately, our small sample size of western red bats captured during the cold season prevented us from conducting an analysis of cold season western red bat habitat use. Similarly, we attached transmitters to 32 western yellow bats and located roosts for all but 10. A portion of these 10 bats were most likely not located due to long-distance travel out of the study area. The loss of the majority of these 17 bats (7 western red and 10 western yellow bats) may also to have been due to a group of defective transmitters purchased during the 2012 field season.

The majority of western red bats used multiple roosts, usually within the same patch. Only six western red bats used a single roost during this study. Western red bats moved further between roosting locations during the cold season than the warm season. This longer distance traveled in the cold season may be due to

limited foraging resources in the cold season. Western red bats in the control sites had higher roost fidelity than those in the treatment sites. We did not capture western red bats at some of the treatment sites (AHAV in summer, HNWR, Beal Lake, INWR, and YUME). The AHAV has greater spacing between trees but displays far less canopy cover than the other sites. This decrease in canopy cover leads to higher temperatures, which may be the reason we only detected western red bats during the cold season. The HNWR also has greater spacing between trees and less canopy cover than our other sites. Couple this with the small area of the HNWR (< 10 acres), and this may explain why we did not capture a western red bat at this site. The patch at the INWR (4 acres) was our smallest in area, which may explain why we did not capture any western red bats there. We did not capture any western red bats at Beal Lake (121 acres) or YUME (350 acres). The YUME site was relatively immature (lower canopy height) compared to our other treatment sites and may not support suitable roosting habitat yet. The Beal Lake site had a low percent of cottonwoods relative to the size of the site, and most of the site consisted of lower canopy height willow or mesquite habitat, which may be why red bats were not detected. The CVCA (669 acres) and PVER (1,352 acres) are quite large in comparison to the treatment sites where we did not capture western red bats. We used the 52 roosts located for western red bats and the 31 roosts located for western yellow bats to carry out objectives 2 and 3.

Our second objective was to describe roost site characteristics used by western red and western yellow bats within the LCR MSCP project area and control sites. We detected western red bats roosting in six tree species. Most western red bats (85%) roosted in Fremont cottonwood, while an additional 10% were located in other broadleaf deciduous trees (sycamore, Goodding's willow, and sugar hackberry). The remaining 5% of western red bat roosts were in evergreen trees (athel and palm trees). These findings indicate that western red bats selected roosting sites in cottonwood or other broadleaf deciduous trees. Western red bats rarely roost in available evergreen species even in the cold season following deciduous leaf drop. We observed some deciduous trees at treatment sites never completely drop their leaves even in winter, which would provide more potential roosting locations.

Western yellow bats roosted exclusively in palm trees in all detections. This study indicates that western yellow bats are strongly associated with the presence of non-native palm trees. We detected western yellow bats at a much higher rate in the treatment sites than the control sites. The treatment sites along the LCR are adjacent to highly manipulated residential and agricultural lands. These adjacent land uses provide an array of available suitable palm trees for western yellow bat roosting. While we detected numerous western yellow bat roosts adjacent to the treatment sites, none were detected in the treatment sites. In contrast to the treatment sites, the control sites were generally located in areas that were not adjacent to developed lands. Thus, the control sites lacked the adjacent non-native palm tree component required for western yellow bat roosting habitat.

The third objective of the study was to evaluate the current distribution of western red and western yellow bats in relation to determinate habitat affinities within the LCR MSCP project area and control sites. We approached this objective with a three-scale methodology: micro (roosting tree), meso (roosting patch), and macro (roosting landscape). Each of these three scales provides estimates of western red and western yellow bats habitat affinities.

At the micro-scale, western red and western yellow bats were associated with roost tree characteristics. Western red bats had significant relationships across the control and treatment, gender, and age classes. Western red bats in the control sites roosted in trees that were significantly taller than the adjacent trees, while western red bats in the treatment sites roosted in trees that did not differ significantly from the adjacent trees. These findings for treatment sites are not surprising given that the roost tree and nearest neighbor trees were most likely the same age, planted at the same time, and exposed to similar growing conditions. The DBH for roosting trees did not differ significantly between the control roosting trees and the treatment roosting trees, while the control trees had significantly larger DBH in the control plots than the non-roosts of both the treatment and control. Again, these findings for treatment sites are not surprising given the restoration method. Though the results for control sites point toward a trend of western red bats selecting significantly taller roost trees with a significantly larger DBH, we cannot extrapolate these data to a larger scale because only the nearest neighbor trees were considered.

Western red bats roosted at a significantly higher portion of the roost tree in the control when compared with the treatment sites. Male western red bats roosted in trees with a larger DBH than females, and subadult western red bats roost in taller trees with larger DBH than adults. These significant relationships indicate that western red bats at the control sites use trees with different characteristics than those in the LCR treatment sites. Western red bats in the control sites appear to select the largest available tree and roost at a higher point than available in the treatment sites. This larger tree may be providing more roosting choices on the micro-scale as compared to neighbor non-roost trees. Specifically, western red bats at control sites selected a tree that has a mean height between 15 and 17 m and a mean DBH of 59–75 cm. In contrast, roosting trees in the treatment sites are shorter (13–15 m) and narrower (DBH = 28 to 50 cm). Therefore, in order to manage for western red bat habitat, tree size appears to be a primary variable of concern based on these data.

In contrast to western red bats, western yellow bats only had a significant relationship with a single variable, tree height. Tree height did not differ significantly across control roost, treatment roost, or treatment non-roost, while the treatment roost was significantly taller than the control non-roosts only. Therefore, the primary factor driving western yellow bat roosting selection is likely the presence of palm trees rather than any defining characteristic of that palm tree.

Although our sample size was too small for the complexity of our models to definitively make any recommendations at the meso- and macro-scales, we did identify possible habitat affinities for western red and western yellow bats. Western red bat occupancy in the treatment sites was associated with decreases in the area covered by low trees and shrubs at the meso- and macro-scales. This indicates that at the meso- and macro-scales in the treatment sites, western red bats may be selecting for more open patches with less understory. Western red bat occupancy in the control sites was also negatively associated with low woody cover. As the low woody cover increased, western red bat occupancy decreased on the macro-scale. At the meso-scale, western red bat occupancy in the control sites was associated with the SI. As the SI decreased, western red bat occupancy increased. This pattern indicates that western red bats in the control sites may be selecting for roosting patches with a low ratio of edge to patch area. At both the meso- and macro-scales, western yellow bats occupied sites with a high degree of development within and adjacent to the treatment sites. This association with development likely is related to the presence of palm trees in these developed areas.

The final objective of this project was the development of management recommendations for maintaining and creating roosting habitat for western red and western yellow bats within the LCR MSCP project area. We found western yellow bat roosting habitat consists of non-native palms, and they utilized the restoration areas as foraging habitat. Because Reclamation conservation measures include only planting riparian species known to be native on the LCR, it is limited in creating roosting habitat for this species. However, due to the frequent observations of the species utilizing LCR MSCP conservation areas as foraging habitat, it is likely western yellow bats already have sufficient roost trees available.

The original tree plantings at restoration areas were planted in phases and mostly utilized a densely packed design with varying spacing to minimize invasive species such as tamarisk and to maximize tree survivorship. Therefore, the acreage of cottonwood nursery plantings (20 ft on center spacing) within these restoration areas were kept to a minimum 7.5 acres at the CVCA (planted within Phase I) and 6 acres at the PVER (all of Phase I planting). As the nursery plantings have matured, it is evident that tamarisk invasion is minimal at these sites, if not non-existent, and tree survivorship is also high. Based on the roost tree data in table 8, we recommend that tree spacing (especially in cottonwood-dominated areas) be similar to the spacing in these nursery plots when focusing on creating habitat for the western red bat.

The greater spacing at nursery plantings and the plot edges allow the trees to grow taller and develop larger DBH, which may provide more suitable western red bat roosting habitat. In the control plots, western red bats selected the larger tree compared to nearest neighbors. The nursery plantings and edge trees in the treatment plots had individual trees that were similar in height and DBH to those roost trees in the control plots. The cottonwood plantings at both nurseries were

planted 20 ft on center, while Phase I at the CVCA is primarily planted with 4 ft inline spacing and 38-in rows (19 acres), with 3.7 acres planted with 3 ft inline spacing. We recorded only two roosts within the 3 ft inline spacing sections at the CVCA (1 of these located on an edge), with the rest occurring in either the nursery or within the 4 ft inline spacing (n = 20). Several of the roosts that we located within the 4 ft inline spacing were positioned along the edges or near breaks in the canopy where trees were able to grow larger and bats only had to negotiate the densely planted trees for a short distance. We documented all roosts at the PVER within the nursery (n = 6) with the exception of one recorded in Phase II, which implements 6 ft inline spacing and 40-in rows.

