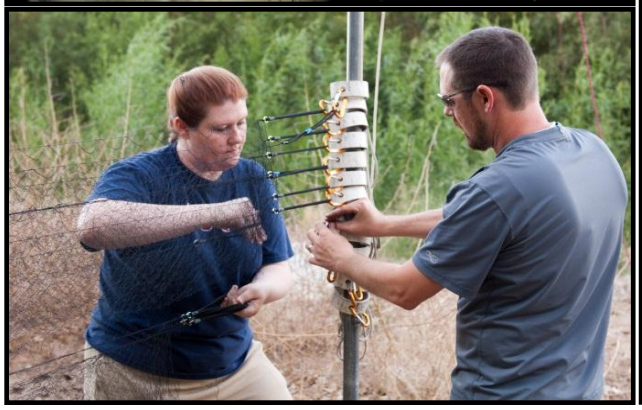
Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Post-Development Bat Monitoring of Habitat Creation Areas along the Lower Colorado River – 2011 Capture Surveys



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January 2012

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Lower Colorado River Multi-Species Conservation Program

Post-Development Bat Monitoring of Habitat Creation Areas along the Lower Colorado River – 2011 Capture Surveys

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Multi-Species Conservation Program
Bureau of Reclamation
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ACRONYMS AND ABBREVIATIONS

AKTP	‘Ahakhav Tribal Preserve
CIBO	Cibola National Wildlife Refuge Nature Trail
CRIT	Colorado River Indian Tribe
CVCA	Cibola Valley Conservation Area
ft	foot/feet
ha	hectare(s)
in	inch(es)
km	kilometer(s)
LCR	lower Colorado River
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
m	meter(s)
mi	mile(s)
mm	millimeter(s)
PAST	Paleontological Statistics Software Package for Education and Data Analysis
Analysis	
PIT	passive integrated transponder
PVER	Palo Verde Ecological Reserve
Reclamation	Bureau of Reclamation

Symbols

% percent

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1 Common and Scientific Names of All Species Captured

ABSTRACT

This was the fifth year of bat capture surveys within habitat creation areas for the Lower Colorado River Multi-Species Conservation Program (LCR MSCP). There are two covered and two evaluation bat species listed under the program. The western red bat (*Lasiurus blossevillii*) and western yellow bat (*Lasiurus xanthinus*) are both tree-roosting species, and the California leaf-nosed bat (*Macrotus californicus*) and Townsend's big-eared bat (*Corynorhinus townsendii*) are both mine- and cave-roosting species that utilize riparian areas as foraging habitat. Four sites were surveyed in 2011. Each site was surveyed once a month from May through September. A total of 735 bats of 13 species were captured during the survey period. This was the first year that all four LCR MSCP species were captured within habitat creation areas. Two sites both showed an increased in western red and western yellow bats compared to 2010. Diversity indices were compared among sites showing similarities among sites of similar age trees. A mark-recapture component may be added for western red and western yellow bats to determine site fidelity. Surveys will continue in 2012 at all four habitat creation areas, and data will be compiled with previous years to give better recommendations for habitat creation for LCR MSCP bat species.

INTRODUCTION

The Bureau of Reclamation (Reclamation) is the lead implementing agency for the Lower Colorado River Multi-Species Conservation Program (LCR MSCP). The LCR MSCP is a 50-year cooperative Federal-State-Tribal-County-Private effort to manage the natural resources of the lower Colorado River (LCR) watershed, provide regulatory relief for the use of water resources of the river, and create native habitat types along the LCR. The LCR MSCP was implemented in October 2005. To restore native habitats, the LCR MSCP will create the following cover types: (1) 5,940 acres (2,404 hectares [ha]) of cottonwood-willow (*Populus fremontii* and *Salix* spp.), (2) 1,320 acres (534 ha) of honey mesquite (*Prosopis glandulosa*), (3) 512 acres (207 ha) of marsh, and (4) 360 acres (146 ha) of backwaters (LCR MSCP 2004).

The western red bat (*Lasiurus blossevillii*) and western yellow bat (*Lasiurus xanthinus*) are covered species under the program. The California leaf-nosed bat (*Macrotus californicus*) and Townsend's big-eared bat (*Corynorhinus townsendii*) are evaluation species under the program. The LCR MSCP uses a variety of methods to monitor covered bat species in these habitat creation areas. In the fall of 2006, a post-development bat survey using acoustic bat detectors was initiated by Reclamation, Technical Service Center, in Denver, Colorado (Broderick 2008). During these acoustic surveys in July and October 2007, a preliminary capture survey began at three of the locations in which acoustic data had been collected (Calvert 2009). In September, a fourth site was surveyed in which only exploratory acoustic work had been done. In 2008, a full season capture survey was conducted. The survey protocol was refined in 2009, and surveys continued in 2010 and 2011. Riparian habitat creation areas along the LCR have only minimally been surveyed for bats in the past (Brown 2006). This new survey is an attempt to increase effort and thus increase the capture of bats to discover whether LCR MSCP covered species are utilizing habitat creation areas.

There are a variety of reasons why bat surveys should include both acoustic and capture techniques. Not all species are successfully surveyed using only one of the two methods (O'Farrell and Gannon 1999). Species such as Townsend's big-eared bats and California leaf-nosed bats are known to echolocate at low intensities, which are often missed using acoustic detectors. If there is a species identification question using acoustic data, then captures may confirm the presence of a species. Capturing bats allows for acoustic reference calls to be made when releasing bats near a bat detector so that additional calls can be included in the reference call library, which allows easier identification of species recorded using bat detectors. The design of future habitat creation areas may also be aided by capturing bats. The location of mist-nets at current sites may allow a better understanding of how bats use riparian areas. Acoustic data show that most bats avoid cluttered areas and forage along edges of riparian forests, in corridors, and openings in forest canopies that create "flyways" for bats (Broderick 2008). Capture techniques may allow for more refined specifications on how to create

corridors and flyways in future sites, which will allow bats to use a larger area of these sites as well as allow biologists to more easily find locations to capture bats during future surveys.

STUDY AREAS

Palo Verde Ecological Reserve

The Palo Verde Ecological Reserve (PVER) is a large-scale LCR MSCP restoration project approximately 6 miles (mi) (10 kilometers [km]) north of Blythe, California (figure 1). Habitat is being created by replacing cultivated crops with native riparian plant species on agricultural fields, utilizing existing irrigation infrastructure. In the last 6 years, over 700 acres (283 ha) of habitat were created. Species that were planted include Fremont cottonwood, Goodding's willow (*Salix gooddingii*), coyote willow (*Salix exigua*), honey mesquite, mule-fat (*Baccharis salicifolia*), desertbroom (*Baccharis sarothroides*), and quailbush (*Atriplex lentiformis*). Most of the habitat is dominated by cottonwood and willow trees, including the area where surveys were conducted (figures 2 and 3). Two of the netting areas were within an area planted in 2006 (figure 2). The other netting area was in a nearby field planted in 2009 (figure 3).

Cibola Valley Conservation Area

The Cibola Valley Conservation Area (CVCA) is approximately 2 mi (3 km) north of Cibola, Arizona, and is also a large-scale LCR MSCP restoration project (figure 1). The habitat is being developed in the same manner and planted with the same species as PVER. In the last 6 years, over 600 acres (243 ha) of habitat was created. Once all phases have been planted, there will be over 1,000 acres (405 ha) of riparian habitat within CVCA. The capture survey area was an 86-acre (35-ha) section planted with cottonwood and willow that was planted in 2006 (figure 4).

Cibola National Wildlife Refuge Nature Trail

The Cibola National Wildlife Refuge Nature Trail (CIBO) is a 34-acre (13.8-ha) site planted in 1999 and is located on the Cibola National Wildlife Refuge Unit 1 Conservation Area. It is 1 mi (1.6 km) southwest of Cibola, Arizona (figure 1). Capture surveys took place in areas where tall cottonwood or mesquite trees lined the trail (figure 5). Goodding's willow, desertbroom, screwbean mesquite (*Prosopis pubescens*), and honey mesquite are additional species found within the site.

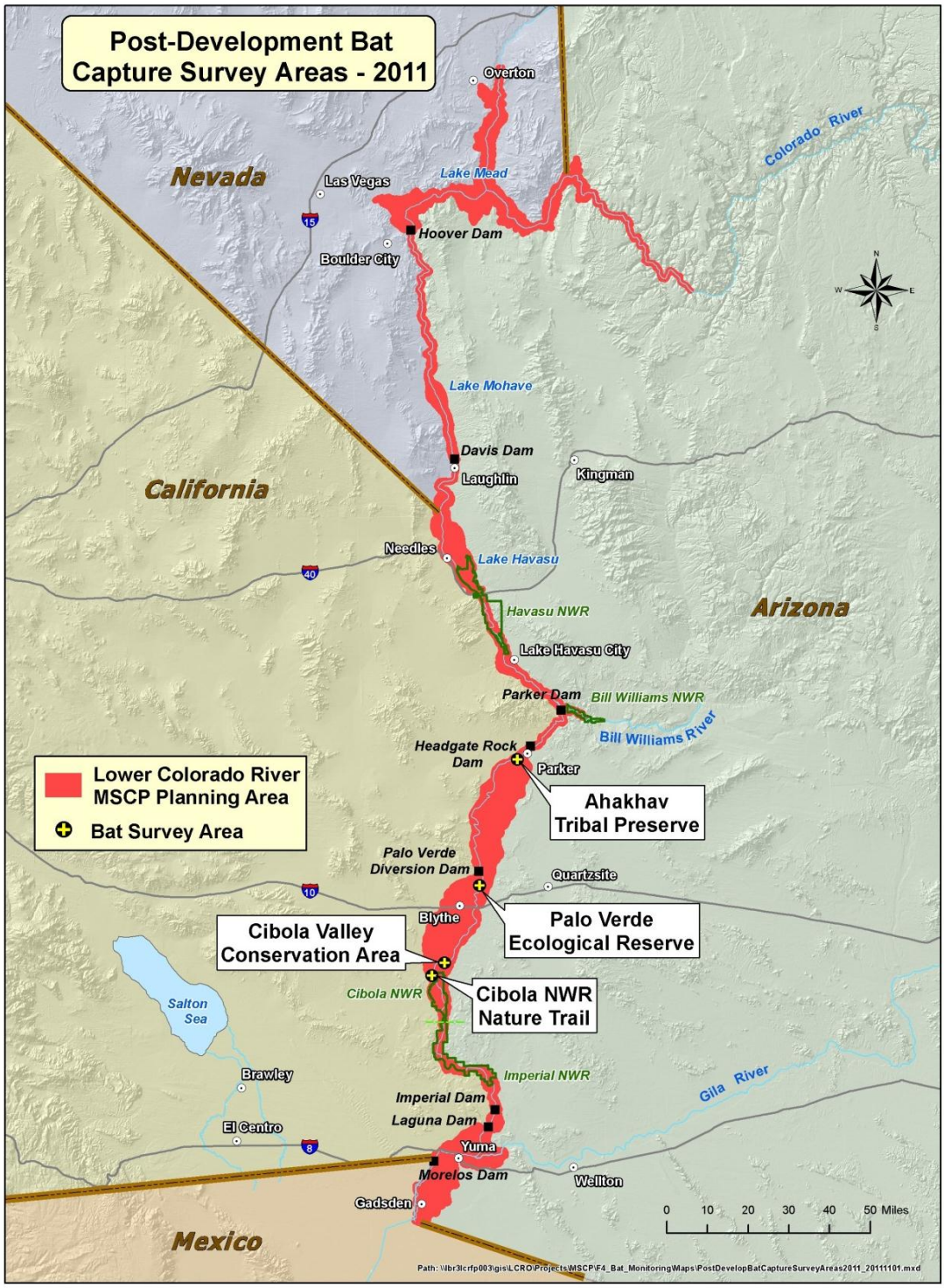

Figure 1.—Bat capture survey areas.

