Appendix G

Determining Foraging and Roosting Areas for Underwood's Mastiff Bat (Eumops underwoodi) Using Radiotelemetry, At Organ Pipe Cactus National Monument, Arizona

Final Summary Report, Year Two – December 2002

Tim Tibbitts[1], Ami Pate[1], Yar Petryszyn[2], and Brian Barns[1].

[1]Organ Pipe Cactus National Monument, 10 Organ Pipe Drive, Ajo, Arizona 85321 and [2]Department of Ecology and Evolutionary Biology, The University of Arizona, Tucson, Arizona 85721.

Abstract

Underwood's mastiff bat (*Eumops underwoodi*) is a large, little-understood tropical species, reaching its northern distribution limit in extreme southern Arizona. One of the few locales where it occurs is Quitobaquito Pond in Organ Pipe Cactus National Monument. Quitobaquito is located on the U.S. - Mexico border next to a busy highway, and is subject to various threats. Further, the border area nearby is undergoing changes due to increasing human population, tourism, increasing industrialization, and changes in land uses. Quitobaquito and the border area are clearly of importance to this bat for foraging, roosting, and accessing water in an arid landscape. To expand our knowledge of this bat's life history and to identify potential management issues, we sought to determine foraging and roosting areas using radiotelemetry. *E. underwoodi* were found to forage widely across and along the international border area. Foraging habitat ranged from rugged wilderness topography to agricultural and semi-urban areas. Unexpectedly, they were found to be roosting in woodpecker cavities in saguaro cactus (*Carnegia gigantea*). This is the first documentation of this species roosting in cactus cavities, and a rare documentation of any bat species doing so.

Introduction

Organ Pipe Cactus National Monument (OPCNM) lies in southwestern Arizona, and is comprised of approximately 330,689 acres of Sonoran Desert plains, bajadas, and rugged mountains. OPCNM is located on the international border with Mexico, with its "sister" park, El Pinacate Reserva de la Biosfera, nearby to the southwest.

Two species of mastiff bats are found in OPCNM; the western mastiff bat (*Eumops perotis*), and Underwood's mastiff bat (*E. underwoodi*). In contrast to the rest of Arizona and the southwest, the widely-distributed *E. perotis* is encountered rarely in OPCNM. However, the regionally "uncommon" *E. underwoodi* is encountered commonly in OPCNM, at Quitobaquito Pond. Underwood's is a little-studied bat of Mexico and Central America (Kiser 1995). The northernmost subspecies, *E. u. sonoriensis*, is limited in distribution to southern Arizona and Sonora, Mexico. In the U.S. it is known only from OPCNM and several other locales southwest of Tucson (Cockrum and Gardner 1960, Hoffmeister 1986, Petryszyn et al. 1996 and 2000). At these southern Arizona locations, *E. underwoodi* has been observed and captured as it visits open ponds to drink on the wing. It seems likely that for this large, fast-flying bat, relatively large, open bodies of water may be important resources for drinking. Quitobaquito Pond (approx. 0.5 ac/ 0.2 ha in extent) is one of very few locations in the arid border area of southcentral and southwestern Arizona where such water resources exist. Quitobaquito is located approximately 100m (328 ft) north of the international boundary.

Quitobaquito is heavily used by park visitors, researchers, and as an illegal border crossing point. The latter use ranges from serving as a *de facto* rest stop along Mexico Highway 2, to smuggling activity. The National Park Service manages

Quitobaquito to ensure the continued survival and security of the endangered endemic Quitobaquito pupfish (*Cyprinodon eremus*), and to provide shallow water habitat for the Rio Sonoyta mud turtle (*Kinosternon sonoriense longifemorale*). The importance of Quitobaquito to local *E. underwoodi* is also a management concern, and was a motivating factor in undertaking this study. Quitobaquito likely faces a variety of increasing pressures and threats. Human activities in general are increasing in the area, as the Sonoran city of Sonoyta is expanding westward along Mexico Highway 2 toward Quitobaquito, and as plans progress to expand Highway 2 from two lanes to four. It has become important to determine the locations of the foraging and roosting habitats of the local *E. underwoodi* so that any conservation issues can be identified. Because of the rarity of *E. underwoodi* in the United States, and the desire to assure that it is being adequately conserved, OPCNM's Resources Management Plan (1994) identified investigating the status of this species as a priority (Project Statement ORPI-N-266). Petryszyn et al. (2000) ultimately recommended attempting to find the local *Eumops* roost site(s) using radiotelemetry.

Recent investigations in OPCNM have developed intriguing preliminary information on *E. underwoodi*. Banding operations by Petryszyn et al. (1996 and 2000) and general bat monitoring by OPCNM staff resulted in high rates of recaptures of *E. underwoodi* banded at Quitobaquito Pond. This implies several things. First, Quitobaquito is clearly a very important watering resource for these bats, as individuals return regularly throughout the year, and over several years. Second, although Petryszyn et al. (1996 and 2000) did not intend their banding project to be a mark-recapture population estimate, the high recapture rate of banded *Eumops* could imply a fairly small local population. In 2000, OPCNM staff carried out a light-tagging project to gain preliminary indications of where the *Eumops* bats frequenting Quitobaquito are foraging and roosting. Visual observations suggested the bats were foraging over a fairly wide local area, including the Quitobaquito area, adjacent Aguajita Wash, desertscrub and hill slopes in both the United States and Mexico, the Rio Sonoyta, and along Mexico Highway 2 (OPCNM unpubl. data). In the latter case, bats were observed foraging low over the highway, sometimes in the headlights of the busy truck traffic.