In addition, we observed five western red bats (three juveniles and two adults) roosting in clusters at the AGUAF, DCRR, and CVCA (attachment 3). In each case, these bats were roosting in large cottonwoods with ample space (trees spaced far apart). The three roosts with bat clusters at the CVCA were all detected in the nursery planting. Trees with greater spacing in the nursery plantings and at the edge of other plantings had the highest western red bat roosting use. The edge trees and the nursery plantings at Reclamation restoration sites appear to provide the most suitable roosting habitat. Only 13.5 acres (7.5 acres at the CVCA and 6 acres at the PVER) are cottonwood nursery plantings. These plantings provide half of the western red bat roosts in the treatment sites. The other half of western red bat roosting locations were in the edges of more densely planted restoration areas. Given that western red bats selected the largest trees in the control sites and trees with open space around them as in the edge and nursery plantings in the treatments, we recommend focusing habitat creation for this species on the production of large cottonwoods with open space on at least one aspect.

Currently, 13.5 acres of Reclamation restoration sites consist of cottonwood nursery plantings, and an additional 47.1 acres of edge habitat (extrapolated from aerial photos) occurs across all treatment sites as of 2013. In addition, younger stands have the potential to become edge habitat over time. The non-edge habitat also has the potential to become more open and for the trees to grow taller and increase in DBH as the stands self-thin. The existing stands could be altered slightly to increase the potential for western red bat occupation through targeted stand thinning and the promotion of large sentinel trees within each restoration area. Based on the locations of western red bat roosts within treatment sites, we believe areas of future habitat creation areas that will be managed as western red bat habitat should include areas of greater tree spacing within larger patches of habitat, such as the nursery plantings at the CVCA and PVER (20 ft on center).

While we believe greater tree spacing will provide the most suitable roosting habitat for western red bats, it will also be cost effective, as the number of trees that need to be purchased and planted will be reduced. Because only 765 acres of roosting habitat needs to be created for the western red bat, this is a minimal amount of area where this spacing would need to be utilized compared to the

total 5,940 acres of cottonwood-willow habitat that needs to be created by the LCR MSCP. In summation, Reclamation restoration sites currently provide some western red bat habitat and have the potential to provide much more habitat as younger stands age, older stands self-thin, targeted thinning is conducted, and sentinel tree growth is promoted.

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ATTACHMENT 1

Summary Results of ANOVA, Fisher's LSDs, and
Associated p-Values for Western Red Bat Roosts (n = 52)

Variable indicates the variable tested across a given comparison. Categories being compared include: treatments (CNR [n = 74], CR [n = 19], TNR [n = 132], and TR [n = 33]), age (adult [n = 19], subadult [n = 5], and non-roost [n = 208]), and gender (male [n = 18], female [n = 6], and non-roost [n = 208]) classes. Values in bold indicate statistical significance. Significant differences among categories are illustrated on figures 3–9 in the main report. Values under each category indicate the mean and standard error for each category.

Variable	F	p	CNR	CR	TNR	TR
Height	7.51	**0.0136**	10.1±0.931	16.1±0.908	14.4±0.745	14.2±0.742
DBH	5.40	**0.0307**	26.7±9.677	66.8±8.622	27.2±12.181	38.7±11.287
Height of live crown base	1.01	0.4439	2.6±1.117	3.9±1.036	4.3±1.614	3.0±1.572
Width of crown at base	2.48	0.1451	2.9±0.766	3.9±0.688	1.8±0.741	2.6±0.639
Width of crown at 2m	0.46	0.7173	4.4±1.365	4.9±1.198	2.3±1.885	3.1±1.814
Width of crown at 4m	1.45	0.3070	4.4±1.578	7.6±1.384	3.1±2.257	4.2±2.189
Width of crown at 6m	1.69	0.2550	4.3±1.991	8.7±1.697	3.8±2.839	4.7±2.745
Width of crown at 8m	2.45	0.1611	5.2±1.738	8.7±1.506	4.7±2.309	4.8±2.258
Percent dead crown	1.12	0.4025	11.6±5.972	15.4±5.482	34.9±7.045	27.3±6.549
Number of apical meristems	0.48	0.7048	3.5±0.961	2.0±0.857	2.2±1.279	2.2±1.208
Roost height	(t) 7.29	**0.0003**	9.6±1.318	*	4.5±1.725	*
Temperature N aspect	1.44	0.3852	29.6±1.769	28.9±1.655	25.9±1.480	26.1±1.411
Temperature E aspect	1.98	0.2944	30.6±1.696	29.1±1.587	26.1±1.419	26.4±1.353
Temperature S aspect	1.86	0.3117	30.6±1.711	29.2±1.601	26.0±1.432	26.8±1.365
Temperature W aspect	1.70	0.3365	30.8±1.971	30.4±1.837	25.7±1.878	26.1±1.782
Vegetation closure at 3m	(t) 1.57	0.2457	*	3.4±0.602	*	4.5±0.545
Vegetation closure at 6m	(t) 1.61	0.3270	*	3.6±0.586	*	4.3±0.531
Vegetation closure at 9m	(t) 1.89	0.3715	*	5.5±0.628	*	5.0±0.833

Variable	F	p	Male	Female	Non-roost
Height	1.54	0.2663	15.0±1.405	14.9±1.838	11.8±1.452
DBH	4.83	**0.0376**	70.0±10.513	39.3±13.616	26.9±10.893
Height of live crown base	0.04	0.9585	3.6±0.870	3.3±1.106	3.4±0.884
Width of crown at base	1.56	0.2614	4.3±0.936	2.1±1.238	2.3±0.961
Width of crown at 2m	1.33	0.3107	5.6±1.333	2.5±1.701	3.4±1.393
Width of crown at 4m	2.29	0.1575	8.4±1.663	4.1±2.134	3.9±1.759
Width of crown at 6m	1.47	0.2810	9.1±2.072	5.9±2.653	4.0±2.211
Width of crown at 8m	0.46	0.6499	8.3±2.142	7.7±3.044	5.3±2.441
Percent dead crown	1.65	0.2461	14.7±5.693	26.8±7.335	20.1±5.709
Number of apical meristems	0.71	0.5192	2.2±0.705	1.9±0.961	3.0±0.715
Roost height	0.14	0.7424	7.9±1.446	7.4±1.738	*
Temperature N aspect	2.32	0.1682	25.9±1.346	31.2±2.112	27.5±1.249
Temperature E aspect	2.68	0.1371	26.2±1.354	31.5±2.063	28.1±1.271
Temperature S aspect	1.99	0.2064	26.7±1.390	31.4±2.104	27.9±1.308
Temperature W aspect	2.07	0.1968	27.0±1.681	32.1±2.364	28.3±1.623
Vegetation closure at 3m	1.02	0.3862	3.6±0.527	4.6±0.795	*
Vegetation closure at 6m	0.18	0.7003	4.1±0.465	3.7±0.755	*
Vegetation closure at 9m	2.57	0.2071	5.1±0.477	6.1±0.609	*

Variable	F	p	Adult	Sub-adult	Non-roost
Height	5.79	**0.0242**	13.8±1.091	18.4±1.579	11.8±1.145
DBH	6.74	**0.0162**	48.1±9.443	84.6±13.434	28.4±10.101
Height of live crown base	0.16	0.8556	3.5±0.907	3.9±1.197	3.3±0.949
Width of crown at base	4.59	**0.0424**	2.4±0.776	6.1±1.123	2.3±0.815
Width of crown at 2m	2.73	0.1185	3.2±1.173	7.8±1.706	3.6±1.277
Width of crown at 4m	3.71	0.0688	5.1±1.461	10.9±2.144	3.9±1.616
Width of crown at 6m	7.61	**0.0116**	5.2±1.532	14.4±2.241	4.1±1.713
Width of crown at 8m	9.62	**0.0074**	4.7±1.390	14.7±2.043	5.4±1.647
Percent dead crown	0.43	0.6654	17.0±5.445	23.5±7.503	20.1±5.608
Number of apical meristems	0.78	0.4856	1.9±0.684	2.6±0.973	3.0±0.711
Roost height	0.88	0.4464	7.5±1.368	8.8±1.765	*
Temperature N aspect	1.31	0.3281	26.1±1.499	29.7±1.898	27.6±1.347
Temperature E aspect	1.65	0.2593	26.3±1.497	30.1±1.872	28.2±1.367
Temperature S aspect	1.59	0.2697	26.6±1.512	30.4±1.889	28.1±1.382
Temperature W aspect	1.77	0.2387	26.9±1.789	31.1±2.159	28.4±1.685
Vegetation closure at 3m	0.04	0.8526	3.9±0.519	4.1±0.704	*
Vegetation closure at 6m	0.19	0.6907	3.8±0.524	4.2±0.704	*
Vegetation closure at 9m	1.30	0.3371	5.2±0.468	5.9±0.584	*