Figure 2.—Netting areas (in red) at PVER, Phase 1.

Figure 3.—Netting area (in red) at PVER, Phase 4.

Figure 4.—Netting area (in red) at CVCA, Phase 1.

Figure 5.—Netting areas (in red) at CIBO.

‘Ahakhav Tribal Preserve

The ‘Ahakhav Tribal Preserve (AKTP) is a 150-acre (61-ha) site located 3 mi (5 km) south west of Parker, Arizona, on Colorado River Indian Tribe (CRIT) land (see figure 1). This site consists of fields of cottonwood, willow, and mesquite planted as part of an agreement between CRIT and Reclamation. The capture survey area was planted in 2001 and has the largest trees of the site (figure 6). Cottonwood, Goodding’s willow, and coyote willow were planted in the area.

METHODS

Mist-netting was the only technique used to capture bats during the 2011 surveys. Depending on net locations, five different net lengths were used, including 6-meter (m) (19.7-foot [ft]), 9-m (29.5-ft), 12-m (39.4-ft), 15-m (49.2-ft) and 18-m (60-ft) Avinet Inc., nets, which were all 2.6 m (8.5 ft) tall with a 38-millimeter (mm) (1.5-inch [in]) mesh size. High net setups were used at all of the sites. These high nets were constructed by stacking regular nets (8.5 ft [2.6 m] tall) on top of each other using poles in which a pulley system had been made to reach the higher stacked nets. The setup used three nets stacked on top of each other (known hereafter as a triple high net) (figure 7). The triple high net was used to capture bats that fly higher and where single nets were easily avoided.

Figure 6.—Netting areas (in red) at AKTP.

Nets were set up at a site in an area such as a flyway where bats would be more concentrated. These flyways were usually corridors within the site where a space such as a road or trail was created between two areas of plantings. Netting perpendicular to an edge was also attempted at two sites (PVER and CVCA). The size of the net was determined by the width of the corridor in order to maximize the area where bats could be captured. In some areas where it appeared that a single triple may be easily avoided by a bat, nets were placed together to make avoidance of one of the nets by the bat less likely. Nets were set up in a V or L formation where a bat might be funneled from one net into the other (figure 7). These techniques have been used successfully by Bat Conservation International (J. Tyburec, personal communication).

During netting, two types of bat detectors were used in order to obtain reference calls of captured bats when released as well as to discover whether bat activity in the area was changing over the course of the evening. Bat detectors record the high frequency calls of bats, which are above the audible range of humans. Software is later used to analyze each call for species-specific characteristics such as frequency, length, and slope. The Anabat SD2 bat detector (Titley Electronics) was connected to an HP iPAQ pocket PC running AnaPocket software. The AR-125 bat detector (Binary Acoustics Technology) was also used, which records bat calls as full spectrum .wav files. It was connected to a Samsung Q1 Ultra tablet PC running SPECTR Mobile software.

Figure 7.—Two triple high nets set up in an L formation at CVCA.

Once a bat was captured, species, age, sex, and reproductive status were determined. Measurements such as forearm and ear length were also taken if necessary to identify the species. If the species was one for which acoustic reference calls were needed, a small 1-in (2.5-centimeter) long glow stick was glued (using a nontoxic glue stick) onto the ventral fur to be used as a light tag (Kunz and Weise 2009). Once the bat was released, it was followed with the bat detector until it flew too far to be recorded. All acoustic file names saved on the HP iPAQ or the Samsung Q1 Ultra were written on the data sheet for species confirmation and later added to the acoustic reference library.

Genetic sampling was conducted on captured bats if needed for future genetic studies or species identification. If a species was found in a new locality, a voucher specimen may have been taken and deposited into an accredited museum. Genetic samples were taken from the wing using a 2-mm or 3-mm biopsy punch. All tissues were stored in 95 percent ethanol.

Surveys began at sunset and continued for 4.5 hours (weather permitting). Each site was surveyed once a month from May to September for a total of five survey sessions. If covered species were recorded acoustically during other times of the year, an exploratory survey was conducted. A minimum of three triple high set ups were used at each site. These standardizations were taken from an unpublished protocol (available upon request) that was created using data from the 2007 and 2008 LCR MSCP bat surveys.

In 2011, the total net hours of effort were calculated for each site. A 6-m net was used as the minimum net size. A 6-m net set for 1 hour equaled 1 net hour of effort, a 9-m net set for 1 hour equaled 1.5 net hours, a 12-m net set for 1 hour equaled 2 hours, etc., allowing for better comparisons among sites when the total net effort varied.

Several statistical tests were run to compare species diversity and quantitative similarity of data. The data were first compared using the Program R (v. 2.9.2) to determine if the data were nonparametric by creating a quantile-comparison plot. Then, a Kruskal-Wallis rank sum test was used to determine if the capture rates were similar enough that they could be compared to one another. Data were compared both among all sites in 2011 as well as between years at the same site. The data were then compared using the Paleontological Statistics Software Package for Education and Data Analysis (PAST) (v 2.03) for a number of diversity measures, and a *p* value for significant difference was calculated for each measure using bootstrapping computer analysis methods.

Multiple diversity indices were used and compared among sites using PAST. PAST allows different aspects of diversity to be measured and compared using other indices. The Shannon index measures both species richness and species evenness and combines them to calculate a value that reflects both. The transformed (N1) Shannon index was also used for graphically comparing indices. Other indices measure species evenness, dominance, or richness. In analyzing additional indices, it may be possible to determine if certain aspects of diversity are driving differences seen among sites. The indices calculated using PAST are described in table 1 (Hammer et al. 2001). PAST was then used to perform a bootstrap analysis comparing these different diversity indices between years for each site and among each site for 2011 data. One thousand replicates with replacement were produced each with the same total number of individuals as in each original sample, and a 95-percent confidence interval was then calculated (Hammer et al. 2001).

RESULTS

See appendix 1 for a list of common and scientific names of all species captured.

Palo Verde Ecological Reserve

Capture surveys were conducted at PVER for the second year in 2011. Three triple high net sets were used for each survey for a total of 405 net hours of effort.

Table 1.—Explanation of diversity indices calculated in PAST and used to compare sites

Index	Description
Taxa S	Number of species (*S*)
Individuals	Total number of individuals (*n*)
Dominance	Dominance = 1 – Simpson index. Ranges from 0 (all taxa are equally present) to 1 (one taxon dominates the community completely). D = sum((ni/n)2) where ni is number of individuals of taxon i.
Shannon index	*H = -sum((ni/n)ln(ni/n))* where ni is number of individuals of taxon i.
Simpson index	Simpson index = 1 – dominance. Measures "evenness" of the community from 0 to 1. Note the confusion in the literature: Dominance and Simpson indices are often interchanged.
Evenness e^H/S	Evenness value based on the H value from Shannon index.
Menhinick	Menhinick's richness index – the ratio of the number of taxa to the square root of sample size.
Margalef	Margalef's richness index: *(S-1)/*ln*(n)* where *S* is the number of taxa and *n* is the number of individuals.
Equitability J	Equitability. Shannon index divided by the logarithm of number of taxa. This measures the evenness with which individuals are divided among the taxa present.
Fisher alpha	Fisher's alpha – a diversity index, defined implicitly by the formula *S=a**ln*(1+n/a)* where *S* is number of taxa, *n* is number of individuals, and *a* is the Fisher's alpha.
Berger-Parker	Berger-Parker dominance: simply the number of individuals in the dominant taxon relative to *n*.

A total of 136 bats of 10 species were captured. The big brown bat (*Eptesicus fuscus*) was the most commonly captured species. Townsend's big-eared bat was the only LCR MSCP covered species not captured. The highest captures and species richness were found during the July survey (table 2).

Table 2.—Species captured at PVER for each survey month in 2011

Species	May	June	July	August	September	Totals
Big brown bat	2	6	35	23	9	75
Pallid bat	0	3	14	5	1	23
Cave myotis	0	7	1	2	0	10
Western yellow bat	0	0	6	3	0	9
Western red bat	1	0	1	0	3	5
California leaf-nosed bat	2	2	0	0	1	5
Yuma myotis	0	2	2	0	0	4
California myotis	0	0	1	0	1	2
Mexican free-tailed bat	0	0	0	2	0	2
Western mastiff bat	1	0	0	0	0	1
Totals	6	20	60	35	15	136

Most species had a higher female to male sex ratio, though all western red bats captured were males (table 3). The pallid bat (*Antrozous pallidus*) was the only species with a similar ratio of adults to juveniles captured, and most species had only a few juveniles captured (table 3). Except for western red bats (which were all males), more adult females were found to be reproductively active compared to adult males (figure 8). Only the California myotis (*Myotis californicus*) and Mexican free-tailed bat (*Tadarida brasiliensis*) had no individuals captured with signs of reproduction (see figure 8).

Table 3.—Sex and age ratios for all species at PVER in 2011

Species[1]	Sex (male:female)	Age (adult:juvenile)
Pallid bat	6:16	12:10
Big brown bat	22:51	47:25
Western mastiff bat	0:1	1:0
Western red bat	5:0	5:0
Western yellow bat	3:6	5:4
California leaf-nosed bat	3:2	5:0
California myotis	2:0	1:1
Cave myotis	2:8	10:0
Yuma myotis	1:3	2:2
Mexican free-tailed bat	1:1	2:0

[1] Four individual bats escaped before sex and age could be determined.