With preliminary indications suggesting a general area used for foraging (OPCNM unpubl. data), published literature led us to expect *E. underwoodi* would roost in locations where they would have a substantial vertical drop to return to flight after roosting. This expectation paralleled speculations of others, that because of its morphology of long, narrow wings designed for fast, long flight *E. underwoodi* may need a vertical drop of considerable distance to achieve flight (e.g. Kiser 1995), and roosting in cliff crevices should be expected (Kiser 1995, M. Rabbe, AGFD pers. comm.). However, roosting in tall trees and palms has also been described (Watkins et al. 1972 and Hellebuyck et al. 1985, both in Kiser 1995), suggesting a height of perhaps 10m (33 ft) may be adequate. We expected to find that *E. underwoodi* roosts in crevices in rocky outcrops or cliffs on steep mountain slopes, possibly considerable distances from Quitobaquito.

Methods

We captured bats September 20-22, 2001, June 4, 5 and 10, 2002, and August 2-3, 2002. Bats were captured using two 2.6m x 12m mist nets deployed across Quitobaquito Pond end-to-end. The nets were opened at dusk, and kept open until after midnight. We serviced the nets using an aluminum jonboat and two kayaks. Only personnel with current rabies pre-exposure vaccines handled bats. Bats were removed from the net and taken to shore for processing. Bats of non-target species (chiefly *Nyctinomops femerosacca*) were identified to species and sex, then released. *Eumops* bats were identified to species, sex, and age, and measured for weight and forearm length. For radiotelemetry, we used BD-2 transmitters (Holohil Systems, Ltd), weighing 1.53g each, with pulse rates ranging from 1.88 to 1.90 pulses/second. Before attachment on *Eumops* bats, the transmitters were turned on and the signal tested with a receiver setup. We then slightly trimmed the intrascapular fur and attached the radiotransmitter between the shoulder blades, using non-toxic Skin-Bond® medical adhesive. We trimmed the radio antenna so that it extended slightly beyond the tail.

We carried out radiotelemetry tracking September 22 - October 2, 2001, June 4-16, 2002, and August 2-6, 2002. We used 5-element directional antennae (Wildlife Materials, Inc.) mounted on 2-meter aluminum masts and secured in Bogen 3126 tripods. To read directional bearings, we fixed a compass to an aluminum bracket mounted on the aluminum mast and calibrated to geographic north. We used R-1000 (Communications Specialists, Inc.) and TRX-1000 (Wildlife Materials, Inc.) telemetry receivers. Radio trackers monitored for radio signals from sunset onward, from hilltops, from roving stations based in the back of a pickup truck, and on foot. Trackers recorded compass bearings for every minute they received a signal, until the signal was lost or the bat had returned to its roost site. During 2001 and the initial nights of 2002, radiotracking continued through the night. In 2001, we found that after a bat returned to a roost near midnight, it virtually never re-emerged until after sunset the following day. As a result of this observation, and because of travel limitations and security concerns imposed by the international border, in 2002 we rarely maintained nightlong monitoring after the bats had returned to a roost near midnight. When observations indicated that, after significant foraging movements, a bat was remaining stationary in a known roost area near midnight, monitoring was often terminated.

The general locations of bats were followed through the night in real-time, by observers using two-way radios to communicate their respective compass bearings on the radio signals. Specific bat locations were determined for as many 1-minute intervals as possible for each night, by finding the crossbearings of two to five simultaneous compass readings for the radio signal direction, as measured by observers. All observers recorded the locations of their stations using geographic positioning system (GPS) units. The observers' directional readings were then projected from their observation points in a geographical information system (ArcView 3.2) to plot the bats' positions.

Results

We captured, outfitted with radiotransmitters, and tracked four *E. underwoodi* and no *E. perotis*. We captured two *E. underwoodi* in 2001 and another two in 2002. This was an unusually low number of *E. underwoodi* captures for Quitobaquito. It is possible that more *Eumops* were not caught because of the large numbers of non-target species that were captured - primarily *Nyctinomops femerosaccus*. In 2001, we captured two *Eumops* bats and 328 bats of other species, for a ratio of non-target to *Eumops* of 164 to 1, or *Eumops* comprising 0.6% of all captures. In 2002, we captured two *Eumops* bats and 259 bats of other species, for a ratio of non-target to *Eumops* of 129.5 to 1, or *Eumops* comprising 0.77% of all captures. These large numbers of non-target captures resulted in nearly constant bat handling activity at the nets, with headlamps and other associated activities. During most evenings we often heard *E. underwoodi* flying over the net, identifiable by their distinctive vocalizations (Cockrum and Gardner 1960, Constantine 1961). We suspect that the high level of activity by humans and captured non-target bats were likely to be scaring *E. underwoodi* away from the net, thus preventing capture. In 1994-1995, Petryszyn et al (1994) caught 35 *Eumops* and 267 non-target species, for a total proportion of captures of 11.6% *Eumops*. In 1996, Petryszyn et al (2000) caught 10 *Eumops* and 413 non-target species, for a total proportion of captures of 2.3% *Eumops*. Petryszyn et al. (2000) noted a rise in *Nyctinomops* captures coincidental with reduction in *Eumops* captures between the 1994-1995 work and 1996, and suggested there may be a connection. Our large numbers of captures of *Nyctinomops* in 2001-2002 may indicate an increasing trend in that species, with concomitant and consequent reductions in *Eumops* capturability. However, it is also possible that *Eumops* numbers, or their use of Quitobaquito, have experienced a true decline since 1994-1995. Of the four *E. underwoodi* that were instrumented, three yielded valuable data. These three individuals, *Eumops* #218, #239, and #284, were each tracked almost nightly for up to two weeks. For all three bats, we were able to determine foraging areas, travel routes, and roost sites, with a high degree of precision. The other bat, *Eumops* #198, was radiotracked September 21, 2001 and may have been detected briefly on September 22, but never afterwards. We speculate that contact with *Eumops* #198 was lost early because either the bat left the general region, or the radiotransmitter fell off, or

ceased to transmit. No data from *Eumops* #198 are presented here.

