Lower Colorado River Multi-Species Conservation Program

Balancing Resource Use and Conservation

Final Project Report: Elf Owl Detectability Study 2010–2011

January 2012

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Lower Colorado River Multi-Species Conservation Program

Final Project Report: Elf Owl Detectability Study 2010–2011

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Multi-Species Conservation Program
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ABSTRACT

Much of the project area for the Lower Colorado River Multi-Species Conservation Program (LCR MSCP) lies within the historic range of the Elf Owl (*Micrathene whitneyi*). Elf Owls were greatly reduced within the Lower Colorado River valley during the 20th century as a result of development, water diversion, and loss of riparian gallery forest (Halterman et al. 1989, Rosenberg et al. 1991). Recently, however, the LCR MSCP has begun to recover riparian vegetation along the Lower Colorado River, with the intent of creating habitat for Elf Owls and other covered species. Prior to the initiation of this project, only one Elf Owl had been detected in the LCR MSCP project area during call broadcast surveys, near Blankenship Bend in 2009 (Beth Sabin, *pers. comm.*). It was unclear whether this rarity of detections was reflective of the actual rarity of Elf Owls, or was instead a result of inadequacies in call broadcast survey methods or low responsiveness of the species to call broadcasts under some conditions. This two-year study addressed the need to evaluate and optimize the call broadcast survey protocol by systematically testing the responsiveness of Elf Owls to call broadcasts as a function of different survey parameters. The tested parameters included time of night, distance between the call broadcast location and the owl, illumination, and presence of dense vegetation. This study was conducted at the Bill Williams River National Wildlife Refuge (BWRNWR), part of which lies within the LCR MSCP project area, and where there had been recent indications of a breeding population of Elf Owls. Most of the Elf Owl territories we confirmed over two field seasons were located in transitional riparian – upland "edge" habitat, and most nest cavities were confirmed in saguaro cactuses. Twelve owl pairs (seven in 2010, five in 2011) were subjected to systematic responsiveness tests. Our results indicated that presence of dense vegetation and distance had the greatest effects on responsiveness. When vegetation density between the call broadcast station and nest cavity was low (i.e. typical upland or transitional vegetation), responses were usually recorded at distances up to 250 m, and somewhat less often at longer distances. This "effective survey distance" was substantially attenuated, however, when the broadcast signal had to travel through expanses of dense vegetation (i.e. typical riparian woodland) to reach the targeted bird. Our observations suggested that the ability of human surveyors to hear responses over long distances and through extensive dense vegetation was often the reason for an apparent non-response. During the second project year (2011), we also investigated owl movements by radio telemetry, and made additional efforts to determine whether Elf Owls in the study area used riparian woodland habitat for nesting. We confirmed two nesting territories in riparian woodland in 2011, but concluded that Elf Owls in the BWRNWR nest mainly along the riparian - upland interface, where saguaro cactus cavities are abundant. The results of this study provide a sufficient basis to generate detailed recommendations for a standardized LCR MSCP Elf Owl discovery survey protocol, which is described herein.

INTRODUCTION

The "American Recovery and Reinvestment Act of 2009 Elf Owl Studies" project (also known as the "Elf Owl Detectability Project") was conducted in March – early June of both 2010 and 2011 as part of the Lower Colorado River Multi-Species Conservation Program (LCR MSCP). The LCR MSCP is "a long-term plan to conserve at least 26 species along the Lower Colorado River from Lake Mead to the Southerly International Boundary with Mexico through implementation of the Habitat Conservation Plan" (USBR 2006, p. 4). This document reports on the Elf Owl Detectability Project's goals, methods, results, conclusions, and recommendations.

Much of the project area for the LCR MSCP lies within the historic range of the Elf Owl (*Micrathene whitneyi*). Elf Owls are small, nocturnal, migratory birds that nest in cavities excavated by other species, primarily woodpeckers (the natural history information in this paragraph is summarized from the comprehensive review article by Henry and Gehlbach 1999). Elf Owls are "sit and wait" predators that take a variety of arthropods from the ground, the foliage layer, or the air, and they may run, hop, or fly for short distances during pursuit of prey. Males typically defend a territory containing multiple cavities. Activity is usually greatest during and just after dusk. Except for short "recess" excursions that occur primarily at dusk, females remain in the nest cavity starting 1 – 2 weeks before laying and until the clutch begins to fledge. During this period, the female alone performs incubation and is frequently fed at the nest cavity by the male. Elf Owls are known to nest both in riparian woodlands and in upland areas, particularly where saguaro cactuses are present. Preferred nesting habitat varies by region. In the Sonoran Desert, nests are most commonly located in saguaro cactuses. In New Mexico and Texas, Elf Owls tend to select nest cavities in "thorn woodlands" over riparian woodlands. In the Colorado River system, there are historical accounts of Elf Owls nesting in riparian woodlands, although its relative frequency is unclear. Preferred nesting habitat within a particular area appears to be a function of the density of nest cavities (with higher densities strongly preferred), and may also be related to the distribution of nest cavity competitors.

Elf Owl populations along the Colorado River were greatly reduced during the 20th century as a result of water diversions, invasive plants, and development (Halterman et al. 1989, Rosenberg et al. 1991, USBR 2008). As a result, the Elf Owl is a covered species under the LCR MSCP, which is creating large patches of riparian woodland that may promote the return of Elf Owls (USBR 2006).

Call broadcast surveys conducted during the breeding season are the standard method used for detecting presence and estimating densities of Elf Owls (Boal and Bibles 2001). Elf Owl call broadcast surveys were conducted in the LCR MSCP project area in the mid-2000s, but they resulted in the detection of just one owl located near Blankenship

Bend in 2009 (Beth Sabin *pers. comm.*). Interpreting this result is problematic because the responsiveness of Elf Owls to call broadcast surveys is not well quantified, particularly within riparian woodland habitat. In order to assess whether LCR MSCP habitat creation projects benefit Elf Owls, it is therefore necessary to determine the responsiveness of Elf Owls to call broadcasts under controlled conditions, and in habitat(s) relevant to the LCR MSCP. We note that in this report, "responsiveness" is used to refer to whether or not a given owl responds to call broadcasts in a manner that allows the call broadcast surveyor to register their presence. This contrasts somewhat with "detectability", which as defined in this study refers to the likelihood that Elf Owls, if present in a survey area, will be detected when implementing a particular call broadcast protocol.

The Bill Williams River National Wildlife Refuge (BWRNWR) was selected as a study area because it contains the only known and well-established breeding population of Elf Owls in or near the LCR MSCP project area. Part of the BWRNWR lies within the LCR MSCP project area, and it contains large expanses of riparian woodland that approximate the historic conditions of the LCR MSCP riparian corridor.

The primary focus of this study was to determine Elf Owl responsiveness to call broadcast surveys in the LCR MSCP environment under controlled conditions. This information is then available to optimize the survey protocol to increase overall detectability. Our general approach was to first locate and confirm Elf Owl territories and cavity locations using systematic exploratory area searches and call broadcast surveys. Next, we subjected owls in known territories to different call broadcast scenarios to record their responses. Key elements of the call broadcast protocol, such as distance to bird and time of night, were systematically varied to determine their relative impact on responsiveness.

The main goals originally identified for the Elf Owl Detectability Project were as follows:

1) Systematically quantify how distance, time of night, illumination, vegetation density, habituation, and other factors affect the responses of Elf Owls to call broadcast surveys.
2) Recommend an optimized survey protocol, including number of seasonal surveys and long-term survey effort.
3) Estimate the overall likelihood of detection of the species, when present, if the recommended methods are implemented.

Secondary goals included providing USBR with better information about Elf Owl home range, activity patterns, and habitat use within the study area.

METHODS

Study Area

Based on discussions with other researchers and agency personnel, we learned that an Elf Owl population was present in the BWRNWR (Figure 1) as recently as 2008.

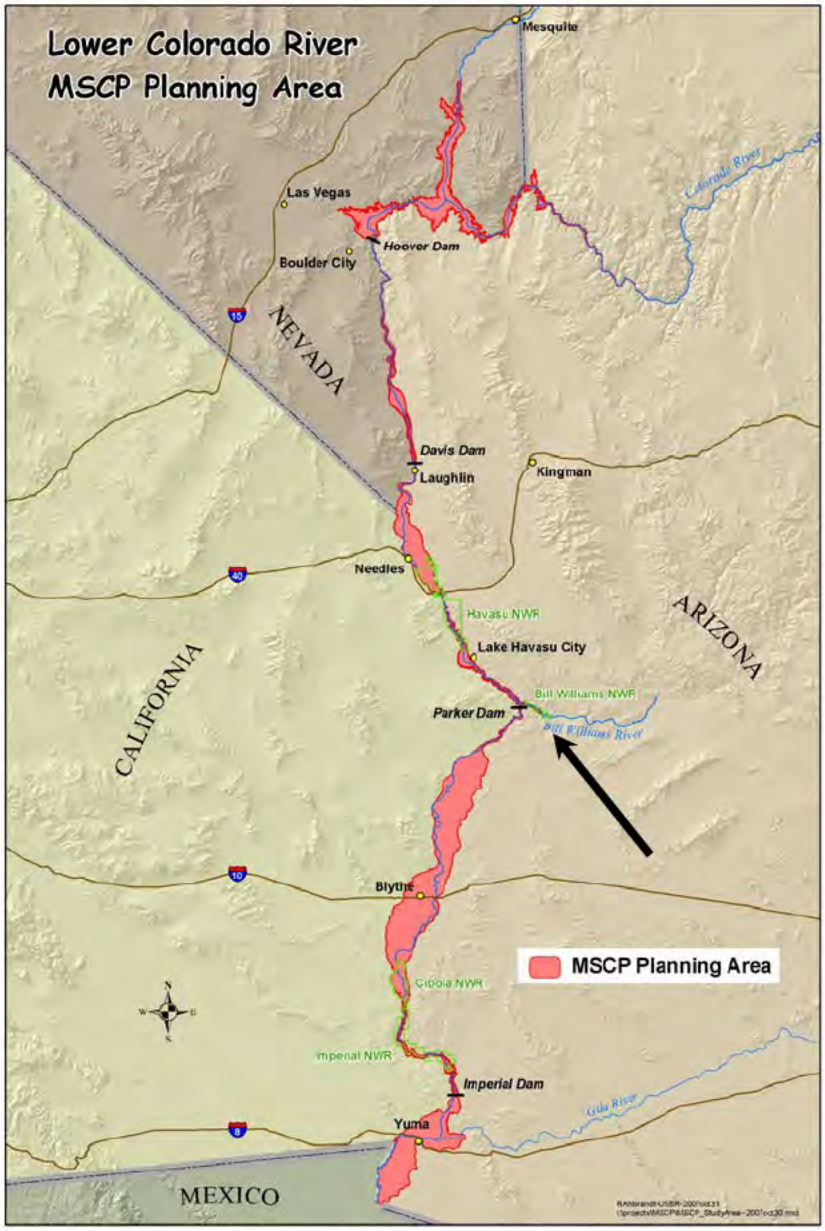


Figure 1. Location of the LCR MSCP project area (in red). The Bill Williams River NWR study area is indicated by the black arrow (map created by Ray Ahlbrandt, USBR).

This population was chosen for the study because it is the nearest known population to the LCR MSCP project area, because the riparian habitat in the BWRNWR is comparable in many respects to historic riparian habitats in the LCR MSCP project area, and because part of the BWRNWR lies within the LCR MSCP project area. Our study was conducted mostly on the western portion of the BWRNWR, closest to the confluence with the Colorado River, but limited work was also conducted as far east as the Mineral Wash and the Planet Ranch access roads.

The BWRNWR has a wide floodplain dominated by cottonwoods, willows, and tamarisk (Figure 2). Along the edges of the riparian woodland is a transitional zone of "edge" habitat, where riparian vegetation is interspersed with mesquite, saguaro cactus, and other upland or transitional plant species typical of the region. The hydrology of the Bill Williams River is controlled by Alamo Dam, and significant flooding can occur during dam releases.

Figure 2. Floodplain of the Bill Williams River National Wildlife Refuge. Photo by Amy Leist.

Study Plan

Field work during each of the two field seasons (2010 and 2011) occurred between 1 March – 3 June, a period that coincides with the Elf Owl's arrival on the refuge, territory establishment, mating, incubation, and (in some cases) early brood rearing.

The generalized sequence of field activities during each field season was as follows:

1) Prepare, mark, and map a network of exploratory survey routes within and adjacent to the refuge's riparian zone (early March).

2) Perform exploratory surveys in a systematic manner along these routes to inventory Elf Owls and determine their nesting sites, territories, and/or activity centers. Exploratory surveys involved a combination of passive listening at regularly-spaced stations, call broadcasts, and emergence observations (mid-March – early May).

3) Conduct responsiveness tests on owls in well-delineated territories to determine the relative importance of different survey parameters (April – May).

4) Capture and radio-tag Elf Owls to make observations of activity patterns and home range sizes, and to further pinpoint nest cavity locations and document behaviors (April – May).

In order to systematically test responsiveness and explore the parameters that may cause it to vary (step #3), it is necessary to know the approximate location of an individual owl when attempting to elicit its response with call broadcasts. This was the critical difference between our approach and standard call broadcast surveys. We originally planned to determine owl locations by using telemetry observations on radio-tagged birds. However, capturing owls proved to be challenging and time-consuming, and we found it comparatively easy to locate each individual bird visually or aurally once their nest site was confirmed. Additionally, the small transmitters suitable for Elf Owls produced relatively weak transmissions, and obtaining reliable position estimates by telemetry therefore required substantial and potentially disruptive movements by the researcher. These considerations made it impractical to achieve good sample sizes using telemetry to localize the tested owls. We therefore developed an alternative strategy for localizing owls in conjunction with responsiveness testing. This approach involved using two researchers to conduct every responsiveness test: a "surveyor" who operated the call broadcast equipment at a predetermined distance from the nest cavity and recorded any responses that he/she detected, and a passive "observer" located close to the bird's assumed location at or near the nest cavity. The observer's function was to determine, through passive listening and observation, whether the owl was indeed where it was assumed to be before the call broadcasts began. Furthermore, the observer was able to record owl behaviors and responses independently from the surveyor during the responsiveness tests, adding significant context and detail to our findings. Using this approach, we were able to confirm that the target owl was present near the nest cavity during 92% of all responsiveness tests conducted. For the remaining 8% of the responsiveness tests, the absence of owls could not be strictly confirmed by our method, and we bear this ambiguity in mind in discussing and interpreting our results. Interestingly, six of the eight instances when presence of the owl was not confirmed occurred in the pre-dawn test period (see Results).

All data sheets used in the study of the Elf Owl detectability study are presented in Appendix 1.

Training

Prior to engaging in any field work, field crew members were familiarized with the Elf Owl vocalization repertoires using recordings obtained from multiple sources ("Stokes Field Guide to Bird Songs: Western Region", 1999 ed.; "Peterson Field Guide to Western Bird Songs", 1992 ed.; "The Cornell Laboratory of Ornithology's Bird Songs of the Rio Grande Valley and Southwestern Texas", 2000 ed.). Field crew members also studied and utilized the categorization of vocalizations as described by Ligon (1968) and Henry and Gehlbach (1999). Additionally, each crew member was tested for their ability to hear Elf Owl call broadcasts (at standard volume, see below) over a range of distances. Under optimal conditions (no audible wind, no physical impediments to sound transmission), every field crew member on the project could reliably hear broadcasts from 500 m. Ability to hear broadcasts diminished beyond this distance, with no member of the field crew able to hear broadcasts beyond 650 m. One field crew member from 2010 continued on the project into 2011, providing continuity between years.

Assumptions

According to available information, Elf Owl responsiveness to call broadcasts should in most cases be attributable to the male, which is more vocal, more mobile during the breeding season, and more likely to defend the territory (Ligon 1968, Henry and Gehlbach 1999). We also note that the same published sources provide detailed descriptions of Elf Owl vocalizations, and regard certain types of vocalizations as sex-specific. Our study was not designed to evaluate these assumptions, but observations made during the course of our field work, considered in concert with subsequent chromosomal determination of sex for eight birds, tended to reinforce them (see Results).