The pocketed free-tailed bat (*Nyctinomops femorosaccus*) was not captured in 2011, but two new species, the California leaf-nosed bat and western mastiff bat (*Eumops perotis*), were captured this year (table 4). For LCR MSCP covered species, capture rates increased for western red bats and California leaf-nosed bats, but slightly decreased for western yellow bats. While capture rates were lower in 2011, species richness increased by one (figure 9). July had the highest capture rate, but June had the highest diversity in 2011. Species diversity was higher in all months except August compared to 2010 (figure 10).

Shannon diversity also increased from an N1 of 3.34 in 2010, to 4.51 in 2011. All diversity indices increased in 2011 compared to 2010 (table 5). Both dominance indices decreased in 2011, meaning there was less dominance of a single species compared to 2010 (table 5). In general, when species diversity increases, species dominance decreases. When these diversity indices were compared between years at PVER using bootstrapping, four indices were found to be significantly different (table 6).

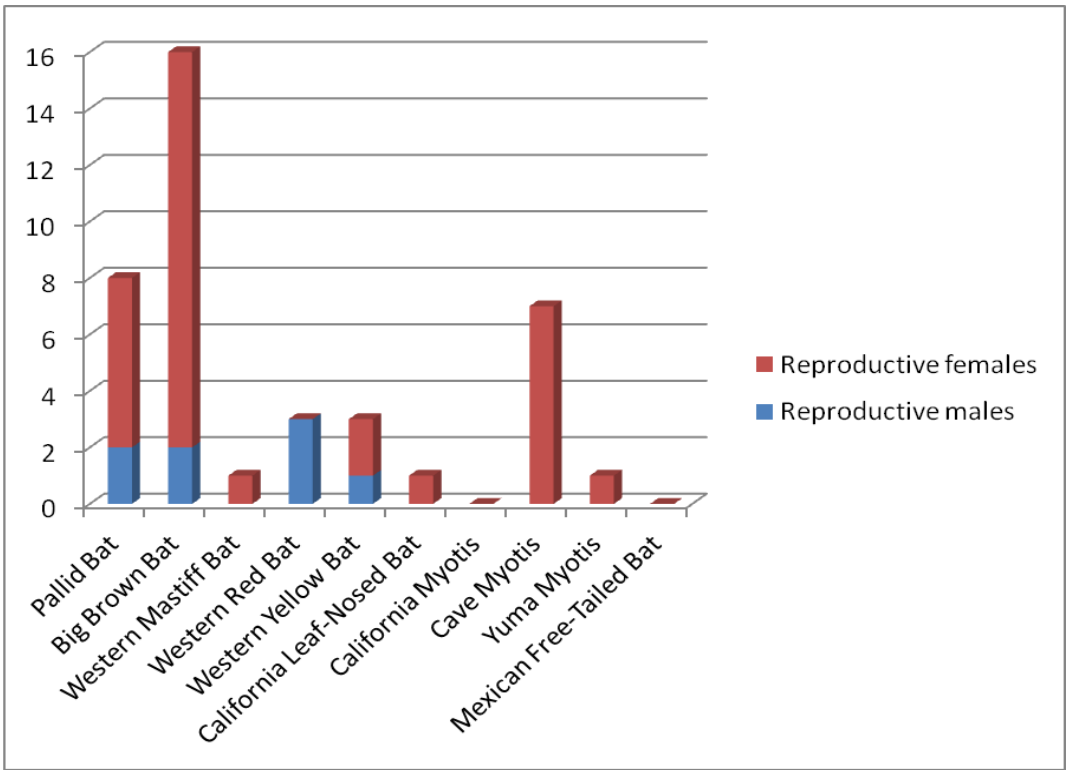

Figure 8.—Ratio of reproductive adults by sex at PVER in 2011.

Table 4.—All species captured across all years at PVER

Species	2010	2011	All years
Big brown bat	154	75	229
Pallid bat	7	23	30
Cave myotis	31	10	41
Western yellow bat	12	9	21
Yuma myotis	16	4	20
Western red bat	3	5	8
California leaf-nosed bat	0	5	5
California myotis	3	2	5
Mexican free-tailed bat	2	2	4
Pocketed free-tailed bat	4	0	4
Western mastiff bat	0	1	1
Totals	232	136	368

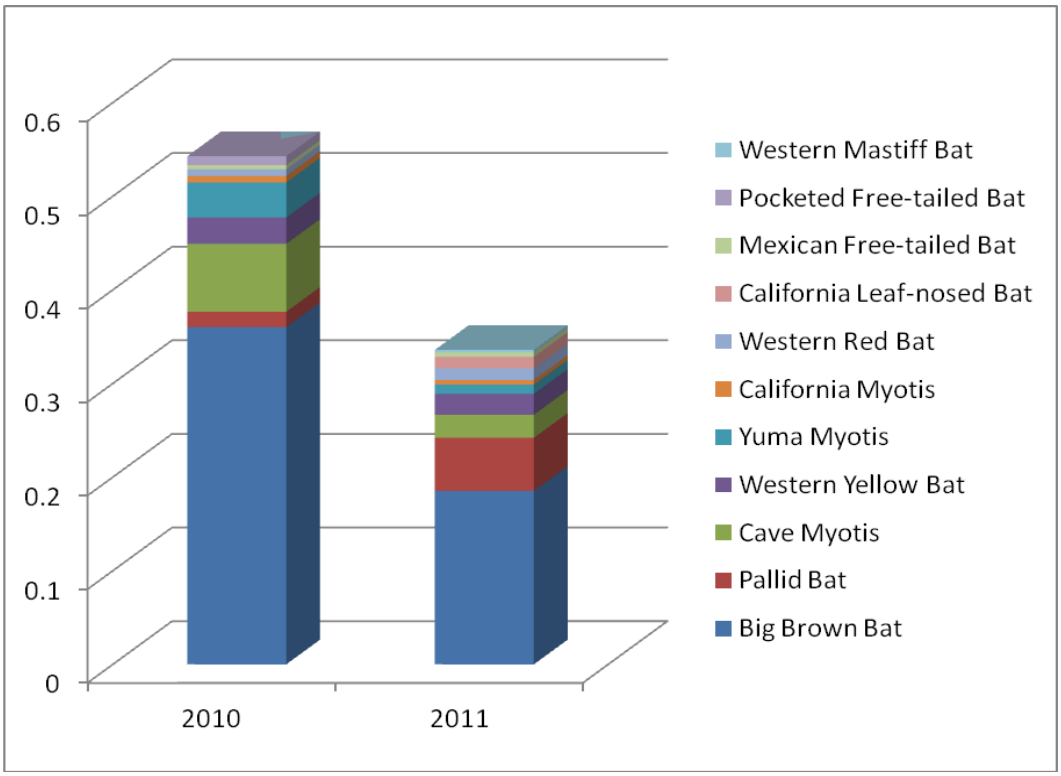

Figure 9.—Captures per net hour for both years at PVER.

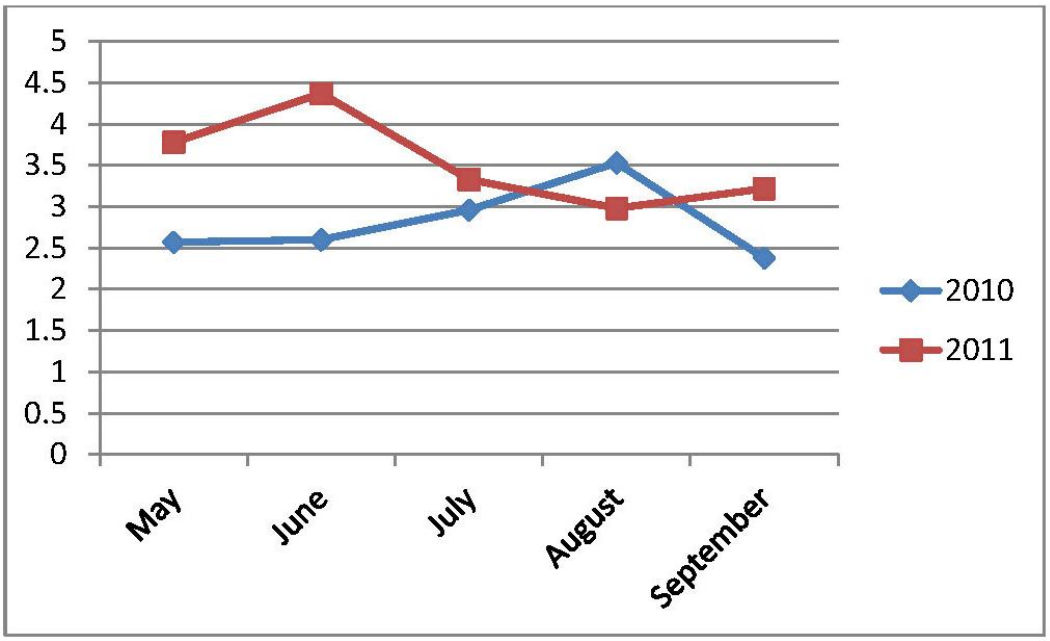

Figure 10.—Shannon N1 diversity index compared across month and year at PVER.

Table 5.—Diversity indices across years at PVER

Index	2010	2011	All years
Taxa S	9	10	11
Individuals	232	136	368
Dominance	0.4675	0.3466	0.4136
Shannon H	1.208	1.507	1.380
Simpson index	0.5325	0.6534	0.5864
Evenness e^H/S	0.3717	0.4514	0.3614
Menhinick	0.5909	0.8575	0.5734
Margalef	1.469	1.832	1.693
Equitability J	0.5496	0.6546	0.5756
Fisher alpha	1.862	2.488	2.133
Berger-Parker	0.6638	0.5515	0.6223

Table 6.—Bootstrapping *p* values comparing 2010 and 2011 at PVER
(Values that show significant differences are in bold)

Index	2010 vs. 2011
Taxa S	$p = 0.712$
Dominance	**$p = 0.038$**
Shannon H	**$p = 0.028$**
Evenness e^H/S	$p = 0.184$
Simpson	**$p = 0.038$**
Menhinick	$p = 0.125$
Margalef	$p = 0.188$
Equitability J	$p = 0.062$
Fisher alpha	$p = 0.134$
Berger-Parker	**$p = 0.027$**

Cibola Valley Conservation Area

This was the third year that capture surveys were conducted at CVCA. Three triple high net sets were used at each of the five surveys for a total of 303.75 net hours of effort. A total of 260 bats of nine species were captured (table 7). The big brown bat was the most commonly captured species. The Townsend's big-eared bat was the only LCR MSCP covered species not captured. The highest captures and species richness were found during the July and August surveys (table 7). Most species had higher capture rates of females, though western yellow bats had an almost equal sex ratio, and western red bats had a higher ratio of males (table 8). Higher capture rates were found for adults of all species, with only four of the nine species having any juveniles captured (table 8). The Mexican free-tailed bat was the only species with no signs of reproductive activity, and all but one species (western yellow bat) had a higher proportion of reproductive females compared to males (figure 11).