ATTACHMENT 2

Summary Results of ANOVA, Fisher's LSDs, and Associated p-Values for Western Yellow Bat Roosts (n = 31)

Variable indicates the variable tested across a given comparison. Categories being compared include: treatments (CNR [n = 32), CR [n = 8], TNR [n = 92), and TR [n = 23]), age (adult [n = 18), subadult [n = 4), and non-roost [n = 124]), and gender (male [n = 8], female [n = 14], and non-roost [n = 124]) classes. Values in bold indicate statistical significance. Significant differences among categories for tree height are illustrated on figure 10 in the main report. Values under each category indicate the mean and standard error for each category.

Variable	F	p	CNR	CR	TNR	TR
Height	3.49	**0.0499**	5.8±3.362	9.8±3.326	9.8±1.501	14.7±1.443
DBH	1.71	0.2184	44.8±14.041	67.6±14.049	41.7±14.082	73.3±14.028
Height of live crown base	2.46	0.1131	5.1±1.458	7.3±1.425	4.6±1.456	8.7±1.399
Width of crown at base	2.86	0.0814	2.0±0.786	1.9±0.875	3.6±0.726	4.2±0.745
Width of crown at 2m	1.37	0.3035	3.2±0.617	2.9±0.639	3.9±0.622	4.5±0.630
Width of crown at 4m	0.42	0.7455	3.6±.976	3.9±1.232	4.3±0.784	4.3±0.805
Percent dead crown	2.00	0.1675	31.8±7.358	42.4±7.538	22.7±7.289	38.9±7.022
Roost height	(t)5.79	**0.0285**	*	7.4±2.239	*	13.1±2.258
Temperature N aspect	0.03	0.9914	36.8±2.196	36.7±2.196	37.2±2.124	36.6±2.142
Temperature E aspect	0.72	0.5572	37.1±2.207	37.9±2.0234	36.9±1.935	39.0±1.935
Temperature S aspect	0.83	0.5006	36.2±2.298	36.2±2.298	37.9±2.216	39.6±2.216
Temperature W aspect	0.02	0.9955	38.7±2.689	38.5±2.689	39.1±2.673	39.2±2.673
Vegetation closure at 3m	0.12	0.7585	*	1.9±0.529	*	2.2±0.518
Vegetation closure at 6m	0.56	0.5337	*	2.0±0.474	*	2.5±0.437

Variable	F	p	Male	Female	Non-roost
Height	0.65	0.5361	13.1±2.295	10.9±1.353	10.1±1.496
DBH	0.18	0.8373	44.2±23.309	59.7±11.836	58.8±13.054
Height of live crown base	0.66	0.5300	4.8±2.014	7.4±1.132	6.5±1.236
Width of crown at base	7.64	**0.0057**	4.7±1.090	3.5±0.709	1.2±0.770
Width of crown at 2m	4.68	**0.0295**	5.4±1.045	3.6±0.689	2.2±0.741
Width of crown at 4m	1.26	0.3352	5.3±1.071	3.8±0.797	3.1±0.904
Percent dead crown	0.38	0.6926	25.9±10.279	35.6±5.945	35.6±6.549
Roost height	3.40	0.2275	16.9±4.571	11.7±2.212	*
Temperature N aspect	0.42	0.6658	38.8±3.879	35.9±2.047	37.3±2.224
Temperature E aspect	0.11	0.8936	39.1±2.957	37.3±2.103	37.7±2.223
Temperature S aspect	0.39	0.6861	39.3±4.525	37.9±2.399	36.4±2.564
Temperature W aspect	0.48	0.6261	41.0±4.387	37.5±2.269	39.7±2.513
Vegetation closure at 3m	2.08	0.1949	3.32±0.841	2.13±0.486	1.4±0.515
Vegetation closure at 6m	3.56	0.0859	4.00±0.759	2.22±0.439	1.6±0.465

Variable	F	p	Adult	Sub-adult	Non-roost
Height	0.39	0.6861	11.4±1.175	12.4±2.573	10.4±1.382
DBH	0.05	0.9540	55.4±11.145	62.7±23.634	58.5±12.973
Height of live crown base	0.11	0.8993	6.6±1.126	7.543±2.466	6.3±1.332
Width of crown at base	5.95	**0.0135**	3.7±0.533	4.2±1.069	1.7±0.668
Width of crown at 2m	2.20	0.1502	3.9±0.500	4.7±1.017	2.9±0.595
Width of crown at 4m	0.77	0.4943	4.2±0.692	4.9±1.191	3.5±0.872
Percent dead crown	0.07	0.9295	33.2±5.777	31.3±12.235	35.5±6.916
Temperature N aspect	0.82	0.5509	36.1±1.854	41.3±4.178	38.0±2.369
Temperature E aspect	0.04	0.9571	37.7±1.822	37.3±2.728	37.9±2.053
Temperature S aspect	0.54	0.6504	37.9±2.081	41.1±3.968	37.2±2.526
Temperature W aspect	2.59	0.2784	36.9±1.991	45.9±3.999	40.9±2.365
Vegetation closure at 3m	1.33	0.4295	2.5±4.782	2.5±1.069	1.4±0.535
Vegetation closure at 6m	1.28	0.4380	2.6±.461	3.0±1.033	1.6±0.517

ATTACHMENT 3

Meso- and Macro-Occupancy Modeling Results

Occupancy models used to estimate western red bat detection and occupancy for patch size treatment sites (meso-scale) along the lower Colorado River. Due to the small samples size, it should be noted that this analysis should not be used to define any type of habitat parameters for these two species. This analysis became more of an exercise of how the data could be analyzed if the sample size was sufficient.

Model†	$QAIC_c$	$\Delta QAIC_c$	$QAIC_c$ weight (w_i)	Model likelihood	Parameters	Beta association
1.) Ψ (LowHgt), γ(.), ε(.), *p*(.)	71.44	0.00	0.32	1.00	3	(-)
2.) Ψ (Area), γ(.), ε(.), *p*(.)	71.44	0.00	0.32	1.00	3	(-)
3.) Ψ (Rip), γ(.), ε(.), *p*(.)	71.44	0.00	0.32	1.00	3	(-)
4.) Ψ (Agr), γ(.), ε.(), *p*(.)	76.98	5.54	0.02	0.06	3	(+)
5.) Ψ (HighHgt), γ(.), ε(.), *p*(.)	77.90	6.46	0.01	0.04	3	(+)

† Ψ = occupancy probability, γ = colonization, ε = extinction, *p* = detection probability, (.) = estimated as constant, (LowHgt) = percent area of shrub and low forest < 5 meters, (Area) = area of each delineated patch, (Rip) = percent composition of riparian vegetation per plot*, (Agr) = percent composition of agriculture per plot*, and (HighHgt) = percent area of shrub and forest > 5 meters.
* Developed from remote sensed imagery; see "Methods," objective 3, in the main report.

Occupancy and detection probability of western red bats (LABL) for patch size treatment sites (meso-scale) between 2011 and 2013 along the lower Colorado River

Year	LABL detection (p)	Occupancy (naïve)	Occupancy (modeled)	Standard error	Detection probability
2011	0.20	0.40	(0, 1.0)	*	0.39
2012	0.41	0.50	(0, 1.0)	*	0.39
2013	0.14	0.40	(0, 1.0)	*	0.39

* Models were overparameterized to calculate associated standard errors.