Call Broadcast Equipment and Volume

Chatter calls (see below) obtained from the Stokes recordings (see above) were used for all call broadcasts (the same tracks are provided to USBR as a project deliverable for reference). Call broadcast equipment consisted of a small MP3 player attached to a pair of AA-battery-operated RadioShack clamshell speakers. At maximum volume, this system produced a peak sound output of 65-70 db as measured by a handheld decibel meter located 1 m from the speaker, and 58–63 db at 30 m. In 2010, this output level was chosen for use in call broadcast surveys for several reasons: 1) the field crew subjectively determined that it approximated the actual call volume of Elf Owls in the study area, 2) broadcasts at this volume were audible to observers at 450 m, the greatest distance specified in the responsiveness testing protocol (see below), 3) given the native audio levels of the recorded calls, the equipment used could not greatly exceed this volume without distortion, and 4) louder calls may draw in birds from territories other than the one being targeted, complicating interpretation of findings. Some surveys (for example, Hardy et al. 1999; Hardy and Morrison 2000) have used higher broadcast volumes (100-110 db near the speaker) that clearly exceed natural Elf Owl vocalization volumes, but we saw no compelling reason to do this for the purpose of our study.

To support our rationale for this approach, we measured natural Elf Owl "chatter" vocalizations (i.e. Ligon (1968) Calls A and B, the same vocalizations that were broadcast in our protocols) at several locations in 2011 using the same handheld decibel meter. Four good readings were obtained, as follows: 1) 58 db at 30 m (owl vocalizing from saguaro cavity); 2) 64 db at 30 m (owl vocalizing from outside cavity); 3) 54 db at 50 m (owl vocalizing from within dense vegetation); 4) 59 db at 10 m (owl vocalizing from within dense vegetation). These readings confirmed that our call broadcast protocol approximated the natural volume of Elf Owl chatter calls.

Exploratory Surveys

In order to find Elf Owl territories suitable for testing responsiveness, it was necessary to conduct exploratory surveys during the period when owls were arriving from migration. Because of the dense vegetation that characterizes the study area's floodplain, a system of exploratory survey trails was prepared during each field season by clearing enough vegetation and downed wood to allow passage on foot by surveyors. This trail system was designed to pass through habitat thought to be suitable for Elf Owls based on previous surveys, published literature, and information obtained from biologists familiar with the study area. To the extent possible, we used trails that had been previously prepared and marked during other research activities on the BWRNWR. However, several trail segments required additional clearing and marking, which was performed in accordance with requirements established by refuge personnel. Along each designated survey trail, listening stations were formally established, waypointed, and marked at 50 m intervals.

Exploratory surveys to locate Elf Owls consisted of both passive listening and call broadcast surveys conducted along this trail system, always between dusk and midnight. All exploratory surveys were conducted by surveyors working in pairs. Passive listening surveys occurred first (21 – 28 March in 2010, 14 – 28 March in 2011), in order to minimize interference during the critical period of territory establishment. Passive surveys were performed by stopping for 3 minutes at each listening station. Surveyors listened quietly during this period and estimated the direction and bearing from which any Elf Owl vocalizations were heard.

Call broadcast surveys were conducted on each trail segment after the initial round of passive surveys (29 March – 5 May in 2010, 22 March – 20 April in 2011). At every third station (150 m intervals), 25 seconds of Elf Owl chatter calls (six call iterations, with a few seconds between each iteration) were played, with directionality of the speakers rotated among the four cardinal directions, followed by a 35 second listening period. This one-minute cycle was then repeated two more times from the same location. Three minutes of passive listening was conducted on each intermediate (50 m interval) station.

Territory and Nest Site Determination

For each Elf Owl that was detected during the exploratory surveys, additional surveys and dusk-emergence observations were conducted for several nights over a period of

approximately two weeks to determine whether or not a territory had been established, and to identify that bird's nest cavity and/or center of activity. Dusk emergence observations involved an observer taking up position, before dusk, in a location near to the suspected nest cavity. Elf Owls typically became active around the cavity while there was still sufficient light to allow for approximately 15 minutes of sight observations, and they were also relatively vocal during this period. Establishment of a territory was confirmed only when:

1) Clear evidence was obtained that two birds were present in the vicinity of a nest cavity. This required both sight observations of two birds at the cavity, and exchanges of vocalizations.
2) Both birds remained present at the nest cavity area over a period of two weeks or longer.

Additional Riparian Surveys

Most Elf Owl territories that we confirmed during the course of the study were located along the riparian - upland edge, with nesting cavities located in saguaro cactuses. After 2010, it was unclear whether this distribution of owl territories was representative of the BWRNWR, or rather a result of difficulties inherent in locating territories within the riparian woodland interior. These difficulties stemmed from two factors: 1) the limited extent of survey trails available in the woodland interior, and 2) obstructed viewing conditions within dense woodland that interfered with emergence observations. Because the habitat context of Elf Owl nesting is an important consideration for the LCR MSCP, we devoted extra effort in 2011 to investigating all possible riparian woodland interior territories. Specifically, woodland interior areas where localized owl activity was noted during the exploratory survey period were re-surveyed in May using call broadcasts during the post-dusk period. The premise for this effort was that any functional territories should be well-established and active in May, and could be confirmed by owl responses, even if specific cavity locations could not be determined.

Responsiveness Testing

Once each pair's nest cavity or activity center was determined, formal responsiveness experiments were conducted. In 2010, we designed these experiments (hereafter, "tests") to investigate the effects of distance and time of night on owl responsiveness. Distance to bird is a particularly critical, if obvious, parameter. As it increases, it inevitably lessens the likelihood of an owl response and reduces the ability of the surveyor to hear a response. These distance effects, either singly or in combination, place bounds on effective survey distance, the determination of which was a primary goal of this study. We selected three different call-playback distances to test, 100 m, 250 m, and 450 m. The maximum distance was chosen because based on our field crew training results (see above), this distance was slightly less than the greatest distance at which all field personnel could reliably hear call broadcasts that approximated natural Elf Owl vocalization volume. We assumed, in other words, that call broadcast surveys would be ineffective at distances much greater than 450 m, even if only as a result of human

hearing limitations. We also divided the night-time hours into three periods for the purposes of experimental design: Dusk (30 minutes after sunset until 23:00h), Midnight (23:00-02:00h), and Predawn (03:00h until 30 minutes before sunrise).

In 2010 and 2011, experimental matrices were constructed consisting of different combinations of distance and time of night for each territory. The order in which each permutation of distance and time was tested varied among the owls tested. No owl was subjected to responsiveness tests on sequential nights. All tests on a given bird were therefore conducted at least two days apart, and more often 3-4 days apart. Responsiveness tests were only conducted when wind conditions did not produce consistent, audible noise (i.e. < 12 km / hr wind speed, as measured by handheld Kestrel® wind speed indicators).

Each responsiveness test was conducted by a pair of researchers working together, the "surveyor" and the "observer". At least 10 minutes prior to initiation of the call broadcast, the observer quietly approached to within 25 m of the previously-determined nest cavity location and waited in a concealed location. By passive listening and visual observation, this observer could usually determine whether the owl was present near, its expected location, and detect any movements made in association with vocal responses. In practice, owl presence was confirmed in several ways. Most often, the observer recorded a vocal response from the area near the nest cavity that was elicited by the call broadcast. In some cases, the observer noted vocal responses to broadcasts that were not heard by the surveyor. In still other cases, the observer detected the owls when pairs exchanged relatively quiet localization calls prior to initiation of call broadcasts. Owls occasionally reacted to the observer's approach with "scolding" calls, and on a few occasions the observer noted movements of owls without vocalization. Finally, birds that had been radio-tagged prior to a responsiveness test (see below) could be localized by telemetry. By one means or another, the observer was then able to confirm that the target owls were indeed present close to their nest cavity for the large majority of tests (see Results for details). However, the responsiveness test was fully conducted regardless of whether or not the observer confirmed the presence of an owl. Lack of confirmation, however, played an explicit role in determining how results were analyzed and interpreted (see Results). We further note that in all cases when owl presence was not confirmed during the course of a given responsiveness test, owls were detected in the territory during subsequent tests or observations.

At a predetermined time, the surveyor, who was located at the correct experimental distance from the nest cavity as determined by GPS, conducted a standard call broadcast protocol. This protocol was the same as for the exploratory broadcast surveys (see above), except that a fourth one-minute broadcast cycle (25 seconds of playing, consisting of six chatter calls with a few seconds between each, followed by 35 seconds of listening time) was added, along with a subsequent five-minute quiet listening period at the broadcast station. These additions were made as insurance against missing any late-responding birds. Although there is no specific basis for broadcast cycles consisting of 25 seconds of playback and 35 seconds of listening, our ratio of playback to listening time is roughly similar to the that used by by Hardy et al. (1999), and in the unpublished Elf Owl

broadcast survey prepared by M. Ingraldi and S. Lowery of the Arizona Department of Fish and Game.

Both the surveyor and observer recorded vocalizations of owls leading up to and throughout the test. The test was classified as having elicited a positive response only if the response – usually in the form of Ligon's (1968) Call A or B (i.e. "chatter call") – was heard by the surveyor. Both the surveyor and observer also recorded the time elapsed from the initiation of call broadcast until first response was heard, information that was ultimately important in determining the degree to which the broadcast protocol could be shortened without compromising detectability. The surveyor also recorded information about environmental conditions at the time of the test (see Appendix 1). Of particular note, moon phase and moon position in sky were recorded. These factors were combined to produce an "illumination index" that could range from "0" (no visible moon) to "5" (full moon high in the sky). Appendix 2 summarizes how illumination values were assigned to various combinations of moon phase and position.

Because there were few riparian territories at the BWRNWR, and because those that did exist could not practicably be used for responsiveness tests, we developed an indirect method to test the effect of dense vegetation on owl responsiveness in 2011. This involved using edge territories, but establishing broadcast points, where possible, in locations that were separated from their targeted nest cavities by dense vegetation. Therefore, call broadcast stations in 2011 were characterized in one of two ways:

1) "obstructed" = the linear path from the broadcast station to the nest cavity was dominated by continuous or nearly continuous vegetation with an average canopy height at least as tall as a typical nest cavity (approximately 5 m; see Results), or
2) "unobstructed" = the linear path from the broadcast station to the nest cavity was not unobstructed by tall, dense vegetation as previously defined.

We always selected broadcast stations that could unambiguously be assigned to one of the two categories without conducting time-consuming measurements or assessments of vegetation. Because local geography and the locations of survey trails determined where it was possible to establish obstructed broadcast stations, this element of the 2011 experimental design was relatively opportunistic, and could not be fully balanced with regard to distance and location. Finally, using the definition given above, we were able to retroactively classify a small number of 2010 call broadcast stations as obstructed.

Because of the large number of crossed factors (time, distance, illumination, obstruction), the limited number of moon cycles within the available testing period, and loss of survey nights due to wind conditions, the experimental test matrices for 2010 and 2011 were not fully populated and not entirely symmetrical (i.e. not all combinations of factors were equally represented; see Results). Comparisons of responsiveness as a function of individual factors (time, distance, illumination, vegetation density) or combinations of factors were analyzed by Chi-Square goodness of fit tests in Minitab software, release 14. Because multiple tests were conducted, p-values should be interpreted conservatively.

Capture, Radio Telemetry, and Sexing

Limited radio-tagging and telemetry was conducted during the course of this project. Radio-tagging required owls to first be captured. Mist-netting proved to be the most effective method of capture, although it was labor and time intensive. For each mist-netting attempt, a pair of mist nets (38 mm mesh size, 4-tier design, 12 m and 9 m in length) was installed before dark in a favorable location near a known owl nest cavity site. The nets were opened 30 minutes after dusk. Two speakers were placed on either side of the nets, and connected by extension cords to an MP3 player that was operated from a concealed location. The call broadcasts described above were played periodically to draw birds into the nets. This mist-netting technique was modified from methods used for capturing Willow Flycatchers (*Empidonax traillii*; Sogge et al. 2001).

When an owl was captured, it was removed from net, processed to obtain standard morphometric measurements, and fitted with a standard aluminum USFWS-issued bird band. Feathers in the interscapular zone (area of approximately 1 cm x 0.5 cm) were clipped to stubble length (~ 2 mm), the area was cleaned with an alcohol swab, allowed to dry, and a small (ATS model A2445, less than 3% of adult body weight) glue-on radio transmitter was affixed to this area using cyanoacrylic glue. Two secondary tail feathers were collected for subsequent chromosomal sex determination, and the owl was released. All released birds were observed immediately after release and in subsequent visits, and confirmed to be alive and mobile.

In 2011, we also experimented with use of net poles as a less labor-intensive alternative to mist-nets, but had no success despite significant effort. The net pole consisted of a hoop of 1 m diameter, formed from a flexible plastic rod and darkened with a wrapping of black vinyl tape, affixed to an extendable pole. A piece of mist-net was mounted within the hoop. The hoop was placed in front of a known nest cavity, at a distance of approximately 0.35 m, and call broadcasts played in an attempt to either: 1) encourage an owl (presumably female) to exit from the cavity and be caught in the net, or 2) encourage an owl (presumably male) to return to the cavity and be caught in the net. This process was attempted on four different occasions, an in all cases, owls appeared to be fully aware of the net apparatus, and easily avoided it. Following these efforts, we reverted to using mist nets, as described above, for further capture attempts.

In 2010, radio-telemetry was primarily used to pinpoint nest cavity locations and to help localize birds for the purposes of responsiveness testing. We also gathered a limited amount of information on owl movements and habitat use. Radio-tagged owls were monitored periodically in 2010 using hand-held telemetry receivers with Yagi antennas. The telemetry efforts were conducted on an *ad hoc* basis, as opportunities arose during the course of the other field work. An exception to this general approach occurred for some birds that were tagged before their nest cavities and/or breeding status had been determined. In these cases, telemetry efforts were more systematic until nest cavity locations and mating status were confirmed.

In 2011, two radio-tagged birds were tracked over the course of several nights to gather more detailed information about activity budgets, habitat use, and home range. A third owl was successfully radio-tagged for this purpose, but lost its tag too soon to generate substantial data. For each of the successfully-tagged birds, an observer equipped with a handheld receiver was on station throughout the course of a given night, taking observations to determine location every 10-15 minutes to the extent possible. For each observation, owl position was determined as precisely as possible (using multiple bearings preferentially, or single bearings with estimated distances where necessary), and any indications of activity type were noted.

Secondary feathers were plucked from each captured bird and submitted to the Animal Genetics Laboratory in Tallahassee, FL (www.avianbiotech.com), for chromosomal sex determination.

Habituation

In 2011, two confirmed owl territories were selected for studying habituation. These territories were not used for the responsiveness tests described previously. The protocol for the habituation testing was to subject the territory to a standard call broadcast survey on three or four subsequent nights, always just after dusk, at a broadcast distance of 200 m, in unobstructed habitat conditions (see above). The goal of the habituation tests was to determine whether or not responsiveness waned as the call broadcast survey became more familiar to the owl.

Timeline of Major Activities

Table 1 describes the timeline of major study activities.

Table 1. Timeline for major activity categories in 2010 and 2011.

Activity	*2010*	*2011*
Training, survey routes cleared and marked, and survey stations way-pointed	March 1 - 22	March 1 – 23
Exploratory surveys to detect Elf Owls and emergence observations to determine nest sites and/or activity centers	March 21 – May 12	March 14 – May 3
Trapping attempts and telemetry	April 1 – May 22	April 21 – June 3
Responsiveness tests	April 9 – June 2	April 1 – June 1
Additional riparian surveys	N/A	May 9 – 24
Habituation tests	N/A	May 12 - 23

Unusual flooding occurred along the Bill Williams River throughout most of March 2010, which prevented full access to the floodplain interior. Therefore, the survey trail system was first established along the margins of the floodplain. As flooding receded, additional trail segments were added within the flood plain interior. The same survey trail system was used in 2011, with the addition of some new segments intended to provide better coverage of riparian interior areas, and a few other modest adjustments. During both years, most of the survey trails were concentrated in the western part of the refuge, but more limited survey trails were also established farther to the east in the Planet Ranch area.

