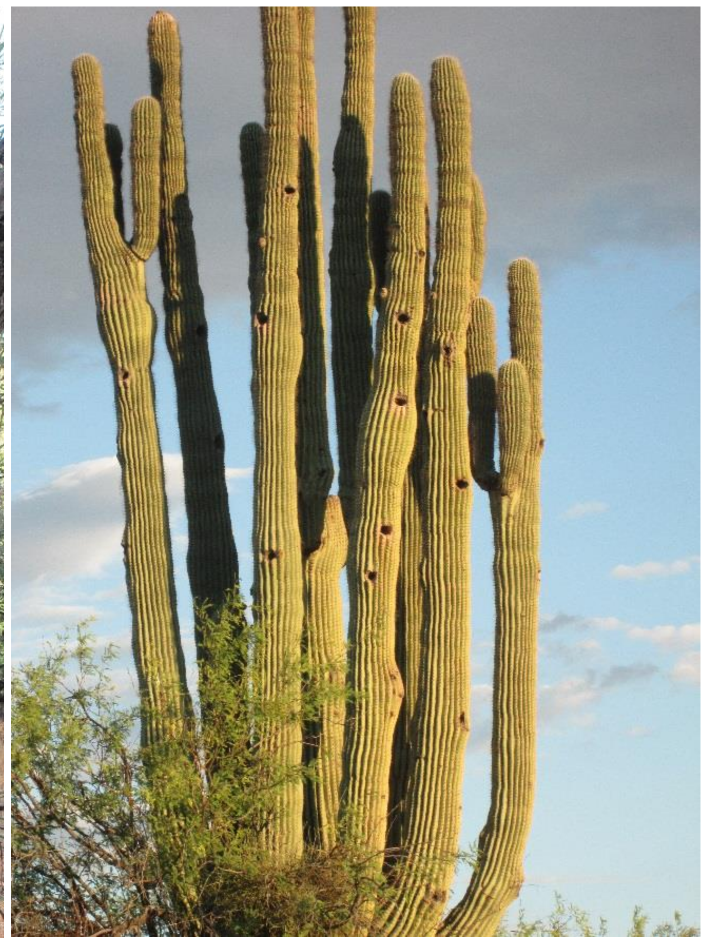
Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Elf Owl Home Range and Habitat Study

2015 Annual Report



August 2017

Work conducted under LCR MSCP Work Task C24

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National Park Service
Bureau of Land Management
Bureau of Indian Affairs
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The Nature Conservancy

Lower Colorado River
Multi-Species Conservation Program

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2015 Annual Report

Prepared by:

Dr. John D. Boone, Great Basin Bird Observatory

and

Dr. Aaron D. Flesch, University of Arizona, School of Natural Resources and the Environment

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

ADS	arborescent desert scrub (vegetation type)
AIC_c	Akaike's information criterion adjusted for small sample sizes
Bill Williams River NWR	Bill Williams River National Wildlife Refuge
BLM	Bureau of Land Management
CI	confidence interval(s)
DS	desert shrubland (vegetation type)
DW	desert woodland (vegetation type)
e.g.	*exempli gratia*; for example
ER	exotic riparian (vegetation type)
GBBO	Great Basin Bird Observatory
GLMM	generalized linear mixed models
i.e.	*id est*; that is
km/h	kilometer(s) per hour
LB	lower bound
LCR MSCP	Lower Colorado River Multi-Species Conservation Program
m	meter(s)
MEFF	mobile electronic field form(s)
MR	mesic riparian (vegetation type)
n	sample size
N/A	not applicable
Reclamation	Bureau of Reclamation
SE	standard error
UB	upper bound
XR	xeric riparian (vegetation type)

Symbols

Δ	an increment of a variable
$\approx$	approximately
χ^2	Chi-square statistic
°	degrees
$>$	greater than
$\geq$	greater than or equal to
$<$	less than
%	percent
$\pm$	plus or minus

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ABSTRACT

The elf owl (*Micrathene whitneyi*), a covered species under the Lower Colorado River Multi-Species Conservation Program (LCR MSCP), occurs within the LCR MSCP planning area during spring and summer, but its current distribution is much more restricted than in the past. In 2015, the Great Basin Bird Observatory and University of Arizona completed the first season of field work for a 3-year project designed to provide the Bureau of Reclamation with data characterizing elf owl responsiveness and habitat use in riparian areas. The goal of the first field season was to characterize patterns of elf owl occurrence across a broad study area in Arizona. Of specific interest was assessing the frequency with which elf owls occupy areas dominated by riparian vegetation, the significance of riparian vegetation to elf owls, and environmental factors that are good predictors of elf owl occurrence. Data were collected across several important environmental gradients to provide maximal interpretational and biological context. These included geographic (i.e., latitude and longitude), elevation, and vegetation gradients, and included three riparian (mesic, xeric, exotic) and three upland vegetation types (desert woodland, mixed or arborescent desert scrub, and desert shrubland). A stratified sampling design was developed to optimally allocate field effort across these gradients and vegetation types. Data were collected using standardized discovery surveys[1] for elf owls and by characterizing environmental attributes focused on vegetation structure and composition at each station at which owl surveys were performed regardless of whether or not an owl detection occurred.

Discovery surveys were performed along 112 transects that included 1,397 stations across southern and western Arizona, totaling 193 kilometers of transect effort. A total of 855 elf owl detections were recorded during discovery surveys, which represented about 553 unique individuals. The probability of elf owl occurrence increased markedly with the presence of mature (> 3 meters tall and > 20 centimeters diameter at breast height) saguaro cacti (*Carnegiea gigantea*). Occurrence probabilities at stations dominated by mesic and xeric riparian vegetation were much higher in areas with saguaros (mean ± standard error = 0.43 ± 0.03 mesic; 0.42 ± 0.03 xeric) than without saguaros (0.13 ± 0.01 mesic; 0.11 ± 0.02 xeric) and lowest at stations dominated by exotic riparian vegetation without saguaros (0.00–0.04 ± 0.00–0.02). In the absence of any riparian vegetation, the probability of elf owl occurrence was low regardless of whether saguaros were present (0.12–0.20 ± 0.04–0.18) or absent (0.00–0.09 ± 0.00–0.06), although sample sizes were low (n = 55). With regard to plant species composition in riparian areas, the probability of elf owl occurrence increased with cover of broadleaf deciduous trees other than willow (*Salix* sp.) and with cover of mesquite (*Prosopis* spp.).

[1] Discovery surveys are call-playback surveys conducted at a series of locations (hereafter referred to as stations) for the purpose of determining species (elf owl) presence.

By surveying a large number of riparian areas across southern and western Arizona, potential study sites were identified for more intensive efforts in future years of this project. Coupled with data to be gathered during the upcoming 2016–17 field seasons, this project will greatly augment the understanding of how elf owls use riparian vegetation along the sampled gradients.

INTRODUCTION

To assist the Bureau of Reclamation (Reclamation) in its goal of implementing conservation under the auspices of the Lower Colorado River Multi-Species Conservation Program (LCR MSCP), the Great Basin Bird Observatory (GBBO), in collaboration with the University of Arizona, School of Natural Resources and the Environment as a project subcontractor, is conducting elf owl (*Micrathene whitneyi*) research through the 2015–18 time period. The overall goals of the entire 4-year project are to:

1) Determine the occurrence of elf owls in riparian areas and adjacent upland environments within the Sonoran Desert region of Arizona during the breeding season

2) Identify nesting territories occupied by elf owls and characterize elf owl territories

3) Experimentally investigate elf owl responsiveness to call-playback to finalize a protocol for elf owl surveys in the LCR MSCP planning area

This document describes methods, data analysis, and the results of work performed during the project's initial 2015 field season. The purpose of the 2015 field season was to accomplish the first project goal listed above and to facilitate the selection of study sites for more intensive work in 2016 and 2017. Subsequent field seasons will focus on the second and third goals, which are not discussed further in this document.

The occurrence of elf owls within the LCR MSCP planning area is, at the present time, far too limited to generate robust inferences about the species' habitat use. Therefore, it is necessary to examine patterns of elf owl occurrence in a broader area to understand their responsiveness and habitat use in riparian areas sufficiently well to implement LCR MSCP conservation measures. The Sonoran Desert region of western and southern Arizona was identified as a suitable study area for gathering the required information. Within this region, a "gradient approach" was used to guide sampling design and data analyses. Described more fully below, gradient sampling involves identifying critical ecological, elevational, and climatological gradients along which elf owl occurrence could plausibly vary in a systematic way and using these gradients to guide the selection of study sites and inform data interpretation. Findings from the portions of those gradients most relevant to the LCR MSCP planning area can then be highlighted for LCR MSCP applications.

To determine the occurrence patterns of elf owls within the defined study area, the following tasks were performed in 2015:

1) Identified a large number of riparian sites where potential breeding habitat for elf owls were present.

2) Conducted discovery surveys[2] in as many of these sites as possible (covering both riparian and adjacent upland areas) to determine where breeding elf owls were present.

3) Collected rapid environmental assessment data to characterize the areas that were surveyed regardless if owls were detected or not.

4) Performed analyses to identify factors that were associated with the occurrence of elf owls.

METHODS

Site Identification and Selection

A two-step process was followed to choose study sites. The initial step was to identify a large number of candidate sites across the study area within which elf owls could plausibly occur, and a second step was the selection of a subset of these candidate sites for conducting discovery surveys.

Initial site identification was based on several criteria. First, candidate sites had to be located within or immediately east (i.e., southeastern Arizona at the far western edges of the Chihuahuan Desert) of the Sonoran Desert in Arizona. This study area was selected because information from this region has the greatest transferability to the LCR MSCP planning area based on major similarities in riparian vegetation structure and composition.

Second, candidate sites needed to collectively provide coverage across broad-scale geographical, elevational, and vegetation gradients. The geographical gradient was defined by the entire east-west and north-south extents of the study area. The elevational gradient was defined as the range of elevations from the western portion of the Bill Williams River National Wildlife Refuge (Bill Williams River NWR) approximately (≈)130 meters (m) to ≈1,200 m, at which point lowland riparian vegetation associations similar to those in an LCR MSCP planning area transition to more montane associations dominated by different tree species. The vegetation gradient ranged across three pre-defined riparian vegetation types: mesic, xeric, and exotic, and three pre-defined upland vegetation types: desert woodland, mixed or arborescent desert scrub, and desert shrubland. The mesic riparian type was of particular interest in this study, and thus, the presence of that type where it was potentially suitable for elf owls was the main criterion of interest in identifying candidate survey sites. Sites without

[2] Discovery surveys are call-playback surveys conducted at a series of locations (hereafter referred to as stations) for the purpose of determining species (elf owl) presence.

mesic riparian vegetation were considered only to the extent necessary for creating a balanced gradient sampling approach (see below) and because they facilitate inferences on the significance of mesic riparian vegetation versus other vegetation types. Because mesic riparian vegetation is spatially limited and unevenly distributed throughout the study area, it was not possible to obtain idealized site representation across all defined gradients. However, every effort was made to identify candidate sites within underrepresented portions of the defined gradients.

Finally, for practical reasons, candidate sites were limited to lands where right-of-entry permits could be obtained relatively easily. These included public lands managed by Federal, State, and county agencies, and lands managed by The Nature Conservancy of Arizona. Some private lands were also considered where access was thought to be obtainable when those lands were important for obtaining adequate coverage of defined gradients (see above) or were similar to riparian areas along the lower Colorado River.

Guided by these criteria, sites with broadleaf deciduous riparian vegetation (i.e., mesic riparian vegetation type) were identified using existing Geographic Information System data. Those data sources included the Arizona State-Wide Freshwater Assessment that was compiled by The Nature Conservancy of Arizona in 2010 (http://azconservation.org/downloads/category/ freshwater_assessment). These spatial data describe the presence and location of surface water along drainages throughout Arizona in various categories that are highly associated with the presence of broadleaf deciduous riparian vegetation. The specific process used was as follows:

1) Drainage reaches classified in the Geographic Information System layer as "perennial," "regulated," or "effluent" were selected for consideration. In addition, some reaches classified as "formerly perennial," "intermittent," or "ephemeral" were selected for consideration if other information or previous familiarity with the site suggested that broadleaf deciduous riparian vegetation might be present.

2) The selected reaches were projected in Google Earth and examined over aerial photographs.

3) Landownership of selected reaches was determined using data from the Arizona State Land Department (http://gis.azland.gov/webapps/parcel/) and some county sources.

4) Reaches that met all of the described criteria were determined to be candidate sites for elf owl discovery surveys.

Using this procedure, a list of 28 candidate survey sites was created (table 1). This list excluded the Bill Williams River NWR within the LCR MSCP planning

Table 1.—Names, general locations, and management jurisdictions of candidate study sites for elf owl discovery surveys in 2015
(All locations are in Arizona. Names of tributaries along the major drainages listed here are not given.)

Name and general location	Jurisdiction*
Big Sandy River above Alamo Lake	Arizona State Parks, Bureau of Land Management
Upper Bill Williams River below Alamo Lake	Bureau of Land Management
Santa Maria River above Alamo Lake	Arizona State Parks, Bureau of Land Management
Big Sandy River near Wickieup, Arizona	Private
Date Creek north of Date Creek Mountains northwest of Congress, Arizona	Arizona State Lands Department, private
Lower Gila River near Painted Rock Reservoir and Gila Bend, Arizona	Bureau of Land Management
Middle Hassayampa River Valley near Wickenburg, Arizona	The Nature Conservancy
Middle Gila River near Avondale and Buckeye, Arizona	Bureau of Land Management, Arizona State Lands Department, other
Lower Agua Fria River and tributaries near Lake Pleasant and Black Canyon City, Arizona	Bureau of Land Management, Arizona State Lands Department, other
Upper Agua Fria River and tributaries between Black Canyon City and Cordes Junction, Arizona	Bureau of Land Management, Arizona State Lands Department, other
Lower Verde River near Bartlett Reservoir	U.S. Forest Service
Lower Verde River near Horseshoe Dam	U.S. Forest Service
Middle Verde River and nearby tributaries between Clarkdale, Arizona and Horseshoe Dam	U.S. Forest Service, National Park Service
Vekol Wash west of Casa Grande, Arizona	Bureau of Land Management
Lower Salt River between Saguaro Lake and Granite Reef Dam	U.S. Forest Service
Middle Salt River between Roosevelt Dam and U.S. Route 60, including Cherry Creek	U.S. Forest Service
Lower Santa Cruz River west of Red Rock	Arizona State Lands Department, Pima County
Middle Santa Cruz River near of Tucson, Arizona	Arizona State Lands Department, Pima County, city of Tucson
Upper Santa Cruz River near Tubac, Arizona	National Park Service, easements
Cienega Creek and Davidson Canyon east of Tucson, Arizona	Pima County
East and south of Rincon Mountains - Rincon Creek and nearby drainages, east of Tucson, Arizona	National Park Service, Pima County, private
Middle Gila River Valley between Florence and Winkelman, Arizona	Bureau of Land Management, Arizona State Lands Department, other
Lower San Pedro River near Winkelman, Arizona	The Nature Conservancy
Middle San Pedro River near Mammoth, Arizona and tributaries on east side of Catalina Mountains	Bureau of Land Management, U.S. Forest Service
Upper San Pedro River at and above Saint David, Arizona	Bureau of Land Management
Aravaipa Creek east of Winkelman, Arizona	The Nature Conservancy, Bureau of Land Management
Arivaca Creek west of Arivaca, Arizona	U.S. Fish and Wildlife Service
Upper Gila River above and below Safford, Arizona	Bureau of Land Management, private

area because the presence of elf owls there has already been well confirmed (GBBO 2012). Most of the candidate sites were known or deemed likely to contain Fremont cottonwood-willow (*Populus fremontii-Salix* spp.) riparian vegetation (i.e., mesic riparian vegetation), along with other vegetation types, but a smaller number were selected that likely contained only xeric riparian woodlands to adhere to a gradient sampling approach.