Occupancy models used to estimate western red bat detection and occupancy for patch size control sites

Model†	$QAIC_c$	$\Delta QAIC_c$	$QAIC_c$ weight (w_i)	Model likelihood	Parameters	Beta association
1.) Ψ (LowHgt), γ(.), ε(.), *p*(.)	80.55	0.00	0.20	1.00	5	(-)
2.) Ψ (HighHgt), γ(.), ε(.), *p*(.)	80.55	0.00	0.20	1.00	5	(+)
3.) Ψ (ShapeID), γ(.), ε(.), *p*(.)	81.31	0.76	0.14	0.68	5	(-)
4.) Ψ (Area), γ(.), ε.(), *p*(.)	81.31	0.76	0.14	0.68	5	(+)
5.) Ψ (.), γ(.), ε(.), *p*(.)(NULL)	82.68	2.13	0.07	0.34	4	(NA)

† Ψ = occupancy probability, γ = colonization, ε = extinction, *p* = detection probability, (.) = estimated as constant, (LowHgt) = percent area of shrub and low forest < 5 meters, (HighHgt) = percent area of shrub and low forest >5 meters, (ShapeID) = area to perimeter ratio of each delineated patch, (Area) = area of each delineated patch, and (NULL) = the Null hypothesis model.

Comparison of occupancy and detection probability estimates of western red bats (LABL) for patch size control sites (meso-scale) between 2011 and 2013

Year	LABL detection (p)	Occupancy (naïve)	Occupancy (modeled)	Standard error (modeled)	Detection probability
2011	0.13	0.33	(0, 1.0)	*	0.31
2012	0.29	0.75	(0.43[a], 0.80[b])	0.22	0.31
2013	0.17	0.50	(0.58[a], 0.72[b])	(0.20, 0.25)	0.31

* Models were overparameterized to calculate associated standard error.
[a] Extinction from previous year.
[b] Colonization from previous year.

Model[†]	$QAIC_c$	$\Delta QAIC_c$	$QAIC_c$ weight (w_i)	Model likelihood	Parameters	Beta association
1.) Ψ (Agric), γ(.), ε(.), *p*(.)	77.00	0.00	0.24	1.00	5	(+)
2.) Ψ (Evh), γ(.), ε(.), *p*(.)	77.00	0.00	0.24	1.00	5	(-)
3.) Ψ (Agric), γ(.), ε(.), *p*(t)	77.50	0.50	0.19	0.78	7	(+)
4.) Ψ (Agric_water), γ(.), ε.(), *p*(.)	79.00	2.00	0.09	0.37	6	(-,+)
5.) Ψ (Water_Rip), γ(.), ε(.), *p*(.)	79.00	2.00	0.09	0.37	6	(-,+)
6.) Ψ (Rip_Bio5), γ(.), ε(.), *p*(.)	79.00	2.00	0.09	0.37	6	(-,+)
7.) Ψ (.), γ(.), ε(.), *p*(.)(NULL)	79.00	3.79	0.04	0.15	4	NA

[†] Ψ = occupancy probability, γ = colonization, ε = extinction, *p* = detection probability, (.) = estimated as constant, (t) = estimated separately for each survey passes, (Agric) = percent composition of agriculture per plot*, (Evh) = average vegetation height per plot, (water) = percent composition of water plot, (Rip) = percent composition of riparian vegetation per plot*, and (Bio5) = average maximum temperature of warmest month per plot.
* Developed from remote sensed imagery; see “Methods,” objective 3, in the main report..

Comparison of western red bat (LABL) modeled occupancy and detection probability at treatment sites (macro-scale) between 2011 and 2013 along the lower Colorado River

Year	LABL detection (p)	Occupancy (naïve)	Occupancy (modeled)	Standard error	Detection probability
2011	0.20	0.60	(0, 1.0)	*	0.43
2012	0.41	0.50	(0, 0.75)	0.18	0.43
2013	0.14	0.40	(0, 0.56)	0.27	0.43

* Models were overparameterized to calculate standard error.

ATTACHMENT 4

Narrative of Western Red and Western Yellow Bat Captures, Roosting Detections, and Meso-Scale (Roosting Patch) Delineation

TREATMENT SITES

‘Ahakhav Tribal Preserve (AHAV)

We mist netted at the AHAV on 18 occasions from 2011–13. During our trapping effort, we captured two western red bats, both in the cold season (deploying one transmitter). We detected one adult male, and one escaped our net before we could record any biological data. We also captured 10 western yellow bats, all in the warm season (deploying 8 transmitters). We detected three adult males, five adult females, and two juvenile females. We located all roosts in palms surrounding the AHAV.

2011

We captured one western red bat and three western yellow bats at the AHAV during 2011. We deployed transmitters on each bat and were able to find roosting locations for all bats.

- We captured the male western red bat at the AHAV in the cold season and were only able to track it for 2 days. The bat foraged north of the capture site for 10 minutes and then headed directly up river. We were unable to relocate the bat the night of March 16 or the morning of March 17 pre-sunrise. However, we did locate this bat the afternoon of the 17th roosting in a Mexican fan palm (*Washingtonia robusta*) located within a recreational vehicle park in Parker, Arizona. We searched the adjacent area and from the Imperial National Wildlife Refuge survey site to the Havasu National Wildlife Refuge site along the length of the lower Colorado River (LCR) for the next 2 weeks, the bat was not detected again. Given the late cold season capture date (March 16) and the direct northern movements of this bat, it was likely a migrant and/or a cold season resident moving to its warm season range.

- We captured a female western yellow bat on May 23. It was tracked to a Mexican fan palm in a backyard near Parker, Arizona. We observed the bat roosting in the palm on May 24, 25, and June 1. This repeated use of the same roosting site indicates that it is a warm season resident along the LCR.

  We netted two female western yellow bats at the AHAV on the night of July 21. We tracked one of the bats to a Mexican fan palm near a home south of the trapping site. We monitored this bat foraging over the agricultural fields south of the AHAV after its release and found it roosting in the palm at approximately 2300 hours. We observed the bat roosting in this palm on July 22 but did not find it again, suggesting it may have been a migrant moving through the LCR corridor.

- We found the other female western yellow bat roosting in a Mexican fan palm on the California side of the LCR. This palm was also on private property. We observed the bat roosting in this palm on July 22 and July 25, leading us to believe the bat is a warm season resident along the LCR.

2012

We detected one western red bat and captured five western yellow bats, tracking three individuals. We detected the western red bat during cold season surveys and the western yellow bats in the warm season. We located roosts for two of the three western yellow bats.

- The western red bat we detected escaped our net before we could record any biological data.

- We captured one male western yellow bat at the AHAV on May 24. We fitted the bat with a transmitter and tracked it for a week. We detected the bat on May 25 and 26 at the same roost, an old Mexican fan palm just outside of Parker, Arizona.

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

- 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, we monitored the bat 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.

2013

We captured and placed transmitters on two adult female western yellow bats during the warm season.

- On May 13, we tracked one of the bats to a Mexican fan palm that was previously used as a roost in 2012. We observed the bat roosting in this location on May 14, 15, 16, 20, and 21.

- We tracked the other western yellow bat to two Mexican fan palms on the California side of the river. We did not initially detect the bat on May 14. We did find the bat roosting in a front yard on May 15 and 16. We could not locate the bat on May 20 but did find it at a nearby Mexican fan palm on May 21.