Recordings and Photography

In 2011, we used a handheld shotgun microphone (Sennheiser®) and professional digital recorder (Marantz®) to record a variety of Elf Owl vocalizations at the BWRNWR on an opportunistic basis. These recordings are provided to USBR as a project deliverable. Additionally, in early June, we used a pole-mounted "peeper cam" to locate and visually examine the contents of three different Elf Owl nest cavities in saguaro cactuses, and to photograph owls in the nest cavities.

RESULTS

Exploratory Surveys and Territory Determination

The survey trail system is shown in Figures 3 – 6, along with all Elf Owl detections recorded during exploratory surveys. In 2010, the first owl detections occurred during the initial exploratory survey on 21 March and detections continued regularly thereafter. In 2011, exploratory surveys began one week earlier (14 March), and detections were sporadic for the subsequent two weeks (single detections on 15, 19, and 22 March). Detection frequency during these early exploratory surveys did not increase until about 28 March in both years. Appendix 3 shows a simplified summary of all detections gathered during exploratory surveys (the full data set has been submitted to USBR electronically). Our data indicate that Elf Owls began arriving mid-March during the two years of our study at the BWRNWR (this assumes that birds are detectable almost immediately upon arrival). Arrivals accelerate in late March and continue into early, and possibly, mid-April. Confirming territory establishment required several nights of observation over approximately two weeks; therefore, we can only approximate dates of territory establishment by reporting the dates when territories were confirmed, which ranged from 6 April to 2 May. The earlier date is probably more meaningful biologically, as some of our territory confirmations almost certainly occurred later than their actual establishment dates because of field work scheduling issues.

Figure 3. Exploratory survey trail system for the western part of the Bill Williams River National Wildlife Refuge in 2010. Also shown are the locations of all initial Elf Owl detections during the course of exploratory surveys.

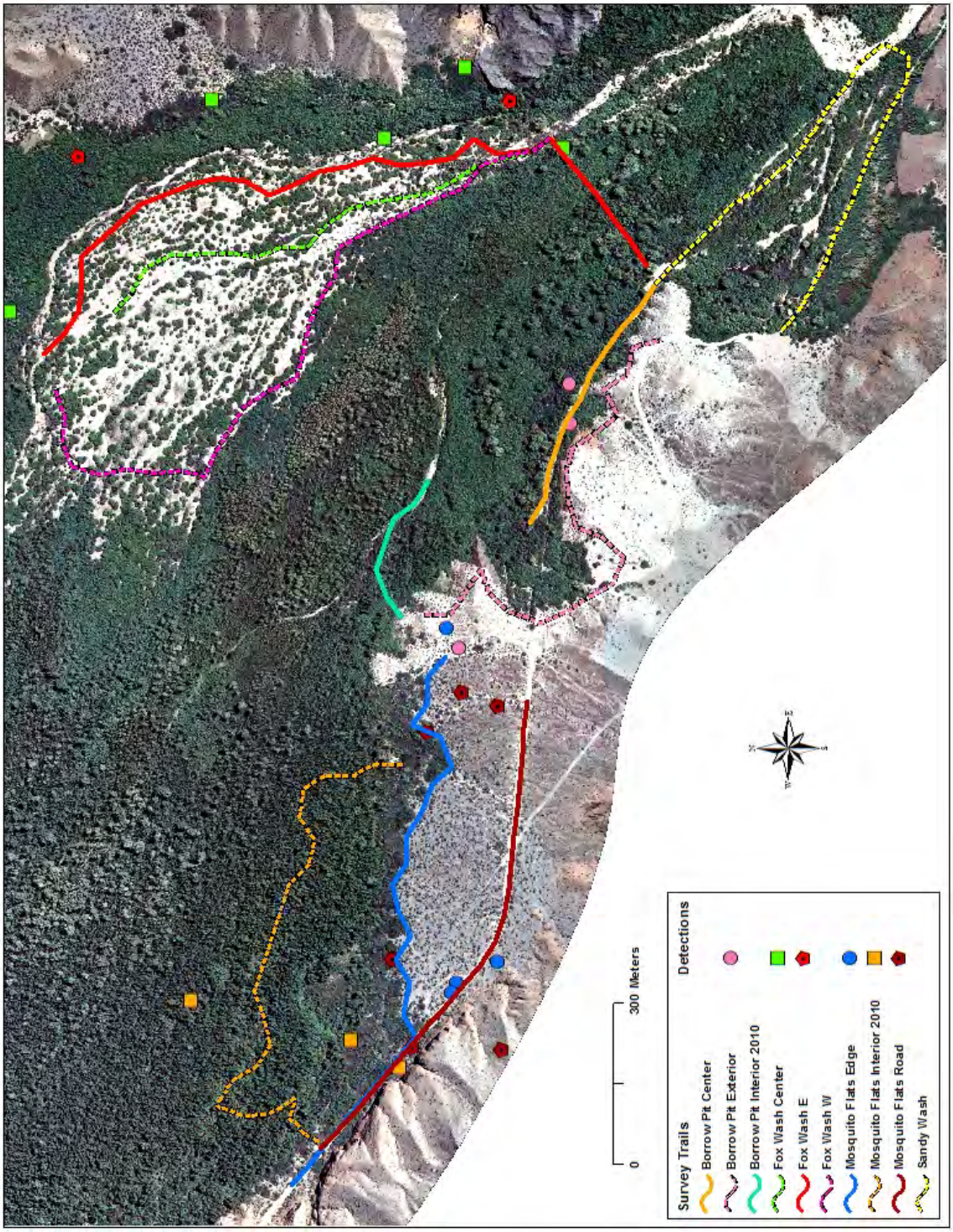


Figure 4. Exploratory survey trail system for the Planet Ranch area of the Bill Williams River National Wildlife Refuge in 2010. No Elf Owls were detected during these surveys.

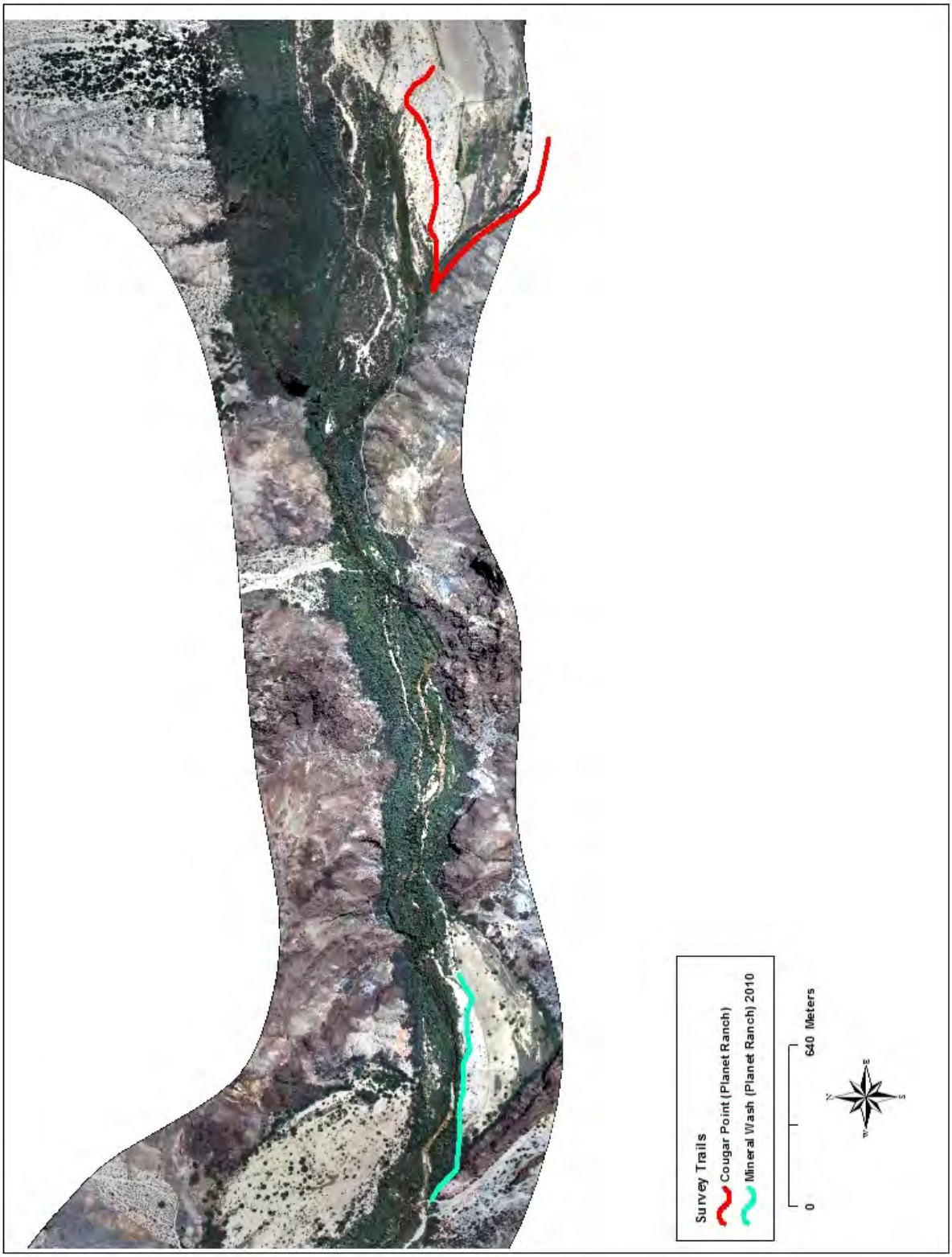


Figure 5. Exploratory survey trail system for the western part of the Bill Williams River National Wildlife Refuge in 2011. Also shown are the locations of all initial Elf Owl detections during the course of exploratory surveys.

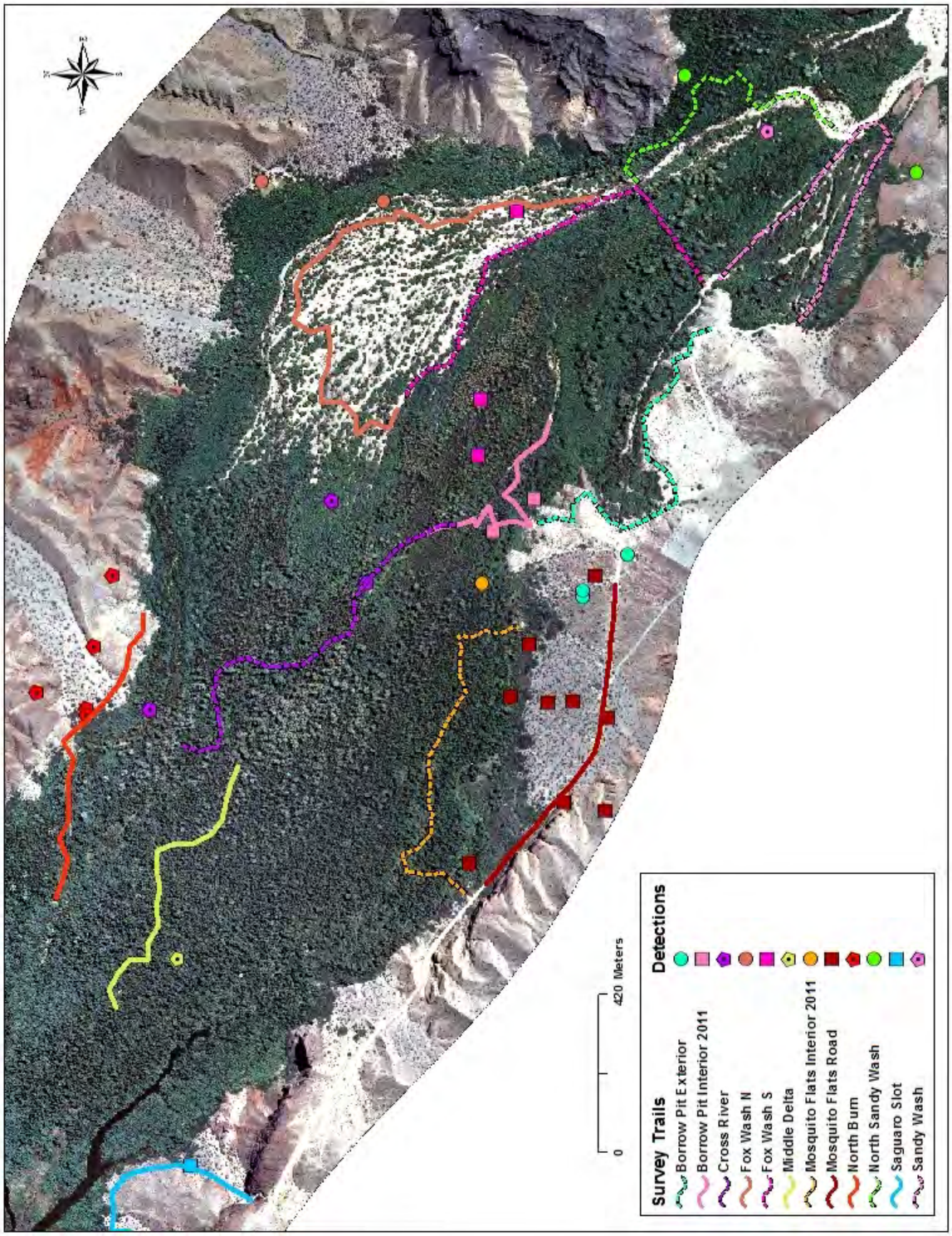
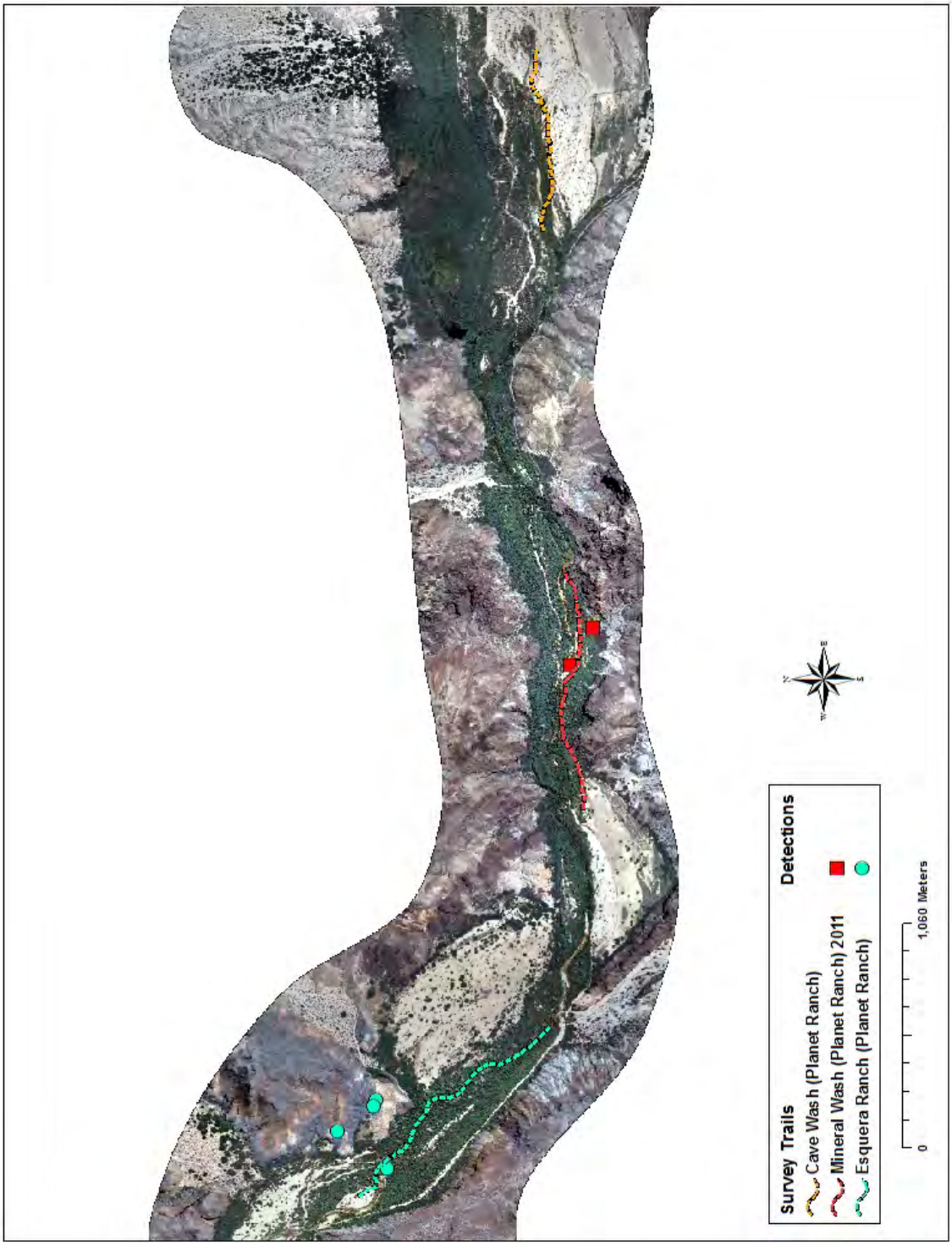