From among this list of candidate sites, the selection of locations for discovery surveys was left to the discretion of survey crews based on permitting considerations, logistical feasibility, on-the-ground conditions, access issues, desirability of establishing multiple survey locations within some of the larger sites, and the stratification targets (see below). Adherence to these targets was monitored on an ongoing basis as the field season progressed to ensure idealized stratification was maintained to the extent possible. Sites where discovery surveys were actually conducted are discussed in the "Results" section.

Sampling Strategy

Vegetation types were defined as outlined in table 2. Typical examples of each vegetation type are shown in figures 1–6.

An idealized stratification of survey effort was developed with respect to vegetation type and the presence or absence of mature saguaro cacti (*Carnagiea gigantea*) with the potential to support nest cavities, which is illustrated in table 3. Specifically, two-thirds of the total survey effort was targeted at sites where mesic riparian vegetation was present, with the remaining effort divided equally between xeric and exotic riparian types. Within each riparian type, effort was stratified equally among three adjoining upland vegetation types and between areas with and without mature saguaro cacti. There was not a corresponding quantitative stratification with respect to geographical and elevational gradients for two reasons:

1) Adding additional factors to the formal stratification that was invoked for vegetation type would have resulted in insufficient within-stratum replication.

2) The widely dispersed and spatially limited extent of potential elf owl breeding habitat, coupled with the practicalities of access and permitting, would have made a formal stratification using geography or elevation inherently problematic.

For these reasons, geographic and elevation gradients within the study area were treated as analytical factors rather than design factors, and efforts to accomplish

Table 2.—Vegetation classification system for describing elf owl habitat, modified from Anderson and Ohmart (1976)
(Also included is a system for rating vegetation structure)

Riparian vegetation community type	Criteria
Mesic riparian	Dominated by broadleaf deciduous species, primarily Fremont cottonwood and willow (*Salix* spp.), but may include Arizona ash (*Fraxinus velutina*) or Arizona black walnut (*Juglans major*), but with little or no western sycamore (*Platanus racemose*). Exotics may be present but not dominant.
Exotic riparian	Dominated by saltcedar (*Tamarix* spp.) or other exotics, including Russian olive (*Elaeagnus angustifolia*); may also include some mesquite (*Prosopis* spp.) or native broadleaf species but not as dominants.
Xeric riparian	Dominated by microphyllous species, including but not limited to mesquite (*Prosopis* spp.), catclaw acacia (*Acacia greggii*), and palo verde (*Parkinsonia* spp.)
Upland vegetation community type	**Criteria**
Desert woodland	Dominated by desert woodlands typical of upland areas with more mesic conditions or deeper soils or juniper (*Juniperus* spp.) woodlands, which could offer high-quality foraging habitat to elf owls. Desert woodland is typically more open than xeric riparian, and not part of the drainage channel, and it is taller and more structured than arborescent desert scrub.
Arborescent desert scrub	Dominated by palo verde, mixed cacti, or other similar arborescent associations typical of the Arizona upland subdivision of the Sonoran Desert, which could offer some foraging and nesting habitat to elf owls.
Desert shrubland	Dominated mainly by shrubs or subshrubs such as creosote (*Larrea tridentata*) and bursage (*Ambrosia* spp.) typical of (but not limited to) the Lower Colorado River Valley subdivision of the Sonoran Desert, which likely offer little foraging and nesting habitat for elf owls. This classification was also used for upland communities that had little vertical structure, such as old agricultural fields and stands of short (<1 m) woody shrubs and subshrubs.
Vegetation structure	**Criteria**
1	Very sparse vegetation: < 5% canopy cover in upper canopy layer.
2	Sparse vegetation: 5–10% canopy cover in upper canopy layer.
3	Open vegetation: 10–20% canopy cover in upper canopy layer.
4	Low vegetation cover: 20–40% canopy cover in upper canopy layer.
5	Moderate vegetation cover: 40–60% canopy cover in upper canopy layer.
6	High vegetation cover: 60–80% canopy cover in upper canopy layer.
7	Closed vegetation cover: > 80% canopy cover in upper canopy layer.

Figure 1.—Mesic riparian vegetation type.

Figure 2.—Xeric riparian vegetation type.

Figure 3.—Exotic riparian vegetation type.

Figure 4.—Desert woodland vegetation type.

Figure 5.—Arborescent desert scrub vegetation type.

Figure 6.—Desert shrubland vegetation type.

Table 3.—Idealized stratification of survey stations across all transects
(Two- and three-letter codes refer to defined vegetation types as follows:
MR = mesic riparian; ER = exotic riparian; XR = xeric riparian; DW = desert woodland, ADS = arborescent desert scrub; and DS = desert shrubland.)

Riparian type	Adjacent upland type	Mature saguaros?	Percent of survey stations
MR	DW	Yes	11.1
MR	DW	No	11.1
MR	ADS	Yes	11.1
MR	ADS	No	11.1
MR	DS	Yes	11.1
MR	DS	No	11.1
ER	DW	Yes	2.8
ER	DW	No	2.8
ER	ADS	Yes	2.8
ER	ADS	No	2.8
ER	DS	Yes	2.8
ER	DS	No	2.8
XR	DW	Yes	2.8
XR	DW	No	2.8
XR	ADS	Yes	2.8
XR	ADS	No	2.8
XR	DS	Yes	2.8
XR	DS	No	2.8

good coverage across these gradients were qualitative but largely successful. In a similar fashion, efforts were made to span the gradient from narrower linear stands of riparian vegetation to larger, more extensive patches.

Discovery Surveys

All data on elf owl occurrences in 2015 were collected by conducting discovery surveys. Stations were grouped into transects within which point spacing was 150 m, an interval that was based on the previous GBBO elf owl study

(GBBO 2012). Transects surveyed in 2015 consisted of 8–19 stations, which translates to an overall length of 1,000–2,850 m. The exact length of a given transect was left to the discretion of field crews depending on local conditions, difficulty of access, patch size of potential elf owl habitat, and the need to adhere as closely as possible to an idealized sampling stratification.

In order to maximize the number of sites surveyed in 2015, each transect was visited only once, and transects were laid out and waypointed immediately prior to surveys. A protocol for a rapid transect layout is given below. The purpose of the protocol was to ensure that each transect covered local vegetation gradients, from pure riparian vegetation to upland vegetation, while maintaining the desired survey emphasis on riparian areas. The following rules also served to largely randomize distances between stations and the riparian-upland ecotone, preventing a potential sampling bias.

1) Lay out transects during afternoon hours (or morning hours, if heat conditions dictate) on the same day as the discovery survey, which will begin at dusk.

2) Begin the transect at a random point alongside the main drainage channel or well within the riparian corridor if it is difficult to reach the drainage channel. This point will be the first station.

3) Mark and waypoint successive stations at 150-m intervals along a bearing approximately 15° from the orientation of the drainage channel in narrow riparian strips (< 50 m average width) and approximately 45° from the axis of the drainage channel in broader riparian zones such as those along major river valleys. The actual bearing used can deviate as necessary to take advantage of usable pathways and clearings, but it should angle away from the main drainage channel as close to the specified bearings as possible.

4) Continue along this approximate bearing, marking and waypointing stations, until reaching a point approximately 100 m into adjacent uplands, measured perpendicularly from the riparian-upland ecotone.

5) Change course at this point, angling back toward the drainage channel at a return angle that approximates your original departure angle.

6) Upon reaching the drainage channel, or the closest practicable point to the channel, change course again, angling away from the channel as described in step 3. Where it is feasible to cross the main drainage channel, the transect may continue along the same bearing until reaching 100 m into upland vegetation on the other side of the drainage channel.

7) Repeat steps 3–6 until the desired number of stations have been marked and waypointed.

8) In large riparian zones > 300 m wide, or where it is not practical or safe to cross drainage channels, transects will remain on one side of the channel. If riparian vegetation on the other side of channels appears suitable for elf owls, a different transect can be created on the other side. In narrower riparian zones where it is feasible to cross the main drainage channel, a transect may extend to both sides of the channel as described in step 6.

Discovery surveys commenced at dusk, and continued for up to 4 hours. This corresponds to the period when elf owls are most vocal and responsive based on past efforts (GBBO 2012). Discovery surveys were not conducted during periods of continuous precipitation or when the windspeed was sufficient to create consistently audible noise (typically > 20 kilometers per hour [km/h] sustained windspeed for most observers). Call-playback levels were identical to those used by GBBO in 2010–11 (GBBO 2012; ≈ 69 decibels at 1 m and ≈ 60 decibels at 30 m from the speaker). Call-playbacks were performed at every station within the transect and were configured as follows:

1) An initial 60 seconds of passive listening upon arriving at the station to detect and record elf owls that were calling before playback initiation.

2) Playback of three repetitions of a 1-minute recorded call cycle on a Fox Pro game caller, with each 1-minute cycle comprised of:

    a. 25 seconds of elf owl vocalizations consisting of six call iterations of territorial chatter calls

    b. 35 seconds of silence for passive listening

3) After the 3-minute playback period, an additional 60 seconds at the station for listening and to record required data

4) A total of at least 5 minutes was allotted to each station, but more time was allowed if needed to record data.

5) While moving along the transect to the next station, surveyors were allotted up to three minutes to stop for passive listening (usually at 50-m intervals), especially when listening conditions were suboptimal due to environmental noise or dense vegetation. This passive listening sometimes helped surveyors to refine their position estimates for calling owls and to estimate the total number of individuals present.

In addition to basic information on location, date, time, and surveyor identification, data collected during discovery surveys included items listed below.

1) Environmental conditions, including windspeed in kilometers per hour measured by Kestrel unit, ambient noise category, and moon phase (table 4).

Table 4.—Explanation of wind categories, noise categories, and moon phase categories

Wind category	Explanation
0	Calm; smoke rises vertically (< 2 km/h)
1	Smoke drifts (2–5 km/h)
2	Light breeze felt on face; leaves rustle (6–12 km/h)
3	Leaves and twigs in constant motion (13–19 km/h)
4	Small branches move; raises loose paper; dust rises (20–29 km/h)
5	Fresh breeze; small trees sway (30–39 km/h)
6	Strong breeze; large branches moving; wind whistling (40–50 km/h)
Noise category	**Explanation**
0	Quiet; normal background noises; no interference
1	Low noise; might be missing some songs/calls of distant owls
2	Medium noise; detection radius is probably substantially reduced
3	High noise; probably detecting only the loudest/closest owls
Moon phase	**Explanation**
Not visible	Not visible during survey
Crescent	3 days ± the occurrence of phase
Quarter	3 days ± the occurrence of phase
Gibbous	3 days ± the occurrence of phase
Full	3 days ± the occurrence of phase

2) Number of elf owl detections and time of each detection.

3) Type of elf owl call associated with each detection. These were as defined in Ligon (1968) and included:

   a. Territorial calls (used by males to attract mates and advertise).

   b. Agitated territorial calls (used by males in territorial defense).

   c. "Pew" contact calls (used by both sexes and not considered in and of itself as evidence of territoriality), though they may be exhibited by territorial pairs.

4) Estimated compass bearing and distance from the observer to the calling elf owl. These could not be determined precisely or in a fully standardized way but relied on the surveyor's perception of the direction from which the response came and the distance from point to the responding elf owl. Estimating distance was especially imprecise, as perceived distance could vary for reasons other than actual distance, including vegetation conditions, call type, elf owl position, and possibly individual elf owl variation. Surveyors were experienced avian biologists, and during early-season training they compared distance and direction estimates to responding elf owls to calibrate their perceptions to the extent possible.

5) Where possible, a field estimate of the vegetation type from which the elf owl was calling. In some cases, this could not be reliably determined in the field under nighttime conditions but was assessed later by plotting estimated elf owl positions on aerial imagery.

6) Distance of estimated elf owl positions to the riparian/upland edge. This distance was estimated in the field if possible or alternately assessed later by plotting estimated elf owl positions on aerial imagery.

Assessments

Each station, regardless of whether or not an elf owl detection occurred, was characterized using a rapid assessment protocol that relied primarily on visual estimation of selected environmental attributes and distances. Most of assessed attributes described either properties of the station itself, or properties of a 75-m-radius circle centered on stations, a scale that corresponds roughly to a typical elf owl home range (Ligon 1968; Gamel and Brush 2001). Rapid assessments of stations along each transect were made during daylight hours immediately after or while transects were being established and waypointed but before elf owl surveys commenced. Most attributes were assessed and recorded in the field, but some were generated post-hoc with the assistance of aerial imagery. The rapid assessment attributes (omitting basic location and time attributes) are listed below.

1) General vegetation category present immediately around the station. Three options were possible: "riparian," "ecotone," or "upland." Riparian vegetation comprised any mixture of the mesic, xeric, or exotic riparian vegetation types described earlier. Ecotone vegetation consisted of some mixture of the riparian and upland types. Upland vegetation was comprised of any mixture of the desert woodland, arborescent desert scrub, or desert shrubland vegetation types described earlier.

2) Distance from the station to the riparian/upland vegetation edge. Surveyors could estimate this distance in the field using either a rangefinder or by pacing when the distance was relatively short or the edge was in view. Alternately, the distance was estimated later by plotting station coordinates on top of an imagery layer (either in Google Earth or in the GPSMotionX app depending on which provided better visual resolution of the edge location) and using the software-provided measurement tool to determine distance to the edge. The vegetation edge (where riparian vegetation transitioned into upland vegetation was often narrow and distinct, but in other cases a broader transitional zone was present). In the latter cases, surveyors visually estimated the center of this band as well as possible and estimated the distance from the station to this center.

3) Width of the riparian corridor along a perpindicular line across the main channel passing through the station. As with the previous item, surveyors had the option to use a rangefinder or pacing to obtain this estimate in the field or to obtain the estimate later using imagery in Google Earth or the GPSMotionX app.

4) Specific vegetation types (see table 2, above) present within a 75-m-radius circle surrounding the station. More than one vegetation type, along with its proportional extent within the circle, could be recorded.

5) Average vegetation structural category (see table 2, above) for each of the vegetation types present within the 75-m circle.

6) Average height of riparian and upland vegetation types within the 75-m circle.

7) Percent volume (to the nearest 10% for values between 20 and 80% and to the nearest 5% otherwise) of each dominant tree species within the 75-m circle.

8) Distance to the nearest snag at least 24 inches in diameter at breast height within 200 m of the station.

9) Distance to the nearest mature saguaro (> 3 m tall and > 20 centimeters in diameter at breast height, as determined by eye) within 200 m of the station, in four 90° quarters delineated by drainage orientation and a perpendicular line across the drainage orientation.

Finally, all stations were photo-documented by taking four wide-angle photographs from a standing position at each of the stations, facing in the four orthogonal directions determined by the predominate orientation of the drainage (upstream, downstream, 90° to the right while facing upstream, and 90° to the left while facing upstream). Photos were of sufficient resolution to discern vegetation conditions.

Data Management and Analysis

Several steps were taken to ensure that data were recorded accurately and correctly. After each discovery and habitat survey session, surveyors (who worked in pairs) exchanged either their Trimble units to review one another's mobile electronic field form (MEFF)-based data or exchanged paper data forms for those instances in which MEFFs were not used. Any questionable data entries were brought to the attention of the surveyor who originally recorded them for possible correction. After this step, Trimble data were uploaded to Pathfinder software for further review or entered into Pathfinder manually in the case of paper-based data. This step was either performed or supervised in all cases by GBBO's David Vander Pluym or Alicia Arcidiacono, both of whom have worked multiple years on LCR MSCP projects and have high levels of competence and familiarity with MEFFs and Pathfinder. Once in Pathfinder, data were then differentially corrected, and any resulting coordinates that appeared problematic when plotted on base maps were further examined and corrected if appropriate. A final review of the data was conducted before the data were delivered to the Reclamation point-of-contact for further review. Any issues identified during this review were brought to the attention of GBBO and corrected as appropriate. After all reviews, data were bundled and submitted to Reclamation via the SharePoint system per Reclamation protocols. In addition, as a prerequisite to data analysis, Dr. Aaron Flesch reviewed and plotted tabular data to identify any outliers that might indicate data recording errors. If outliers in the data were detected, they were collectively assessed and corrected as appropriate; all corrected data were resubmitted to Reclamation.

Data analysis first focused on summarizing effort, environmental conditions, and distribution of elf owls at study sites, and second on assessing associations between probability of elf owl occurrence and various environmental and spatial variables.