For *Eumops* #218, #239, and #284, roosting habitat and roost sites were located relatively easily. On the first several mornings of the project in 2001, stationary radio signals from *Eumops* #218 indicated the bat was roosting in low-lying desertscrub habitat in Mexico, between the international boundary and the nearby Rio Sonoyta. We suspected roosting in woodpecker cavities in saguaro cactus. This suspicion was based on the lack of other conceivable alternatives, the abundance of potential roost cavities in saguaros, and a pronounced directionality of the radio signal suggesting it was passing through a narrow opening. On September 27, 2001 this suspicion was confirmed. A 9-meter (30 ft) tall saguaro approximately 415m (1361 ft) south of the international border was located as the suspected roost, based on pre-dusk radio signal. Beginning at 1858hr, two probable *Eumops* were observed flying in succession out of a cavity near the top of the saguaro. Soon after, *Eumops* #218 emerged. We located subsequent roost sites for *Eumops* #218, #239, and #284 in similar fashion, and found all three roosting in woodpecker cavities in saguaro cactus, in the western portion of the Rio Sonoyta valley (Figure G-1). All three bats changed cavities from night to night, but seemed to cycle between a fairly small number of cavities. These favored roosts were typically within 1 km (1.6 mi) of one another. Each bat was confirmed day-roosting in only two individual saguaros each, and *Eumops* #284 used a third as a temporary night roost on one occasion. However, several nights for each bat

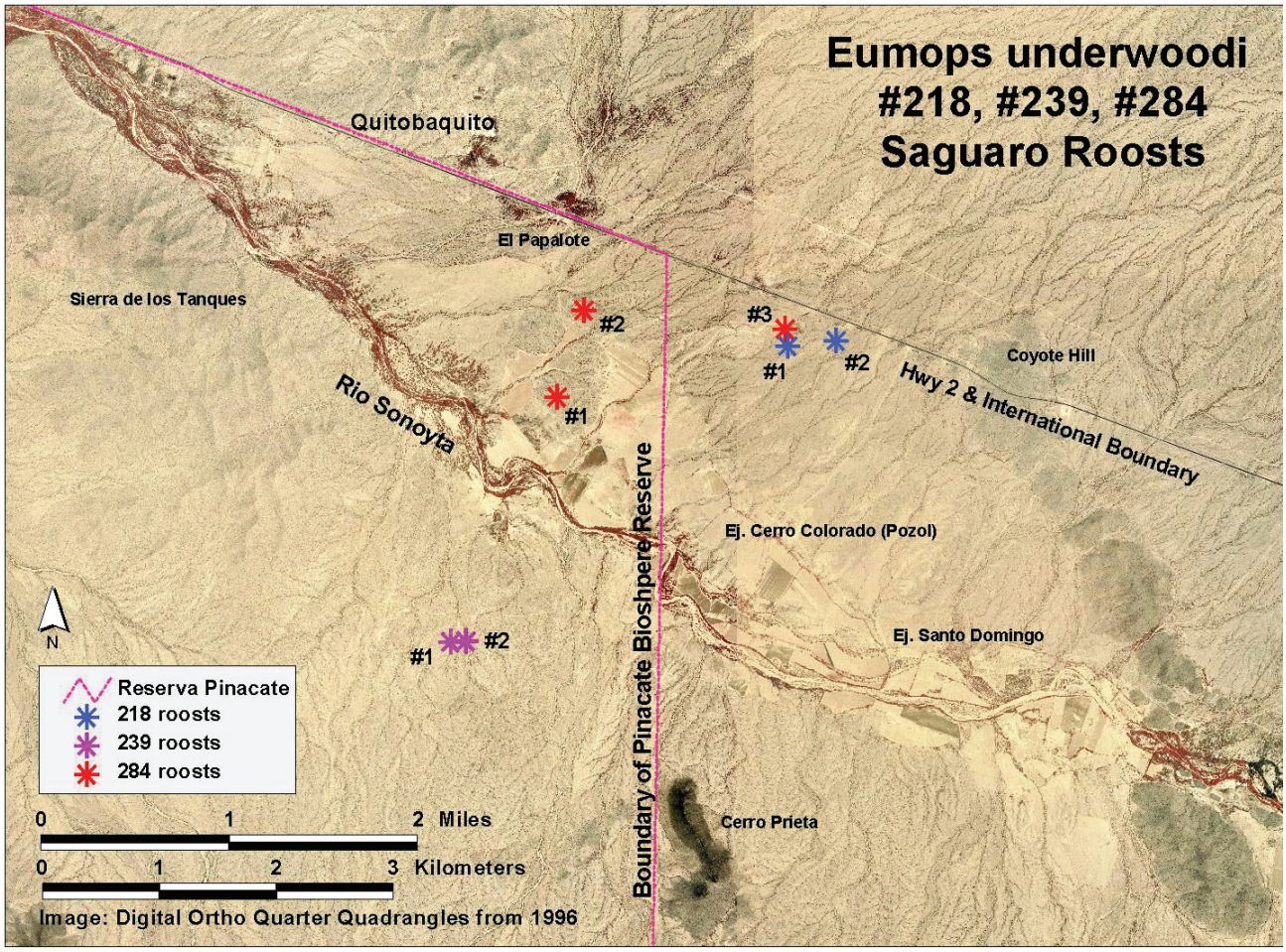

Figure G-1. Locations of roost sites in saguaro cactus, for Eumops underwoodi #218, #239, and #284, along the U.S./Mexico border.

we did not confirm the specific roost saguaro, but only confirmed that the bat radio signal had gone stationary and faint near midnight (typical of a roosting bat), at the cross bearings of a known roost saguaro. It is possible that in those cases, the bat may have roosted in a saguaro other than a known one, but so close as to be indistinguishable by radiotelemetry triangulation.