Table 7.—Species captured at CVCA for each month

Species	May	June	July	August	September	Totals
Big brown bat	7	11	62	43	16	139
Pallid bat	7	3	16	8	1	35
Yuma myotis	3	1	17	13	0	34
Western yellow bat	1	0	1	12	0	14
Cave myotis	3	3	4	6	1	17
California myotis	5	0	1	3	0	9
Western red bat	0	4	1	1	1	7
California leaf-nosed bat	0	0	2	1	0	3
Mexican free-tailed bat	0	0	0	0	2	2
Totals	26	22	104	87	21	260

Three species that had been captured in previous years were not captured in 2011, including the canyon bat (*Parastrellus hesperus*), hoary bat (*Lasiurus cinereus*), and Arizona myotis (*Myotis occultus*) (table 9). Total capture rates increased substantially in 2011, with increases from western red and western yellow bats as well as the pallid bat, contributing to the overall higher rate (figure 12). Shannon diversity was higher in May compared to the previous 2 years and was similar to 2010 for June–September (figure 13). Shannon diversity again increased in 2011 (N1 of 3.29 in 2009, 3.91 in 2010, and 4.52 in 2011).

All but one diversity index increased in 2011 compared to 2010 (table 10). Both dominance indices decreased in 2011, meaning there was less dominance of a

Table 8.— Sex and age ratios for all species at CVCA in 2011

Species[1]	Sex (male:female)	Age (adult:juvenile)
Pallid bat	11:21	27:5
Big brown bat	54:81	94:41
Western red bat	4:2	7:0
Western yellow bat	6:7	13:0
California leaf-nosed bat	0:3	3:0
California myotis	3:6	9:0
Cave myotis	7:10	16:1
Yuma myotis	8:26	24:10
Mexican free-tailed bat	1:1	2:0

[1] Nine individual bats escaped before age and sex could be determined.

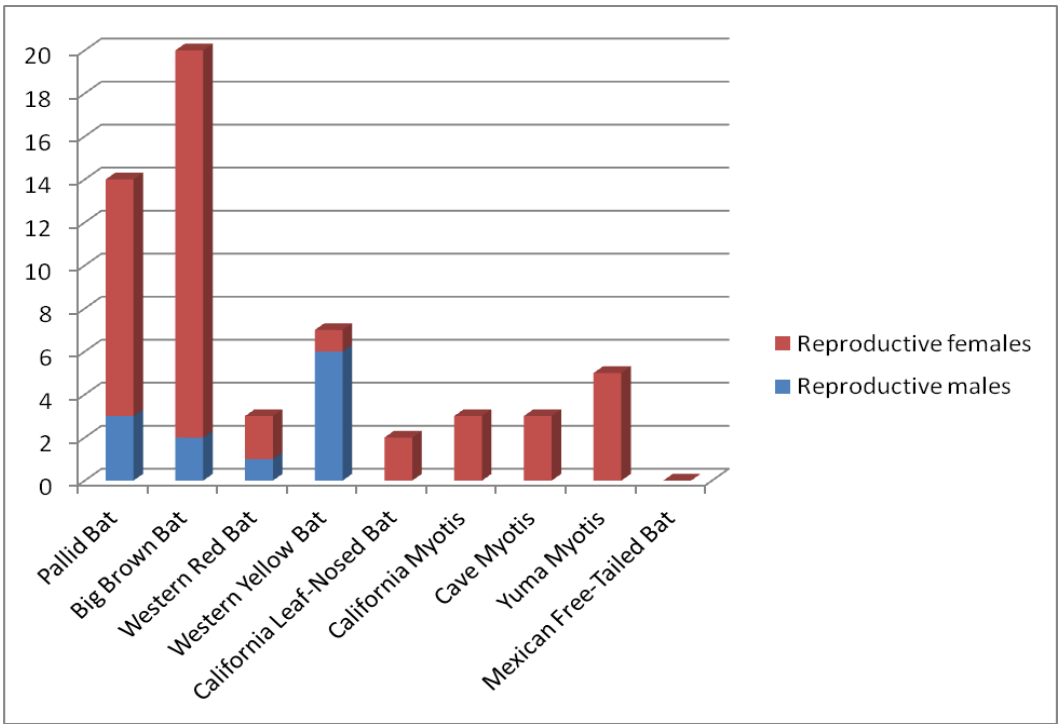

Figure 11.—Ratio of reproductive adults by sex at CVCA in 2011.

Table 9.—All species captured across all years at CVCA

Species	2009	2010	2011	All years
Big brown bat	86	101	139	326
Yuma myotis	7	37	34	78
Pallid bat	9	8	35	52
Cave myotis	4	16	17	37
Western yellow bat	5	4	14	23
California myotis	2	10	9	21
Western red bat	3	0	7	10
California leaf-nosed bat	1	0	3	4
Mexican free-tailed bat	2	0	2	4
Canyon bat (W. pipistrelle)	1	3	0	4
Arizona myotis	0	2	0	2
Hoary bat	1	0	0	1
Totals	121	181	260	562

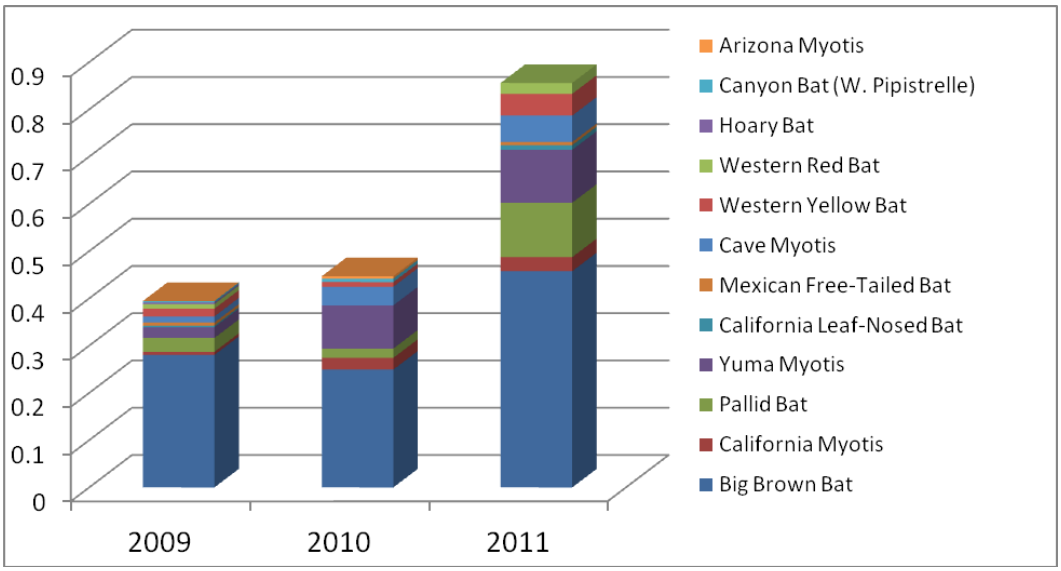

Figure 12.—Captures per net hour between years at CVCA.

single species compared to previous years (table 10). When these diversity indices were compared between years using bootstrapping, there was no statistical difference between 2010 and 2011, but differences were found when 2009 was compared to 2010 and 2011 (table 11).

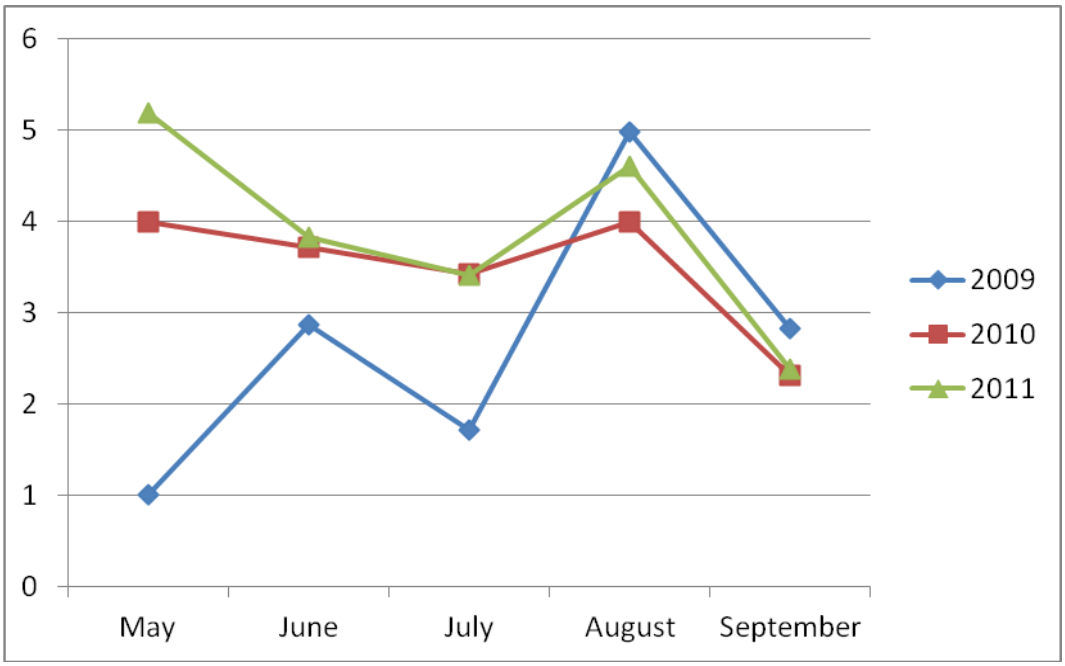

Figure 13.—Shannon N1 diversity index compared across month and year at CVCA.