A first step involved summarizing effort, environmental conditions, the frequency of occurrence (percent of stations where elf owls were present), and the number of elf owl detections across a range of design (i.e., vegetation type) and non-design (i.e., watersheds and jurisdictional authority) groupings. Frequency of occurrence and the number of elf owl detections at stations were examined versus the number of unique individual elf owls detected because that latter attribute is subject to high levels of uncertainty. To facilitate identification of prospective study sites for 2016 and 2017 efforts, the summary contrasted elf owl detections in mesic riparian vegetation both with and without mature saguaro cacti nearby because the latter situation suggests elf owls may occupy home ranges dominated entirely by riparian vegetation, which is of interest to Reclamation.

As a second step, factors were identified that explained the variation in the occurrence of elf owls. More specifically, generalized linear mixed models (GLMMs) were developed to estimate associations between the occurrence of elf owls and various vegetation and other environmental factors. These models estimated the probability of elf owl occurrence at the scale of individual survey stations using a binary response variable (elf owl detected or undetected) and a logit link function. Thus, GLMMs were equivalent to mixed-effects logistic regression. GLMMs are preferable to alternative methods such as generalized estimator equations because the resulting variance components (e.g., random effects) are directly interpretable and because the amounts of spatial process variation in occurrence explained by covariates can be estimated (Franklin et al. 2000; Bolker et al. 2009).

To address the potentially confounding effects of elf owls that were present but undetected during discovery surveys (e.g., MacKenzie et al. 2006), only a subset of survey data were considered when building GLMMs. The criteria for filtering data were:

1) Detections were excluded if an elf owl's position was estimated at > 100 m from stations. This distance was selected based on prior efforts that indicate detectability of a nesting, territorial male elf owl is ≈ 1.0 at 100 m from stations during the spring survey season even in dense vegetation (GBBO 2012). Also, because most of the assessment attributes were also recorded within a similar distance from stations (e.g., 75 m), this approach also augmented the precision of estimated model coefficients.

2) Detections that involved non-territorial elf owls (based on call type, see above) were excluded.

3) To increase independence, an attempt was made to include each unique individual elf owl only once in the analyses. It was not unusual for a given elf owl to be detected at two or more sequential stations along a transect, though we note that it was not possible to determine with complete assurance the instances in which these multiple detections occurred nor to entirely standardize the process by which judgments about individual elf owl identities were made. Rather, surveyors had to qualitatively assess information about the estimated distances, directions, and timing of elf owl responses, along with knowledge of local habitat configuration, to make their best judgments about individual elf owl identities. When an individual elf owl was detected from more than one station in the judgment of the surveyor, only the detection with the shortest estimated distance between the point and elf owl was included in the analysis.

Because stations along the same transects are not independent observations, and because responses from stations along the same transects and transects within the same watersheds are correlated, GLMMs were structured with three potential random effects: (1) transect identity as a random intercept, (2) transect nested within watershed as nested random intercepts, and (3) both transect and watershed as individual random intercepts. To determine optimal structures of the random effects, model selection techniques were employed that compared Akaike's information criterion adjusted for small sample sizes (AIC_c) among full models with the same fixed effects and each of those three random effects structures, and the top-ranked structure was used in subsequent models (Burnham and Anderson 2002; Zuur et al. 2009; Mazerolle 2012); following those sources, nested models within a ΔAIC_c of 2 points were considered as competitive when assessing both fixed and random effects. Random effects were evaluated for each set of models associated with the three modeling strategies described below. The lme4 library in R was used to fit GLMMs and estimate fixed and random effects (Bates et al. 2015; R Development Core Team 2016). All GLMM were fit by maximum likelihood using the adaptive Gauss-Hermite quadrature option in R, which is more accurate than alternatives such as Laplace approximation (Bolker et al. 2009).

Three modeling strategies were undertaken to build GLMMs that each addressed a different question. The first strategy assessed how the odds and probability of occurrence of elf owls varied among riparian and upland vegetation type and with the presence of mature saguaro cacti. Thus, this model fit dominant riparian and upland vegetation type and presence/absence of saguaros as additive nominal explanatory factors. No interactions were considered in the final models because small sample sizes within some groupings resulted in model convergence problems and because where models did converge, they were not justified based on model selection criteria. Fixed-effects estimates from that model were then used to compute the odds and probability of occurrence within each combination of those three design strata. Model selection was not used to evaluate support for fixed effects because models included only nominal design variables around which the sampling strategy was structured. To evaluate the effects of these nominal factors, Wald "Type III" tests, which test for the significance of each explanatory variable under the assumption that all other variables entered in the model equation are present, were also computed.

The second strategy assessed the explanatory power of various continuous vegetation variables such as vegetation height and species volume that were fit as fixed effects. An appropriate set of explanatory variables was obtained by first eliminating one variable from correlated ($r \geq 0.65$) pairs and then using backwards variable elimination on a full model that included all covariates and biologically plausible interactions (Zuur et al. 2009). Due to the large number of potential explanatory variables, a backwards elimination was conducted on the structural (e.g., vegetation height and cover) and compositional (e.g., volume of individual species or species groups) variables separately, and then variable sets were combined and re-evaluated (Ramsey and Schafer 2013). The resulting model was further refined by adding, subtracting, or changing the fixed effects and evaluating resulting changes in AIC_c to develop a final model from which inferences were made. For variables that were redundant (e.g., saguaro presence and density), competing models were compared that included each effect to determine the best predictor of occurrence, and the selected variable was used in all subsequent model building steps. Because vegetation volume data for individual plant species were often correlated with data on species groups, they were considered separately when building models, and AIC_c was used to identify variables that best explained the data.

The third strategy explored a series of additional models to assess the effects of three spatial factors (elevation, latitude, and longitude), and whether the influence of various riparian or upland vegetation variables (including important variables included in our final model from the second strategy) depended on them. By considering interactions between vegetation and those spatial factors, such models addressed the question of whether the importance of some factors varied geographically, which should be of interest to Reclamation given their efforts at the extreme western edge of an elf owl's geographic range. All spatial factors were considered on the standardized (*z*-scored) scales to improve model convergence.

Before model building, a series of variable evaluation, refinement, and reduction steps were performed to streamline analyses and better meet model assumptions. First, histograms of all continuous factors were plotted and some variables natural log transformed to reduce skew and potential for outliers in residuals where needed. Second, point-center quarter data for saguaros were converted from distances to relative densities by calculating the exponent of mean distances, weighting by number of quarters in which saguaros were present, and dividing by 10,000 (e.g., the number of square meters in a hectare). Third, the numerical midpoint of categorical cover (e.g., structural category) values was used to quantify cover at stations. Finally, plant species volume data were reduced by first combining values among similar or redundant species and then combining species into various physiognomic or life-form groups (e.g., microphyllous species, broadleaf deciduous, etc.). The volume of rare plant species and physiognomic or life-form groups was not considered when developing models because sample sizes were low and data composed mainly of zeros.

To evaluate models and validate fit, scaled residuals were plotted against fitted values and patterns in the mean, and variance of those values and presence of outliers with large influence were examined (Bolker 2015). Additionally, to validate the necessity of random intercepts, estimates of random effect variances were confirmed to be greater than zero. All models reported here met these assumptions, and there was no evidence of overdispersion in any final models. Finally, because receiver operating characteristic curves, which are typically used to evaluate logistic regression models, are not valid for mixed models, classification accuracy was assessed using more simplistic methods.
This involved using predicted probabilities from models, assuming that values ≥ 0.5 represented predicted elf owl occurrences, and calculating the proportion of cases that were correctly classified based on field observations.

Training, Timeline, and Personnel

Field crews assembled in early March 2015 and engaged in training, orientation, and field season preparation. The training and orientation program lasted approximately 1 week and included an introduction of project goals and protocols, field training in all techniques to be employed, and thorough treatment of data recording standards and data management requirements and duties. Crew members were familiarized with elf owl vocalization using recordings obtained from multiple sources, covering all the vocalization types described by Ligon (1968) and Henry and Gehlbach (1999). Additionally, each crew member was tested to ensure that they have adequate hearing ability to detect elf owl call-playbacks and vocalizations from at least 400 m under optimal conditions (no audible wind and no physical impediments to sound transmission). Telemetry training was conducted during this period and estimates to determine the accuracy of telemetry position fixes made. All field techniques were conducted under realistic but controlled field conditions to ensure comparability across the entire field team, particularly with regard to data collection that involves the estimation of distances or the rapid classification of vegetation type and habitat parameters.

Specifically, the training program served a standardization function and was designed to:

1) Ensure that field technicians had sufficient ability to properly recognize elf owl vocalizations.

2) Identify and calibrate any significant differences in crew members' threshold distance for hearing calls.

3) Calibrate crew members' estimation of habitat parameters, distances to detected owls, and estimation of telemetry distances and bearings under controlled circumstances. If non-trivial differences in estimations existed among crew members, efforts were made to obtain more closely converging estimates through comparison and repetition. Generally, the goal during training was to limit interobserver estimation variability to 10% if possible, but no more than 20%. This level of measurement error is not likely to appreciably change the categories that are assigned to specific attributes, and it is deemed analytically acceptable for a rapid habitat assessment approach.

Data collection began on March 17, 2015, and continued until June 5, 2015. Personnel involved in data collection were: Dr. Aaron Flesch, David Vander Pluym, Alicia Arcidiacono, Keith Brennan, Carlos Gonzalez Sanchez, and Diane Wong-Kone.

RESULTS

Summary Information

During the 2015 field season, discovery surveys were conducted along 112 transects across southern and western Arizona. That effort included 1,397 stations located between 181 and 1270 m elevation. Vegetation and environmental features were assessed at all stations. On average, transects included 12.5 ± 0.24 (± standard error [SE]) stations (range = 5–19 stations). Assuming exactly 150 m between stations, survey effort totaled 192.8 kilometers of transects (range = 0.6–2.7 kilometers per transect).

Effort was distributed across a large number of study sites (figure 7, table 5) that included all the general regions and watersheds in which 2015 surveys were proposed (see table 1). Few surveys were conducted in southwestern Arizona because broadleaf riparian vegetation was largely absent from this region. Effort spanned 9 major watersheds and portions of 38 drainages. Effort was greatest in the Bill Williams River watershed in western Arizona (25% of stations), which is the region most similar to that found in the Lower Colorado River Valley and thus most relevant to Reclamation’s management targets for elf owls. Effort in the Bill Williams River watershed spanned all major river bottoms, including the Santa Maria (10 transects), Big Sandy (5 transects), and Bill Williams (8 transects) Rivers, and smaller drainages such as Date Creek (5) and Bouse Wash (1). Effort was moderately high in the San Pedro (18% of stations), Verde (14%), and Gila (14%) watersheds. Coverage in the Gila watershed was spatially broad and spanned locations between 181 m elevation near Painted Rock Reservoir to 1103 m elevation in the Gila Box region east of Safford (figure 7). Effort was lowest in the Santa Cruz (7%), Agua Fria (7%), Brawley (6%), Salt (5%), and Hassayampa (4%) watersheds.

At the watershed scale, effort in mesic riparian vegetation was greater than that in other vegetation types except in the Brawley, Gila, Hassayampa, and Salt watersheds where broadleaf deciduous vegetation cover was rare. At the station scale, effort in riparian vegetation was much greater than that in uplands, and that effort was focused largely in mesic versus xeric or exotic riparian vegetation, except in those watersheds where broadleaf deciduous vegetation cover was rare (table 6). Across all stations, 78% were placed in riparian vegetation or along its ecotone versus 22% in upland vegetation. With regard to dominant vegetation communities within 75 m of the 1,397 stations, 95% of stations included at least some riparian vegetation versus 66% with at least some upland vegetation. Among stations where riparian vegetation was present within 75 m, mesic riparian vegetation was dominant at 51% of stations, with less xeric (33%) and especially exotic (16%) riparian types. Among stations where upland vegetation was present within 75 m of the station, arborescent desert scrub was dominant at 45% of stations with less desert woodland (32%) and scrubland (23%).

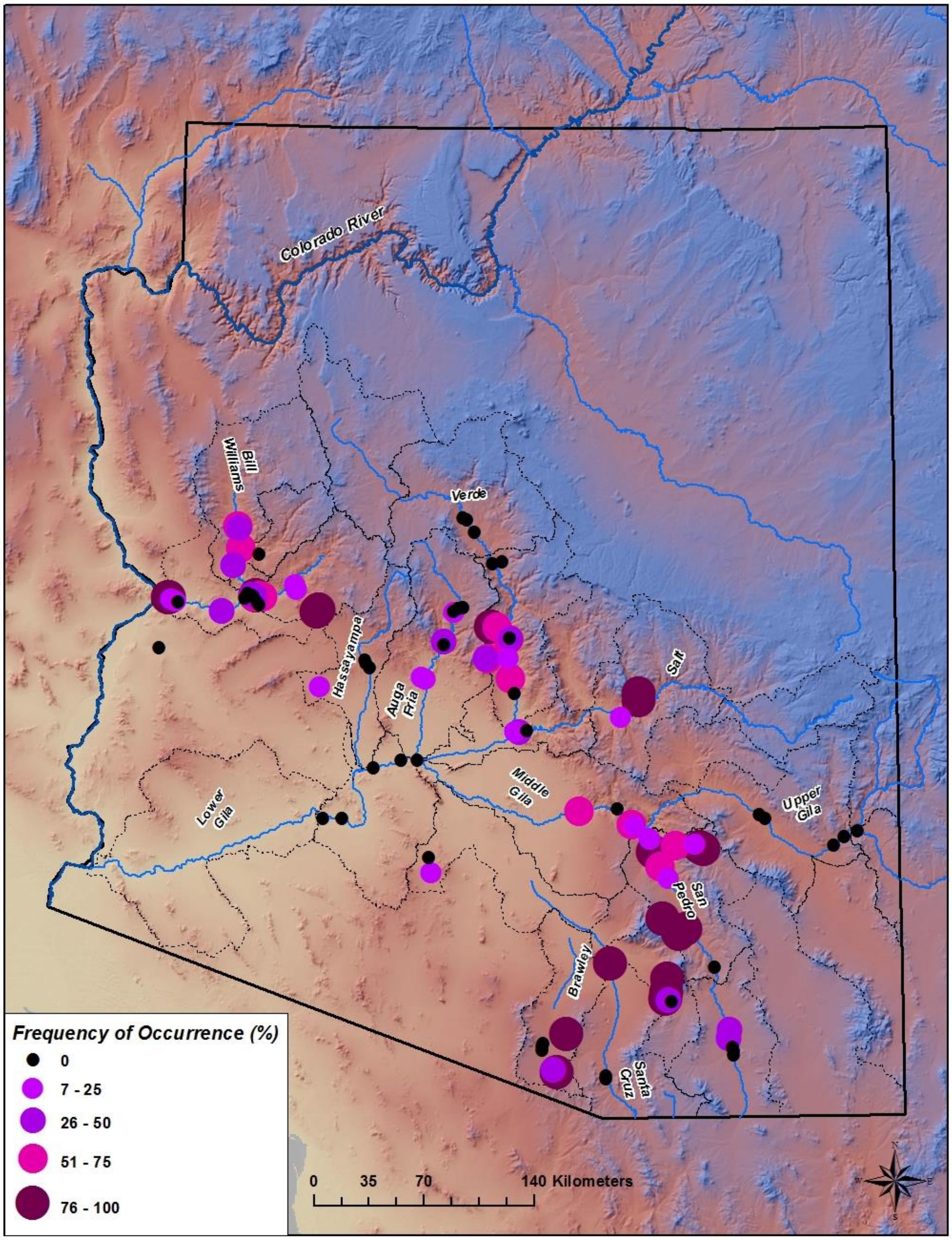

Figure 7.—Distribution and frequency of occurrence of elf owls at stations (*n* = 1,212) along 112 transects across southern and western Arizona, March – June 2015.
The names and boundaries (hatched lines) of 11 watershed regions are illustrated.

Table 5.—Elf owl detections at 112 transects (*n* = 1,397 stations) in southern and western Arizona, March – June 2015
(Columns indicating "Percent stations" within riparian, upland, or ecotone vegetation refer to the vegetation type occurring immediately surrounding the survey point.)