Roost saguaros different only slightly in setting. *Eumops* #239 used saguaros in rolling, undeveloped bajada topography south of the Rio Sonoyta (Figure G-1.) *Eumops* #284 roosted in a small area of undeveloped, slightly undulating topography surrounded by agricultural fields, and also used a saguaro within a few hundred meters of Mexico Highway 2 as a temporary night roost (Figure G-1.). Eumops #218 day-roosted in several saguaros also located within a few hundred meters of Mexico Highway 2 (Figure G-1.). Saguaros selected for roosting were all fully mature, large individuals with several arms and multiple cavities (Figure G-2). While the roost cavity was often high on the plant, on several occasions the bats selected lower cavities, sometimes on an arm. We determined that *E. underwoodi* roosts both solitarily, and in small groups. As noted above, on September 27, 2001, *Eumops* #218 had roosted with two other probable *Eumops*. On September 30, 2001, we videotaped four probable *Eumops* emerging from a cavity, followed soon after by *Eumops* #218. In 2002, we observed *Eumops* #239 and #284 roosting singly, never with other bats.

The three *Eumops* bats displayed comparable home ranges and foraging areas (Figure G-3.). All three roosted in the western part of the Rio Sonoyta valley, approximately 1.5 to 4.2 km (1-2.6 mi) south or southeast of Quitobaquito, near the northeastern corner of El Pincate Biosphere Reserve. (Figure G-3). All three ranged eastward and southward during probable foraging movements. All three engaged in movements generally along the axis of the Rio Sonoyta valley, but ranged north and south onto adjacent bajadas and mountain slopes. All three incorporated the city of Sonoyta, Sonora, in their home ranges.

Figure G-2. Eumops underwoodi roost site in saguaro cactus (note woodpecker cavities). Pinacate Biosphere Reserve, Sonora, Mexico. June 2002.

Nightly activity and home range summaries for Eumops #218, #239, and #284 are presented in Tables G-1, G-2, and G-3, respectively. Geographic mapping of nightly and cumulative home ranges are presented in Appendix 1 (*Eumops* #218), Appendix 2 (*Eumops* #239), and Appendix 3 (*Eumops* #284). Our radiotelemetry data suggested that *Eumops* #218 did not return to Quitobaquito Pond in the two weeks between its capture and October 2, 2001. It is possible this individual avoided Quitobaquito for some period after the capture experience, instead taking water at reservoirs or sewage ponds near Sonoyta. In 2002, radiotelemetry data suggested both *Eumops* #239 and #284 returned to Quitobaquito within several days of their capture. However, they did not make nightly visits to the pond.