Table 10.—Diversity indices compared across years at CVCA

Index	2009	2010	2011	All years
Taxa S	11	8	9	12
Individuals	121	181	260	562
Dominance	0.5182	0.3669	0.3303	0.3722
Shannon H	1.191	1.364	1.509	1.452
Simpson	0.4818	0.6331	0.6697	0.6278
Evenness e^H/S	0.2992	0.4891	0.5025	0.3558
Menhinick	1	0.5946	0.5582	0.5062
Margalef	2.085	1.347	1.439	1.737
Equitability J	0.4969	0.6561	0.6868	0.5842
Fisher alpha	2.94	1.713	1.809	2.155
Berger-Parker	0.7107	0.558	0.5346	0.5801

Table 11.—Bootstrapping *p* values comparing 2009, 2010, and 2011 at CVCA (Values that show significant differences are in bold)

Index	2009 vs. 2010	2010 vs. 2011	2009 vs. 2011
Taxa S	*p* = 0.143	*p* = 0.717	*p* = 0.345
Dominance	***p* = 0.009**	*p* = 0.396	***p* = 0.002**
Shannon H	*p* = 0.249	*p* = 0.172	***p* = 0.019**
Evenness e^H/S	***p* = 0.001**	*p* = 0.833	***p* = 0.003**
Simpson	***p* = 0.009**	*p* = 0.396	***p* = 0.002**
Menhinick	***p* = 0.017**	*p* = 0.828	***p* = 0.013**
Margalef	***p* = 0.022**	*p* = 0.745	***p* = 0.014**
Equitability J	***p* = 0.012**	*p* = 0.554	***p* = 0.002**
Fisher alpha	***p* = 0.022**	*p* = 0.747	***p* = 0.013**
Berger-Parker	***p* = 0.004**	*p* = 0.639	***p* = 0.002**

Cibola National Wildlife Refuge Nature Trail

This was the fifth year that capture surveys were conducted at CIBO. Three triple high net sets were used for each survey for a total of 286.8 net hours of effort. It should be noted that due to a nearby storm that brought high winds to the site in August, the nets were only opened for just over an hour. A total of 70 bats of seven species were captured in 2011. The big brown bat was the most commonly captured species, and the California leaf-nosed bat was the only LCR MSCP species captured (table 12). Unlike the previous sites, females only outnumbered males in two species (table 13). More juvenile captures were also found in two species at CIBO (table 13). The California myotis was the only species that had adult males captured showing signs of reproductive activity, and two species, the canyon bat and cave myotis (*Myotis velifer*), showed no signs of reproductive activity (figure 14).

Table 12.—Species captured at CIBO for each month

Species	May	June	July	August	September	Totals
Big brown bat	1	2	25	0	0	28
Pallid bat	3	3	3	0	2	11
California leaf-nosed bat	0	3	2	0	3	8
California myotis	4	3	4	0	2	13
Yuma myotis	1	2	4	0	0	7
Cave myotis	0	1	0	0	0	1
Canyon bat (W. pipistrelle)	0	0	1	1	0	2
Totals	9	14	39	1	7	70

Table 13.—Sex and age ratios for all species at CIBO in 2011

Species[1]	Sex (male:female)	Age (adult:juvenile)
Pallid bat	6:5	9:2
Big brown bat	20:7	10:17
California leaf-nosed bat	1:7	8:0
California myotis	4:9	13:0
Cave myotis	1:0	1:0
Yuma myotis	4:2	3:4
Canyon bat	0:2	1:1

[1] Two individual bats escaped before age and sex could be determined.

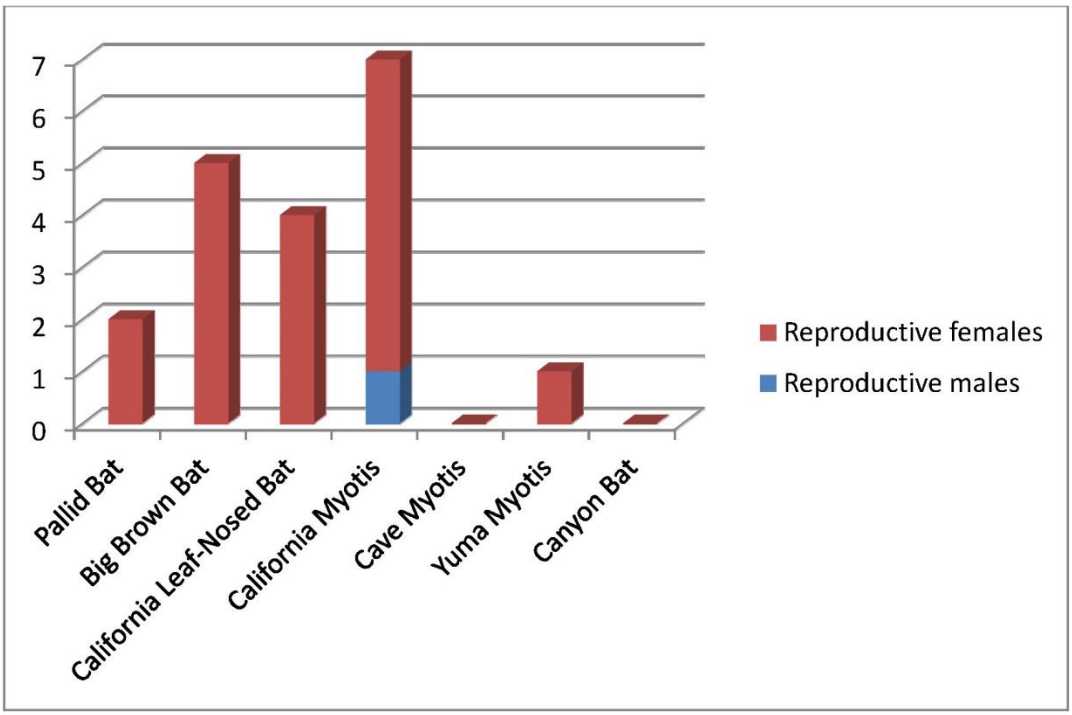

Figure 14.—Ratio of reproductive adults by sex at CIBO in 2011.

Species richness remained consistent to previous years with the exact same species captured in both 2010 and 2011 (table 14). The California leaf-nosed bat remained the only MSCP species to be captured every year. Capture rates increased compared to 2010, though they were not as high as 2009 when a high number of big brown bats were captured (figure 15). It should be noted that prior to 2009, surveys at CIBO were not conducted during all of the same months, so

Table 14.—All species captured across all years at CIBO

Species	2007	2008	2009	2010	2011	All years
Big brown bat	2	13	121	37	28	201
California myotis	0	3	27	6	13	49
Pallid bat	1	13	8	7	11	40
Yuma myotis	1	0	4	4	7	16
California leaf-nosed bat	14	4	4	5	8	35
Cave myotis	0	0	0	3	1	4
Hoary bat	1	2	0	0	0	3
Western yellow bat	0	2	0	0	0	2
Mexican free-tailed bat	0	0	1	0	0	1
Canyon bat	0	0	0	1	2	3
Myotis species	0	0	1	0	0	1
Totals	19	37	166	63	70	355

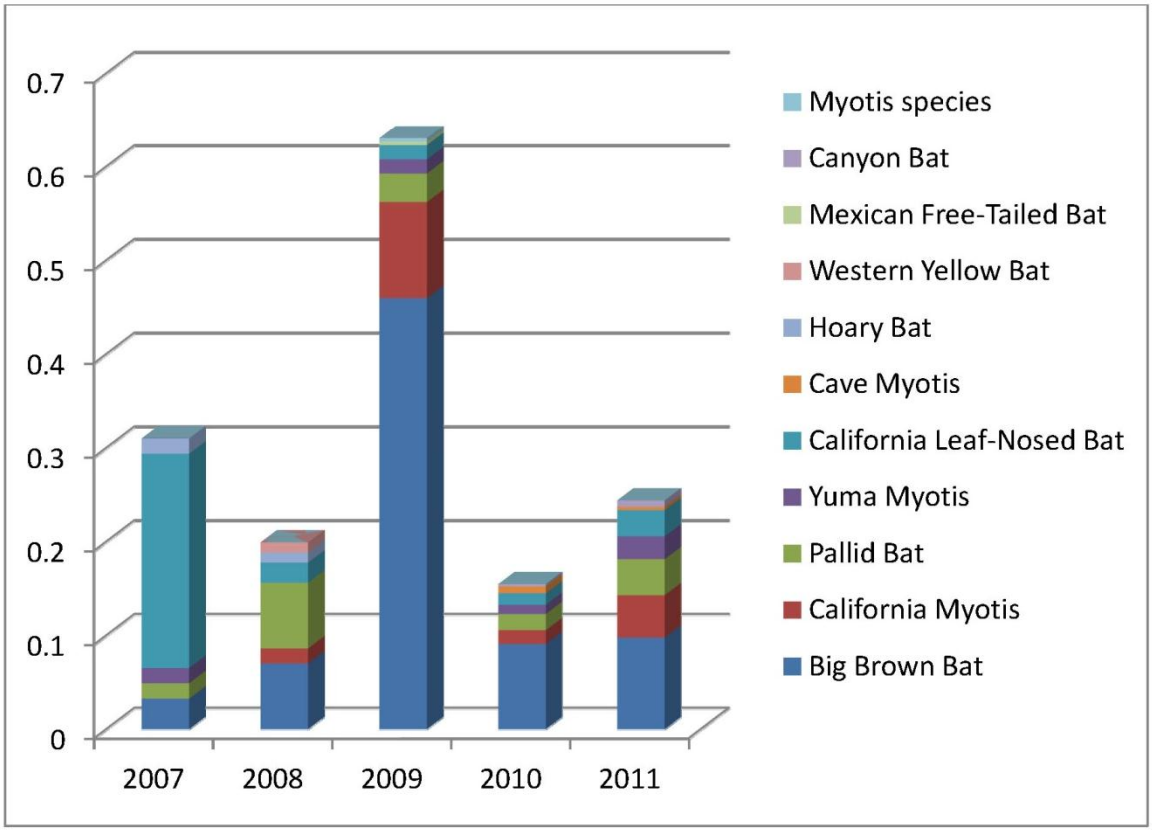

Figure 15.—Captures per net hour between years at CIBO.

any comparisons with those previous years should be made with caution. Species diversity was higher during the first three surveys compared to 2009 and 2010 (figure 16). Diversity was low during the August survey due to the shortened survey time. September was the month with the greatest similarity in diversity across years.