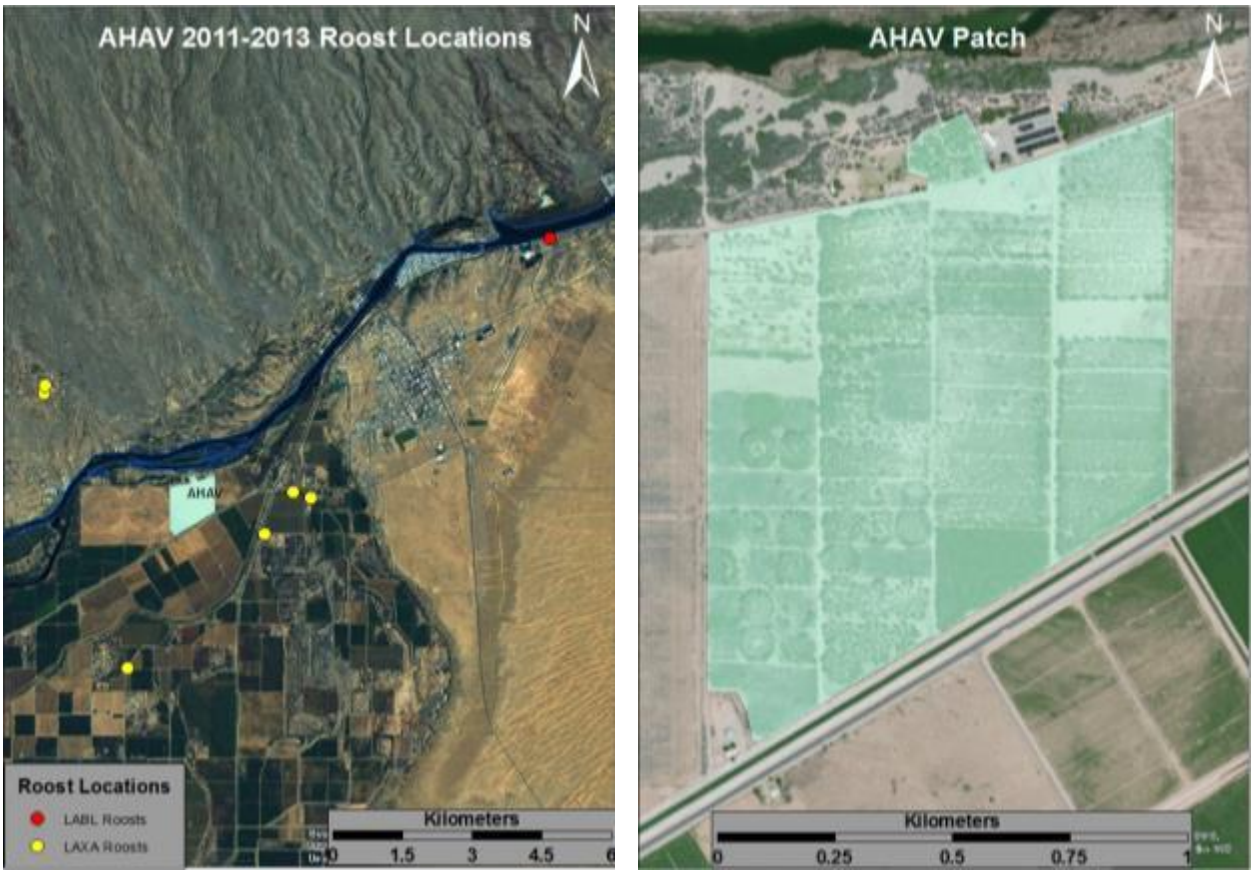

Figure1.—Western red and western yellow AHAV bat roosting locations and habitat patch.

Beal Lake

We mist netted at Beal Lake on seven occasions during the 2013 season and did not capture a western red or western yellow bat.

2013

We did not record any western red or western yellow bats during the 2013 trapping season.

Figure 2.—Beal Lake habitat patch.

Cibola Valley Conservation Area (CVCA)

We mist netted at the CVCA on 16 occasions from 2011–13. During this time, we captured 14 western red bats and deployed 10 transmitters. We detected three male western red bats during our cold season surveys and captured the rest during the warm season. We detected seven adult males, two juvenile males, and five adult females. We detected all of the western red bat roosts (except for two) within Phase I (planted in 2006) of the CVCA restoration area. We did not detect a western red bat roosting in Phase II (planted in 2008), which is adjoining and immediately south of Phase I. We located the other two roosts on the Cibola National Wildlife Refuge.

We captured eight western yellow bats during our trapping efforts and deployed eight transmitters all during the warm season. We detected three adult males, one juvenile male, three adult females, and one juvenile female. We located all roosts in palms surrounding the CVCA.

2011

We captured and tracked three western red bats and two western yellow bats at the CVCA. All captures and tracking occurred during warm season surveys. We located roosts for two of the western red bats and one of the western yellow bats at the CVCA. The first western yellow bat was tracked into California and lost. The two western red bats were detected roosting within the restoration area after being released. We found the third western red bat deceased in the restoration area; the cause of death was not determined. The bat was found approximately 300 meters from our mist netting location.

- The first male western red bat we captured was located roosting in a Fremont cottonwood (*Populus fremontii*) on June 22 and 23. This bat was located again on June 24 in a different cottonwood within the restoration area. This second roost was approximately 100 meters from the bat's previous roost. The bat's transmitter was recovered, likely due to grooming, on June 27 near the June 24 roost. The repeated detection of this bat within the CVCA site indicates it is a warm season resident.

- We detected the second male western red bat on June 22, 23, 24, and 27 in a cottonwood near the capture site. The repeated observation of this bat in the CVCA site indicates that it is a warm season resident.

- We captured a female western yellow bat at the CVCA on May 25. We fitted this bat with a transmitter, and almost immediately upon release, the bat flew north and out of range of our telemetry gear. An intensive search ensued with four people searching for 5 days. We searched north and south along the LCR and into California, but we never picked up the signal again. Due to this bat's movement, it was most likely a migrant moving along the LCR.

- We captured a second female western yellow bat at the CVCA on July 19 and tracked it to a Mexican fan palm on the bank of the LCR. We observed the bat roosting in the palm on July 20, 21, and 22 The repeated observation of this bat suggests it is a warm season resident on the LCR.

2012

We captured seven western red bats and four western yellow bats at the 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 the 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 cottonwoods. The bat roosted in the CVCA treatment site as well as the Cibola National Wildlife Refuge (CNWR). All six roosting sites were within 7 kilometers (km) of the capture site, suggesting that this bat is a cold season resident along 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 western red bat 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 CVCA. We fitted the western yellow bat with a transmitter; 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 meters 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.

2013

We captured four western red bats and two western yellow during the warm season, deploying transmitters on all of them.

- We captured an adult female western red bat on May 15. Unfortunately, we found the transmitter had been shed to the ground on May 16.

- We captured and placed a transmitter on another adult female western red bat on June 19. We tracked this bat to three separate cottonwood roosts within the patch we captured her in. We detected roosts on June 20, 21, 24, and 29. The bat was roosting in the same location on June 24 and 29.

- We captured and deployed a transmitter on a juvenile male western red bat on July 17. We observed this bat foraging along a canal to the south of the patch for approximately 3 hours before he roosted in a cottonwood for the night. On July 18, we observed this bat roosting in a cluster of six bats. On July 19, we observed the bat roosting alone in a nearby cottonwood and again observed a cluster of six bats at the original roost. On July 22, we observed the bat roosting alone in a cottonwood to the south of the first two roosts, with three bats roosting in the original roost. On July 23, we detected the bat roosting in the cottonwood immediately adjacent to the July 22 roost in a cluster of seven bats. We did not observe any bats at the original roost on July 23.

- We also captured an adult female western yellow bat on the night of July 17. We tracked this bat to a Mexican fan palm in the riverside community just north of the CVCA. We detected the bat roosting in this palm on July 18, 19, 22, and 23.

- We captured and placed a transmitter on an adult male western red bat the night of August 21. We detected the red bat roosting in a cottonwood near the trapping location on August 22 and in a Goodding's willow (*Salix gooddingii*) within the patch on August 23.

- We also captured an adult male western yellow bat on August 21. We tracked this bat to a date palm (*Phoenix dactylifera*) roost in a farmhouse front yard. We collected locations for this bat on August 22, 23, and 28.