Figure 6. Exploratory survey trail system for the Planet Ranch area of the Bill Williams River National Wildlife Refuge in 2011. Also shown are the locations of all initial Elf Owl detections during the course of exploratory surveys



Although it was not always possible to distinguish between individual birds with certainly, we estimate that at least 12 different Elf Owls were detected during exploratory surveys in 2010 (more detection points are shown in Figure 3, but more than one point may have been attributable to a given owl). Of these, seven were ultimately successful in becoming mated and establishing territories in the study area. These seven territories were given place names that served to identify each nesting pair (Table 2, Figure 7), and all of these territories were used in responsiveness testing. Although a substantial proportion of the survey trails passed through the riparian woodland interior, all seven of the established territories that were identified were located in riparian-upland edge habitat. For six of these territories, the main nest cavity was either confirmed or strongly suspected in a saguaro cactus, based on dusk-emergence observations. The nest cavity for the seventh territory was not precisely located, but was narrowed down using further surveys and dusk emergence observations to a small area containing both saguaros and mesquite trees.

Table 2. List of confirmed Elf Owl territories, corresponding abbreviations used in this report, and matrix showing how each territory was used in both years of the study (Resp = Responsiveness testing, Hab = Habituation testing, NU = Present but not used, NP = Territory not known or confirmed in this year). All territories listed below were located along the riparian edge except Fox Wash S, which was located in a semi-open "wash" location in the riparian woodland interior, and Borrow Pit N, which was located in the riparian woodland interior.

Territory Name	*Abbreviation*	*2010*	*2011*
Cassie's Marsh	CM	Resp	Resp
Cliff Side	CS	Resp	Resp
Secret Garden	SG	Resp	Resp
Saguaro Slot	SS	Resp	Resp
Saguaro Hill	SH	Resp	Resp
Kryptonite Saguaro	KS	Resp	NP
Fox Tunnel	FT	Resp	NP
Fox Wash S	FWS	NP	Hab
North Burn	NB	NP	Hab
Borrow Pit N	BPN	NP	NU

We estimated that at least 15 different Elf Owls were detected during exploratory surveys in 2011. From these initial detections, we positively identified eight territories (Table 2, Figure 8), five of which were nearly identical with regard to cavity location to territories established in the previous year. Two of the territories (FWS and BPN) required additional surveys (see section below) and were not fully confirmed until relatively late in the field season. As in 2010, territories were primarily located in edge habitat, but the two late-confirmed territories were located in the riparian woodland interior (FWS and BPN). Of the eight territories, five were used for responsiveness tests, two for habituation tests, and one was not used for testing due to lack of accessibility (Table 2).

Figure 7. Elf Owl territories confirmed in 2010. All territories were used for responsiveness testing.

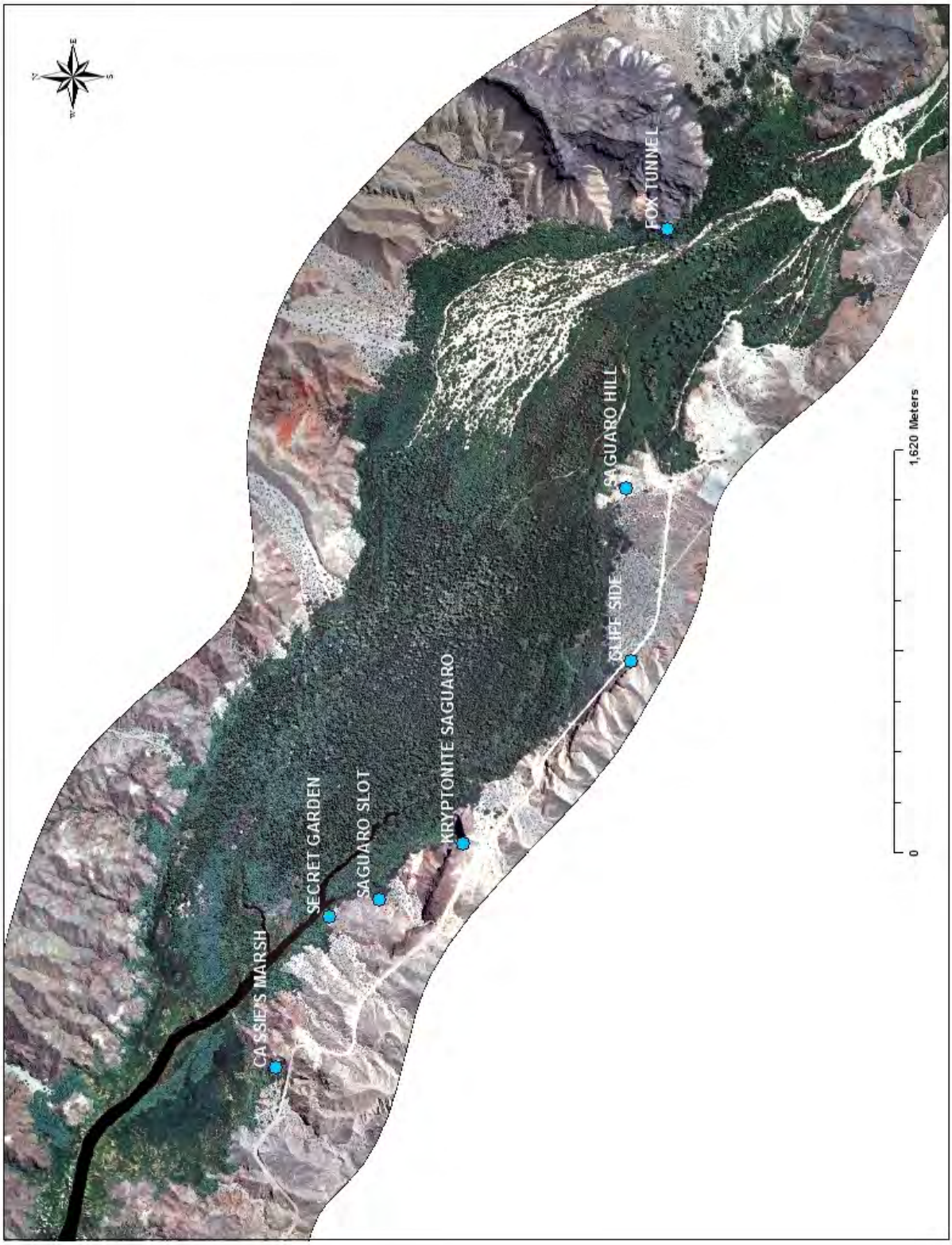
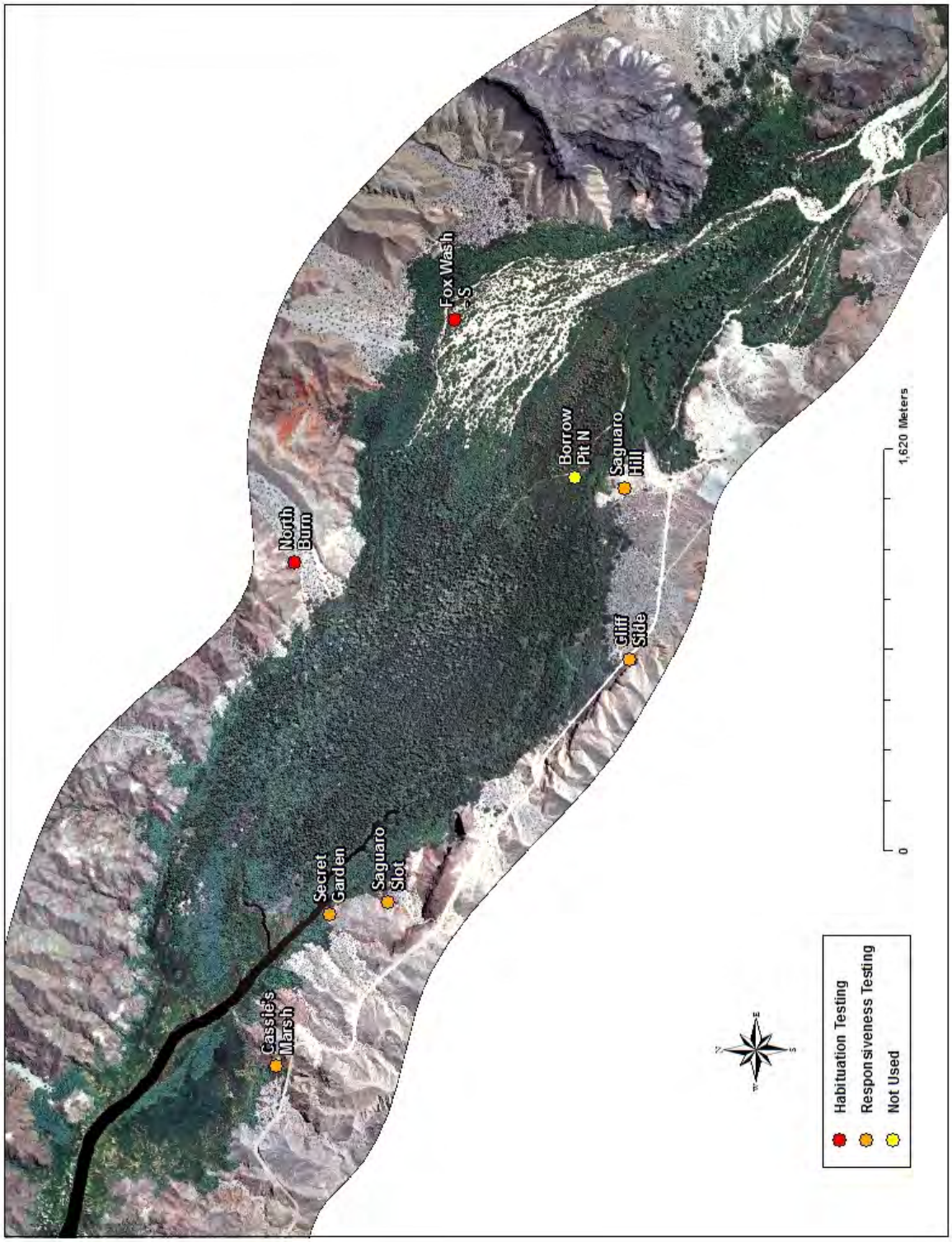


Figure 8. Elf Owl territories confirmed in 2011. Five territories were used for responsiveness testing, two for habituation testing, and one territory was not used for testing due to access difficulties and the late date of territory confirmation.



Additional Riparian Surveys

After the exploratory survey efforts in 2011, we had identified seven potential territories located in the riparian woodland interior. Because it is very difficult to make emergence observations in this setting due to limited mobility and lack of good vantage points, we could not confirm these territories or pinpoint nest cavity locations using our standard approach. Instead, we conducted additional call broadcast surveys in the second week of May or later, when any existing territories should have become be well-established. Of the seven potential territories in the riparian interior, we were able to confirm continued presence of owls in only two (Table 3, Figure 9). Owls were not responsive, and presumed absent, in the other five locations. This suggests that earlier detections at these sites involved owls that did not ultimately establish a territory near the original detection points. The activity centers for the two confirmed riparian territories were approximately 95 m (Borrow Pit N) and 140 m (Fox Wash S) inside the riparian habitat edge (Figure 8), which were also the approximate respective distances to the nearest saguaros. Therefore, it seems likely that the nest cavities associated with the two confirmed riparian territories were located in trees rather than cactuses.

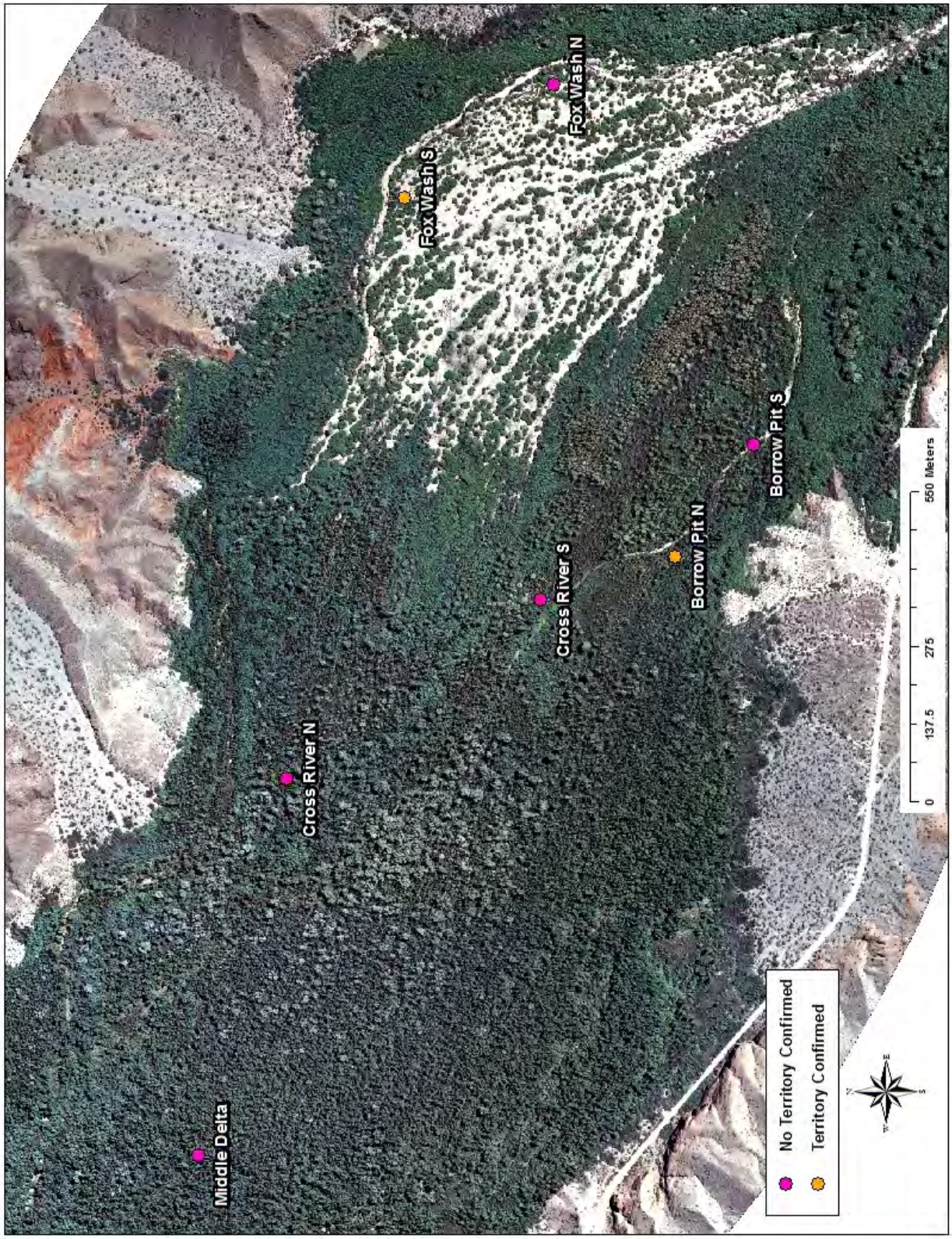
Table 3. List of possible riparian interior territories in 2011, and outcome of additional call broadcast surveys in these locations.