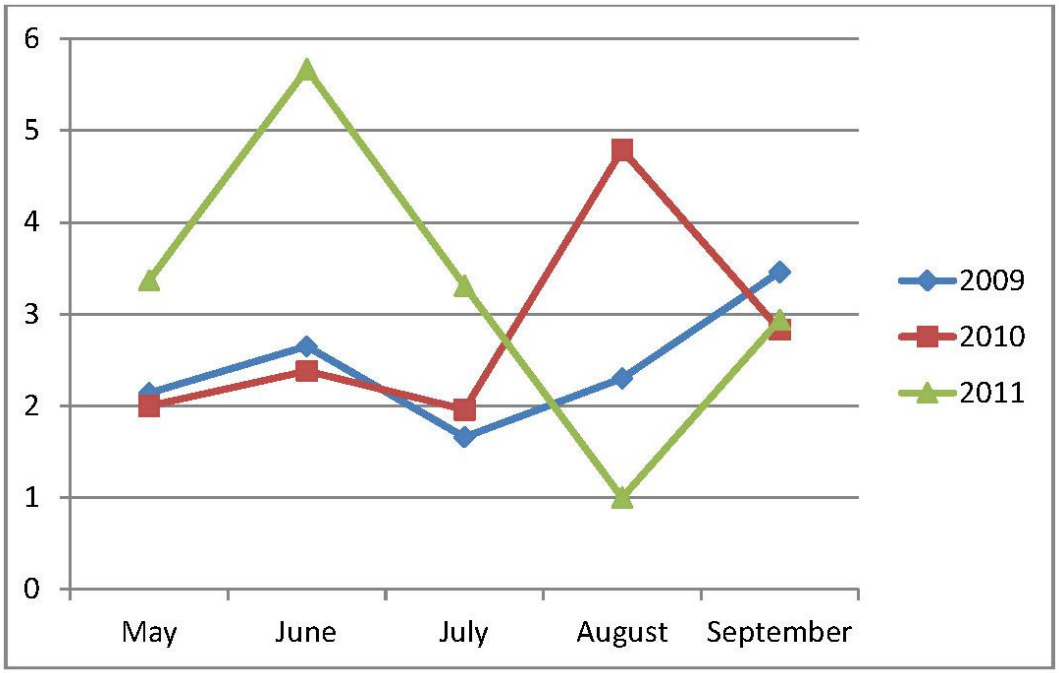

Figure 16.—Shannon N1 diversity index compared across month and year at CIBO.

Most diversity indices have increased each year (table 15). It should be noted that only data from 2009 to 2011were used in statistical comparisons due to the lower effort in previous years (the third triple high was added to all sites in 2009). Both dominance indices showed decreases each year, meaning there was less dominance of a single species compared to previous years (table 15). When these diversity indices were compared between years using bootstrapping, 2009 versus 2011 showed the most significant differences, while 2010 versus 2011 showed the least (table 16).

‘Ahakhav Tribal Preserve

This was the fifth year that capture surveys were conducted at AKTP. Only a single survey was conducted in 2010 during the month of February to determine winter use of the site by western red bats. No summer surveys were conducted in 2010 due to a delay in permitting. Permission was again granted prior to the start

Table 15.—Diversity indices compared across years at CIBO

Index	2009	2010	2011	All years
Taxa S	6	7	7	10
Individuals	165	63	70	354
Dominance	0.5681	0.3792	0.2433	0.3664
Shannon H	0.8817	1.368	1.61	1.388
Simpson	0.4319	0.6208	0.7567	0.6336
Evenness e^H/S	0.4025	0.5608	0.715	0.4005
Menhinick	0.4671	0.8819	0.8367	0.5315
Margalef	0.9793	1.448	1.412	1.533
Equitability J	0.4921	0.7028	0.8276	0.6026
Fisher alpha	1.221	2.015	1.936	1.914
Berger-Parker	0.7333	0.5873	0.4	0.5678

Table 16.—Bootstrapping *p* values comparing 2009, 2010, and 2011 at CIBO (Values that show significant differences are in bold)

Index	2009 vs. 2010	2010 vs. 2011	2009 vs. 2011
Taxa S	$p = 0.783$	$p = 1.000$	$p = 0.771$
Dominance	**$p = 0.022$**	**$p = 0.040$**	**$p = 0.000$**
Shannon H	**$p = 0.007$**	$p = 0.104$	**$p = 0.000$**
Evenness e^H/S	$p = 0.152$	$p = 0.103$	**$p = 0.002$**
Simpson	**$p = 0.022$**	**$p = 0.040$**	**$p = 0.000$**
Menhinick	$p = 0.060$	$p = 0.907$	$p = 0.102$
Margalef	$p = 0.076$	$p = 0.907$	$p = 0.113$
Equitability J	**$p = 0.020$**	$p = 0.085$	**$p = 0.000$**
Fisher alpha	$p = 0.075$	$p = 0.907$	$p = 0.104$
Berger-Parker	**$p = 0.032$**	**$p = 0.033$**	**$p = 0.000$**

of the 2011 summer survey season. Only summer capture data are being compared in the tables and figures below, but a winter season survey was conducted in both 2009 and 2010, and each resulted in the capture of a western red bat. Three triple high net sets were used for all surveys for a total of 405 net hours of effort. A total of 272 bats of 9 species were captured in 2011. This is the only site where there were more captures of the pallid bat than of the big brown bat (table 17). The western red bat was the only LCR MSCP species not captured in 2011.

Table 17.—Species captured at AKTP for each month

Species	May	June	July	August	September	Totals
Pallid bat	9	31	54	4	0	98
Big brown bat	6	9	61	5	1	82
Arizona myotis	26	2	4	4	0	36
California leaf-nosed bat	2	9	2	4	2	19
Cave myotis	4	5	4	2	0	15
Western yellow bat	1	0	3	7	0	11
Yuma myotis	2	0	3	3	0	8
California myotis	0	1	0	0	0	1
Townsend's big-eared bat	0	0	1	0	0	1
Myotis species	1	0	0	0	0	1
Totals	51	57	132	29	3	272

The pallid bat was the only species that had a higher capture rate for males versus females (table 18). All other species had higher rates for females, with the western yellow bat having an almost equal sex ratio. Very few juveniles comprised the total of bats captured, with only four species having captures of both adults and juveniles. All but one species showed reproductive activity (figure 17).Species richness decreased by one in 2011, but this was the first year that a Townsend’s big-eared bat was captured at any habitat creation area (table 19). Total capture rates were slightly higher than in 2008 or 2009 (figure 18). While capture rates increased for most species, the Yuma myotis had a lower capture rate compared to 2008 and 2009.

Species diversity was only compared between 2009 and 2011 due to differences in survey timing in previous years. The first three survey months showed similar diversity indices between years (figure 19). Diversity indices slightly decreased, and dominance indices slightly increased from 2009 to 2011 (table 20). When these diversity indices were compared between years, there were no values with a significant difference (table 21).

Table 18.—Sex and age ratios for all species at AKTP in 2011

Species[1]	Sex (male:female)	Age (adult:juvenile)
Pallid bat	73:23	85:10
Big brown bat	19:61	71:9
Arizona myotis	4:31	32:3
Western yellow bat	5:6	10:1
California leaf-nosed bat	4:15	19:0
California myotis	0:1	1:0
Cave myotis	4:10	14:0
Yuma myotis	1:7	8:0
Townsend's big-eared bat	1:0	1:0

[1] Six individual bats escaped before age and sex could be determined.

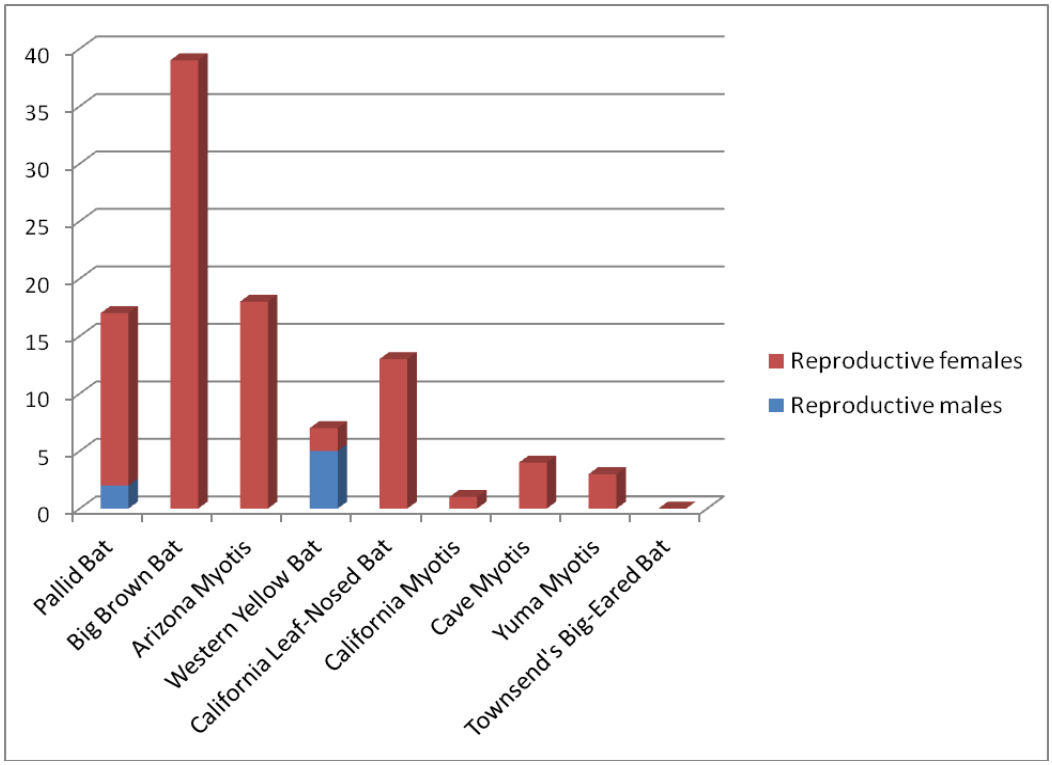

Figure 17.—Ratio of reproductive adults by sex at AKTP in 2011.