Watershed drainage	Transects	Stations	Minimum elevation (m)	Maximum elevation (m)	Percent stations in riparian	Percent stations in ecotone	Percent stations in upland	Total detections	Percent stations with detections
Agua Fria	**8**	**99**	**486**	**1097**	**64.6**	**5.1**	**30.3**	**21**	**15.2**
Agua Fria River	5	61	609	1035	65.6	4.9	29.5	17	18.0
Morgan City Wash	2	26	486	549	57.7	7.7	34.6	4	15.4
Silver Creek	1	12	1036	1097	75.0	0.0	25.0	0	0.0
Bill Williams	**31**	**342**	**177**	**914**	**64.0**	**11.7**	**24.3**	**189**	**36.8**
Big Sandy River	5	61	365	609	75.4	3.3	21.3	54	47.5
Bill Williams River	8	84	177	365	56.0	15.5	28.6	35	29.8
Bouse Wash*	1	8	229	235	25.0	75.0	0.0	0	0.0
Burro Creek	1	10	609	656	70.0	0.0	30.0	0	0.0
Date Creek	5	60	405	914	70.0	11.7	18.3	45	53.3
Hackberry Wash	1	12	609	609	58.3	25.0	16.7	1	8.3
Santa Maria River	10	107	365	566	63.6	8.4	28.0	54	36.4
Brawley	**6**	**85**	**1015**	**1090**	**67.1**	**5.9**	**27.1**	**84**	**37.6**
Arivaca Creek	2	28	1048	1090	67.9	3.6	28.6	29	64.3
Buenos Aires National Wildlife Refuge washes (three unnamed drainages)	3	43	1015	1066	65.1	7.0	27.9	0	0.0
San Juan Wash	1	14	1040	1072	71.4	7.1	21.4	55	100.0
Gila	**16**	**202**	**181**	**1103**	**70.8**	**11.9**	**17.3**	**30**	**11.4**
Gila River	14	176	181	1103	71.6	12.5	15.9	29	12.5
Vekol Wash	2	26	544	609	65.4	7.7	26.9	1	3.8
Hassayampa	**4**	**54**	**609**	**671**	**55.6**	**20.4**	**24.1**	**2**	**3.7**
Dead Horse Wash	1	17	631	671	52.9	23.5	23.5	2	11.8
Hassayampa River	3	37	609	610	56.8	18.9	24.3	0	0.0

Table 5.—Elf owl detections at 112 transects (n = 1,397 stations) in southern and western Arizona, March – June 2015
(Columns indicating "Percent stations" within riparian, upland, or ecotone vegetation refer to the vegetation type occurring immediately surrounding the survey point.)

Watershed drainage	Transects	Stations	Minimum elevation (m)	Maximum elevation (m)	Percent stations in riparian	Percent stations in ecotone	Percent stations in upland	Total detections	Percent stations with detections
Salt	**6**	**70**	**425**	**913**	**62.9**	**8.6**	**28.6**	**57**	**45.7**
Cherry Creek	2	25	852	913	56.0	12.0	32.0	46	96.0
Salt River	4	45	425	670	66.7	6.7	26.7	11	17.8
San Pedro	**18**	**248**	**609**	**1270**	**83.1**	**8.1**	**8.9**	**262**	**46.4**
Alder Canyon	1	11	1219	1270	63.6	0.0	36.4	44	100.0
Aravaipa Creek	4	56	792	1055	73.2	21.4	5.4	75	73.2
Buehman Canyon	2	36	914	1036	66.7	11.1	22.2	92	91.7
San Pedro River	11	145	609	1191	92.4	2.8	4.8	51	20.7
Santa Cruz	**8**	**99**	**732**	**1096**	**67.7**	**10.1**	**22.2**	**130**	**52.5**
Cienega Creek	3	37	1036	1071	59.5	10.8	29.7	20	43.2
Posta Quemada Canyon	1	13	1036	1096	53.8	23.1	23.1	39	100.0
Rincon Creek	1	13	975	975	69.2	0.0	30.8	50	100.0
Santa Cruz River	2	26	985	1005	92.3	7.7	0.0	0	0.0
Tumamoc Hill washes	1	10	732	789	50.0	10.0	40.0	21	100.0
Verde	**15**	**198**	**487**	**1269**	**60.6**	**11.1**	**28.3**	**80**	**28.8**
Cave Creek	2	28	933	1269	32.1	17.9	50.0	27	67.9
Clear Creek	1	13	1032	1036	76.9	7.7	15.4	0	0.0
Indian Springs Wash	1	13	792	855	53.8	15.4	30.8	11	61.5
Seven Springs Wash	1	13	1094	1108	7.7	0.0	92.3	10	61.5
Sycamore Creek	1	7	670	684	71.4	28.6	0.0	2	28.6
Tangle Creek	1	14	853	914	71.4	7.1	21.4	18	71.4
Verde River	8	110	487	1213	70.9	10.0	19.1	12	9.1

* Located in a small watershed to the south of the Bill Williams watershed.

Table 6.—Actual effort across each combination of riparian and upland vegetation communities with and without mature saguaro cacti that were surveyed for elf owls with discovery surveys in southern and western Arizona, March – June 2015
("Percent difference" values are percent differences between proposed (see table 3) and actual sampling effort. Dominant vegetation communities in both riparian and upland communities were measured within 75 m of stations, and presence of saguaros was measured within 200 m of stations.)

Riparian vegetation type Upland vegetation type	Number of saguaros			Number of saguaros			Total*		
	Number of stations	Percent of all stations	Percent difference	Number of stations	Percent of all stations	Percent difference	Number of stations	Percent of all stations	Percent difference
Mesic riparian	**410**	**33.8**	**0.5**	**175**	**14.4**	**-18.9**	**585**	**48.3**	**-18.4**
Desert woodland	114	9.4	-1.7	31	2.6	-8.5	145	12.0	-10.2
Arborescent desert scrub	48	4.0	-7.1	104	8.6	-2.5	152	12.5	-9.7
Desert shrubland	25	2.1	-9.0	17	1.4	-9.7	42	3.5	-18.7
None	223	18.4	N/A	23	1.9	N/A	246	20.3	N/A
Exotic riparian	**140**	**11.6**	**3.2**	**59**	**4.9**	**-3.5**	**199**	**16.4**	**-0.2**
Desert woodland	22	1.8	-1.0	4	0.3	-2.5	26	2.1	-3.4
Arborescent desert scrub	10	0.8	-2.0	29	2.4	-0.4	39	3.2	-2.3
Desert shrubland	26	2.1	-0.7	15	1.2	-1.6	41	3.4	-2.2
None	82	6.8	N/A	11	0.9	N/A	93	7.7	N/A
Xeric riparian	**160**	**13.2**	**4.8**	**213**	**17.6**	**9.2**	**373**	**30.8**	**14.1**
Desert woodland	49	4.0	1.2	20	1.7	-1.1	69	5.7	0.1
Arborescent desert scrub	21	1.7	-1.1	116	9.6	6.8	137	11.3	5.8
Desert shrubland	51	4.2	1.4	38	3.1	0.3	89	7.3	1.8
None	39	3.2	N/A	39	3.2	N/A	78	6.4	N/A
No riparian vegetation	**22**	**1.8**	**N/A**	**33**	**2.7**	**N/A**	**55**	**4.5**	**N/A**
Desert woodland	9	0.7	N/A	5	0.4	N/A	14	1.2	N/A
Arborescent desert scrub	3	0.2	N/A	21	1.7	N/A	24	2.0	N/A
Desert shrubland	10	0.8	N/A	7	0.6	N/A	17	1.4	N/A

* Total percentages may differ slightly from the sums of component percentages due to rounding errors.

The idealized stratification of sampling effort proposed was closely followed, except where rarity of combinations of strata precluded such allocation (tables 3 and 6). For example, effort in mesic riparian vegetation in areas without saguaros was within 1% of that proposed but 19% lower in areas with saguaros due to the rarity of saguaros in or close to broadleaf deciduous vegetation (see table 6). Effort in exotic riparian vegetation was within 4% of that proposed in all combinations of strata, whereas effort in xeric riparian areas tended to be higher due to high cover of microphyllous tree species even in areas dominated largely by broadleaf deciduous riparian vegetation (see table 6).

Study sites spanned multiple jurisdictional or land management designations (attachment 1). They included private lands owned by various individuals and entities, and lands managed by the Bureau of Land Management, U.S. Forest Service, U.S. Fish and Wildlife Service, Pima County, National Park Service, State of Arizona (State Parks and State Trust lands), and other agencies, and lands owned by The Nature Conservancy, which spanned five different preserves (attachment 1).

Elf Owl Detections

A total of 855 detections of elf owls were recorded, representing an estimated 553 unique individuals. One or more elf owls were detected at 33% of stations and 43% of transects. The number of elf owl detections per station ranged from 0 to 6 and averaged 7.6 ± 1.1 detections per transect (range = 0–58). Elf owls were typically detected close to stations; median detection distance was 83 m, and average detection distance was 104 ± 3 m from stations, with only 25% at distances > 140 m. After censoring detections of elf owls estimated to be > 100 m from a station, non-territorial elf owls, and those detected more than once in the best judgment of surveyors, 22% of 1,212 stations were occupied by elf owls, with the remaining stations censored from the analyses. Presence/absence data from those stations were used when developing GLMMs (see "Data Management and Analysis" in the "Methods" section, above).

Elf owls were detected within all nine major watersheds surveyed (see table 5 and figure 7). At the scale of stations, frequency of elf owl occurrence was greatest in the eastern portion of the study area in the Santa Cruz (53%), San Pedro (46%), and Salt (46%) River watersheds (table 3), where average vegetation cover and height were often higher than in other watersheds (tables 7a–b). In contrast, the frequency of elf owl occurrence was moderate in the Bill Williams (37%), Brawley (38%), and Verde (29%) watersheds, and lower in the Agua Fria (15%), Gila (11%), and Hassayampa (4%) watersheds.

Elf owls were detected in mesic riparian vegetation in 78% (n = 7 of 9) of watersheds (all except Gila and Hassayampa), and 50% (n = 19 of 38) of drainages (table 8). When standardized by effort (e.g., number of stations),

Table 7a.—Riparian vegetation conditions for 112 transects (*n* = 1,397 stations) surveyed for elf owls across 9 major watersheds in southern and western Arizona, March – June 2015

(Cover, height, and dominant vegetation community were assessed within 75 m of stations, and width of riparian vegetation corridor was measured at larger scales around stations. Cover and height means refer to riparian vegetation types present with 75 m only. Riparian vegetation types are mesic riparian [MR], xeric riparian [XR], and exotic riparian [ER]). Bolded values are at watershed scale.)

Watershed drainage	Number of stations	Riparian width (m) (mean ± SE)	Percent cover (mean ± SE)	Height (m) (mean ± SE)	Percent of stations with MR*	Percent of stations with XR*	Percent of stations with ER*	Percent of stations without riparian*
Agua Fria	**99**	**82 ± 5**	**37.2 ± 2.3**	**5.4 ± 0.3**	**76**	**18**	**0**	**6**
Agua Fria River	61	97 ± 6	30.9 ± 2.5	5.2 ± 0.4	87	7	0	7
Morgan City Wash	26	65 ± 6	41.4 ± 5.4	5.4 ± 0.7	38	54	0	8
Silver Creek	12	45 ± 4	60.0 ± 3.9	7.0 ± 0.6	100	0	0	0
Bill Williams	**342**	**587 ± 22**	**47.4 ± 1.4**	**5.4 ± 0.2**	**42**	**31**	**18**	**8**
Big Sandy River	61	615 ± 39	48.0 ± 2.6	5.7 ± 0.4	49	13	33	5
Bill Williams River	84	866 ± 54	55.0 ± 3.1	6.3 ± 0.4	50	15	23	12
Bouse Wash**	8	227 ± 31	30.0 ± 0.0	2.4 ± 0.2	0	100	0	0
Burro Creek	10	116 ± 5	35.0 ± 5.0	4.1 ± 0.6	10	80	0	10
Date Creek	60	199 ± 16	31.8 ± 2.5	4.7 ± 0.3	38	53	0	8
Hackberry Wash	12	178 ± 23	31.9 ± 7.0	1.9 ± 0.3	0	92	0	8
Santa Maria River	107	685 ± 28	54.1 ± 2.4	5.7 ± 0.3	45	25	22	7
Brawley	**85**	**162 ± 12**	**43.6 ± 1.8**	**4.5 ± 0.3**	**21**	**72**	**0**	**7**
Arivaca Creek	28	211 ± 25	52.5 ± 2.9	7.2 ± 0.5	64	32	0	4
Buenos Aires National Wildlife Refuge	43	113 ± 13	37.4 ± 2.4.	3.3 ± 0.2	0	91	0	9
San Juan Wash	14	218 ± 16	45.0 ± 4.8	2.9 ± 0.3	0	93	0	7
Gila	**202**	**975 ± 66**	**48.8 ± 1.5**	**5.1 ± 0.2**	**12**	**24**	**60**	**3**
Gila River	176	1089 ± 72	52.2 ± 1.6	5.4 ± 0.3	14	14	69	3
Vekol Wash	26	201 ± 32	25.6 ± 2.1	2.8 ± 0.2	0	92	0	8

Table 7a.—Riparian vegetation conditions for 112 transects (*n* = 1,397 stations) surveyed for elf owls across 9 major watersheds in southern and western Arizona, March – June 2015

(Cover, height, and dominant vegetation community were assessed within 75 m of stations, and width of riparian vegetation corridor was measured at larger scales around stations. Cover and height means refer to riparian vegetation types present with 75 m only. Riparian vegetation types are mesic riparian [MR], xeric riparian [XR], and exotic riparian [ER]). Bolded values are at watershed scale.)

Watershed drainage	Number of stations	Riparian width (m) (mean ± SE)	Percent cover (mean ± SE)	Height (m) (mean ± SE)		Percent of stations with MR*	Percent of stations with XR*	Percent of stations with ER*	Percent of stations without riparian*
Hassayampa	**54**	**286 ± 20**	**49.6 ± 3.7**	**6.5 ± 0.5**		**44**	**50**	**0**	**6**
Dead Horse Wash	17	115 ± 15	22.9 ± 2.3	3.1 ± 0.3		0	94	0	6
Hassayampa River	37	364 ± 16	61.9 ± 4.0	8.1 ± 0.6		65	30	0	5
Salt	**70**	**547 ± 48**	**38.2 ± 2.4**	**4.0 ± 0.3**		**19**	**57**	**20**	**4**
Cherry Creek	25	250 ± 27	42.6 ± 4.2	4.6 ± 0.8		32	64	0	4
Salt River	45	711 ± 61	35.8 ± 3.0	3.6 ± 0.3		11	53	31	4
San Pedro	**248**	**582 ± 28**	**54.0 ± 1.1**	**9.5 ± 0.3**		**72**	**22**	**6**	**0**
Alder Canyon	11	55 ± 4	62.7 ± 3.0	9.5 ± 0.3		100	0	0	0
Aravaipa Creek	56	285 ± 18	60.9 ± 2.7	10.8 ± 0.6		89	9	2	0
Buehman Canyon	36	116 ± 9	44.8 ± 3.4	7.5 ± 0.8		47	53	0	0
San Pedro River	145	852 ± 30	53.0 ± 1.3	9.4 ± 0.3		69	21	9	1
Santa Cruz	**99**	**324 ± 33**	**57.2 ± 2.3**	**10.4 ± 0.6**		**58**	**38**	**0**	**4**
Cienega Creek	37	177 ± 14	58.0 ± 4.4	11.4 ± 0.8		76	16	0	8
Posta Quemada Canyon	13	103 ± 13	51.5 ± 4.8	7.5 ± 1.3		31	69	0	0
Rincon Creek	13	219 ± 10	44.6 ± 5.1	5.9 ± 0.7		38	54	0	8
Santa Cruz River	26	798 ± 58	68.5 ± 3.3	15.2 ± 0.7		77	23	0	0
Tumamoc Hill washes	10	63 ± 13	48.5 ± 5.2	3.5 ± 0.2		0	100	0	0

Table 7a.—Riparian vegetation conditions for 112 transects (*n* = 1,397 stations) surveyed for elf owls across 9 major watersheds in southern and western Arizona, March – June 2015

(Cover, height, and dominant vegetation community were assessed within 75 m of stations, and width of riparian vegetation corridor was measured at larger scales around stations. Cover and height means refer to riparian vegetation types present with 75 m only. Riparian vegetation types are mesic riparian [MR], xeric riparian [XR], and exotic riparian [ER]). Bolded values are at watershed scale.)