Territory Name	*Date(s) of additional surveys*	*Outcome*
Fox Wash S	5/10	Territory confirmed
Borrow Pit N	5/24	Territory confirmed
Borrow Pit S	5/24	No territory
Cross River N	5/9, 5/22	No territory
Cross Rive S	5/9, 5/22	No territory
Fox Wash N	5/10	No territory
Middle Delta	5/22	No territory

Responsiveness Testing

To systematically examine responsiveness of Elf Owls to call broadcasts, a series of tests were conducted beginning in 2010 using different combinations of distance from bird and time of night (see Methods). Moon phase and position (i.e. illumination) were recorded during each test as well, although they could not be treated as *a priori* factors in designing the experiments because the entire testing period occurred within < 2 complete lunar cycles. In 2011 (and retroactively for 2010), the responsiveness tests were further categorized based on whether or not dense vegetation was present along the pathway between the call broadcast apparatus and the nest cavity (i.e. “obstructed” vs. “unobstructed”). Tables 4 and 5 show the experimental matrices for the responsiveness tests in 2010 and 2011 respectively, and the dates on which each test was conducted.

Figure 9. Location of tested and confirmed Elf Owl territories located in the riparian woodland interior, 2011.



Partway through the testing process in 2010, we noted that Elf Owls had been responding reliably to call broadcasts at the shortest testing distance (100 m). Therefore, completion of the planned tests for this shorter distance were de-prioritized to ensure that all tests for the intermediate (250 m) and longer (450 m) distances could be completed within the available time. In addition, a few of the originally-planned experimental permutations proved to be unworkable due to topography, and some nights of data collection were lost due to unacceptably high wind speeds. In 2011, some of the 100 m tests were intentionally omitted from the experimental matrix to allow us to conduct other elements of the 2011 study design, such as habituation testing and additional surveys to explore possible riparian territories.

Table 4. Testing dates in 2010 for different permutations of distance to bird (100, 250, and 450m) and time of night, as previously defined. O = permutations that were omitted, as explained above. X = permutations that could not be tested due to local topography, as explained above. Tests that were retroactively classified as "obstructed" are shaded.

Pair	*Dusk 100m*	*Dusk 250m*	*Dusk 450m*	*Mid-Night 100m*	*Mid-Night 250m*	*Mid-Night 450m*	*Predawn 100m*	*Predawn 250m*	*Predawn 450m*
CM	O	6/2	5/28	O	5/5	5/8	5/2	5/12	5/19
SG	4/26	5/13	5/28	5/31	5/18	5/10	O	5/1	5/6
SS	4/9	5/4	5/20	4/19	5/8	5/27	4/12	5/18	5/12
KS	5/19	5/12	X	5/5	5/28	X	5/1	5/9	X
CS	4/26	5/29	5/7	O	5/11	5/4	5/2	5/19	5/23
SH	O	5/13	5/20	5/31	5/10	5/27	5/1	5/18	5/6
FT	5/6	5/30	6/2	O	5/11	5/19	O	5/23	5/28

Table 5. Testing dates in 2011 for different permutations of distance to bird (100, 250, and 450m) and time of night, as previously defined. O = permutations that were omitted, as explained above. Shaded cells indicate trials that were conducted through dense vegetation.

Pair	*Dusk 100m*	*Dusk 250m*	*Dusk 450m*	*Mid-Night 100m*	*Mid-Night 250m*	*Mid-Night 450m*	*Predawn 100m*	*Predawn 250m*	*Predawn 450m*
CM	4/28	O	5/13	O	5/6	5/21	5/17	5/2	5/27
SG	O	5/5	5/16	O	6/1	5/25	5/1	5/10	5/22
SS	4/28	5/16	5/11	O	5/2	5/22	O	6/1	5/27
CS	4/24	5/10	5/30	O	5/6	5/1	O	5/17	5/24
SH	O	6/1	5/5	O	5/1	O	5/28	5/13	5/24

The stations from which responsiveness broadcasts were made were selected along a concentric ring of the appropriate radius from the nest cavity location, as shown in Figures 10 – 16 (for 2010) and Figures 17 – 21 (for 2011) . In 2010, obstruction was not an explicit part of the study design, and generally the stations chosen for call broadcasts were based on accessibility and absence of features (rock outcrops or clumps of dense vegetation) that might have negatively influenced responsiveness. The main exception to

Figure 10. Locations of points from which call broadcasts were played at the Cassie's Marsh territory in 2010. In each label, the prefix indicates time of night (D = Dusk, M = Midnight, P = Pre-dawn) and the suffix indicates distance (in meters).

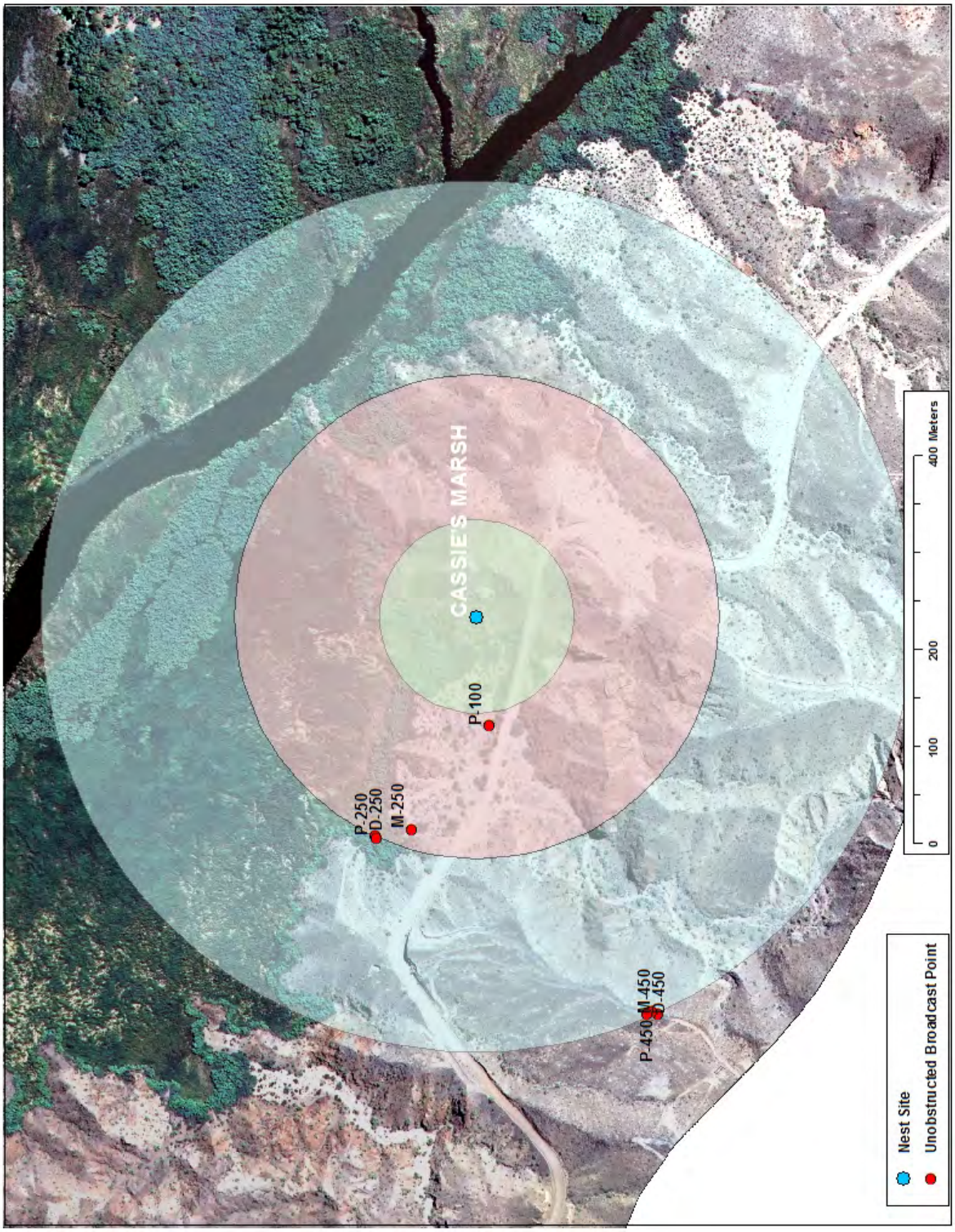


Figure 11. Locations of points from which call broadcasts were played at the Cliff Side territory in 2010. In each label, the prefix indicates time of night (D = Dusk, M = Midnight, P = Pre-dawn) and the suffix indicates distance (in meters).

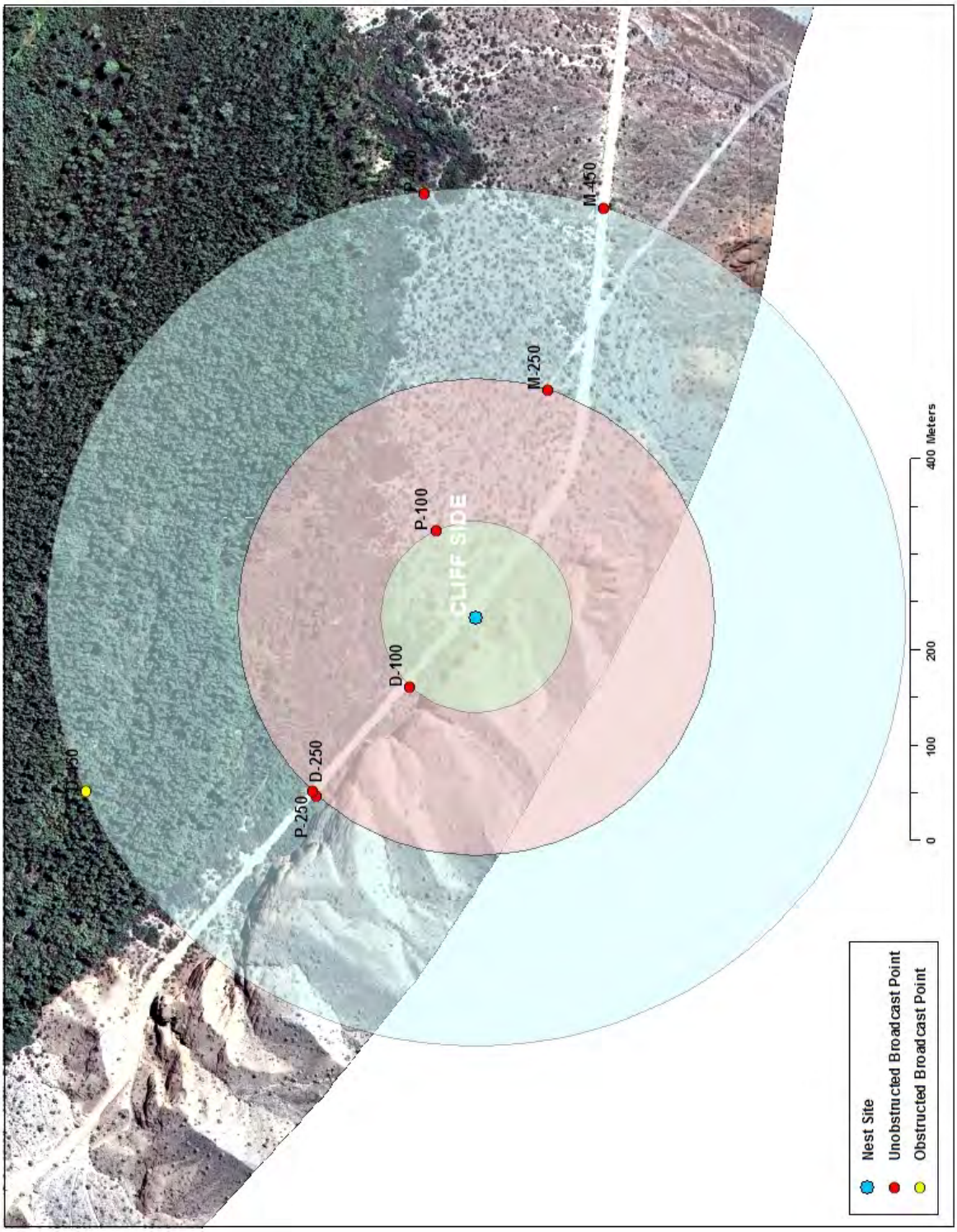


Figure 12. Locations of points from which call broadcasts were played at the Fox Tunnel territory in 2010. In each label, the prefix indicates time of night (D = Dusk, M = Midnight, P = Pre-dawn) and the suffix indicates distance (in meters).

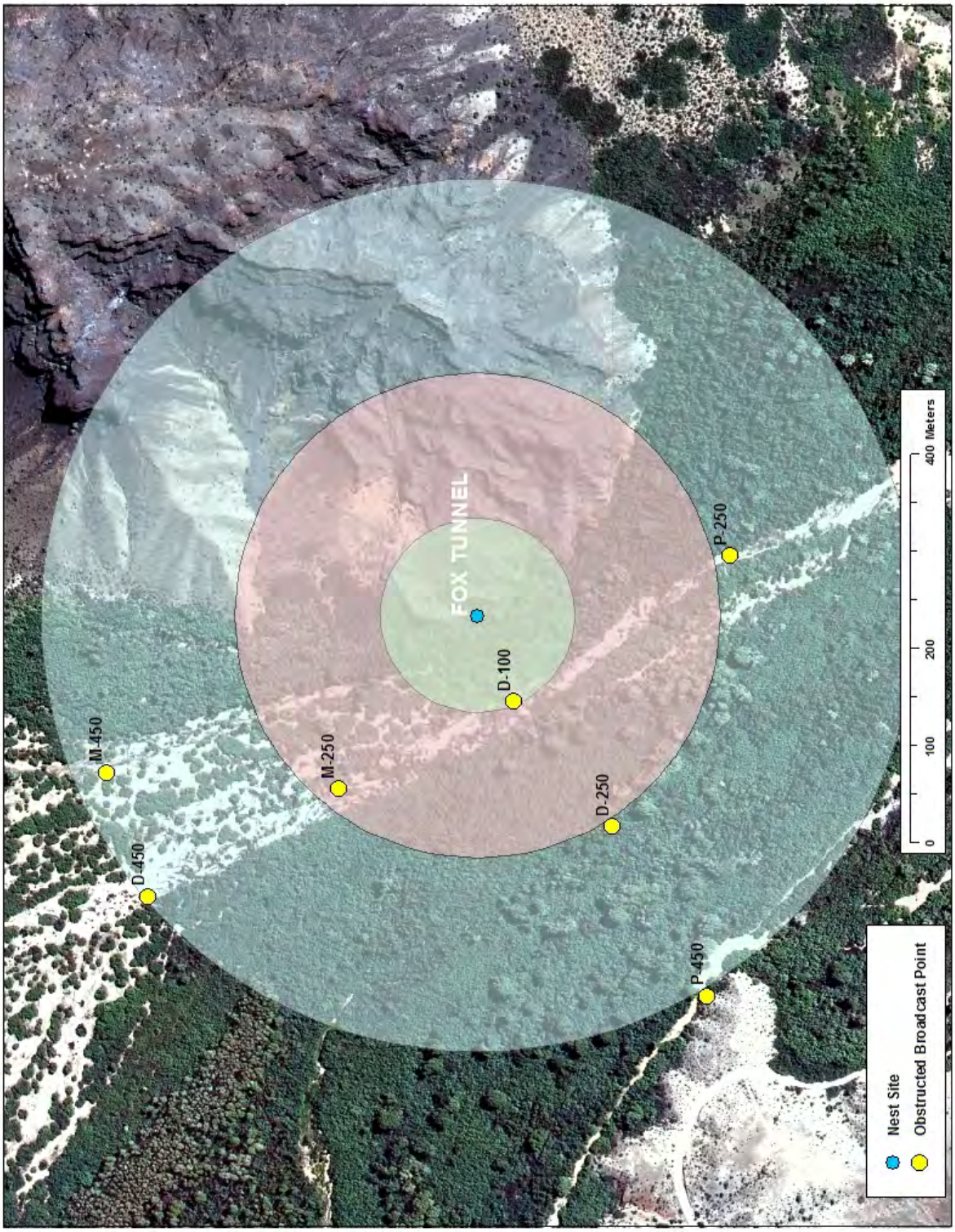


Figure 13. Locations of points from which call broadcasts were played at the Kryptonite Saguaro territory in 2010. In each label, the prefix indicates time of night (D = Dusk, M = Midnight, P = Pre-dawn) and the suffix indicates distance (in meters).