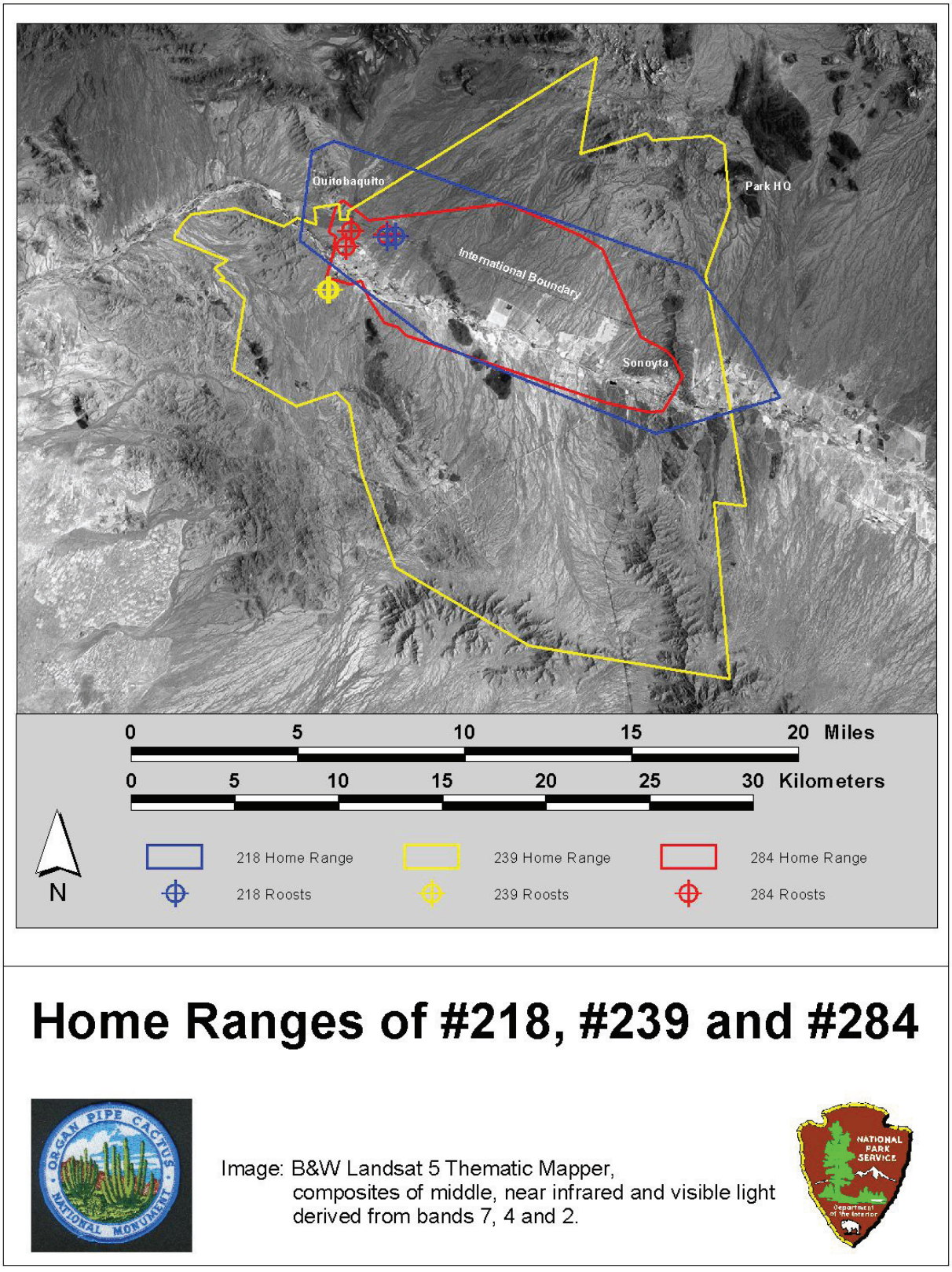

Figure G-3. Total cumulative home ranges for *Eumops underwoodi* #218, #239, and #284. Organ Pipe Cactus N.M., Arizona.

Table G-1. Daily time, activity, and home range summary for Eumops #218, Organ Pipe Cactus N.M., Arizona.

Date	[1]Time exit from roost	[2]Time return to roost	Elapsed time	Nightly Home Range Area				Movements / Comments
				Acres	Miles^2	Hectares	Km^2	
9-21-01	[3]0000 hr	0520 hr	5 hr 20 min	2,673	4.18	1,082	10.8	From Quitobaquito and Quitobaquito Hills southeastward to near Coyote Hill obs. Point, then return west to roost.
9-22-01	1900 hr	0530 hr	10 hr 30 min	24,534	38.33	9,928	99.3	Western Sonoyta Valley, then southeastward to Sonoyta, Sonoyta Hills, then return west to roost.
9-23-01	1855 hr	2310 hr	5 hr 15 min	15,377	24.02	6,223	62.2	Western Sonoyta Valley, then southeastward to Sonoyta, Sonoyta Hills, then return west to roost.
9-24-01	1905 hr	2035 hr	1 hr 30 min	7,141	11.15	2,890	28.9	Remained in western and middle Sonoyta valley
9-25-01	1855 hr	2305 hr	4 hr 10 min	6,136	9.58	2,483	24.8	Remained in western and middle Sonoyta valley
9-26-01	1905 hr	2250 hr	3 hr 45 min	6,060	9.46	2,452	24.5	Western Sonoyta Valley, then southeastward to Sonoyta Hills, then return west to roost.
9-27-01	1905 hr	2300 hr	3 hr 55 min	7,640	11.93	3,092	30.9	Western Sonoyta Valley, then southeastward to Sonoyta and beyond to eastern edge of city, then return west to roost.
9-30-01	1837 hr	Unknown	Unknown	-	-	-	-	Weather cancellation
10-2-01	1830 hr	>2330 hr	>5 hr	9,329	14.57	3,775	37.8	Western Sonoyta Valley, then soutgheast to Sonoyta, Sonoyta Hills, then return west to roost.
		Total net home range:		39,624	61.91	16,035	160.4	"Total" figures are the total *net* home range areas, not the sum of nightly ranges, which had substantial nightly geographical overlap.

[1]Time certain; direct observation.
[2]Time approximated by suddenly diminished signal strength at fixed location, observed by several stations. Often confirmed shortly afterward by direct local signal location.
[3]Time released after capture/instrumentation at Quitobaquito.

Table G-2. Daily time, activity, and home range summary for Eumops #239, Organ Pipe Cactus N.M., Arizona.

Date	[1]Time exit from roost	[2]Time return to roost	Elapsed time	Nightly Home Range Area Acres	Miles^2	Hectares	Km^2	Movements / Comments
6-4-02	0252 hr[3]	0307 hr	15 min	1,572	2.46	636	6.4	Flew almost directly from Quitobaquito release to roost
6-5-02	2005 hr	0015 hr	4 hr 10 min	30,008	46.89	12,144	121.4	From roost eastward to Sonoyta and return to roost
6-6-02	2021 hr	>2315 hr	>2 hr 54 min	23,678	36.99	9,582	95.8	From roost eastward to Sonoyta and return to roost
6-7-02	2015 hr	2243 hr	2 hr 28 min	27,590	43.11	11,165	111.6	From roost eastward to Sonoyta and return to roost
6-8-02	2022 hr	2243 hr	2 hr 21 min	3,861	6.03	1,563	15.6	Remained in roost vicinity in western Rio Sonoyta valley. High winds from southeast.
6-9-02	2008 hr	2241 hr	2 hr 31 min	15,609	24.39	6,317	63.2	From roost eastward to Sonoyta and return to roost
6-10-02	2008 hr	2109 hr	1 hr 1 min	12,483	19.50	5,052	50.5	Remained in western Rio Sonoyta valley.
6-11-02	2015 hr	2250 hr	2 hr 35 min	21,357	33.37	8,643	86.4	From roost northeastward to Sonoyta Mts, possibly Senita Basin area (?) and return to roost.
6-12-02	2013 hr	2130 hr	1 hr 17 min	10,670	16.67	4,318	43.2	Remained in western Rio Sonoyta valley.
6-13-02	2014 hr	0010 hr	4 hr 13 min	46,444	72.57	18,795	187.9	From roost northeastward to Sonoyta Mts, Senita Basin, southern Puerto Blanco Mts, return to roost.
6-14-02	2009 hr	0050 hr	4 hr 41 min	70,333	109.89	28,463	284.6	Remained in western Rio Sonoyta valley.
6-15-02	2015 hr	>2130 hr	>1 hr 15 min	15,907	24.85	6,437	64.4	From roost eastward to midsection of Rio Sonoyta valley
6-16-02	2018 hr	0020 hr	4 hr 2 min	53,889	84.20	21,808	218.1	From roost northeastward to Senita Basin area (?), then Sonoyta, then return to roost
6-20-02		-	-	-	-	-	-	Informal check: radio still operational. Based on radio signal, bat appeared to emerge from favored saguaro roost.
			Total net home range:	117,066	182.92	47,375	473.7	"Total" figures are the total *net* home range areas, not the sum of nightly ranges, which had substantial nightly geographical overlap.