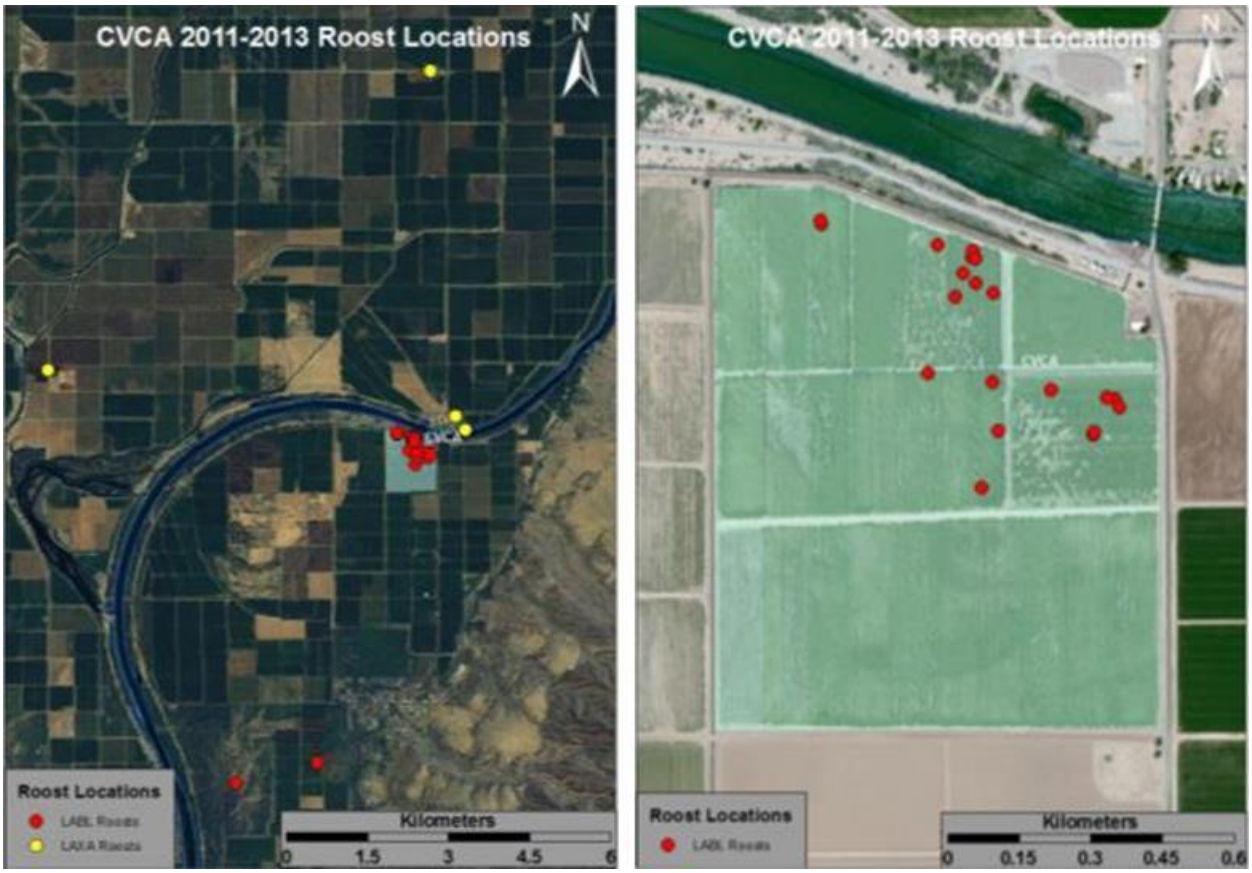

Figure 3.—Western red and western yellow bat CVCA roosting locations.

Havasu National Wildlife Refuge (HNWR)

We mist netted at the HNWR on 10 occasions from 2011–12. We captured one male western yellow bat and deployed a transmitter. In conjunction with Bureau of Reclamation (Reclamation) biologists, we made the decision to replace the HNWR with Beal Lake for the 2013 trapping season. We made the decision to switch to Beal Lake because the vegetation structure more closely resemble our other treatment sites and because of the low capture numbers at the HNWR.

2011

We captured and tracked a single western yellow bat at the HNWR during the warm season.

- We captured the male western yellow bat on June 27. The bat was having trouble flying upon release so he was placed 2 meters above the ground in a nearby cottonwood and found at the same location on June 28. He was observed attempting to shed his transmitter with his foot. His transmitter signal was picked up again on June 29, 10 meters from the previous roost. The signal appeared to be coming from the ground, but an exhaustive search of the leaf litter yielded nothing. This bat most likely shed his transmitter while roosting in the cottonwood above where the signal was received. Given that this bat was placed in the roosting tree, it was treated as a non-selected roosting site in the analysis.

2012

We did not detect any western red or western yellow bats during the 2012 season.

Figure 4.—HNWR habitat patch.

Imperial National Wildlife Refuge (INWR)

We mist netted at the INWR on six occasions from 2011–12. We did not capture any western red or western yellow bats. In conjunction with Reclamation biologists, we made the decision to replace this site with Yuma East Wetlands for the 2012 warm season and 2013 season because the vegetation structure more closely resembled our other treatment sites and because of the low capture numbers at the INWR. The trapping site at the INWR consisted of a small cottonwood-willow patch not planted by Reclamation.

2011

We did not detect any western red or western yellow bats during the 2011 trapping season.

2012

We did not detect any western red or western yellow bats during the 2012 cold season.

Figure 5.—INWR habitat patch.

Palo Verde Ecological Reserve (PVER)

We mist netted at the PVER on 15 occasions from 2011–13. We captured 13 western red bats and deployed 9 transmitters. We detected nine adult males, one juvenile male, two adult females, and one juvenile female. We detected all western red bat roosts within the PVER with the exception of one bat that roosted in the restoration area as well as an athel tree to the north. All roosts at the PVER occurred in Phase I (planted 2006) with the exception of one roost located in Phase II (planted 2007).

We also captured 13 western yellow bats, deploying 9 transmitters. We detected three adult males, four juvenile males, four adult females, one juvenile female, and one bat that escaped the net before we could collect any biological data. We located all western yellow bat roosts in palms surrounding the PVER.

2011

We captured and tracked three western red bats and two western yellow bats to roosts at the PVER. We captured one red bat in the cold season and two in the warm season. We tracked western yellow bats to roosts in the warm season. We attached transmitters to a female and male western yellow bat at the PVER on July 20.

- We were able to follow the male western red bat captured at the PVER during the cold season for 14 days before the transmitter battery life concluded. We captured this bat on February 23. We observed the bat foraging north into the agricultural fields adjacent to the PVER. The bat foraged above these fields for approximately 1 hour. We then observed the bat returning to the PVER and roosting in a cottonwood approximately 50 meters from the trapping site on February 23. We detected the bat roosting in a cottonwood on February 24 and in the same tree on February 28. We tracked the bat to an athel tamarix and honey mesquite hedge row stand on March 2, and found the bat roosting in an athel tree. We detected the bat a second time at the athel roost on March 7. We located the bat back at the PVER on March 8 roosting two trees north of its original roost in another cottonwood. Our final location for this bat was back in the athel roost on March 9. This bat moved between two roosting locations repeatedly. This movement and the multiple detections over a 2-week period indicates it is a cold season resident along the LCR.

- The first western red bat we captured during the warm season was a male on May 24. We were only able to track this bat for 2 days before he was able to groom his transmitter off. We observed the bat foraging over the agricultural fields bordering the PVER after being released. We found the bat roosting on May 25 in a cottonwood. We located the bat on May 26 approximately 100 meters from the previous roost in a cottonwood. We

found the transmitter directly below the bat on the ground. The repeated locations in the same roosting area indicates this bat is a warm season resident.

- We captured and tracked a second male western red bat foraging up the LCR to the area around the Palo Verde Dam. This bat stayed in the area for approximately 2 hours before returning to the PVER. We tracked this western red bat to a cottonwood within the PVER. We detected the bat roosting in the same cottonwood on July 21, 22, and 25. The repeated detection of this bat along the LCR indicates that it is a warm season resident.

- We captured a female western yellow bat on July 20. We tracked this female to a Mexican fan palm near a home on the west side of N Intake Blvd. We found the female roosting in the palm on July 21, 22, and 25.

- We captured and tracked a male western yellow bat to a stand of Mexican fan palms within a locked residential yard on July 20. We were not able to determine the specific tree the bat was roosting in, but all trees within the grouping shared similar characteristics as far as height and dead skirt length. We observed the bat roosting in the group of palms on July 21, 22, and 25.

2012

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

- We caught two male western red bats on May 23 and fitted them 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. We also fitted a male western yellow bat 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 cottonwood on three occasions over the course of 2 weeks. We located this roost 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. We also captured a male western yellow bat on June 20. We tracked this bat through the night, but the signal was lost heading south. We then captured a male adult and subadult western red bat on June 20 but did not attach transmitters because of low weight (subadult 9 grams) and 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 meters north of Interstate 10. We obtained two detections on this bat 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.

2013

We captured one western red bat and three western yellow bats during the trapping season, deploying transmitters on all of them.

- We captured and placed a transmitter on an adult male western red bat on June 18. We observed this bat roosting in a single cottonwood within the PVER on June 19, 20, 21, 24, and 29.

- We captured and placed transmitters on two juvenile female western yellow bats on July 16. We observed the first female roosting in the same Mexican fan palm southwest of the restoration area along an irrigation canal on five occasions (July 17, 18, 19, 22, and 23). We also observed the second female roosting in a Mexican fan palm on the same five occasions. We located this roost even further southwest, closer to US 95.

We also captured and deployed a transmitter on an adult female yellow bat the night of August 20. We tracked this bat to a Mexican fan palm in a residential area of Blythe, California. We observed this bat roosting in this palm on August 21, 22, 23, 28, and 29.