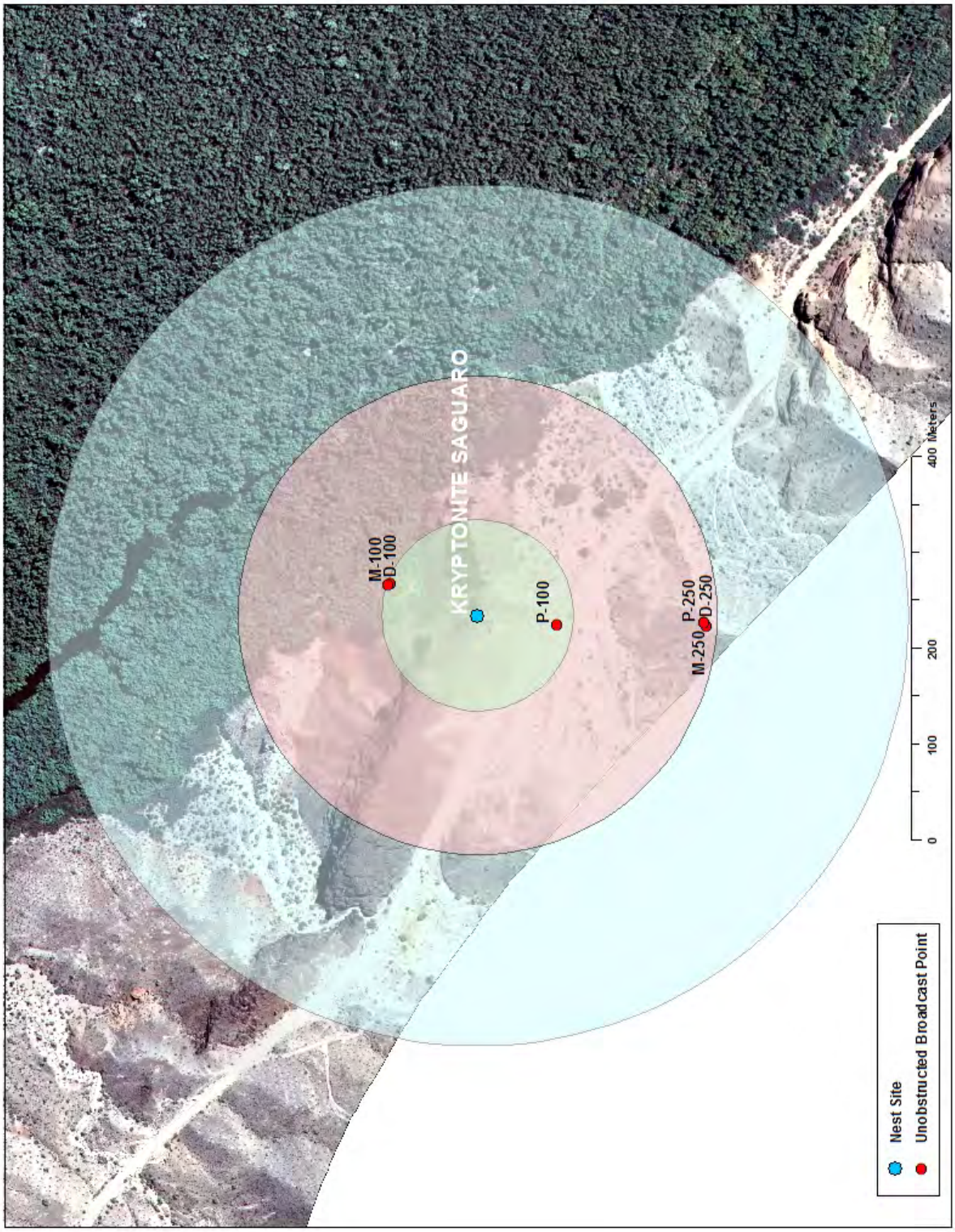


Figure 14. Locations of points from which call broadcasts were played at the Saguaro Hill territory in 2010. In each label, the prefix indicates time of night (D = Dusk, M = Midnight, P = Pre-dawn) and the suffix indicates distance (in meters).

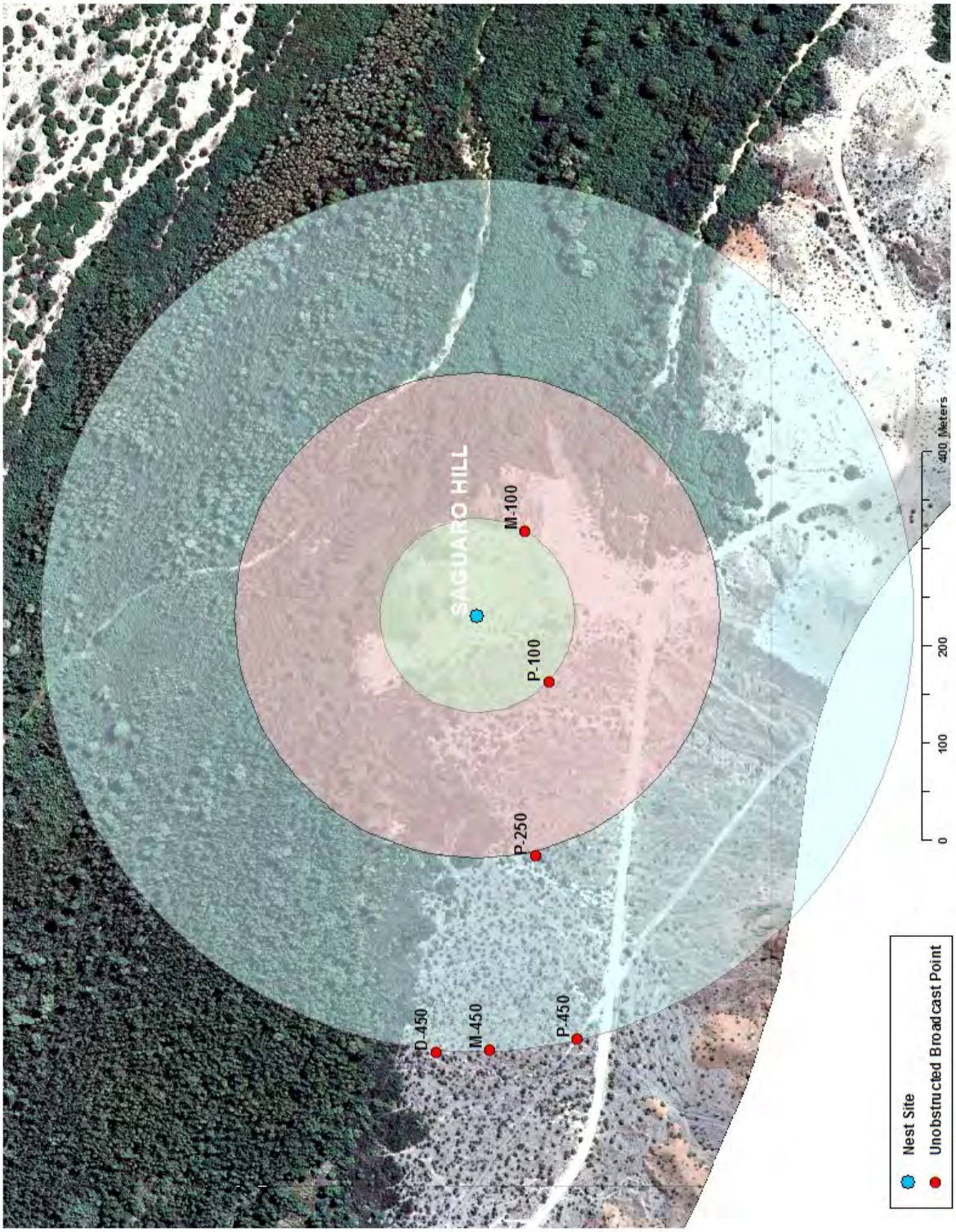


Figure 15. Locations of points from which call broadcasts were played at the Saguaro Slot territory in 2010. In each label, the prefix indicates time of night (D = Dusk, M = Midnight, P = Pre-dawn) and the suffix indicates distance (in meters).

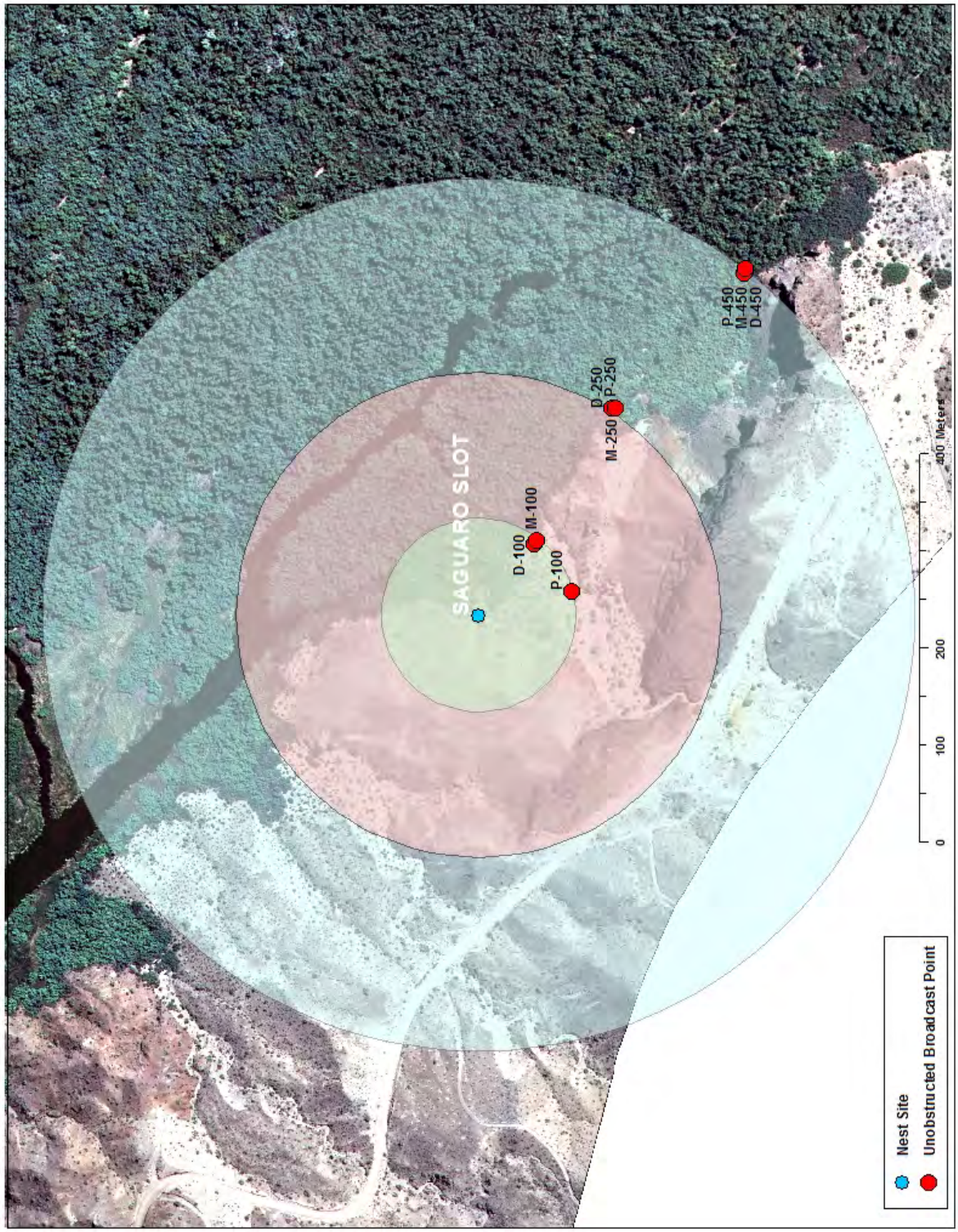


Figure 16. Locations of points from which call broadcasts were played at the Secret Garden territory in 2010. In each label, the prefix indicates time of night (D = Dusk, M = Midnight, P = Pre-dawn) and the suffix indicates distance (in meters).

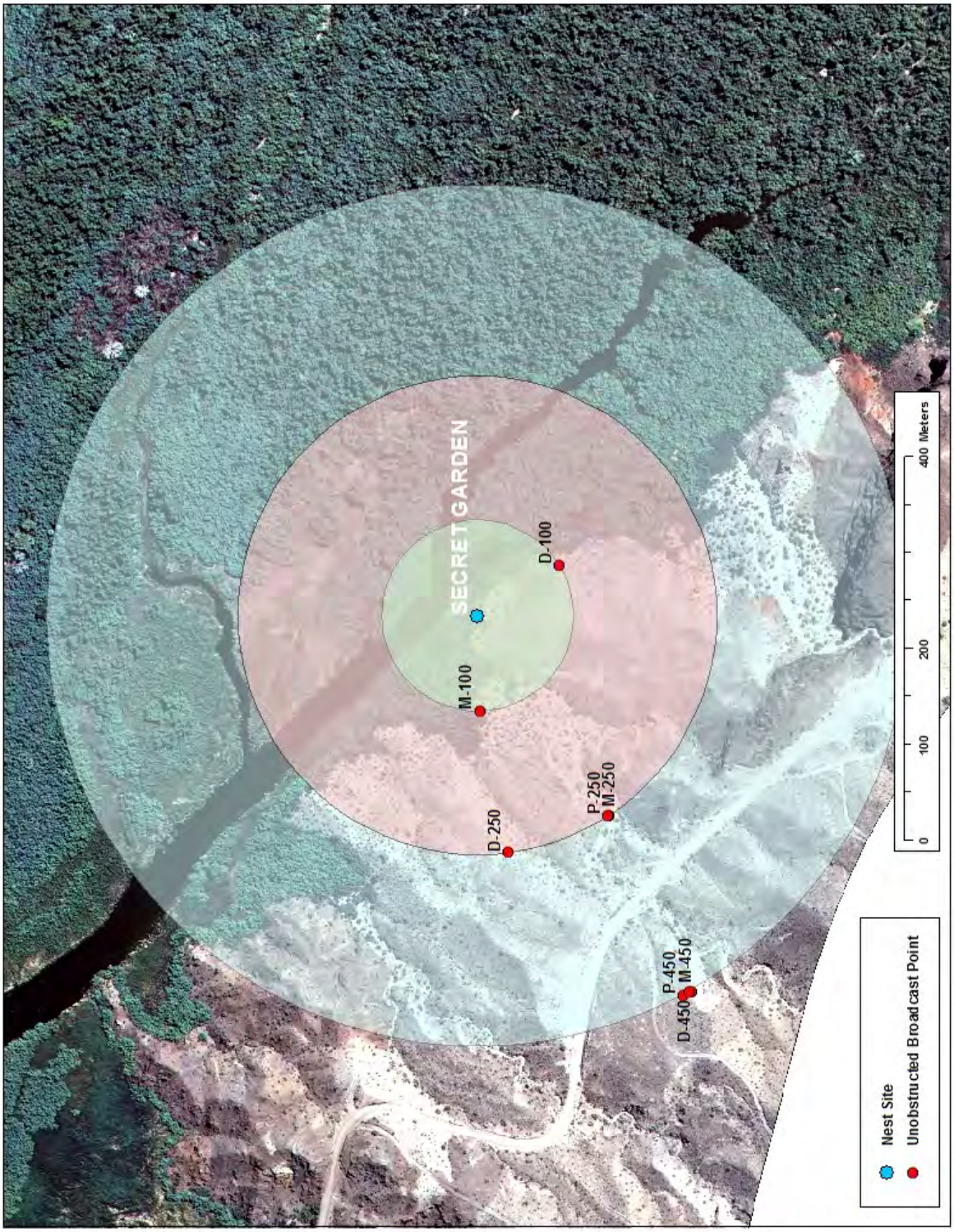


Figure 17. Locations of points from which call broadcasts were played at the Cassie's Marsh territory in 2011. In each label, the prefix indicates time of night (D = Dusk, M = Midnight, P = Pre-dawn) and the suffix indicates distance (in meters).