[1]Time certain; direct observation.
[2]Time approximated by suddenly diminished signal strength at fixed location, observed by several stations. Often confirmed shortly afterward by direct local signal location.
[3]Time released after capture/instrumentation at Quitobaquito.

Table G-3. Daily time, activity, and home range summary for Eumops #284, Organ Pipe Cactus N.M., Arizona.

Date	[1]Time exit from roost	[2]Time return to roost	Elapsed time	Nightly Home Range Area				Movements / Comments
				Acres	Miles^2	Hectares	Km^2	
8-2-02	2247 hr [3]	0046 hr	1 hr 59 min	250	0.39	101	1.0	From release at Quitobaquito to local activity near roost
8-3-02	2008 hr	2103 hr	55 min	845	1.32	342	3.4	Remained in western Rio Sonoyta valley, including probable return to Quitobaquito
8-4-02	2001 hr	2356 hr	3 hr 55 min	21,826	34.10	8,833	88.3	From roost northeastward, probably to Senita Basin, then Sonoyta, and return to roost.
8-5-02	1958 hr	2340 hr	3 hr 42 min	1,861	2.91	753	7.5	Remained in western Rio Sonoyta valley. Intermediate roost 2045-2329 hrs near Highway 2; then return to original roost.
8-6-02	2002 hr	2044 hr	42 min	15,834	24.74	6,408	64.1	From roost eastward to Sonoyta and return to roost
		Total net home range:		24,617	38.46	9,962	99.6	"Total" figures are the total *net* home range areas, not the sum of nightly ranges, which had substantial nightly geographical overlap.

[1]Time certain; direct observation.
[2]Time approximated by suddenly diminished signal strength at fixed location, observed by several stations. Often confirmed shortly afterward by direct local signal location.
[3]Time released after capture/instrumentation at Quitobaquito.

Discussion

Roosting

Woodpecker cavities in saguaro cactus were the only roost habitat documented in this study. All saguaros used for roosting were located in the Rio Sonoyta valley, in Mexico, in an area just south and southeast of Quitobaquito Springs (Arizona) and approximately 21-24 km (13-15 miles) west of the city of Sonoyta (Figures 1 and 2). This general area was also used extensively in roving movements assumed to constitute foraging, just after emerging from and just prior to returning to roosts. Near the roost sites, bats moved over low, relatively flat terrain, and also along low hills and rocky ridges of the Sierra los Tanques in Pinacate Biosphere Reserve in Mexico, and the Quitobaquito Hills in the U.S.

To our knowledge, this study provides the first documentation of *E. underwoodi* or any *Eumops* bat using woodpecker cavities in saguaro cactus for roosting. Concurrent with our study, and in northwestern Sonora near our study area, A. Flesch observed probable *Eumops* bats roosting in saguaro cavities. Flesch was inspecting saguaro cavities in daytime, using a micro-video camera as part of his study on ferruginous pygmy-owls (*Glaucidium brasilianum*) (A. Flesch, University of Arizona, pers. comm. August 2002). Use of saguaro cavities for roosting has been documented for the big brown bat (*Eptesicus fuscus*) (Cross and Huibregtse 1964). Pape (1998) also observed several bats, believed to be *E. fuscus* and/or the pallid bat *(Antrozous pallidus*), emerging from a saguaro cavity. S. Morales observed one probable bat of unknown species inside a saguaro cavity in the Tucson region (S. Morales, Harris Environmental Group, Inc. pers. comm. September 2002*).* Also in the Tucson area, Stutchbury (1991) observed a small bat entering a saguaro at dawn. These records are all those we could verify, for any bats species roosting in saguaro cavities. However on consideration, saguaro cavities may offer a valuable roost habitat, at least for solitary roosting or roosting in small numbers. Saguaro cavities provide a dark environment, with thermal protection and considerable security from predators. Saguaro cavities are typically approximately 2 to 4 liters (122 - 244 in^3) in volume. Considering that *E. underwoodi* is the second-largest North American bat, the roost site height above ground should be adequate for any other resident species to achieve flight. In Sonoran Desert bajadas, plains, and valley landscapes where caves, mines, and rock crevices may be rare or absent, saguaro cavities are a typically abundant and well-distributed potential roost resource.

At the start of this project, we accepted the prevailing view that *Eumops* bats would be found roosting in a site where they would be afforded a considerable free-fall to gain flight – perhaps 10m (32 feet) or more. We anticipated roost sites in cliffs or steep rocks of the Bates, Puerto Blanco, or Cubabi mountains. Our visual observations (and documented in the September 30, 2001 videotape) found that *E. underwoodi* exiting a saguaro cavity and swooping downward only 2 to 4 meters were able to achieve level or ascending aerodynamic flight. This conforms with records of *E. underwoodi* roosting in tall trees and palms as described by Watkins (et al. 1972) and Hellebuyck (et al. 1985, both in Kiser 1995). Saguaro cactus are abundant across many bajada settings of southern Arizona, although not at the higher elevations of *E. underwoodi* records in the upper Altar Valley area reported by Cockrum and Gardner (1960). *E. underwoodi* may also find roosting opportunities in tall to relatively small cliffs across the region.