Watershed drainage	Number of stations	Riparian width (m) (mean ± SE)	Percent cover (mean ± SE)	Height (m) (mean ± SE)		Percent of stations with MR*	Percent of stations with XR*	Percent of stations with ER*	Percent of stations without riparian*
Verde	**198**	**295 ± 22**	**54.1 ± 1.3**	**7.8 ± 0.3**		**76**	**20**	**1**	**4**
Cave Creek	28	87 ± 10	55.7 ± 3.7	7.4 ± 0.5		93	0	0	7
Clear Creek	13	275 ± 13	53.1 ± 7.0	7.3 ± 1.0		85	0	0	15
Indian Springs Wash	13	71 ± 5	54.6 ± 2.4	3.0 ± 0.1		0	100	0	0
Seven Springs Wash	13	45 ± 3	56.2 ± 7.9	9.5 ± 1.3		85	0	0	15
Sycamore Creek	7	52 ± 4	70.0 ± 6.2	6.6 ± 0.6		100	0	0	0
Tangle Creek	14	79 ± 7	60.0 ± 3.5	9.6 ± 0.7		100	0	0	0
Verde River	110	450 ± 33	51.7 ± 1.6	8.1 ± 0.4		74	25	1	1

* Percentages of stations with different types of riparian vegetation may not total to exactly 100% due either to rounding errors or the occasional presence of more than one riparian type within 75 m of some stations.

** Located in a small watershed to the south of the Bill Williams watershed.

Table 7b.—Upland vegetation conditions and saguaro density along 112 transects (*n* = 1,397 stations) surveyed for elf owls across 9 major watersheds in southern and western Arizona, March – June 2015

(Cover, height, and dominant vegetation community were measured within 75 m of stations and saguaro density [within 200 m] was measured at a larger scale around stations. Cover and height means refer to upland vegetation types only. Upland vegetation types are desert woodland [DW], arborescent desert scrub [ADS], and desert shrubland [DS]). Bolded values are at watershed scale.)

Watershed Drainage	Number of stations	Saguaros per hectare (mean ± SE)	Percent cover (mean ± SE)	Height (m) (mean ± SE)		Percent stations with DW*	Percent stations with ADS*	Percent stations with DW*	Percent stations without upland*
Agua Fria	**99**	**3.2 ± 1.2**	**30.2 ± 1.4**	**1.9 ± 0.1**		**16**	**79**	**4**	**1**
Agua Fria River	61	3.6 ± 1.8	31.3 ± 1.9	2.0 ± 0.1		20	75	3	2
Morgan City Wash	26	3.5 ± 1.2	23.1 ± 1.5	2.1 ± 0.1		0	92	8	0
Silver Creek	12	0.0 ± 0.0	40.0 ± 4.6	1.5 ± 0.2		33	67	0	0
Bill Williams	**342**	**0.5 ± 0.1**	**19.2 ± 1.0**	**1.3 ± 0.1**		**7**	**34**	**20**	**39**
Big Sandy River	61	1.0 ± 0.3	16.1 ± 2.7	0.9 ± 0.1		2	36	2	61
Bill Williams River	84	0.2 ± 0.1	17.0 ± 1.8	1.5 ± 0.1		20	20	25	35
Bouse Wash**	8	0.0 ± 0.0	13.1 ± 1.2	1.0 ± 0.0		0	0	100	0
Burro Creek	10	0.7 ± 0.3	32.5 ± 3.3	2.0 ± 0.1		0	100	0	0
Date Creek	60	0.3 ± 0.1	28.5 ± 2.6	1.5 ± 0.1		0	43	32	25
Hackberry Wash	12	0.9 ± 0.5	26.3 ± 5.1	1.5 ± 0.2		0	67	25	8
Santa Maria River	107	0.4 ± 0.1	15.9 ± 1.7	1.1 ± 0.1		6	31	17	47
Brawley	**85**	**0.1 ± 0.0**	**29.4 ± 2.1**	**2.1 ± 0.1**		**56**	**29**	**2**	**12**
Arivaca Creek	28	0.0 ± 0.0	38.6 ± 4.6	1.7 ± 0.2		18	57	4	21
Buenos Aires National Wildlife Refuge	43	0.1 ± 0.1	25.2 ± 2.3	2.6 ± 0.1		81	19	0	0
San Juan Wash	14	0.2 ± 0.1	24.3 ± 4.7	1.5 ± 0.3		57	7	7	29
Gila	**202**	**1.1 ± 0.6**	**18.8 ± 1.4**	**1.1 ± 0.1**		**10**	**19**	**32**	**39**
Gila River	176	1.3 ± 0.6	18.0 ± 1.5	1.1 ± 0.1		12	21	25	42
Vekol Wash	26	0.2 ± 0.2	23.8 ± 3.0	1.1 ± 0.1		0	4	81	15

Table 7b.—Upland vegetation conditions and saguaro density along 112 transects (*n* = 1,397 stations) surveyed for elf owls across 9 major watersheds in southern and western Arizona, March – June 2015

(Cover, height, and dominant vegetation community were measured within 75 m of stations and saguaro density [within 200 m] was measured at a larger scale around stations. Cover and height means refer to upland vegetation types only. Upland vegetation types are desert woodland [DW], arborescent desert scrub [ADS], and desert shrubland [DS]). Bolded values are at watershed scale.)

Watershed Drainage	Number of stations	Saguaros per hectare (mean ± SE)	Percent cover (mean ± SE)	Height (m) (mean ± SE)	Percent stations with DW*	Percent stations with ADS*	Percent stations with DW*	Percent stations without upland*
Hassayampa	**54**	**0.9 ± 0.4**	**25.0 ± 3.0**	**1.4 ± 0.1**	**7**	**46**	**15**	**31**
Dead Horse Wash	17	2.2 ± 1.1	22.8 ± 2.6	2.1 ± 0.1	0	59	41	0
Hassayampa River	37	0.3 ± 0.1	26.1 ± 4.2	1.1 ± 0.2	11	41	3	46
Salt	**70**	**1.1 ± 0.3**	**20.8 ± 2.4**	**1.2 ± 0.1**	**3**	**39**	**19**	**40**
Cherry Creek	25	0.5 ± 0.2	27.9 ± 4.1	1.3 ± 0.2	0	56	16	28
Salt River	45	1.4 ± 0.4	16.8 ± 2.8	1.1 ± 0.2	4	29	20	47
San Pedro	**248**	**0.5 ± 0.1**	**18.2 ± 1.3**	**1.2 ± 0.1**	**25**	**19**	**7**	**49**
Alder Canyon	11	3.3 ± 0.9	46.4 ± 2.4	2.3 ± 0.1	73	27	0	0
Aravaipa Creek	56	0.3 ± 0.1	22.8 ± 3.1	1.2 ± 0.1	36	18	7	39
Buehman Canyon	36	1.5 ± 0.2	27.5 ± 1.8	2.6 ± 0.2	19	75	0	6
San Pedro River	145	0.1 ± 0.0	12.0 ± 1.6	0.7 ± 0.1	19	4	9	68
Santa Cruz	**99**	**0.7 ± 0.2**	**30.3 ± 2.2**	**2.0 ± 0.1**	**33**	**39**	**3**	**24**
Cienega Creek	37	0.2 ± 0.1	38.6 ± 2.8	2.8 ± 0.2	51	38	5	5
Posta Quemada Canyon	13	2.1 ± 0.4	38.5 ± 5.3	2.7 ± 0.3	23	69	0	8
Rincon Creek	13	0.6 ± 0.1	32.3 ± 6.1	1.9 ± 0.3	31	46	0	23
Santa Cruz River	26	0.0 ± 0.0	12.8 ± 4.4	0.8 ± 0.3	27	0	4	69
Tumamoc Hill washes	10	2.5 ± 1.3	32.0 ± 2.0	1.9 ± 0.1	0	100	0	0

Table 7b.—Upland vegetation conditions and saguaro density along 112 transects (*n* = 1,397 stations) surveyed for elf owls across 9 major watersheds in southern and western Arizona, March – June 2015

(Cover, height, and dominant vegetation community were measured within 75 m of stations and saguaro density [within 200 m] was measured at a larger scale around stations. Cover and height means refer to upland vegetation types only. Upland vegetation types are desert woodland [DW], arborescent desert scrub [ADS], and desert shrubland [DS]). Bolded values are at watershed scale.)

Watershed Drainage	Number of stations	Saguaros per hectare (mean ± SE)	Percent cover (mean ± SE)	Height (m) (mean ± SE)	Percent stations with DW*	Percent stations with ADS*	Percent stations with DW*	Percent stations without upland*
Verde	**198**	**0.6 ± 0.2**	**31.6 ± 1.8**	**1.3 ± 0.1**	**42**	**12**	**15**	**31**
Cave Creek	28	0.0 ± 0.0	45.2 ± 2.1	2.1 ± 0.1	75	11	14	0
Clear Creek	13	0.0 ± 0.0	17.7 ± 5.0	1.2 ± 0.3	54	0	0	46
Indian Springs Wash	13	2.9 ± 0.9	39.2 ± 2.9	1.5 ± 0.1	0	38	62	0
Seven Springs Wash	13	0.0 ± 0.0	68.5 ± 2.7	1.3 ± 0.2	23	0	77	0
Sycamore Creek	7	1.5 ± 0.3	38.6 ± 4.0	1.7 ± 0.3	43	43	14	0
Tangle Creek	14	0.1 ± 0.0	50.0 ± 2.1	2.2 ± 0.1	100	0	0	0
Verde River	110	0.6 ± 0.3	21.8 ± 2.4	0.9 ± 0.1	33	11	6	50

* Percentages of stations with different types of upland vegetation may not total to exactly 100% due either to rounding errors or the occasional presence of more than one upland type within 75 m of some stations.

** Located in a small watershed to the south of the Bill Williams watershed.

Table 8.—Elf owl detections in mesic riparian vegetation in southern and western Arizona, March – June 2015, by study site

Watershed Location	Reach	Stations	Total detections	Detections per station	Mean number of saguaros per hectare	Percent stations with saguaros
Agua Fria						
Agua Fria River	Middle	61	3	0.049		70.5
Bill Williams						
Big Sandy River	Upper	27	14	0.519	0.47	14.8
Bill Williams River	Lower	50	9	0.180	0.25	44.0
Date Creek	Upper	26	9	0.346	0.41	84.6
Santa Maria River	Lower	95	20	0.211	0.44	53.7
Santa Maria River	Middle	12	2	0.167	0.49	100.0
Brawley*						
Arivaca Creek	Middle	28	15	0.536	0.00	0.0
Salt						
Cherry Creek	Middle	25	10	0.400	0.49	52.0
San Pedro						
Alder Canyon	Middle	11	8	0.727	3.26	100.0
Aravaipa Creek	Upper	43	53	1.233	0.00	0.0
Buehman Canyon	Upper	19	19	1.000	1.92	100.0
San Pedro River	Lower	39	4	0.103	0.08	15.4
San Pedro River	Middle	40	1	0.025	0.14	27.5
San Pedro River	Upper	66	11	0.167	0.00	0.0
Santa Cruz*						
Cienega Creek	Middle	37	8	0.216	0.21	27.0
Posta Quemada Canyon	N/A	13	5	0.385	2.14	100.0
Rincon Creek	N/A	13	14	1.077	0.58	100.0
Verde						
Cave Creek	Lower	15	5	0.333	0.00	0.0
Cave Creek	Upper	13	12	0.923	0.00	0.0
Seven Springs Wash	Lower	13	9	0.692	0.00	0.0
Sycamore Creek	Lower	7	1	0.143	1.47	100.0
Tangle Creek	Upper	14	12	0.857	0.10	50.0
Verde River	Lower	45	1	0.022	1.59	64.4

drainages with the greatest number of elf owl detections in mesic riparian vegetation were in the San Pedro and Santa Cruz watersheds in eastern Arizona, with moderate numbers in the Bill Williams and Verde watersheds in western and central Arizona, respectively (see table 8). Importantly, saguaros with potential to support nest cavities were present along 74% (n = 17 of 23) of drainage reaches where elf owls were detected in mesic riparian vegetation. Only along Arivaca Creek, upper Aravaipa Creek, upper San Pedro River, upper and lower Cave Creek, and lower Seven Springs Wash were elf owls detected in mesic riparian vegetation in the absence of saguaros, suggesting elf owls in those areas nest in trees (see table 8).

Occurrence Among Vegetation Strata

Random Effects

A model with transect fit as a random intercept provided the best overall description of the data versus models with transect and watershed fit as non-nested ($\Delta AIC_c = 2.96$) or nested ($\Delta AIC_c = 5.64$) random intercepts (attachment 2). This is because estimated variance in occupancy among transects (range = 10.05–13.07) was 4.7 times greater than that among watersheds, depending on the random effects structure considered (attachment 2).

Fixed Effects

Probability of elf owl occurrence varied significantly among two of the three vegetation strata considered as design variables (figures 8 and 9). Differences in probability of occurrence were much greater between stations with and without saguaros ($\chi^2 = 21.39$, $P < 0.001$; Type III Wald tests) than among different riparian ($\chi^2 = 10.07$, $P = 0.018$) and especially upland ($\chi^2 = 2.08$, $P = 0.55$) vegetation types. In terms of odds, the presence of one or more adult saguaro cacti within 200 m of stations increased the odds of elf owl occurrence by a factor of 8.3 ± 1.6 after adjusting for the effects of riparian and upland vegetation type (table 9). In terms of probability of occurrence, the presence of one or more adult saguaro cacti at stations increased the probability of elf owl occurrence from an average of 0.086 in areas where saguaros were absent to 0.33 in areas where they were present, a 0.24 ± 0.04 difference across all combinations of riparian and upland vegetation communities (see attachment 3 for estimated probabilities across strata).