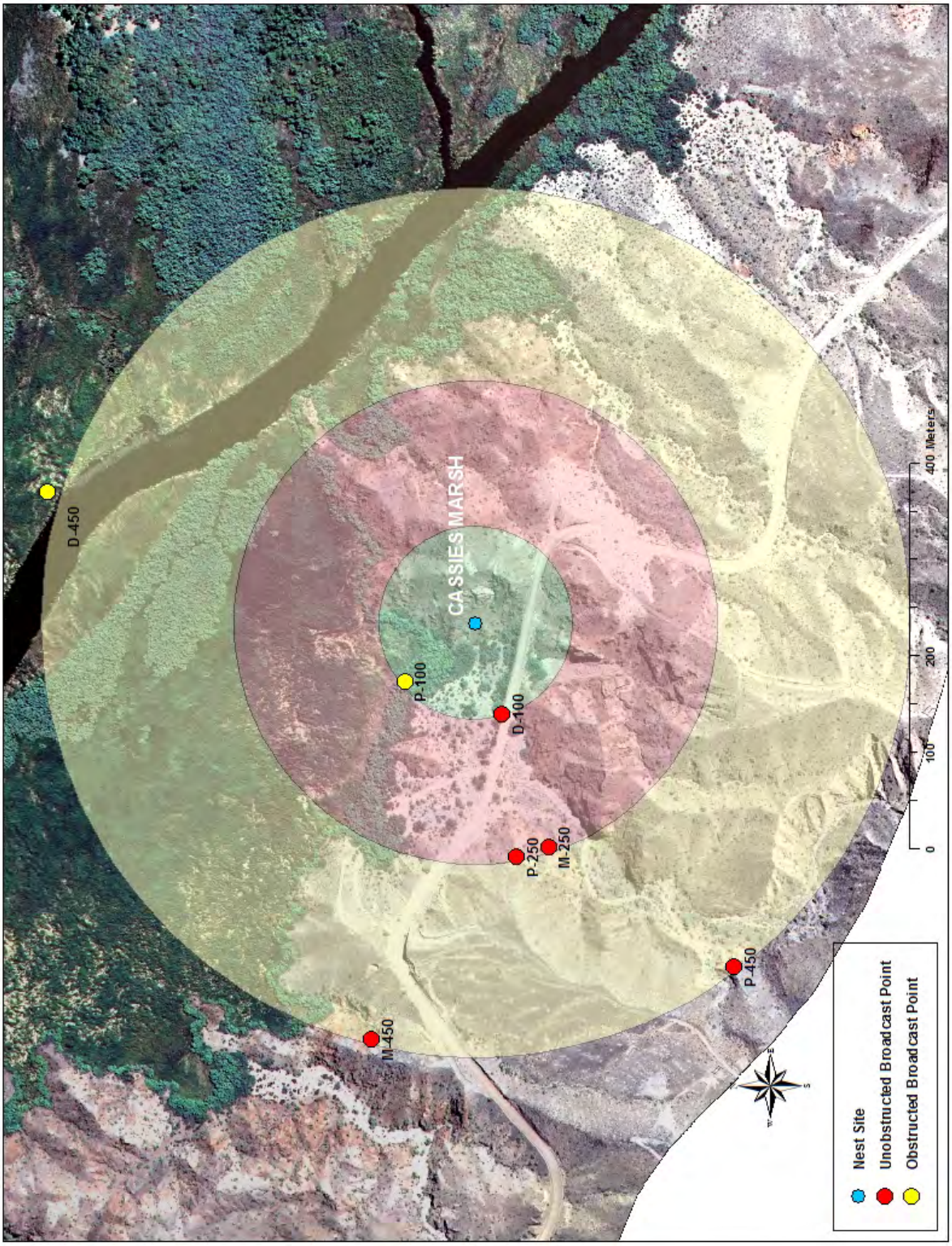


Figure 18. Locations of points from which call broadcasts were played at the Cliff Side territory in 2011. In each label, the prefix indicates time of night (D = Dusk, M = Midnight, P = Pre-dawn) and the suffix indicates distance (in meters).

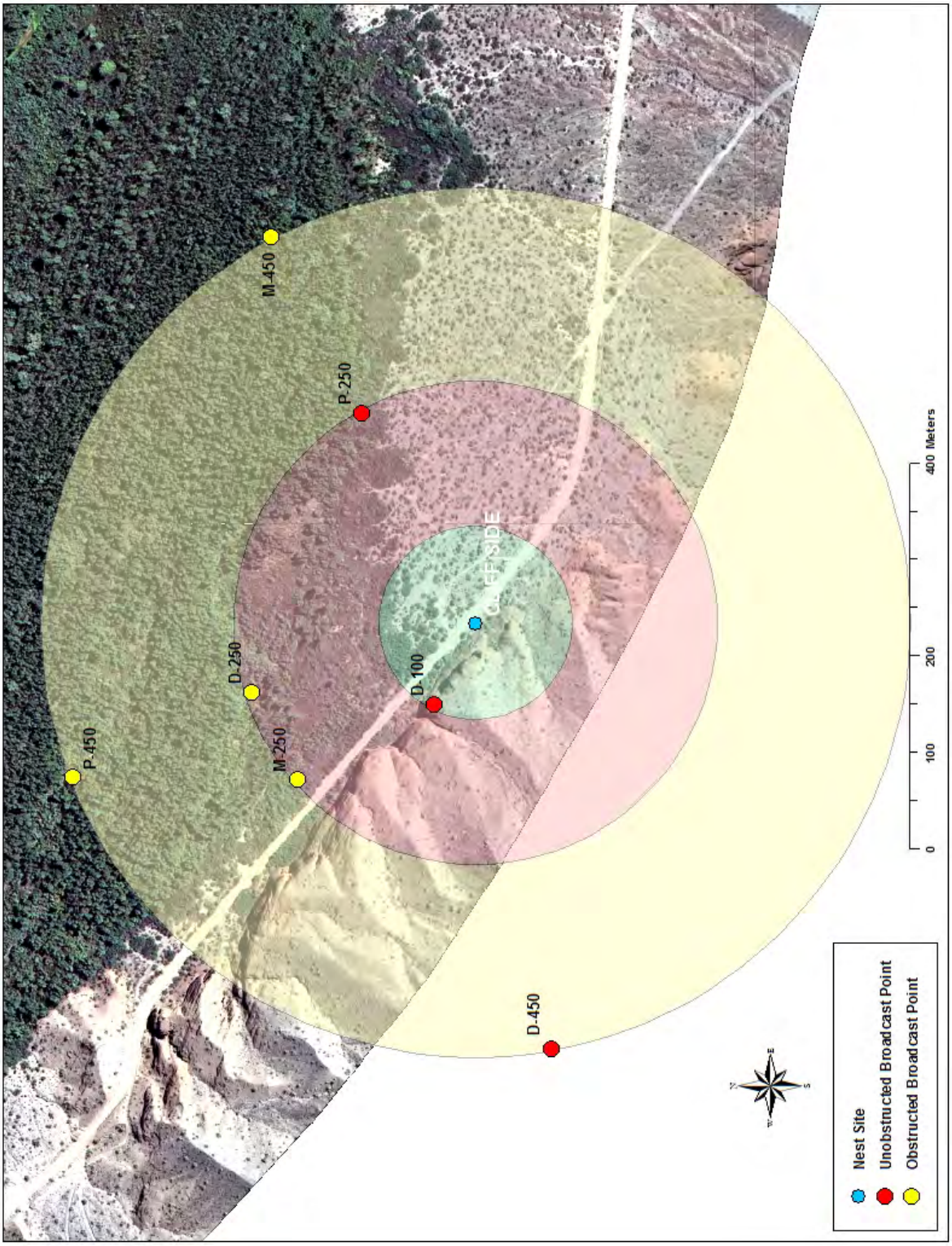


Figure 19. Locations of points from which call broadcasts were played at the Saguaro Hill territory in 2011. In each label, the prefix indicates time of night (D = Dusk, M = Midnight, P = Pre-dawn) and the suffix indicates distance (in meters).

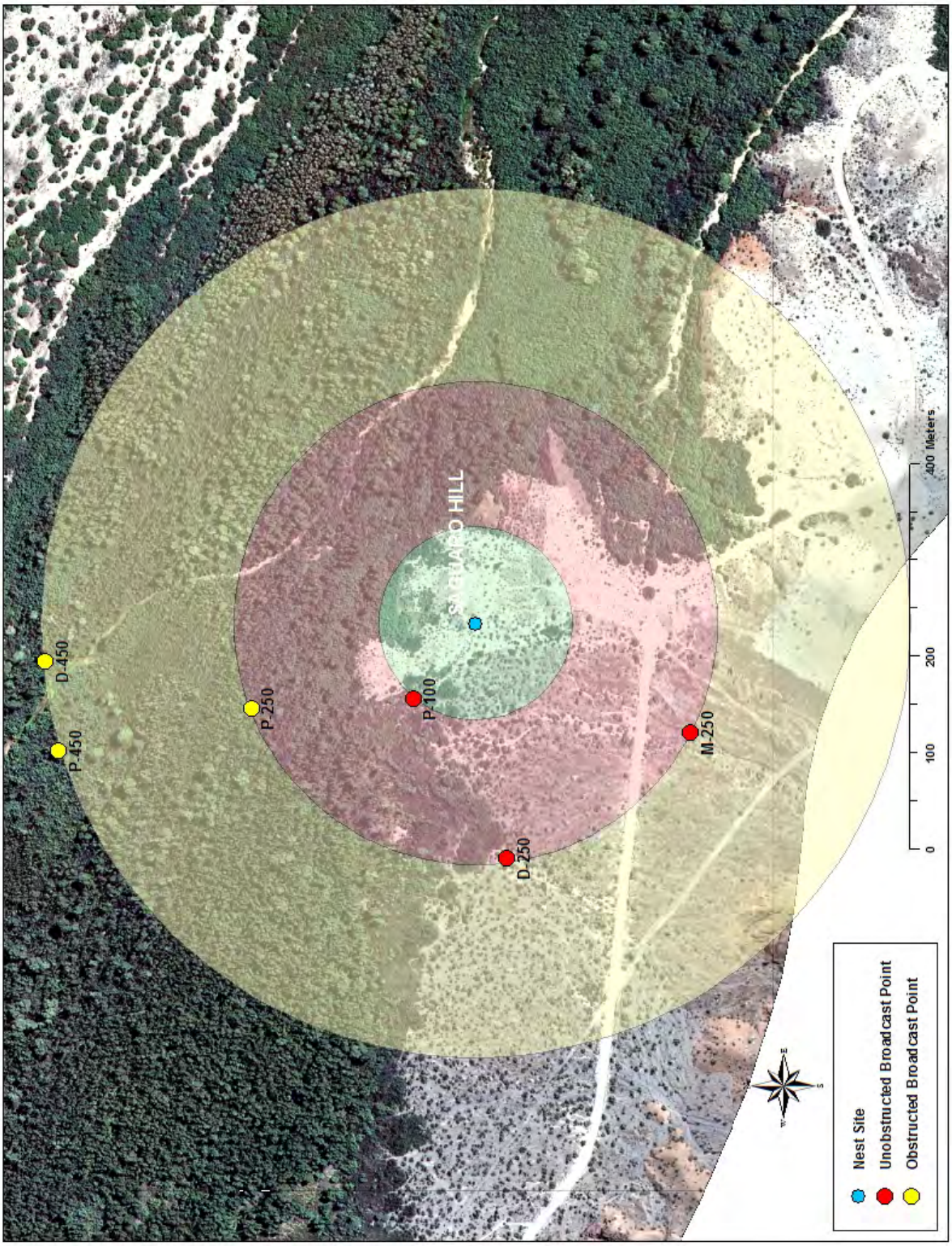


Figure 20. Locations of points from which call broadcasts were played at the Saguaro Slot territory in 2011. In each label, the prefix indicates time of night (D = Dusk, M = Midnight, P = Pre-dawn) and the suffix indicates distance (in meters).