The saguaro-cavity roost sites used by *E. underwoodi* appear to be, on the surface, a nearly unlimited resource. These cavities are excavated by Gila woodpeckers (*Melanerpes uropygialis*), and northern flickers (*Colaptes auratus*, including the "gilded flicker" form). Many other bird species in the study area use these cavities subsequently for nesting, and are known as "secondary cavity nesters" because they are unable to excavate cavities themselves. These include: ash-throated flycatcher (*Myiarchus cinerascens*), brown-crested flycatcher (*M. tyrannulus*), purple martin (*Progne subis*), house finch (*Carpodacus mexicanus*), American kestrel (*Falco sparvarius*), western screech-owl *(Otus kennicottii*), elf owl (*Micrathene whitneyi*), and ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*). In addition, honeybees (*Apis mellifera*) are not uncommonly seen using saguaro cavities – although usually cavities of greater extent (e.g.

injury) than woodpecker cavities. Despite this competition, it is likely that because of their abundance, saguaro cavities are widely available for roosting by *E. underwoodi* in the study area. However, it is possible that with the expansion of Sonoyta and associated changes in land use, the anthropogenic-associated house finch and the non-native European starling (*Sturnus vulgaris*), also secondary cavity nesters, may increase.

The ability of *E. underwoodi* to range up to 24 km (15 mi) or more on foraging bouts from its roost site demonstrates that roost sites do not need to be available in close proximity to foraging areas. Still, some concerns may exist regarding saguaro-cavity roost sites. First, despite a widespread availability of saguaros throughout the study area, all roost sites were in a relatively limited area, low in the Rio Sonoyta Valley, near the western end of this valley. This may suggest that the western Rio Sonoyta valley may have specific attraction as a roosting area – possibly specifically because the water source of Quitobaquito is nearby. On the other hand, our study may have been biased toward detecting roosts in this area because all bats were captured nearby at Quitobaquito. It is possible that other *E. underwoodi* roost elsewhere in saguaro stands, but do not visit Quitobaquito because they are able to find water elsewhere, or selected other saguaro stands for other reasons. At this point, there is not adequate information to speculate what attributes might make one area of saguaros superior or inferior to others for *Eumops* roosting.

Several factors may affect saguaro cactus abundance over time. Livestock grazing is extensive in Mexico in the area of the roost sites. Saguaro seedling establishment and survival are negatively affected by long-term livestock grazing, so some long-term sustainability questions exist. Also, buffelgrass (*Pennisetum ciliare*) infestation is extensive in northern Sonora and especially along the Highway 2 corridor through the Rio Sonoyta valley. This raises medium-range concerns for the viability of saguaro populations. Currently, buffelgrass is intensively eradicated from OPCNM. As long as that program persists, saguaro-cavity availability in OPCNM should remain high.

Foraging

In movements that we assumed to constitute foraging, we found *E. underwoodi* to be foraging in a range of habitats, including undeveloped wilderness, Sonoran desertscrub, mesquite-tamarisk riparian woodland, agricultural areas, rural development, topography ranging from flat to very steep, and the semi-urban small city of Sonoyta (Figure 3). The differences among the three *Eumops* in total cumulative home ranges (Figure 3) seem likely to have been correlated with the amount of movement data collected. The bat tracked the least number of nights (*Eumops* #284) had the smallest cumulative home range, while the bat tracked the longest (*Eumops* #239) accumulated data points defining a much larger home range. This effect may have been compounded by bats engaging in aberrant and restricted foraging movements for the first several nights after the trauma of capture and instrumentation. As illustrated in Tables G-1 – G-3), each bat exhibited night-to-night variation in the location and areal extent of its movements. *Eumops* #239 was radiotracked over the most nights, and likely represents the minimal total home range for the species in this area over the longer term.

We observed bats moving widely throughout the Rio Sonoyta valley and adjacent desert bajadas. At local scales, the bats seemed to be foraging low in desertscrub plains, also above desertscrub, along rocky ridges and mountain slopes, and in artificially lighted areas of Sonoyta. Kiser (1995) reported that the diet of *E. underwoodi* in Arizona east of OPCNM included scarab beetles, short-horned grasshoppers, leafhoppers, and moths. In Michoacan, Mexico, one *E. underwoodi* had remains of large June beetles and long-horned beetles in its stomach (Kiser 1995). It is reasonable to expect that in our study area *E. underwoodi* are feeding on a variety of terrestrial and flying arthropods.

The three *Eumops* bats we examined spent the majority of their flight time over relatively flat terrain in the Rio Sonoyta valley and adjacent bajadas. However, as in a light-tagging project undertaken in 2000 (OPCNM, unpubl. data), we also observed radioed *Eumops* flying around and along topographic features ranging from small

hills (e.g. Quitobaquito Hills) to steep, high, rocky ridges (e.g. Puerto Blanco Mountains). This use was best illustrated by *Eumops* #239, which was radiotracked the longest. Other bats (e.g. #284) may also have visited these topographical features, but this was not detected or confirmed due to limited or inconclusive radiotelemetry data. Observers on ridgetops commonly heard the distinct vocalizations of non-radioed *Eumops* overhead, sometimes seen and heard in groups of six or more, indicating that these bats fairly commonly forage along ridgelines, hilltops, and other raised topographic feature. Our observations suggested *Eumops* may favor windward slopes, as if the bats used favorable wind currents for flight energetics, and/or that upslope winds created predictable concentrations of nocturnal aerial invertebrate prey.