Table 19.—All species captured across all years at AKTP

Species	2007	2008	2009	2011	Total
Pallid bat	4	35	52	98	189
Big brown bat	0	9	35	82	126
Yuma myotis	4	12	23	8	47
California leaf-nosed bat	1	4	13	19	37
Arizona myotis	5	0	12	36	53
Western yellow bat	4	4	6	11	25
Cave myotis	6	0	5	15	26
California myotis	1	1	1	1	4
Western red bat	0	0	1	0	1
Hoary bat	0	0	1	0	1
Mexican free-tailed bat	1	0	0	0	1
Townsend's big-eared bat	0	0	0	1	1
Myotis species	0	0	2	1	3
Totals	26	65	151	272	514

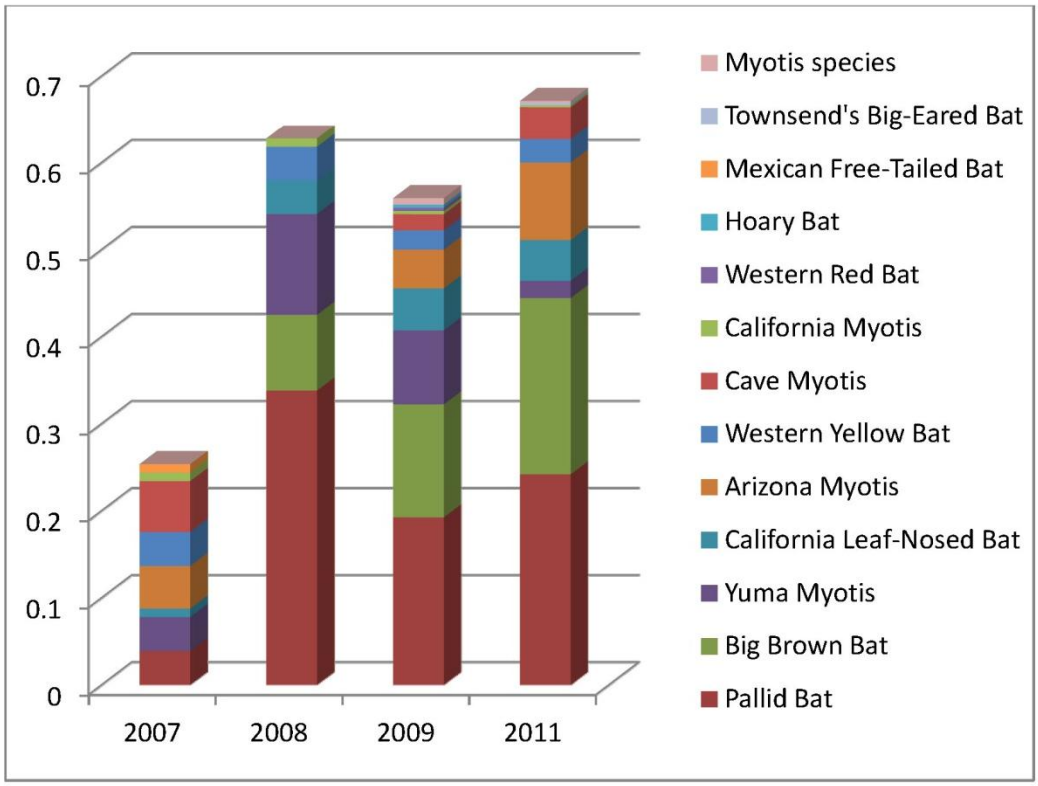

Figure 18.—Captures per net hour between years at AKTP.

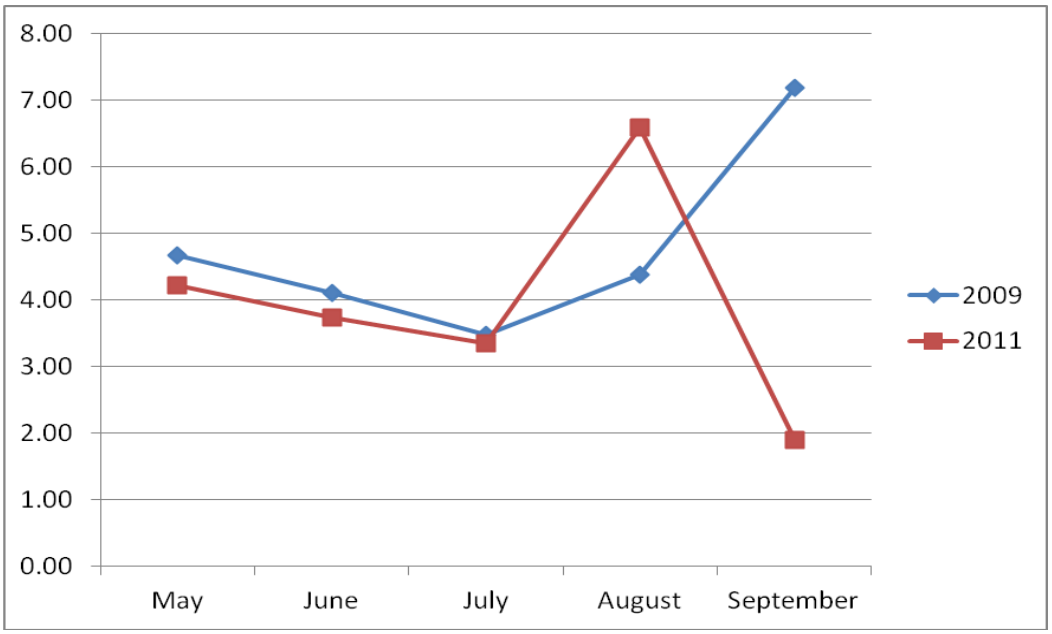

Figure 19.—Shannon N1 diversity index compared across month and year at AKTP.

Table 20.—Diversity indices compared across years at AKTP

Index	2009	2011	All years
Taxa S	10	9	11
Individuals	149	271	420
Dominance	0.2178	0.2505	0.2334
Shannon H	1.756	1.62	1.704
Simpson	0.7822	0.7495	0.7666
Evenness e^H/S	0.5788	0.5612	0.4994
Menhinick	0.8192	0.5467	0.5367
Margalef	1.799	1.428	1.656
Equitability J	0.7625	0.7371	0.7104
Fisher alpha	2.417	1.791	2.068
Berger-Parker	0.349	0.3616	0.3571

Table 21.—Bootstrapping *p* values comparing 2009 and 2011 at AKTP

Index	2009 vs. 2011
Taxa S	*p* = 0.748
Dominance	*p* = 0.198
Shannon H	*p* = 0.116
Evenness e^H/S	*p* = 0.874
Simpson	*p* = 0.198
Menhinick	*p* = 0.100
Margalef	*p* = 0.204
Equitability J	*p* = 0.687
Fisher alpha	*p* = 0.112
Berger-Parker	*p* = 0.776

Site Comparisons

A total of 737 bats were captured of 13 species in 2011 (table 22). All four LCR MSCP species were captured. Species composition varied at each site, with only six species overlapping across all sites surveyed during the summer season. Capture rates were highest at CVCA and lowest at CIBO (figure 20). Species diversity across each month for the sites varied greatly, with AKTP having the highest diversity and CIBO having the lowest diversity in August, though all four sites had a similar diversity in July (figure 21). Diversity indices for 2011 data combined showed that CVCA and PVER had similar indices, and CIBO and AKTP with similar indices (table 23). These same differences and similarities were found when indices were compared using bootstrapping. Significant values were only found when PVER and CVCA were compared to CIBO and AKTP (table 24).

DISCUSSION

This year, four different habitat creation areas were surveyed across the summer period. All surveys, except for the August survey at CIBO, went for the entire survey period each night. While all sites had three triple high nets set each night, placement at each site was not always in similar situations. PVER had two of the three triple high nets set on the edge of the trees, which proved successful last year. Capture rates decreased in 2011, though species richness remained similar. The capture of California leaf-nosed bats at PVER confirmed previous acoustic data.

Table 22.—All species captured across all sites in 2011
(LCR MSCP species in bold)

Species	PVER	CVCA	CIBO	AKTP	Totals
Big brown bat	75	139	28	82	324
Pallid bat	23	35	11	98	167
Yuma myotis	4	34	7	8	53
Cave myotis	10	17	1	15	43
Arizona myotis	0	0	0	36	36
California leaf-nosed bat	**5**	**3**	**8**	**19**	**35**
Western yellow bat	**9**	**14**	**0**	**11**	**34**
California myotis	2	9	13	1	25
Western red bat	**5**	**7**	**0**	**0**	**12**
Mexican free-tailed bat	2	2	0	0	4
Canyon bat (W. pipistrelle)	0	0	2	0	2
Western mastiff bat	1	0	0	0	1
Townsend's big-eared bat	**0**	**0**	**0**	**1**	**1**
Totals	136	260	70	271	737

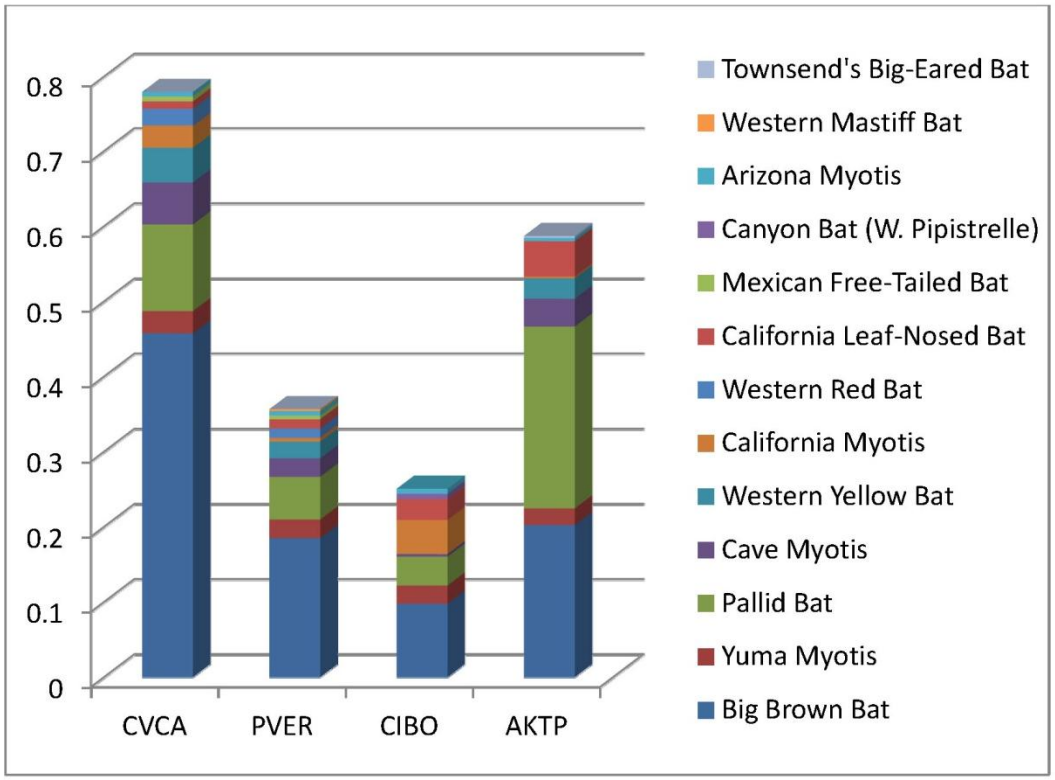

Figure 20.—Species composition based on capture rates per net hour at each site.