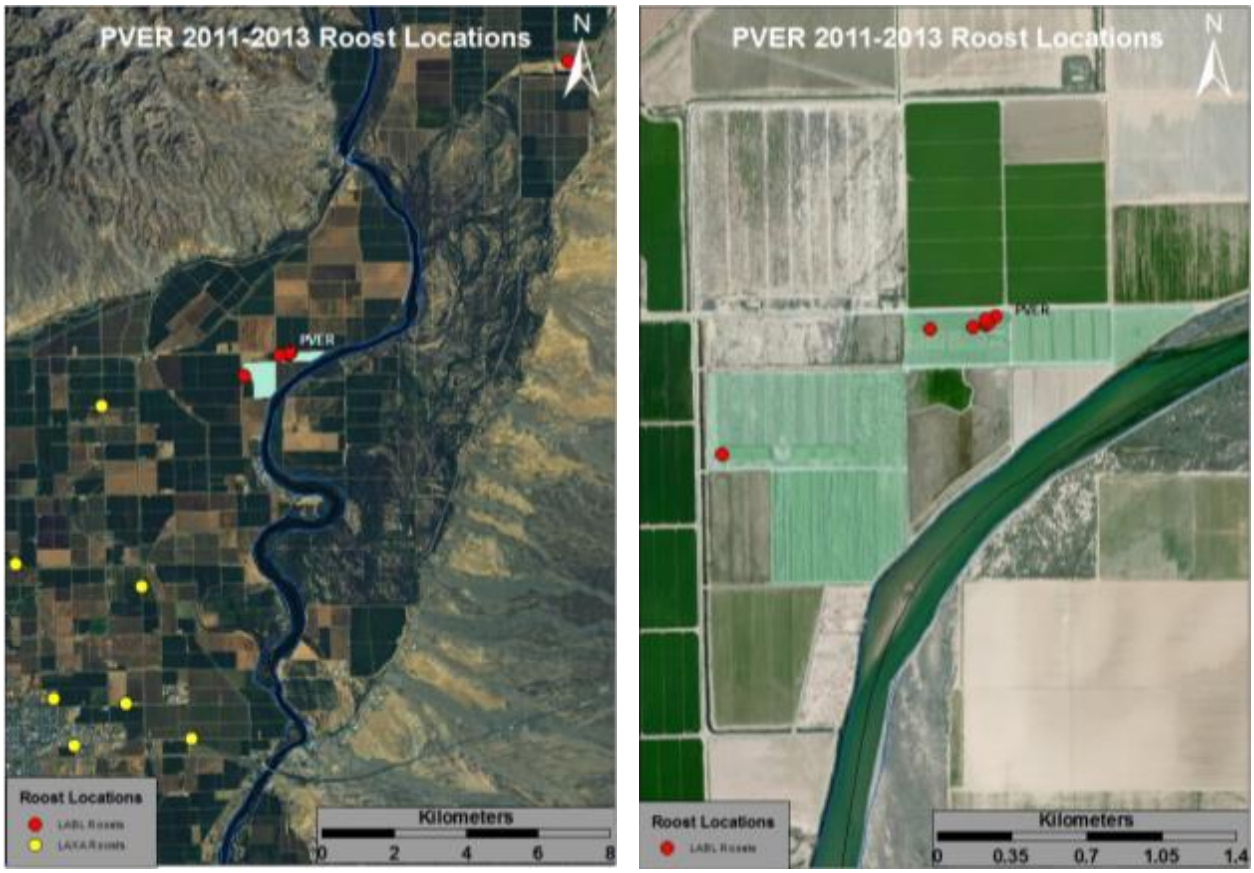

Figure 6.—Western red and western yellow bat PVER roosting locations.

Yuma East Wetlands (YUME)

We mist netted at YUME on 11 occasions from 2012–13. We, along with Reclamation biologists, made the decision to replace the INWR with YUME starting in 2012 because the vegetation community at YUME more closely resembled our other treatment sites. We captured four western yellow bats during warm season trapping and deployed three transmitters. We captured two adult males and two adult females.

2012

We captured two western yellow bats at YUME 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 the 16th. We did not detect this bat again.

2013

We captured two western yellow bats during the warm season and deployed transmitters on both.

- We captured and placed a transmitter on an adult male western yellow bat on May 30. We tracked this bat to two separate Mexican fan palm roosts on May 31 and June 2 and 3. The bat roosted in the same palm on June 2 and 3.

- We captured and placed a transmitter on an adult female western yellow bat on July 30. This bat was lost while we were attempting to track it back to its roost. We searched the surrounding area and attempted to pick up the bat foraging at the restoration area in subsequent days but never detected the signal again. This bat may have migrated out of the area.

Figure 7.—Western yellow bat YUME roosting locations.

CONTROL SITES

Agua Caliente Park (ACP)

We mist netted at ACP on one occasion during the 2011 warm season. We captured two western yellow bats during the warm season and deployed transmitters on both. We detected one adult male and one adult female. We trapped at this location only once because the vegetation community did not match our other control sites. We did not include ACP in our site analysis.

2011

We captured two western yellow bats at ACP on June 16. The first western yellow bat we captured was a non-reproductive female, and the other was an adult male.

- We captured and tracked the non-reproductive female western yellow bat on June 16. We observed this bat roosting in a Mexican fan palm adjacent to the netting site. On June 18 and 22, we detected the female in the same tree. The female was detected again at her original roosting site on June 22.

- We also captured and tracked a male western yellow bat on June 16. We located the male on June 22 roosting south of the park in a Mexican fan palm on private property.

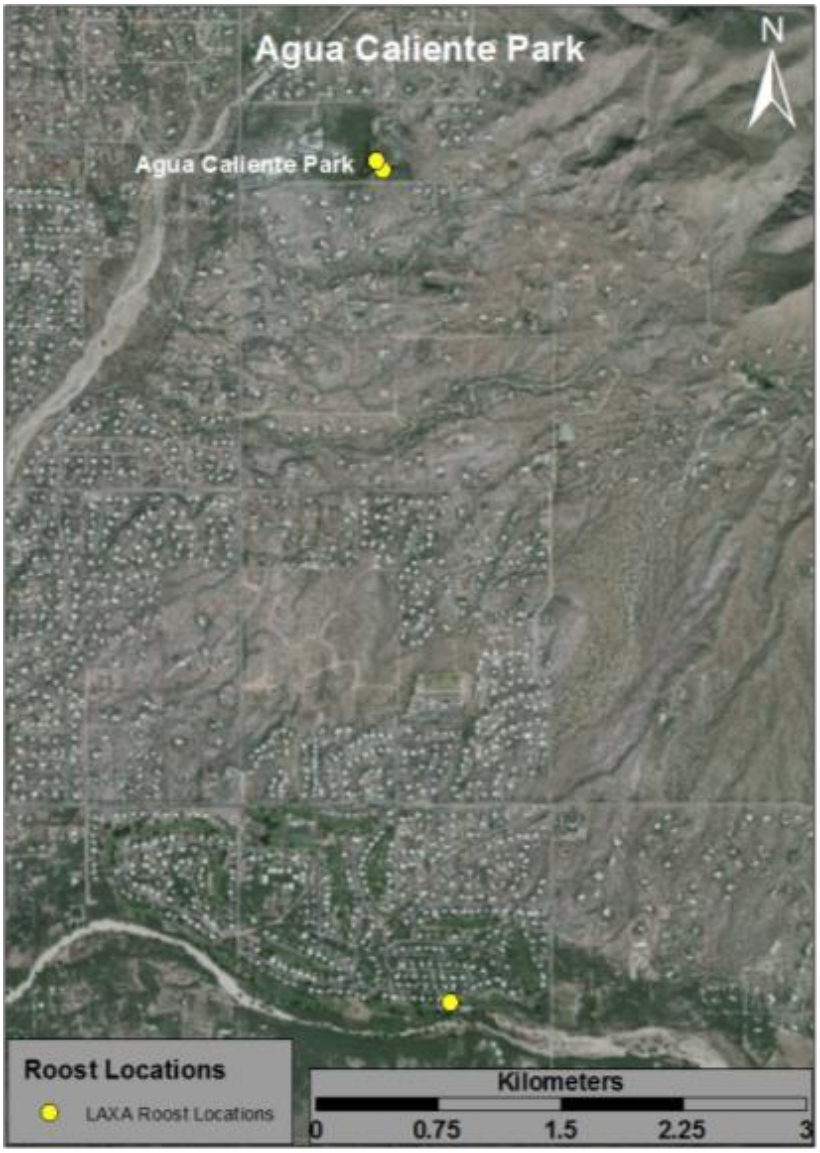

Figure 8.—ACP roost locations.