Compared to stations with no riparian vegetation, the probability of elf owl occurrence was significantly greater at stations where xeric riparian vegetation was dominant, but there was little or no evidence of an effect of dominance of mesic or exotic riparian vegetation after adjusting for other factors (table 9). Where xeric riparian vegetation was dominant, for example, odds of elf owl occurrence increased by a factor of 7.1 ± 2.0, with smaller effects of

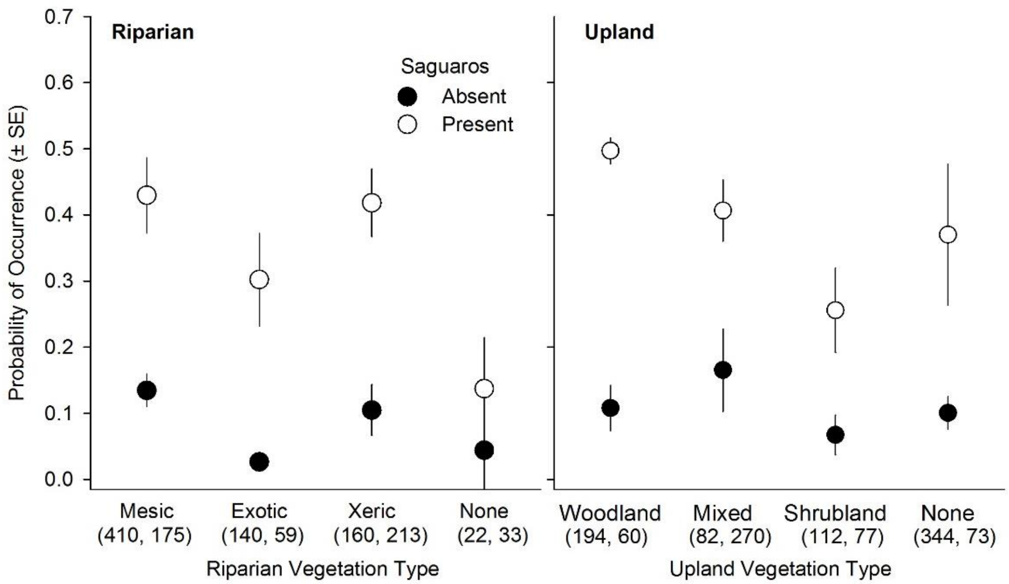

Figure 8.—Variation in the probability of occurrence of elf owls among different riparian and upland vegetation types in areas where adult saguaro cacti were present and absent in southern and western Arizona, March – June 2015. Estimates for each riparian type are pooled across all upland types, and estimates for all upland types are pooled across riparian types. All estimates are means (± 1 SE) of predicted probabilities from mixed effects logistic regression with transect fit as a random intercept, and dominant riparian and upland vegetation type (within 75 m) and presence/absence of adult saguaros (within 200 m) fit as nominal fixed effects. Numbers in parentheses are sample sizes in each group. Along the “Upland” graph X-axis, “Woodland” = desert woodland, “Mixed” = arborescent desert scrub, and “Shrubland” = desert shrubland.

presence of mesic or exotic riparian types and 95% confidence intervals (CIs) of odds overlapped 1.0 (table 9). Nonetheless, on average, probabilities of occurrence were similar at stations dominated by mesic and xeric riparian vegetation and somewhat lower at stations dominated by exotic riparian vegetation after controlling for saguaro effects (see figure 8; attachment 3). In contrast, variation in occurrence among upland vegetation types was much lower despite generally decreasing probabilities of occurrence in upland types along a gradient of decreasing vegetation structure at stations where riparian vegetation and saguaros were present (e.g., from desert woodland to desert shrubland; see figure 8). Importantly, the probability of occurrence was greatest at stations dominated by both mesic riparian vegetation and desert woodlands in uplands where saguaros were present (0.58 ± 0.07; figure 9), which is the combination of strata that typically features the greatest vegetation structure. Moreover, in the absence of riparian vegetation, the probability of occurrence was low regardless of whether saguaros were present, which suggests the importance of riparian vegetation (figures 8 and 9). In contrast, at stations where upland vegetation was absent but saguaros were present, the probability of occurrence was typically high (figures 8 and 9). Low sample sizes and precision in some combinations of

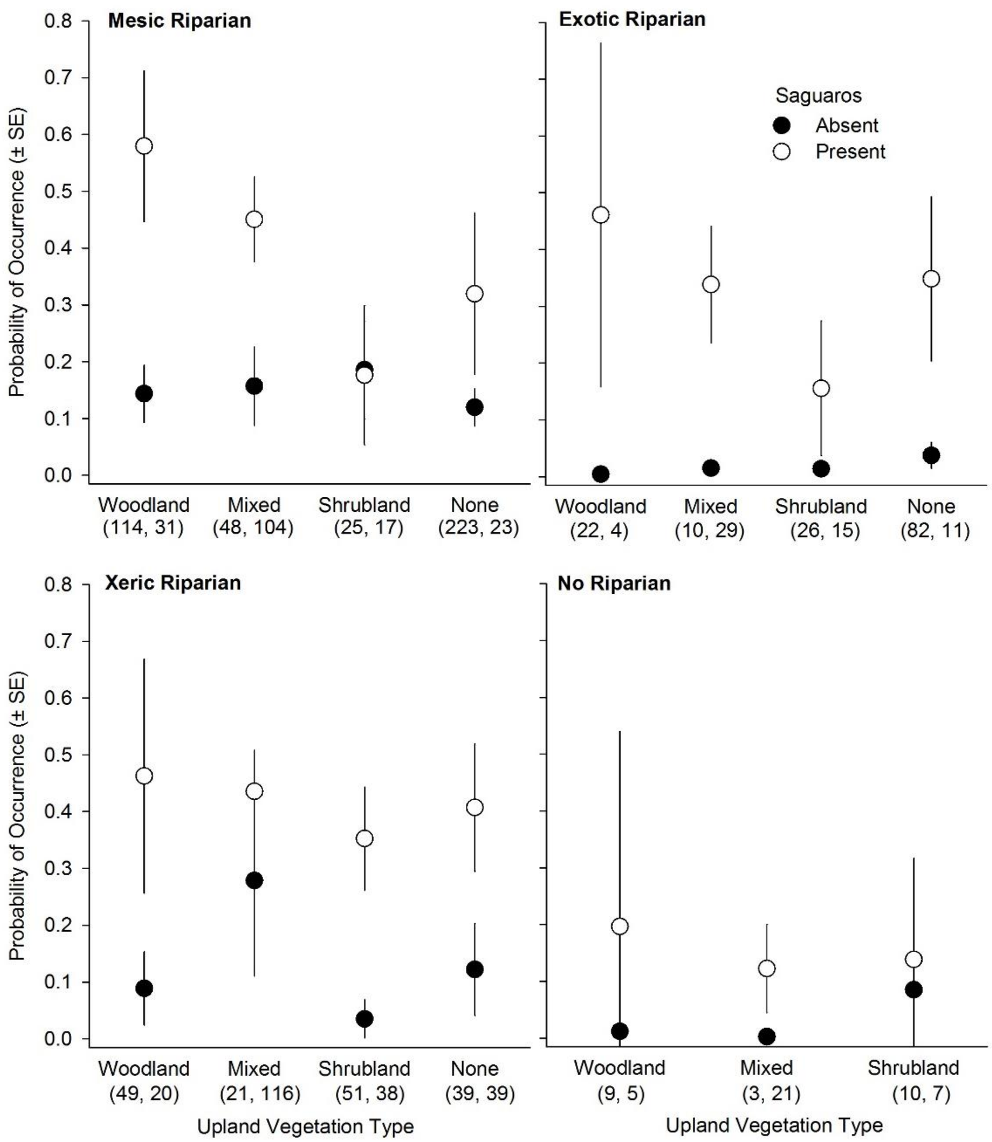

Figure 9.—Variation in the probability of occurrence of elf owls across three different riparian vegetation types and at stations where riparian vegetation was absent among three different upland vegetation types in areas where adult saguaro cacti were present and absent in southern and western Arizona, March – June 2015.

On the X-axes, “Woodland” = desert woodland, “Mixed” = arborescent desert scrub, and “Shrubland” = desert shrubland. Estimates are average (± 1 SE) predicted probabilities from mixed effects logistic regression with transect fit as a random intercept and dominant riparian and upland vegetation type (within 75 m), and presence/absence of adult saguaros (within 200 m) fit as nominal fixed effects. Numbers in parentheses are sample sizes in each group.

Table 9.—Estimated effects of riparian and upland vegetation type and presence of adult saguaro cacti on occurrence of elf owls at stations (*n* = 1,212) in southern and western Arizona, March – June 2015 (Estimates and odds are based on mixed effects logistic regression with transect fit as a random intercept and riparian and upland vegetation type, and presence/absence of adult saguaros (within 200 m) fit as nominal fixed effects. Estimates for both riparian and upland vegetation types are relative to the reference level none or stations where no riparian or upland vegetation was present within 75 m. *Z* and *P* are based on Wald tests. The last two columns note the lower bound [LB] and upper bound [UB] of a 95% CI for each estimate.)

Variable	Estimate	SE	*Z*	*P*	Odds	SE	95% CI LB	95% CI UB
Intercept	-5.05	0.88	-5.77	< 0.0001	0.01	2.40	0.00	0.03
Riparian – mesic	0.99	0.69	1.44	0.15	2.69	1.99	0.74	11.31
Riparian – exotic	0.95	0.79	1.20	0.23	2.58	2.21	0.57	13.10
Riparian – xeric	1.97	0.71	2.76	0.0059	7.14	2.04	1.90	31.87
Upland – desert woodland	-0.26	0.48	-0.53	0.59	0.77	1.62	0.30	1.96
Upland – arborescent desert scrub	0.34	0.38	0.91	0.36	1.41	1.46	0.67	2.95
Upland – desert shrubland	0.031	0.46	0.07	0.95	1.03	1.59	0.41	2.55
Saguaro presence	2.11	0.46	4.62	< 0.0001	8.25	1.58	3.45	20.86

vegetation strata complicated comparisons. Those issues were generally restricted to areas dominated by exotic riparian vegetation or areas with no riparian vegetation, however, where inferences are of lowest priority to Reclamation.

Factors that Explained Occurrence

Preliminary Variable Assessment

The original set of potential explanatory variables was reduced by first assessing pair-wise correlations and then eliminating one variable from correlated pairs. Upland vegetation cover was highly correlated with upland vegetation height ($r = 0.75$, $P < 0.001$), and vegetation height was retained because it is easier to measure and visualize. In contrast, correlations between riparian vegetation cover and riparian vegetation height were lower ($r = 0.49$, $P < 0.001$). Pair-wise correlations between other structural vegetation variables were sufficiently low (e.g., $P < 0.60$) to minimize issues linked to multicollinearity.

Model-based Inferences

Factors that explained variation in elf owl occurrence at stations included one variable that described presence of nest cavities, one variable that described upland vegetation structure, and four variables that described composition of riparian or upland vegetation (table 10). With regard to structural variables, there was a significant interaction between presence of saguaro cacti and height of upland vegetation, with the probability of occurrence increasing with upland height only in areas where saguaros were present (figure 10, table 10). Although the occurrence of elf owls was positively associated with both presence ($\beta \pm$ SE = 2.29 ± 0.41) and density ($\beta \pm$ SE = 1.03 ± 0.24) of saguaro cacti, saguaro presence provided a better overall description of the data (ΔAIC_c = 14.88 for models in which all other factors held constant). With regard to riparian vegetation composition, the probability of elf owl occurrence increased with cover of broadleaf deciduous trees other than willow and with cover of mesquite, and decreased with increasing cover of willow after adjusting for other factors (figure 10, table 10). For example, each 1% increase in mesquite cover increased the odds of elf owl occurrence by a factor of 1.03 ± 1.01, with similar but somewhat smaller effects of broadleaf deciduous cover. With regard to upland vegetation composition, the probability of elf owl occurrence increased with cover of mesquite but at a somewhat lower rate than mesquite cover in riparian areas (table 10). Assuming model predictions ≥ 0.5 equaled occurrences, the final model correctly classified 92.0% of observations. Numerous other potential explanatory variables had little explanatory power. With regard to the potential effects of cavities in tree snags, there was no evidence that the presence of a snag within 100 m of stations explained elf owl occurrence after considering other factors (ΔAIC_c = 1.31). With regard to the amount of riparian vegetation and its proximity, there was no evidence that the width of riparian vegetation corridors (ΔAIC_c = 1.97) or distance to the riparian-upland ecotone (ΔAIC_c = 1.11) explained elf owl occurrence after considering other factors. With regard to the structure of riparian vegetation, there was no evidence that height (ΔAIC_c = 1.95) or cover (ΔAIC_c = 1.31) of riparian vegetation explained elf owl occurrence. Finally, there was also no evidence other compositional variables such as saltcedar (*Tamarix* spp.) cover (ΔAIC_c = 1.92) explained elf owl occurrence.

Geographical Variation

After considering the effects of important habitat variables (table 10), the probability of elf owl occurrence increased with elevation (standardized $\beta \pm$ SE = 0.86 ± 0.40, ΔAIC_c = -2.59) but not with latitude (ΔAIC_c = 1.16) or longitude (ΔAIC_c = 1.66). When considered on the unstandardized scale, the odds of elf owl occurrence increased by a factor of 1.23 ± 0.14 with each 100-m increase in elevation. Despite significant associations with elevation, there was no evidence the associations with habitat variables depended on elevation ($\Delta AIC_c \geq 0.00$ for models with vegetation × elevation interactions). In contrast, there were significant interactions between one habitat variable and both latitude and longitude, suggesting the effects of this resource varied geographically. Specifically, there was an interaction between cover of mesquite in uplands

Table 10.—Vegetation factors that explained the occurrence of elf owls at stations (*n* = 1,212) in southern and western Arizona, March – June 2015

(Estimates and odds are based on mixed effects logistic regression with transect [*n* = 112] fit as a random intercept and the factors noted below fit as fixed effects. Backyards elimination was used to select a set of fixed effects to include in models, and then models were refined by adding, subtracting, and changing terms, and evaluating support using model selection techniques. Random effects variance was estimated at 10.97. *Z* and *P* are based on Wald tests. The last two columns note the lower bound (LB) and upper bound [UB] of a 95% CI for each estimate. Full models used as a basis for backyards elimination are summarized in attachment 4.)

Variable	Estimate	SE	*Z*	*P*	Odds	SE	95% CI LB	95% CI UB
Intercept	-4.74	0.67	-7.04	< 0.0001	0.009	1.96	0.002	0.031
Saguaro presence	1.58	0.57	2.78	0.0054	4.87	1.77	1.61	15.12
Upland vegetation height (m)	-0.48	0.25	-1.88	0.060	0.62	1.29	0.37	1.008
Riparian – broadleaf deciduous tree cover (%)[1]	0.021	0.0072	2.88	0.0040	1.021	1.007	1.007	1.035
Riparian – willow tree cover (%)	-0.022	0.011	-1.95	0.052	0.98	1.011	0.96	1.00
Riparian – mesquite tree cover (%)	0.025	0.0071	3.52	0.0004	1.025	1.007	1.012	1.040
Upland – mesquite tree cover (%)	0.019	0.0073	2.52	0.012	1.019	1.007	1.004	1.034
Saguaro presence × upland vegetation height	0.63	0.29	2.19	0.029	1.87	1.33	1.08	3.34

[1] Equals total cover of all broadleaf species minus willow cover.

and longitude ($\beta \pm$ SE = 0.019 ± 0.0072, $\Delta AIC_c \geq -4.30$) and latitude ($\beta \pm$ SE = 0.013 ± 0.0063, $\Delta AIC_c \geq -1.40$) after adjusting for other important factors. The probability of elf owl occurrence increased markedly with cover of mesquite in uplands in the more mesic, eastern portion of the study area but not in the central or western portions (figure 11). Additionally, the probability of elf owl occurrence also increased with cover of mesquite in uplands in the southern but not central and northern portions of the study area. Such patterns may reflect geographic differences in resource availability, as cover of mesquite in uplands increased markedly from west to east and from south to north.