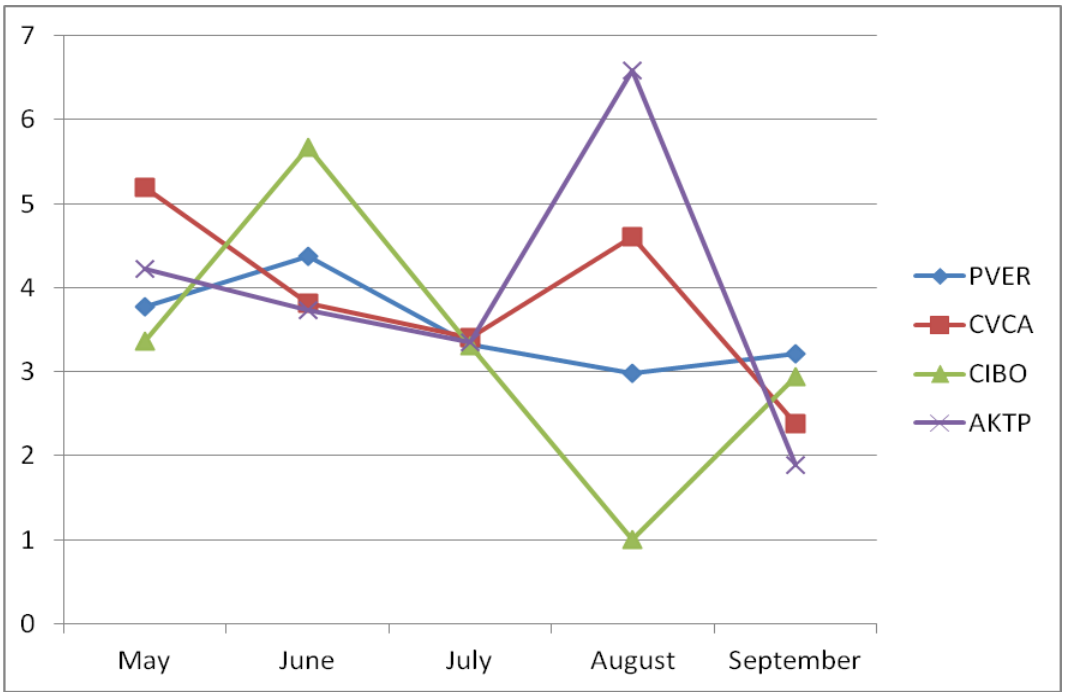

Figure 21.—Shannon N1 diversity index across summer months at each site.

Table 23.—Diversity indices for all sites in 2011

Index	CVCA	PVER	CIBO	AKTP	All sites
Taxa S	9	10	7	9	13
Individuals	260	136	70	270	736
Dominance	0.3303	0.3466	0.2433	0.2497	0.2615
Shannon H	1.509	1.507	1.61	1.622	1.731
Simpson	0.6697	0.6534	0.7567	0.7503	0.7385
Evenness e^H/S	0.5025	0.4514	0.715	0.5625	0.4345
Menhinick	0.5582	0.8575	0.8367	0.5477	0.4792
Margalef	1.439	1.832	1.412	1.429	1.818
Equitability J	0.6868	0.6546	0.8276	0.7381	0.675
Fisher alpha	1.809	2.488	1.936	1.792	2.243
Berger-Parker	0.5346	0.5515	0.4	0.3593	0.4402

Table 24.—Bootstrapping *p* values comparing 2011 data among sites (Significant values in bold)

Index	PVER vs. CVCA	PVER vs. CIBO	PVER vs. AKTP	CVCA vs. CIBO	CVCA vs. AKTP	CIBO vs. AKTP
Taxa S	*p* = 0.614	*p* = 0.097	*p* = 0.781	*p* = 0.391	*p* = 1.000	*p* = 0.317
Dominance	*p* = 0.736	*p* = 0.088	***p* = 0.001**	*p* = 0.129	***p* = 0.003**	*p* = 0.845
Shannon H	*p* = 0.985	*p* = 0.534	*p* = 0.292	*p* = 0.503	*p* = 0.204	*p* = 0.933
Evenness e^H/S	*p* = 0.429	***p* = 0.008**	*p* = 0.208	p = 0.016	*p* = 0.325	*p* = 0.071
Simpson	*p* = 0.736	*p* = 0.088	***p* = 0.001**	*p* = 0.129	***p* = 0.003**	*p* = 0.845
Menhinick	*p* = 0.120	*p* = 0.935	*p* = 0.141	*p* = 0.892	*p* = 1.000	*p* = 0.948
Margalef	*p* = 0.123	*p* = 0.172	*p* = 0.183	*p* = 1.000	*p* = 1.000	*p* = 1.000
Equitability J	*p* = 0.549	***p* = 0.013**	*p* = 0.125	***p* = 0.020**	*p* = 0.230	*p* = 0.095
Fisher alpha	*p* = 0.120	*p* = 0.386	*p* = 0.183	*p* = 1.000	*p* = 1.000	*p* = 0.953
Berger-Parker	*p* = 0.728	***p* = 0.040**	***p* = 0.000**	***p* = 0.043**	***p* = 0.000**	*p* = 0.395

The other triple high net set at PVER was within a narrow corridor in a younger stand of trees that reached just above the top of the net. This set had a lower capture rate compared to the two edge sets. While a corridor appears to be more productive than an edge set when compared to other sites, the younger age of this stand, as well as the narrower width (approximately 6 m (19.7 ft), may be why capture rates were reduced.

At CVCA, one triple high net was used as an edge set for the first time, while the other two were set in an L formation within a narrowing spot on a road (see figure 7). This L formation produced a higher capture rate than expected, including captures of western red and western yellow bats that are normally thought to fly in more open areas. Because the L formation blocked a previous opening on the edge of the road, it may be the reason for the success of this set. When an L or V formation can be used at a set, it is recommended to do so. Reproductively active female western red bats were found at CVCA this year, lending evidence that breeding is occurring within the site.

CIBO again had the lowest capture rates of all sites. Bat activity in general appears to be lower at this site based on acoustic data collected while netting. The patch size of CIBO is much smaller than the other sites; however, other nearby areas have been planted with habitat in the last few years. CIBO is the oldest planted area, but most of the site consists of mesquite and *Baccharis* spp. and only small areas contain mature gallery cottonwood or willow trees. Western red bats have never been captured, and only two western yellow bats have been captured at the site. In comparison, CVCA and PVER have had western red andwestern

yellow bat captures in every year they have been surveyed. Next year, the netting area may be expanded to include an area of densely planted cottonwoods next to CIBO that is more similar to habitat within CVCA and PVER.

Even though AKTP was not surveyed in 2010, it appears that species richness and diversity have remained relatively constant. The one new species found in 2011 was a male Townsend's big-eared bat, an LCR MSCP evaluation species that had never been captured at any other LCR MSCP habitat creation area. It is unknown where this bat came from. The closest known roost is a maternity colony more than 10 mi (15 km) away. Males are usually solitary in the summer season, making it harder to find their roosts across the landscape (Kunz and Martin 1982). While western yellow bats were commonly captured, no western red bats were captured in the summer of 2011. Arizona Game and Fish Department personnel captured one western red bat in March 2011 at the same site. In 2009, western red bats were only captured in February and September. It is possible that western red bats only use AKTP during the winter season and during migration. Surveys will continue in 2012 to better document bat use of this site.

The diversity data analysis showed that PVER and CVCA have a similar diversity of bats, and to a lesser extent, CIBO and AKTP also have a similar diversity. These groupings correspond to the similar age of each site. Most of the net sets at CVCA and PVER were in areas where the trees were planted in the same year (2006). CIBO was planted in 1999 versus AKTP in 2001, but in general, trees of this age tend to be of similar sizes. Tree density may also play a role as the older sites like CIBO and AKTP were planted in lower densities compared to the newer sites (PVER and CVCA) that are planted much more densely. The one difference between CIBO and AKTP is the patch size. AKTP is about three times larger than CIBO. Most of the statistical differences among the sites were related to dominance and evenness indices. Both PVER and CVCA have a single species that dominates captures (big brown bat). CIBO shows some dominance of the big brown bat, but capture rates were much lower in general, and CIBO's capture rate may be too low for statistical analyses. Both the big brown bat and pallid bat have high capture rates at AKTP, resulting in a co-dominance of those two species. It is unknown how capture rates relate to actual population levels within the vicinity of each site. Acoustic data shows higher activity levels by some *Myotis* species (Broderick, in press). These species may be better able to avoid nets than big brown bats.

Previously it was thought that any type of mark-recapture study would not be feasible for most bats along the LCR. Colonial roosting bats would have to be captured at roost sites in order to have a sample size sufficient to allow for recaptures in future seasons, years, etc. Due to the fact that they are solitary roosters, the likelihood of recapture was considered to be very low for tree-roosting bats such as western red and western yellow bats. A recent paper conducted a mark-recapture study that included the eastern red bat (*Lasiurus borealis*). They succeeded in recapturing eastern red bats in multiple years at the

same study sites (Perry 2011). While this study used bands to mark bats, this method has been discouraged by some due to injuries to bat wings (Kunz and Weise 2009). Recent technological advancements have allowed passive integrated transponder (PIT) tags to be reduced in size enough to be safely used for bats. There has been no evidence that PIT tags have been linked to mortality in bats (Kunz and Weise 2009). Because eastern red bats and western red bats are closely related species, it is possible that site fidelity of bats captured on the LCR can be assessed using PIT tags. Because western red and western yellow bats are solitary tree roosters, they have been difficult to study, so information about their natural history is lacking in many areas. Adding a mark-recapture component to the LCR bat capture surveys is recommended because it would add little extra effort and would but provide additional knowledge about tree-roosting species.

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APPENDIX 1

Common and Scientific Names of All Species Captured

Common name	Scientific name
Arizona myotis	*Myotis occultus*
Big brown bat	*Eptesicus fuscus*
California leaf-nosed bat	*Macrotus californicus*
California myotis	*Myotis californicus*
Canyon bat[1]	*Parastrellus hesperus*
Cave myotis	*Myotis velifer*
Hoary bat	*Lasiurus cinereus*
Mexican free-tailed bat	*Tadarida brasiliensis mexicanus*
Pallid bat	*Antrozous pallidus*
Pocketed free-tailed bat	*Nyctinomops femorosaccus*
Townsend's big-eared bat	*Corynorhinus townsendii*
Unknown myotis	*Myotis* spp.
Western mastiff bat	*Eumops perotis*
Western red bat	*Lasiurus blossevillii*
Western yellow bat	*Lasiurus xanthinus*
Yuma myotis	*Myotis yumanensis*

[1] *Parastrellus hesperus* is formerly known as *Pipistrellus hesperus*, the western pipistrelle.