Agua Fria National Monument (AGUAF)

We mist netted at AGUAF on five occasions during the 2013 warm season. We captured two western red bats and deployed transmitters on both. We detected one adult male and one juvenile female.

2013

We captured and placed transmitters on two western red bats during the warm season.

- We captured and deployed transmitters on an adult male and juvenile female western red bat on the night of July 23. We observed the male roosting alone on July 24 in a Goodding's willow just downstream from the capture site. On July 25, we detected the bat roosting in a cottonwood in a cluster of three bats. We located the bat again on July 26 in another nearby cottonwood, this time in a cluster of four bats. On July 27, 29, 30, and 31, we observed the bat roosting in a cluster of four in the same cottonwood as on July 25. We located the bat for a final time and total of eight locations on August 2, roosting in another nearby cottonwood in a cluster of four bats.

- We detected the juvenile female on July 24 in a cottonwood upstream from the capture site roosting with one other bat. We located the bat again on July 25 and 26 in a nearby cottonwood. On July 25, the bat was roosting in a cluster of eight bats and a cluster of seven bats on July 26. We observed the bat on July 27 roosting in the same location as it did on July 24. We did not get a visual on the bat for this occasion. On July 29, 30, 31, and August 2, we detected the bat roosting at another nearby cottonwood in a cluster of seven, five, seven, and eight bats, respectively. On July 29, we detected two bats roosting in the cottonwood where this bat was detected on July 25 and 26 but did not detect any bats using this roost again in subsequent visits.

Figure 9.—Western red bat AGUAF roosting locations.

Bill Williams River National Wildlife Refuge (BWRNWR)

We mist netted at the BWRNWR on 18 occasions from 2011–13. We captured one male western red bat during our surveys but did not attach a transmitter because of weight limitations.

2011–12

We did not capture any western red or western yellow bats at the BWRNWR during 2011 or 2012.

2013

We captured a male western red bat on February 28, but we were unable to attach a transmitter due to insufficient weight.

Figure 10.—BWRNWR habitat patch.

Bill Williams River Cliff Pond (BWRCP)

We mist netted at BWRCP on five occasions during the 2013 warm season and did not capture any western red or western yellow bats.

2013

No western red or western yellow bats were captured at this site during our trapping efforts.

Figure 11.—BWRCP habitat patch.

Cienega Dam (CDAM)

We mist netted at CDAM on six occasions during the 2013 warm season. We captured two western yellow bats and deployed transmitters on both. We detected one adult male and one adult female.

2013

We captured two western yellow bats during the warm season and placed transmitters on both.

- We captured and deployed transmitters on an adult male and female western yellow bat on August 19. We tracked both of these bats throughout the night. Just before sunrise, they both headed northwest into Tucson where signal interference made tracking impossible. We searched the area on multiple days but could not locate either bat. We observed the bats again foraging near the capture site on August 26, but they repeated their actions from the 19th, and we lost the signal again due to interference.

Figure 12.—CDam habitat patch.

Date Creek Ranch (DCRR)

We mist netted at DCRR on five occasions during the 2013 warm season. We captured four western red bats and deployed transmitters on two. We detected one juvenile male and three adult females.

2013

We captured four western red bats during our trapping season but were only able to deploy transmitters on two because of reproductive status.

- We captured two lactating western red bats on June 16 and were unable to attach transmitters.

- We captured and deployed a transmitter on a juvenile male western red bat on July 11. We observed the bat roosting alone in the same cottonwood on July 12, 13, 15, and 24. On July 18, we detected the bat roosting in a nearby cottonwood with one other bat (presumably the mother).

- We captured and deployed a transmitter on an adult female western red bat on the night of August 14. We detected this bat roosting in the same cottonwood on August 15 and 16. On August 15, we observed the bat roosting alone in dead mistletoe (*Viscus album*), and roosting in a cluster of three bats in live mistletoe on the 16th. We detected the bat for a final time on August 22 in a nearby cottonwood roosting in live mistletoe in a cluster of three.

Figure 13.—Western red bat DCRR roost locations.

Hassayampa River Preserve (HRPR)

We mist netted at the HRPR on five occasions during the 2013 warm season. We captured one female adult western yellow bat and deployed a transmitter.

2013

We captured and placed a transmitter on an adult female western yellow bat on June 6. We tracked this bat to two separate Mexican fan palm roosts on June 7, 10, and 11 near the visitor's center. We found the bat roosting in the same palm on June 10 and 11.

Figure 14.—Western yellow bat HRPR roost locations.

San Pedro River Preserve (SPP)

We mist netted at the SPP on 17 occasions from 2011–13. We captured three western red bats and deployed two transmitters. We detected two adult males and one adult female. We detected one of the adult males during cold season trapping.

2011

We detected two western red bats at the SPP during the warm season.

- We captured a male western red bat on June 3. The bat proved elusive after being netted and was not located again until June 7, where we found it roosting in a Mexican fan palm in Dudleyville, Arizona. We detected the bat again on June 8 in the same roost. The repeated detection of this bat in the same roost indicates that this bat is a warm season resident.

- We captured a lactating female western red bat at the SPP on July 1. Due to the bat's weight (9.5 grams) and reproductive status, it was determined not fit for a transmitter and was released.

2012

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 the SPP and later detected the bat three times at two different roosts. Both roosts consisted of a standing live cottonwood with a dead cottonwood leaning against the roost tree. We detected the bat roosting within the dead foliage where the live standing roost tree and the dead tree met. The two roosts are within 200 meters of one another.

2013

We did not record any western red or western yellow bats during the 2013 trapping season.

Figure 15.—Western red bat SPP roost locations.

Santa Cruz River Tumacacori (SCT)

We mist netted at the SCT on 12 occasions from 2012–13. We captured six western red bats but were unable to deploy a transmitter on any of them due to insufficient weight or reproductive status. We detected one adult male, one juvenile male, and three adult females, and one bat escaped before we could collect biological data. We also detected one adult male western yellow bat and deployed a transmitter. We captured all bats during warm season trapping.

2012

We detected four western red bats at the 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 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 grams). The detection of these bats suggests a breeding population of western red bats along the Santa Cruz River in southern Arizona.

2013

We captured two western red bats and one western yellow bat during our trapping season but were only able to deploy a transmitter on the western yellow bat.

- We captured a pregnant western red bat on June 5, so were unable to attach a transmitter.

- We captured a male western red bat and a male western yellow bat on July 18. Unfortunately, the western red bat had an injured wing and was deemed not fit for a transmitter. We did attach a transmitter to the western yellow bat, collecting three separate roosts within 20 meters of each other. The bat moved between Mexican fan palm roosts on July 19, 22, and 26.

Figure 16.—Western yellow bat roost locations and SCT habitat patch.

Three Links Farm (THL)

We mist netted at THL on 11 occasions from 2011–13. We captured three western red bats and deployed one transmitter. We detected two juvenile males and one adult female. All captures took place during warm season trapping. We did not mist net at THL during the 2013 warm season because of access issues with the landowner.

2011

We did not capture any western red or western yellow bats during the 2011 trapping season at THL.

2012

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 insufficient weight. We did attach a transmitter to a post-lactating female. We detected this bat only once, roosting in a cottonwood near the trapping site. During searches along the San Pedro River on July 30 and 31, we did not detect it again.

2013

- We only trapped at THL during the cold season in 2013 and did not detect any western red or western yellow bats.

Figure 17.—Western red bat THL roost location.

West Clear Creek (WCCR)

We mist netted at WCCR on five occasions during the 2013 warm season. We captured four western red bats and deployed transmitters on three. We detected one juvenile male and three adult females.

2013

We captured four western red bats during the 2013 warm season and placed transmitters on three.

- We captured a lactating western red bat on June 12 and were unable to attach a transmitter.

- We captured and placed transmitters on two adult female bats and one juvenile male western red bat on August 13. We observed the first adult female roosting in a nearby cottonwood on August 14, 15, and 19. The bat roosted alone on August 14, and we detected it roosting with one other bat (presumably the mother) on the 15 and 19.

- We tracked the second adult female to a hackberry (*Celtis reticulata*) in a large overgrown thicket and found it roosting there on August 14, 15, and 19. We did not get a visual on this animal due to the thickness of the vegetation.

- We observed the juvenile male roosting alone in a sycamore (*Platanus occidentalis*) directly over a road on August 14, 15, and 29. We also detected the bat in another nearby sycamore on August 19 but could not obtain a visual on that occasion.

Figure 18.—Western red bat WCCR roost locations.