As the western end of the combined home ranges of the three radioed bats was centered on the roost area, the eastern end of their ranges was centered on and defined by the city of Sonoyta, Mexico (Figure 3 and Appendices). Roving telemetry stations in Sonoyta found the bats to be visiting business and residential areas, lighted areas, as well as rocky slopes at the southern base of the Sonoyta Mountains, at the city's edge. The time spent by our radioed *E. underwoodi* in or near Sonoyta - usually 1- 3 hr per visit - strongly suggests the bats foraged for arthropods attracted to artificial lights or other anthropogenic sources, and/or was visiting water sources in or near Sonoyta.

The species demonstrated an ability to cover large areas in a single evening. The largest single- night home range recorded was 284.6 km^2 (109.89 mi^2), for *Eumops #239* on June 14, 2002. All three bats commonly ranged over approximately 100 km^2 (37 mi^2) on a typical night. It is difficult to estimate total linear distances flown per night, because of the meandering routes often used by individual bats. However, most bats on most nights traveled 20-30 km (32-48 mi) at the very least, and often more in the range of 50-100 km (80-160 mi) as a minimum estimate. We observed extensive back-and-forth movements within a given night's home range, e.g. back and forth along long mountain ridges or back and forth across Sonoyta. Such movements suggest that bats may fly hundreds of kilometers per night – and often in just several hours.

Eumops bats varied their foraging habitats from night to night, sometimes favoring undeveloped desert areas, sometimes favoring semi-urban Sonoyta. Even discounting extremes of foraging time (as little as 42 minutes, to as much as 10 hours), bats often varied their foraging time between 1-2 hours and 4 -5 hours (Tables 1-3). This suggests differential foraging success from night to night – or perhaps other phenomena – but also indicates that just several hours of foraging in current habitats were sufficient to sustain an individual bat. Bats usually returned to a roost by midnight, but on two occasions remained active until nearly dawn. Infrequently, an interim short-term night-roost was confirmed (e.g. *Eumops* #284 on August 5, 2002). As noted above in "Methods," nightlong monitoring in 2001 and early 2002, indicated bats usually returned to a roost near midnight, and did not re-emerging until after sunset the following day. Petryszyn et al (1996 and 2000) found that the great majority of *E. underwoodi* were captured at Quitobaquito before midnight, further suggesting little activity in the second half of the night. In the latter stages of the project in 2002, we continued to track bats back to a roost by midnight, but did not monitor for subsequent movements through the night. On one occasion we find that a bat had moved to a different roost between the middle of the night and the following day.

In our study area, *E. underwoodi* clearly has adapted to human influences on the environment, foraging in downtown Sonoyta as well as relatively pristine desert plains and rocky ridges. This suggests that *E. underwoodi* may be able to adapt to continuing human development in the Rio Sonoyta valley, as long as natural preserves also remain available nearby. Ultimately, foraging habitat quality is determined by prey availability. If large-scale insecticide applications took place in the Rio Sonoyta valley, for purposes of agricultural or public health concerns, a negative effect on *Eumops* prey could result. Also, if the Rio Sonoyta itself were to undergo substantial changes, foraging habitat could be negatively (or positively) affected. Even

in its current degraded condition, the Rio Sonoyta does support a mesquite-tamarisk riparian corridor with limited water, which together probably contribute to *Eumops* foraging habitat quality. If the river is further degraded (e.g. through dewatering, overgrazing, etc.) even this diminished resource could be lost. Conversely, if the Rio Sonoyta were rehabilitated, improvements in foraging habitat quality and water availability would likely result.

Water Sources

If it is true that *Eumops* require a relatively large, open water source, such sources in the study area are limited to Quitobaquito Pond, a sewage lagoon just west of Sonoyta, and Xochimilco, an intermittent reservoir on the Rio Sonoyta just east (upstream) of the city. Quitobaquito Pond is tentatively stable. The pond has remained largely unchanged since 1969, when it was last dredged and enlarged. Emergent plants (*Scirpus americana*) are encroaching on the pond perimeter, but have probably reduced the pond diameter by no more than a meter or two in the last 20 years. National Park Service hydrologists have noted that the retaining dam will need maintenance to continue to function. And its location on the border leaves Quitobaquito vulnerable to a wide variety of impacts, malicious or unintended, that could affect water quality and/or water availability. The three bats that were radiotracked extensively did not return to Quitobaquito nightly, or even very often. Several interpretations of this are possible, including: 1) They do not need to access free water nightly; 2) Quitobaquito is one of several water sources that are visited alternatively; 3) The experience of being captured, handled, and instrumented at Quitobaquito served as a deterrent to making return visits for some time.

Other potential water sources exist in the Rio Sonoyta Valley. Based on radiotelemetry data, we suspect that *E. underwoodi* may have visited the sewage treatment ponds just west of Sonoyta. At least during this project, these ponds presented a greater surface area than Quitobaquito. The bats may have used these ponds to drink effluent, or the ponds and surrounding vegetation may also have been a source of arthropod prey. The Rio Sonoyta in its current state seems unlikely to serve as a watering source. Its current surface flow is greatly diminished, reaching as little as 1.5 km in late summer 2002 (Juan Miranda, El Pinacate Reserva Biosfera, pers. comm.). That surface flow is generally a small stream about 2m (6.5 ft) wide, several cm deep (1 to two inches), and narrowly confined within a corridor of mesquite and tamarisk. *Eumops* bats may have difficulty accessing this small, shallow, confined water source. However, the fact that their roost sites were in the broad Rio Sonoyta valley, and transit routes between roost sites and Sonoyta followed the river valley, may suggest that they are in fact using the river as a water source.

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