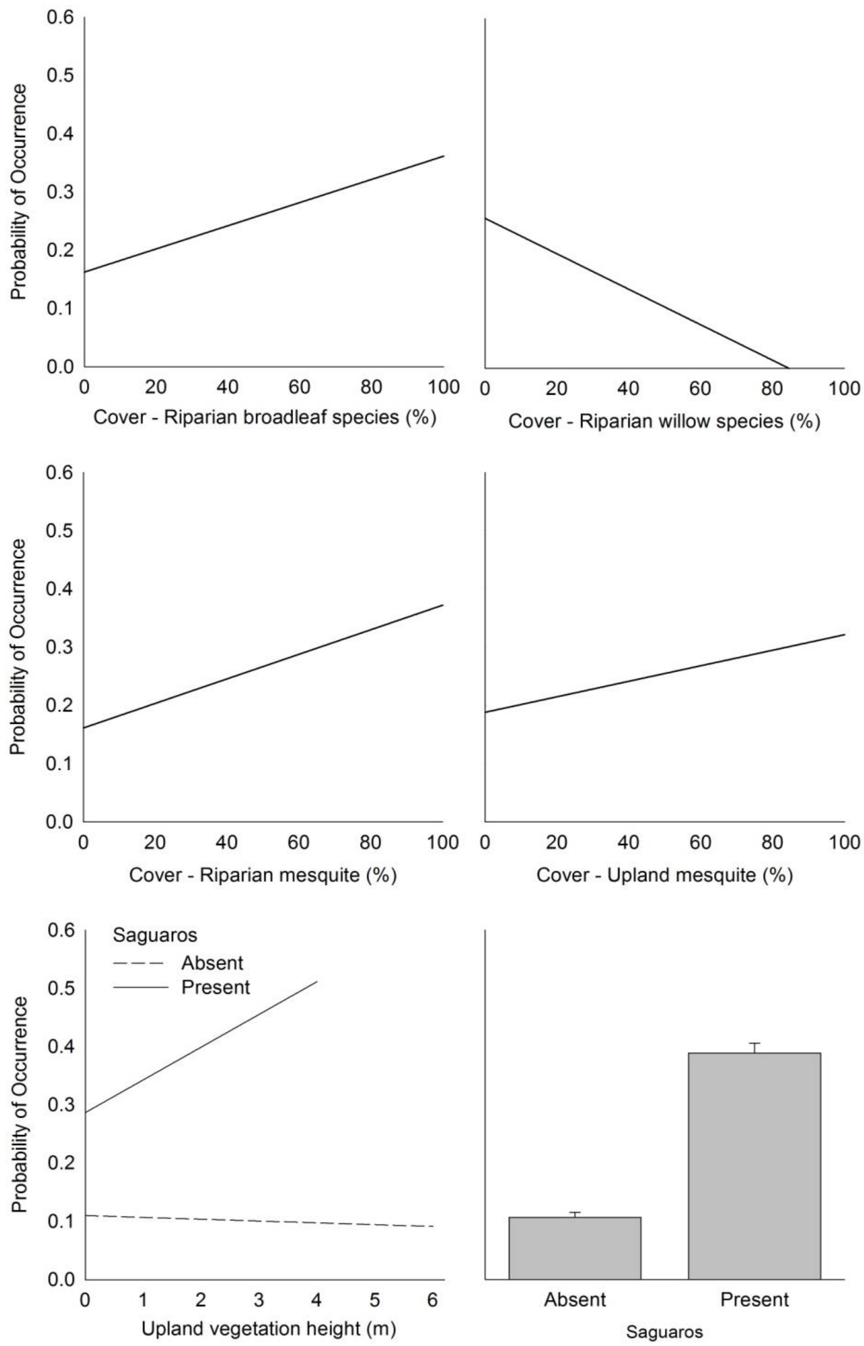

Figure 10.—Vegetation factors that explained occurrence of elf owls at stations (*n* = 1,212) in southern and western Arizona, March – June 2015.
Lines are simple linear models through predictions from a top-ranked mixed effects logistic regression model with transect (*n* = 112) fit as a random intercept and various fixed effects (see table 10). Cover of riparian broadleaf species includes all tree species except willow. Lower left plot shows the effects of upland vegetation height in areas where saguaros were absent and present (e.g., saguaro presence × upland height interaction). Error bars on lower right figure are SE.

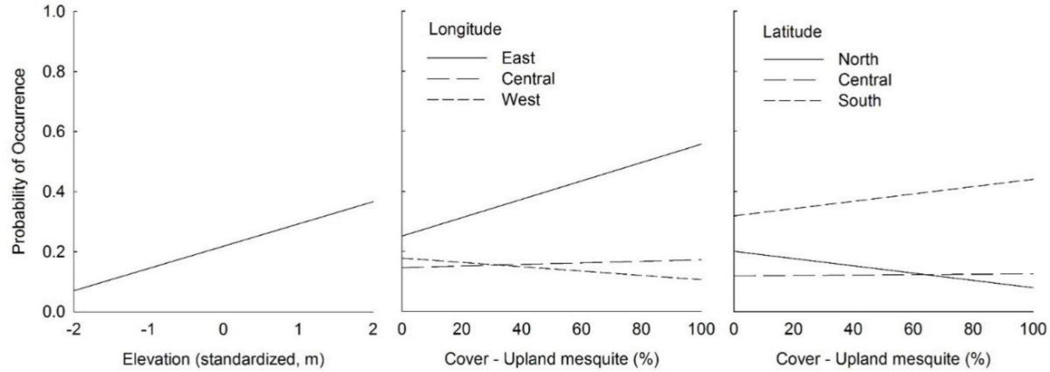

Figure 11.—Effects of elevation and the interactive effects of spatial (longitude and latitude) and vegetation factors on the occurrence of elf owls at stations (*n* = 1,212) in southern and western Arizona, March – June 2015.
Lines are simple linear models through predictions from a top-ranked mixed effects logistic regression model with transect (*n* = 112) fit as a random intercept and various fixed effects.

DISCUSSION

Data collected in 2015 were intended to provide baseline information about the distribution and occurrence patterns of elf owls during the breeding season in lowland riparian areas in the Sonoran Desert of southern and western Arizona. Moreover, objectives also targeted understanding the patterns and frequency with which elf owls occur in or adjacent to riparian vegetation and associations between elf owl occurrence and various potential habitat resources such as the presence and abundance of saguaro cacti, riparian vegetation structure and composition, and other environmental attributes. Efforts in 2015 also focused on providing a list of potential study sites that were suitable for more intensive, future elf owl field work in 2016 and 2017, which will address a broader set of project objectives. Although it was not intended that data from the 2015 field season serve as a basis for management recommendations by themselves, the relatively large sample sizes that were obtained and the rigorous analytic frameworks that were employed produced a broad range of strong inferences, which collectively enhance knowledge of elf owl ecology. In combination with data gathered during two remaining field seasons of this study, insights gained from 2015 will help Reclamation determine conservation measures for the elf owl.

Elf owls were widely distributed throughout the study area, and as suspected based on recent studies, found to be much more abundant outside than inside the LCR MSCP planning area (Sabin 2009; GBBO 2012). In general, probabilities and frequencies of occurrence were much higher in more mesic regions in the eastern portions of the Sonoran Desert, where dense stands of riparian vegetation occurred in close proximity to well-developed upland vegetation and high abundances of large saguaro cacti with potential to support nest cavities.

Collectively, these observations confirm there are a sufficient number of suitable candidate study sites to accomplish the goals of the 2016 and 2017 field seasons. Of particular interest, given Reclamation's management interests, are sites where elf owls occurred in mesic riparian vegetation in the absence of saguaros. Those sites included Arivaca Creek, upper Aravaipa Creek, upper San Pedro River, upper and lower Cave Creek, and lower Seven Springs Wash, where stands of Fremont cottonwoods and willows are present.

Understanding the effects of riparian vegetation, especially riparian vegetation dominated by broadleaf deciduous trees, on the distribution and habitat use of elf owls is a core goal of this study. To address this goal, a sampling strategy was developed that allowed the effects of various combinations of riparian and upland vegetation types, in the presence or absence of potential nest cavities in saguaros, to be isolated and evaluated. In general, the probability of elf owl occurrence in and near riparian vegetation was relatively high in areas dominated by both mesic (e.g., broadleaf trees) and xeric (e.g., microphyllous trees) riparian vegetation but much lower in exotic riparian vegetation dominated by saltcedar. Such patterns are likely due to the dense structure and high vegetation volume that characterize stands of saltcedar, which reduce visibility of insect prey and hamper short foraging flights typical of elf owls (Ligon 1968; Henry and Gehlbach 1999). In the absence of nearby riparian vegetation, however, the probability of elf owl occurrence was low likely due to inadequate levels of vegetation cover for perching, foraging, and other important activities. The probability of elf owl occurrence was greatest in areas dominated by mesic riparian vegetation where desert woodlands and saguaros were present in adjacent uplands. However, occurrence probabilities were similar in areas dominated by xeric riparian woodlands adjacent to those same upland vegetation attributes, which suggests both mesic and xeric riparian areas function similarly in providing habitat to elf owls. Importantly, those combinations of vegetation strata likely offer the highest levels of vegetation structure and heterogeneity encountered during the study. Moreover, there was no statistically significant effect of the presence of mesic riparian vegetation by itself after adjusting for other factors, but strong positive effects of xeric riparian vegetation (see table 9). Such patterns, together with others linked to floristics discussed below, suggest that once sufficient nesting substrates are present, elf owls are largely habitat generalists occurring in a broad range of vegetation types that provide some minimum threshold in vegetation structure (Henry and Gehlbach 1999), and the importance of microphyllous trees such as mesquite. Riparian width and riparian vegetation height were not good predictors of elf owl occurrence, which also suggests a broad range of patch sizes and vegetation types provide habitat for elf owls.

In general, factors linked to the presence or density of nest cavities are highly predictive of the occurrence and abundance of cavity-nesting birds (Newton 1994; Flesch and Steidl 2010). For elf owls in Arizona, virtually all of the few available studies helped identify the importance of nest cavities and, more specifically, of high densities of saguaro cacti with potential to support nest cavities for breeding elf owls (Goad and Mannan 1987; Hardy et al. 1999; Hardy and Morrison 2001). Thus, it is not surprising that the presence of mature saguaros had a greater effect on occurrence that any other environmental factor considered here. The presence of snags with the potential to support cavities, however, were not predictive of occurrence. This suggests a greater overall importance of saguaros to elf owls, potentially, due to lower rates of nest predation in saguaros and the thermal advantages they offer, which are especially important in hotter, more arid regions of the Sonoran Desert (Flesch and Steidl 2010).

Most past studies of elf owls in the Sonoran Desert of Arizona focus on aspects of upland vegetation structure associated with elf owl occurrence, abundance, or habitat selection (Goad and Mannan 1987; Hardy et al 1999; Hardy and Morrison 2001). This study, however, is the first to address the significance of mesic lowland riparian vegetation and associations between elf owls and specific attributes of riparian vegetation structure and composition. With regard to riparian vegetation composition, occurrence was positively associated with increasing dominance of broadleaf deciduous trees other than willow, and with mesquite, but negatively associated with increasing dominance of willows. Those patterns, together with strong positive effects of xeric riparian vegetation and positive effects of mesquite in uplands, suggest the importance of this microphyllous tree species to elf owls and matches similar patterns for ferruginous pygmy-owls (*Glaucidium brasilianum*) in the Sonoran Desert (Flesch 2003; Flesch and Steidl 2010). Associations between elf owls and areas dominated by mesquite may be due to more mesomorphic structure, which provides denser shade and thus better cover from temperature extremes (Suzán et al. 1996), and because mesquite supports a higher abundance or diversity of small vertebrate prey, and likely insects, than many other desert tree species (Germano and Hungerford 1981; Lloyd et al. 1998). Compared to mesquite, for example, the dense branching structure of palo verde (*Parkinsonia* spp.) offers fewer open horizontal limbs with high visibility that afford good foraging perches for elf owls. This last reason likely also explains observed negative associations with willow that are reported here. Willows are characterized by high foliage densities in the lower- and mid-story, which likely reduce visibility of insect prey and hamper short foraging flights typical of elf owls. Once the negative effects of willows were considered, however, increasing dominance of other species of broadleaf trees, such as Fremont cottonwood, which typically have more open structure, had positive effects on elf owl occurrence albeit of somewhat lower magnitude than mesquite.

A valuable aspect of this project's design is that it provides insights into how various combinations of riparian and upland vegetation attributes affect elf owl occurrence and allows one to estimate the independent effects of different vegetation communities in the presence (or absence) of potential nest cavities in saguaros. For example, when saguaros are absent, elf owls are likely constrained to nest in riparian vegetation and tree cavities. Under these circumstances, height and structure of nearby upland vegetation had no effect on the probability of elf owl occurrence. However, when saguaros are present (and therefore likely providing nesting substrates), the probably of elf owl occurrence increases with increasing upland vegetation height and structure. Such results suggest that riparian vegetation alone in the absence of saguaros provides habitat for elf owls.

The probability of elf owl occurrence increased with elevation across the study area, suggesting that areas in the Lower Colorado River Valley may have inherently lower resource levels for the species. Because elevation decreases and thus aridity increases from east to west across the Sonoran Desert, these gradients create more localized distributions of riparian trees and saguaros in the far west and an environment that is more extreme. Although occurrence probabilities did not vary systematically with latitude or longitude, there were interactions between these geographical gradients and one vegetation variable (mesquite dominance), which suggest patterns of occurrence are mediated by changing availabilities of resources. For example, elf owl occurrence increased with cover of upland mesquite in the eastern and southern portions of the study area but not in the central, northern, or western portions. Additional study is need to understand the significance of these patterns for elf owls and management.

In summary, 2015 data indicate that elf owls commonly occupy riparian vegetation within the defined study area of western and southern Arizona, including areas dominated by broadleaf deciduous trees. Data further suggest several marked and highly relevant relationships between elf owl occurrence and various vegetation parameters. A more detailed study of elf owl territory characteristics in the 2016–17 field seasons will attempt to further refine and explore these patterns and their implications for conservation and management of elf owls.

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ATTACHMENT 1

Management Jurisdiction, Location, Effort, and Elf Owl (*Micrathene whitneyi*) Detections at 112 Transects Surveyed for Elf Owls in Southern and Western Arizona, March – June 2015

Table 1-1.—Management jurisdiction, location, effort, and elf owl detections at 112 transects (n = 1,397 stations) surveyed for elf owls in southern and western Arizona, March – June 2015
(Total elf owl detections indicates total observations across all stations, not the number of individual elf owls detected, and frequency is the percent of stations where at least one elf owl was detected.)

Jurisdiction – general Jurisdiction– specific	Drainage	Transects surveyed	Stations surveyed	Elevation minimum (meters)	Elevation maximum (meters)	Total elf owl detections	Frequency of elf owl detections by station
Arizona State Parks							
Dead Horse Ranch State Park	Verde River	1	19	995	1213	0	0.0
Bureau of Land Management (BLM)							
Agua Fria National Monument	Agua Fria River	3	29	914	1035	4	10.3
Agua Fria National Monument	Silver Creek	1	12	1036	1097	0	0.0
BLM – General	Agua Fria River	2	32	609	636	13	25.0
BLM – General	Big Sandy River	1	14	546	548	18	71.4
BLM – General	Bill Williams River	2	23	365	365	0	0.0
BLM – General	Bouse Wash	1	8	229	235	0	0.0
BLM – General	Burro Creek	1	10	609	656	0	0.0
BLM – General	Date Creek	1	10	405	426	6	60.0
BLM – General	Dead Horse Wash	1	17	631	671	2	11.8
BLM – General	Gila River	6	77	181	1103	0	0.0
BLM – General	Morgan City Wash	1	14	498	549	2	14.3
BLM – General	Santa Maria River	9	95	365	426	51	37.9
San Pedro Riparian National Conservation Area	San Pedro River	5	66	1125	1191	11	13.6
Sonoran Desert National Monument	Vekol Wash	2	26	544	609	1	3.8
BLM, private							
BLM, private	Big Sandy River	2	20	365	487	10	25.0
BLM, private	Date Creek	2	24	426	426	0	0.0
BLM, State Wildlife Area							
BLM, Painted Rock Wildlife Area	Gila River	1	9	181	183	0	0.0
BLM, Robbins Butte Wildlife Area	Gila River	1	15	289	296	0	0.0

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(Total elf owl detections indicates total observations across all stations, not the number of individual elf owls detected, and frequency is the percent of stations where at least one elf owl was detected.)

Jurisdiction – general Jurisdiction– specific	Drainage	Transects surveyed	Stations surveyed		Elevation minimum (meters)	Elevation maximum (meters)		Total elf owl detections	Frequency of elf owl detections by station
Bureau of Reclamation									
Cook's Lake preserve	San Pedro River	1	10		670	670		20	80.0
Bureau of Reclamation, private									
BLM, ASARCO	Gila River	1	10		548	549		0	0.0
Maricopa County Parks and Recreation, Bureau of Reclamation									
Lake Pleasant Regional Park	Morgan City Wash	1	12		486	488		2	16.7
National Park Service									
Tumacácori National Historical Park	Santa Cruz River	2	26		985	1005		0	0.0
Tuzigoot National Monument	Verde River	1	14		1036	1036		0	0.0
National Park Service, private									
Saguaro National Park - Rincon Creek	Rincon Creek	1	13		975	975		50	100.0
Pima County									
Cienega Creek Preserve	Cienega Creek	3	37		1036	1071		20	43.2
Colossal Cave Mountain Park	Posta Quemada Canyon	1	13		1036	1096		39	100.0
Private									
ASARCO	Gila River	2	30		605	611		18	46.7
Bob Magill	Gila River	1	11		487	487		11	72.7
Freeport-McMorRan	Gila River	2	24		822	855		0	0.0
Lincoln Ranch	Bill Williams River	1	11		304	304		5	45.5
Steve Dollarhide	Big Sandy River	2	27		609	609		26	51.9

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(Total elf owl detections indicates total observations across all stations, not the number of individual elf owls detected, and frequency is the percent of stations where at least one elf owl was detected.)

Jurisdiction – general Jurisdiction– specific	Drainage	Transects surveyed	Stations surveyed	Elevation minimum (meters)	Elevation maximum (meters)	Total elf owl detections	Frequency of elf owl detections by station
State Trust Land							
State Trust Land	Hackberry Wash	1	12	609	609	1	8.3
State Trust Land	San Juan Wash	1	14	1040	1072	55	100.0
State Trust Land	Santa Maria River	1	12	548	566	3	25.0
State Trust Land, private							
Kimberley Knight and Stefan Wolf	Date Creek	2	26	853	914	39	100.0
The Nature Conservancy							
Three Links Ranch, Dewel Property	San Pedro River	1	12	1012	1030	0	0.0
Aravaipa Canyon Preserve – East	Aravaipa Creek	3	43	975	1055	63	76.7
Aravaipa Canyon Preserve – West	Aravaipa Creek	1	13	792	813	12	61.5
Hassayampa River Preserve	Hassayampa River	3	37	609	610	0	0.0
San Pedro River Preserve	San Pedro River	2	29	609	632	3	10.3
Shield Ranch	Verde River	1	16	917	975	0	0.0
The Nature Conservancy, private							
7B Ranch	San Pedro River	1	16	731	731	4	18.8
Peter Else, H&E Cattle, The Nature Conservancy	San Pedro River	1	12	725	731	13	58.3
University of Arizona, Pima County							
Tumamoc Hill Preserve	Tumamoc Hill washes	1	10	732	789	21	100.0

Table 1-1.—Management jurisdiction, location, effort, and elf owl detections at 112 transects (*n* = 1,397 stations) surveyed for elf owls in southern and western Arizona, March – June 2015
(Total elf owl detections indicates total observations across all stations, not the number of individual elf owls detected, and frequency is the percent of stations where at least one elf owl was detected.)

Jurisdiction – general Jurisdiction– specific	Drainage	Transects surveyed	Stations surveyed		Elevation minimum (meters)	Elevation maximum (meters)		Total elf owl detections	Frequency of elf owl detections by station
U.S. Forest Service									
Coconino National Forest	Clear Creek	1	13		1032	1036		0	0.0
Coronado National Forest	Alder Canyon	1	11		1219	1270		44	100.0
Coronado National Forest	Buehman Canyon	2	36		914	1036		92	91.7
Prescott National Forest	Verde River	1	16		1004	1036		0	0.0
Tonto National Forest	Cave Creek	2	28		933	1269		27	67.9
Tonto National Forest	Cherry Creek	2	25		852	913		46	96.0
Tonto National Forest	Indian Springs Wash	1	13		792	855		11	61.5
Tonto National Forest	Salt River	4	45		425	670		11	17.8
Tonto National Forest	Seven Springs Wash	1	13		1094	1108		10	61.5
Tonto National Forest	Sycamore Creek	1	7		670	684		2	28.6
Tonto National Forest	Tangle Creek	1	14		853	914		18	71.4
Tonto National Forest	Verde River	4	45		487	671		12	22.2
U.S. Fish and Wildlife Service									
Bill Williams River National Wildlife Refuge	Bill Williams River	5	50		177	234		30	40.0
Buenos Aires National Wildlife Refuge	Arivaca Creek	2	28		1048	1090		29	64.3
Buenos Aires National Wildlife Refuge	Buenos Aires National Wildlife Refuge washes	3	43		1015	1066		0	0.0

ATTACHMENT 2

Random Effects Variances, Information Criteria, and Model Fitting Summary for Three Models with Different Random Effects Structures that Explained the Occurrence of Elf Owls (*Micrathene whitneyi*) at Stations in Southern and Western Arizona, March – June 2015

Table 2-1.—Random effects variances, information criteria, and model fitting summary for three models with different random effects structures that explained the occurrence of elf owls at stations (n = 1,212) in southern and western Arizona, March – June 2015
(Estimates are based on mixed effects logistic regression with dominant riparian and upland vegetation communities, and presence/absence of saguaro cacti [*Carnegiea gigantean*] fit as fixed effects. Transect, transect nested within watershed, and watershed and transect treated as independent factors were fit as random intercepts.)

Random effects	**σ^2_1***	**σ^2_2****	**df*****	**AIC_c******
Transect	13.07		9	720.59
Watershed (transect), transect	0.34	12.28	10	726.23
Watershed, transect	2.13	10.05	10	723.55

* σ^2_1 = variance 1.
** σ^2_2 = variance 2.
*** df = degrees of freedon.
**** AIC_c = Akaike's information criterion adjusted for small sample sizes.

ATTACHMENT 3

Predicted Probability of Occurrence of Elf Owls (*Micrathene whitneyi*) at Stations Across Three Different Riparian and Upland Vegetation Communities With and Without Saguaro Cacti (*Carnegiea gigantean*) in Southern and Western Arizona, March – June 2015

Table 3-1.—Predicted probability of occurrence of elf owls at stations (*n* = 1,212) across three different riparian and upland vegetation communities with and without saguaro cacti in southern and western Arizona, March – June 2015
(Estimates are based on mixed effects logistic regression with transect fit as a random intercept and riparian and upland vegetation type, and presence/absence of saguaros (within 200 meters) fit as nominal fixed effects. Sample sizes (*n*) are the number of stations within each strata. Dominant vegetation communities were measured within 75 meters of stations in both riparian and upland vegetation communities, and presence of saguaros was measured within 200 meters.)

	Desert woodland						Arborescent desert scrub						Desert shrubland						No upland vegetation					
	Number of saguaros			Saguaros			Number of saguaros			Saguaros			Number of saguaros			Saguaros			Number of saguaros			Saguaros		
Riparian vegetation type	***n***	**Probability**	**SE[1]**	***n***	**Probability**	**SE**	***n***	**Probability**	**SE**	***n***	**Probability**	**SE**	***n***	**Probability**	**SE**	***n***	**Probability**	**SE**	***n***	**Probability**	**SE**	***n***	**Probability**	**SE**
Mesic riparian	114	0.144	0.026	31	0.580	0.068	48	0.157	0.035	104	0.451	0.038	25	0.181	0.044	17	0.176	0.063	223	0.120	0.017	23	0.319	0.073
Exotic riparian	22	0.004	0.000	4	0.461	0.154	10	0.015	0.006	29	0.338	0.052	26	0.014	0.007	15	0.156	0.061	82	0.038	0.012	11	0.348	0.074
Xeric riparian	49	0.089	0.033	20	0.463	0.105	21	0.279	0.086	116	0.436	0.037	51	0.035	**0.017**	38	0.353	0.046	39	0.122	0.041	39	0.407	0.057
No riparian	9	0.012	0.005	5	0.197	0.175	3	0.003	0.000	21	0.123	0.040	10	0.085	0.064	7	0.139	0.091						

[1] SE = standard error.

ATTACHMENT 4

Full Models Used as a Basis for Backwards Variable Elimination when Modeling Factors that Explained the Occurrence of Elf Owls (*Micrathene whitneyi*) at Stations in Southern and Western Arizona, March – June 2015

Table 4-1.—Full models used as a basis for backwards variable elimination when modeling factors that explained the occurrence of elf owls at stations (*n* = 1,212) in southern and western Arizona, March – June 2015
(Backyards elimination was used to select a set of fixed effects to include in models, and then models were refined by adding, subtracting, and changing terms, and evaluating support using model selection techniques.)

```
Fit Full Model with only structural variables.

Full <- glmer(Obs1 ~ log1p(Hab_rip_wid) + log1p(Hab_rip_dist) + Rip_cover_midpt +
Hab_rip_av_ht +  Hab_upl_av_ht + Sag_Pres200.1 + Snag_pres_100.1 + (1 | ID), data =
Data, family = binomial,control = glmerControl(optimizer = "bobyqa"),nAGQ = 20)

summary(Full)

Generalized linear mixed model fit by maximum likelihood (Adaptive Gauss-Hermite
Quadrature, nAGQ = 20) ['glmerMod']
 Family: binomial  ( logit )
Formula: Obs1 ~ log1p(Hab_rip_wid) + log1p(Hab_rip_dist) + Rip_cover_midpt +
Hab_rip_av_ht + Hab_upl_av_ht + Sag_Pres200.1 + Snag_pres_100.1 +
    (1 | ID)
   Data: Data
Control: glmerControl(optimizer = "bobyqa")

     AIC      BIC   logLik deviance df.resid
   728.5    774.4   -355.3    710.5     1203

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.7754 -0.1923 -0.0874 -0.0525  4.4059

Random effects:
 Groups Name        Variance Std.Dev.
 ID     (Intercept) 11.99    3.463
Number of obs: 1212, groups:  ID, 112

Fixed effects:
                     Estimate Std.  Error z value Pr(>|z|)
(Intercept)         -4.335014   1.501294  -2.888  0.00388 **
log1p(Hab_rip_wid)   0.082449   0.235359   0.350  0.72611
log1p(Hab_rip_dist) -0.104281   0.145095  -0.719  0.47232
Rip_cover_midpt      0.009776   0.007461   1.310  0.19010
Hab_rip_av_ht       -0.017341   0.050366  -0.344  0.73062
Hab_upl_av_ht        0.088716   0.155099   0.572  0.56732
Sag_Pres200.1        2.173127   0.440209   4.937 7.95e-07 ***
Snag_pres_100.1      0.282007   0.361529   0.780  0.43537
---
Signif.  codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
              (Intr) lg1p(Hb_rp_w) lg1p(Hb_rp_d) Rp_cv_ Hb_r__ Hb_p__ S_P200
lg1p(Hb_rp_w) -0.772
lg1p(Hb_rp_d) -0.202 -0.324
Rp_cvr_mdpt   -0.062 -0.187         0.234
Hab_rp_v_ht   -0.188  0.087        -0.011        -0.519
```

```
Hab_pl_v_ht   -0.310 -0.037         0.470         0.040  0.117
Sg_Prs200.1   -0.285  0.076         0.113        -0.010  0.149 -0.097
Sng_p_100.1   -0.073  0.072        -0.040         0.003 -0.147  0.066 -0.012



FullSags2 <- glmer(Obs1 ~ log1p(Hab_rip_wid) + log1p(Hab_rip_dist) + Rip_cover_midpt
+ Hab_rip_av_ht +  Hab_upl_av_ht + Sag_Pres200.1 +  Sag_Pres200.1*log1p(Hab_rip_wid)
+ Sag_Pres200.1*Hab_rip_av_ht +  Sag_Pres200.1*Hab_upl_av_ht + (1 | ID), data = Data,
family = binomial,control = glmerControl(optimizer = "bobyqa"),nAGQ = 20)
summary(FullSags2 )
Generalized linear mixed model fit by maximum likelihood (Adaptive Gauss-Hermite
Quadrature, nAGQ = 20) ['glmerMod']
 Family: binomial  ( logit )
Formula: Obs1 ~ log1p(Hab_rip_wid) + log1p(Hab_rip_dist) + Rip_cover_midpt +
Hab_rip_av_ht + Hab_upl_av_ht + Sag_Pres200.1 + Sag_Pres200.1 *
    log1p(Hab_rip_wid) + Sag_Pres200.1 * Hab_rip_av_ht + Sag_Pres200.1 *
Hab_upl_av_ht + (1 | ID)
   Data: Data
Control: glmerControl(optimizer = "bobyqa")

     AIC      BIC   logLik deviance df.resid
   722.7    778.8   -350.3    700.7     1201

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.2677 -0.1845 -0.0853 -0.0426  7.9104

Random effects:
 Groups Name        Variance Std.Dev.
 ID     (Intercept) 12.44    3.527
Number of obs: 1212, groups:  ID, 112

Fixed effects:
                                  Estimate Std.  Error z value Pr(>|z|)
(Intercept)                      -1.146811   2.166598  -0.529   0.5966
log1p(Hab_rip_wid)               -0.471725   0.334948  -1.408   0.1590
log1p(Hab_rip_dist)              -0.123859   0.149691  -0.827   0.4080
Rip_cover_midpt                   0.010468   0.007637   1.371   0.1705
Hab_rip_av_ht                     0.066695   0.066149   1.008   0.3133
Hab_upl_av_ht                    -0.372515   0.256914  -1.450   0.1471
Sag_Pres200.1                    -2.183273   2.525262  -0.865   0.3873
log1p(Hab_rip_wid):Sag_Pres200.1  0.787820   0.376667   2.092   0.0365 *
Hab_rip_av_ht:Sag_Pres200.1      -0.141864   0.083004  -1.709   0.0874 .
Hab_upl_av_ht:Sag_Pres200.1       0.582416   0.300042   1.941   0.0522 .
---
Signif.  codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
                (Intr) lg1p(Hb_rp_w) lg1p(Hb_rp_d) Rp_cv_ Hb_r__ Hb_p__ S_P200
l1(H__): Hb_r__:S_P200.1
lg1p(Hb_rp_w)   -0.866
lg1p(Hb_rp_d)   -0.122 -0.250
Rp_cvr_mdpt     -0.102 -0.089         0.223
```

```
Hab_rp_v_ht     -0.218  0.058        -0.062        -0.324
Hab_pl_v_ht     -0.469  0.288         0.343         0.040 -0.037
Sg_Prs200.1     -0.741  0.669        -0.012         0.076  0.208  0.412
l1(H__):S_P      0.697 -0.702         0.029        -0.057 -0.046 -0.382 -0.946
Hb_r__:S_P200.1  0.218 -0.057         0.075        -0.120 -0.638  0.079 -0.348  0.127
Hb_p__:S_P200.1  0.373 -0.306        -0.067        -0.018  0.048 -0.765 -0.471  0.370
0.003


> summary(FullComp)
Generalized linear mixed model fit by maximum likelihood (Adaptive Gauss-Hermite
Quadrature, nAGQ = 20) ['glmerMod']
 Family: binomial  ( logit )
Formula: Obs1 ~ Rip_BD_tree + Rip_Mic_tree + Rip_Des_shrub + Rip_BD.Rip_shrub +
Rip_scrub + Rip_Succulent + Rip_TAMSPP + Up_BD + Up_Montane +
    Up_Succulent + Up_MicrophylousTrees + Up_Shrubs + Up_RipSpp +      (1 | ID)
   Data: Data
Control: glmerControl(optimizer = "bobyqa")

     AIC      BIC   logLik deviance df.resid
   746.1    822.6   -358.1    716.1     1197

Scaled residuals:
    Min      1Q  Median      3Q     Max
-3.6451 -0.1811 -0.0855 -0.0521  5.0989

Random effects:
 Groups Name        Variance Std.Dev.
 ID     (Intercept) 15.92    3.989
Number of obs: 1212, groups:  ID, 112

Fixed effects:
                       Estimate Std.  Error z value Pr(>|z|)
(Intercept)          -3.895e+00  8.288e-01  -4.699 2.61e-06 ***
Rip_BD_tree           2.717e-03  7.051e-03   0.385  0.69996
Rip_Mic_tree          2.147e-02  7.686e-03   2.793  0.00522 **
Rip_Des_shrub         6.817e-04  2.847e-02   0.024  0.98090
Rip_BD.Rip_shrub      7.411e-02  7.269e-02   1.020  0.30792
Rip_scrub            -7.356e-03  2.591e-02  -0.284  0.77651
Rip_Succulent        -2.538e+00  2.560e+02  -0.010  0.99209
Rip_TAMSPP           -6.306e-03  9.762e-03  -0.646  0.51827
Up_BD                -1.095e-01  9.805e-02  -1.116  0.26430
Up_Montane           -9.056e-03  1.453e-02  -0.623  0.53303
Up_Succulent         -2.682e-02  1.939e-02  -1.383  0.16667
Up_MicrophylousTrees  1.345e-02  5.393e-03   2.494  0.01263 *
Up_Shrubs            -2.199e-03  5.041e-03  -0.436  0.66268
Up_RipSpp             1.237e-01  8.864e-02   1.396  0.16284
---
Signif.  codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation matrix not shown by default, as p = 14 > 12.
Use print(x, correlation=TRUE)  or
         vcov(x)        if you need it
convergence code: 1
```