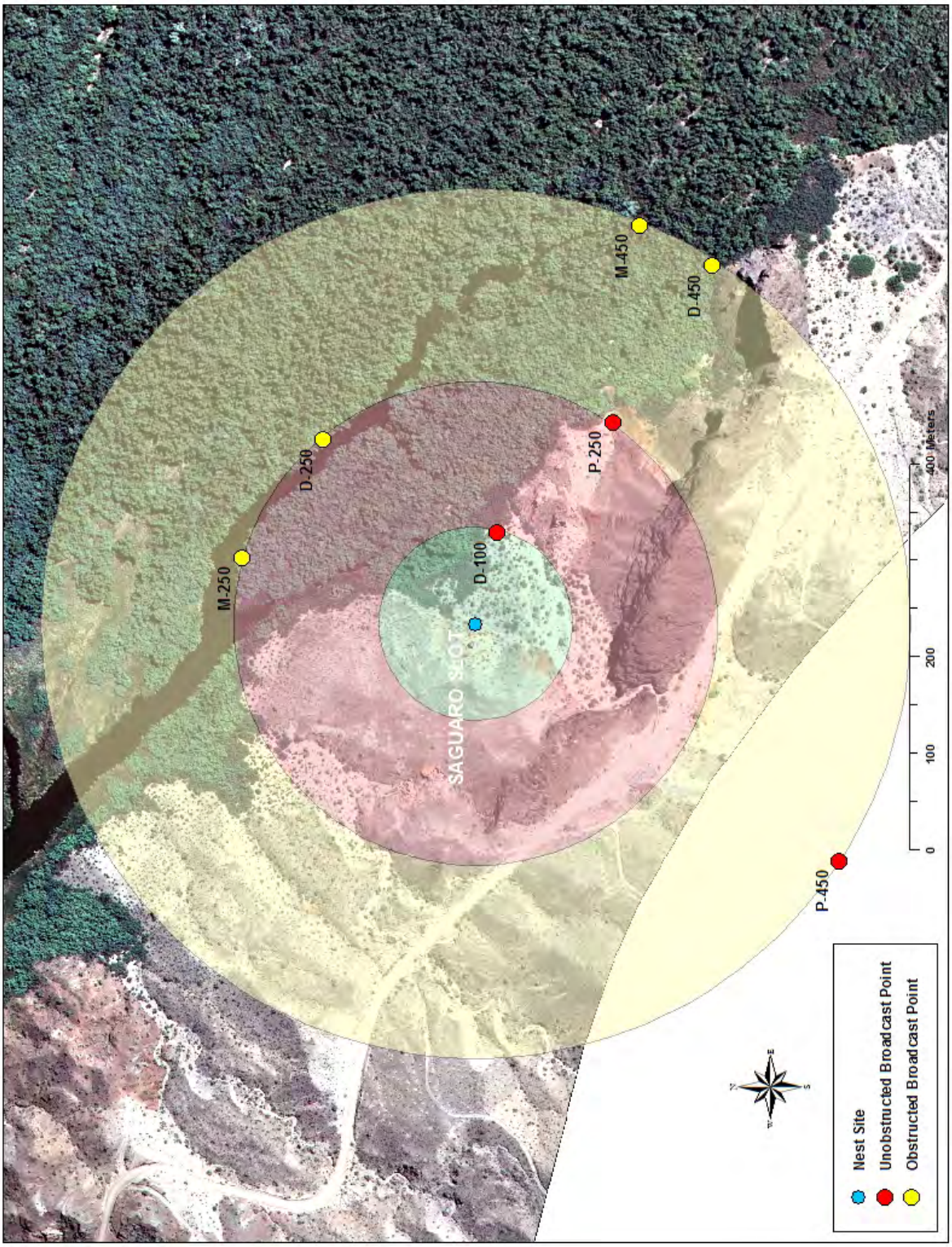
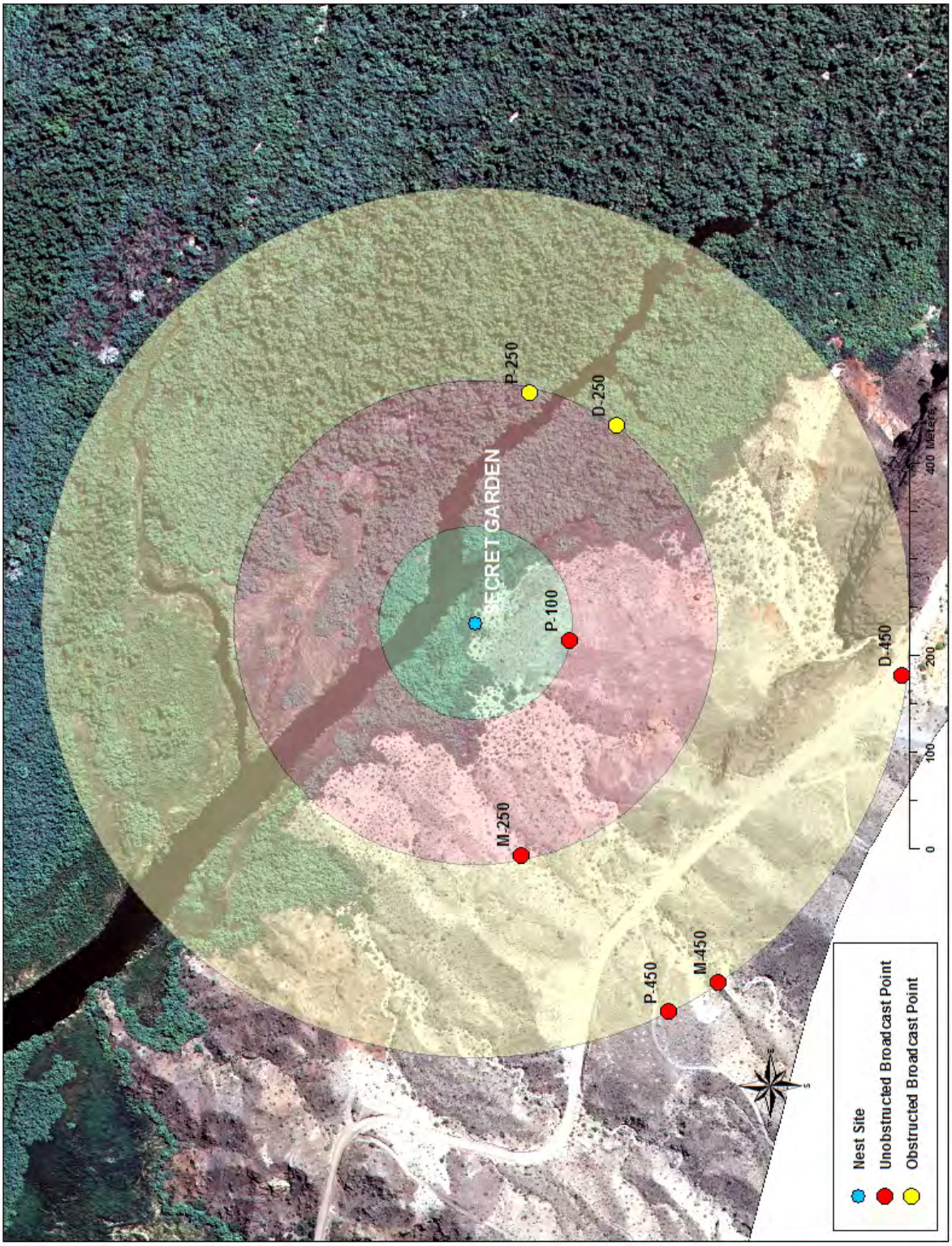


Figure 21. Locations of points from which call broadcasts were played at the Secret Garden territory in 2011. In each label, the prefix indicates time of night (D = Dusk, M = Midnight, P = Pre-dawn) and the suffix indicates distance (in meters).



this pattern occurred at the FT territory, which could only be approached through riparian habitat (see Figure 12). Therefore, all call broadcast stations for this territory were retroactively classified as obstructed. Additionally, one call broadcast station for the SH territory was similarly classified (see Figure 14). In 2011, accessibility of the broadcast station remained a basic requirement, but wherever the local setting and survey trail system allowed, we selected a station obstructed from the nest cavity by dense vegetation (as previously defined). This proved to be possible on 15 of the 34 experimental permutations that were performed.

A total of 87 responsiveness tests were completed during the two years of the study. Several additional tests were aborted in progress, or completed and later discounted because audible wind conditions (> 12 km/h sustained) existed. A condensed version of the responsiveness test data set showing key variables is given in Appendix 4 (the full data set has been provided to USBR electronically). In 79 of the 87 tests, the observer confirmed that the target owl was present near the expected location. It was not immediately clear how to best interpret the eight non-confirmed tests. Five of the eight tests occurred during the predawn time period, when, according to our telemetry findings (see below), Elf Owls are relatively sedentary and inactive in our study area. Furthermore, we confirmed in all eight cases that owls were present in their territories on multiple nights following the tests in question (i.e. territories had not been abandoned). Both of these findings tend to suggest (but not confirm) that Elf Owls were probably present during at least some these tests, but were not detected by the observer and did not respond to call broadcasts. In contrast to our telemetry findings, however, the responsiveness tests where confirmations were obtained suggest that owls were relatively responsive during the predawn period (see below). Because of this ambiguity, we present the data in two alternatives formats below that either include or exclude the eight non-confirmed tests. Because of the small number of non-confirmed test, results tended to be comparable regardless of which alternative was used.

Data from 2010 and 2011 are combined in the results presented below. Summaries and analyses regarding single factors (ignoring other factors) are presented first, followed by summaries and analyses for selected crossed factors. In all cases, responses to broadcasts are considered to have occurred when the surveyor, not the observer, heard Elf Owl vocalizations within the survey period that could clearly be attributed to the target owl. For brevity, Chi-Square tests returning a p value less than 0.05 are referred to below as significant, and those returning a p value less than 0.01 as very significant. Detailed statistical output tables are provided in Appendix 5.

Although obstruction by vegetation was not explicitly incorporated into this study's experimental design until the second field season, it proved to generate one of the most pronounced contrasts within the responsiveness testing data (Table 6). Chi-square tests indicated **responsiveness was lower in obstructed conditions than in unobstructed conditions at a very significant statistical level**. For this reason, unobstructed and obstructed conditions are considered separately in all subsequent results.

Table 6. Effect of obstruction by dense vegetation (as previously defined) on responsiveness, shown as # positive responses / # tests (percent positive responses). All times of night and distances are lumped together in this presentation. Lines designated as "all tests" include the tests for which the observer could not confirm presence of the target owl at the expected location. Lines with "confirmed owls only" exclude these tests.

	Unobstructed	*Obstructed*
All tests (p<0.001)	41/64 (64%)	4/23 (17%)
Confirmed owls only (p<0.001)	41/59 (69%)	4/20 (20%)

Differences in responsiveness for different times of night (Table 7) were not statistically significant for unobstructed conditions, and sample size was not sufficient to conduct this comparison for obstructed conditions. However, the highest observed responsiveness rate was associated with the dusk period.

Table 7. Results of responsiveness tests by time of night, shown as # positive responses / # tests conducted (percent positive responses). All distances are lumped together in this presentation. Lines designated as "all tests" include the tests for which the observer could not confirm presence of the target owl at the expected location. Lines with "confirmed owls only" exclude these tests.

	Dusk	*Midnight*	*Predawn*
Unobstructed, all tests (p=0.41)	15/20 (75%)	11/20 (55%)	15/24 (63%)
Unobstructed, confirmed owls only (p=0.63)	15/20 (75%)	11/18 (61%)	15/21 (71%)
Obstructed, all tests	3/10 (30%)	1/6 (17%)	0/7 (0%)
Obstructed, confirmed owls only	3/9 (0%)	1/6 (17%)	0/5 (0%)

With regard to distance to bird, responsiveness declined with increasing distance (Table 8). Statistical differences in a three-way comparison between the 100 m, 250 m, and 450 m for unobstructed conditions were only marginally significant (p = 0.115 for all tests, p = 0.045 for tests involving only confirmed owls), but when the longer distances were combined and then compared to the 100 m distance in a two-way comparison, significance increased (p = 0.044 for all tests, p = 0.014 for or tests involving only confirmed owls). Statistical distance comparisons could not be conducted for obstructed conditions because of limited sample size.

Table 8. Results of responsiveness tests by distance to bird, shown as # positive responses / # tests (percent positive responses). All times of night are lumped together in this presentation. Lines designated as "all tests" include the tests for which the observer could not confirm presence of the target owl at the expected location. Lines with "confirmed owls only" exclude these tests.

	100 m	*250 m*	*450 m*
Unobstructed, all tests (p=0.115)	15/18 (83%)	15/25 (60%)	11/21 (52%)
Unobstructed, confirmed owls only (p=0.45)	15/16 (94%)	15/24 (63%)	11/19 (58%)
Obstructed, all tests	1/ 2 (50%)	2/10 (20%)	1/11 (9%)
Obstructed, confirmed owls only	1/ 2 (50%)	2/9 (22%)	1/9 (11%)

With regard to the illumination, the illumination index was lumped into low (0), intermediate (1 - 3), and high (4 - 5) categories to improve replication (Table 9). Differences in responsiveness at different illumination levels in unobstructed conditions were not significant. Effects of illumination in obstructed conditions could not be statistically tested due to limited sample size.

Table 9. Results of responsiveness tests as a function of illumination, shown as # positive responses / # tests (percent positive responses). All distances and times of night are lumped together in this presentation. Lines designated as "all tests" include the tests for which the observer could not confirm presence of the target owl at the expected location. Lines with "confirmed owls only" exclude these tests.

	Low	*Intermediate*	*High*
Unobstructed, all tests (p=0.35)	27/39 (69%)	9/14 (64%)	5/11 (45%)
Unobstructed, confirmed owls only (p=0.47)	27/36 (75%)	9/14 (64%)	5/9 (56%)
Obstructed, all tests	1/10 (10%)	2/9 (22%)	1/ 4 (25%)
Obstructed, confirmed owls only	1/8 (13%)	2/8 (25%)	1/ 4 (25%)

Although seasonality was not a focal factor in our experimental design, we did compare responsiveness during the "early" (12 May or earlier) part of the testing period versus the "late" (13 May or later) part of the testing period, for unobstructed conditions (Table 10). The threshold date was selected to make the sample sizes for the early and late periods as equivalent as possible. This comparison could not be conducted for obstructed conditions due to sample size. The difference in responsiveness in the early and late periods was not statistically significant, although it was nearly so when all tests were included.

Table 10. Comparison of early versus late season (defined above) responsiveness tests, shown as # positive responses / # tests (percent positive responses). Only unobstructed tests are included, and all distances and times of night are lumped together in this presentation. Lines designated as "all tests" include the tests for which the observer could not confirm presence of the target owl at the expected location. Lines with "confirmed owls only" exclude these tests.

	Early	*Late*
Unobstructed, all tests (p=0.107)	26/43 (60%)	19/44 (43%)
Unobstructed, confirmed owls only (p=0.23)	26/41 (63%)	19/38 (50%)

There were 34 tests in which the surveyor did not detect an Elf Owl response, but for which the observer confirmed presence of the owl during the period of the broadcast survey. Of these, the observer's supplementary data indicated that (Table 11):

1) On 13 occasions the target owl clearly responded to the broadcast, and the surveyor did not detect the response.
2) On nine occasions the owl vocalized during the period of the call broadcast, but the observer was unsure whether or not the vocalization was elicited by the broadcast. This occurred either because the owl had been vocalizing prior to the

initiation of the broadcast, because two owls were exchanging vocalizations, or because the owl may have been responding to the presence of the observer.

3) On 12 occasions, the owl did not respond to the broadcast.

Table 11. Out of 34 tests with no response noted by the surveyor, number of tests in which the observer noted a confirmed response, probable or possible response, or no response. Each count is further broken down by distance in parentheses. This table excludes the eight tests for which the observer did not confirm presence of the target owl in the expected location.

	Unobstructed	*Obstructed*
Confirmed response	7 (3 at 250m, 4 at 450m)	6 (1 at 100 m, 3 at 250m, 2 at 450m)
Probable / possible response	3 (3 at 450m)	6 (2 at 250m, 4 at 450m)
No response	8 (1 at 100m, 6 at 250m, 1 at 450m)	4 (2 at 250m, 2 at 450m)
Proportion of non-responses (from the surveyor's perspective) with confirmed, probable, or possible responses from observer's perspective	10/18 (56%)	12/16 (75%)

These data indicate that non-responses from the point of view of the surveyor were, in many cases, a result of human hearing limitations rather than lack of an elicited response from the owl. This is particularly notable in obstructed call broadcast conditions. For these, it appears likely that Elf Owls responded to call broadcasts a majority of the time, even at the longer distances, although surveyors noted less than half of these responses. Another interesting observation stemming from these data is that surveyors in unobstructed conditions failed to hear Elf Owl responses three times at 250 m, and at least four times (perhaps up to seven times) at 450 m. Since surveyors had previously been tested for their ability to consistently hear call broadcasts at distances of at least 450 m, this suggests the possibility that in some cases, Elf Owls may respond to call broadcasts at lower than expected volumes.

Summarizing the results of the single-factor analyses, obstruction had the most pronounced effect on responsiveness. Time of night did not have a strong effect, but highest responsiveness occurred during the dusk period. Increasing distance, as expected, had negative impact on responsiveness. Illumination did not have a significant impact on responsiveness, although it was somewhat lower during the brightest illumination periods.

For the purposes of generating guidance for a standardized call broadcast survey protocol, we used the single-factor results presented above to hypothesize "ideal" or "semi-ideal" survey parameters, and then examined responsiveness under these specific combinations of parameters in comparison to all other combinations of parameters. This

exercise was only conducted for unobstructed survey conditions. Our data set for obstructed conditions consisted of 23 tests, only four of which produced a positive response, and thus they are insufficient for this type of statistical examination. Ideal survey parameters under unobstructed conditions were defined as:

1) A 100 m broadcast distance. This was based on the significant statistical result obtained previously.
2) The dusk survey period. This was not based on a statistically significant outcome, but rather on the practical desirability of identifying a single time of night for a survey protocol, the fact that responsiveness was highest (though not significantly so) in the dusk period, and information contained in published literature suggesting that Elf Owls tend to be most vocal and active during dusk and the period immediately following (Henry and Gehlbach 1999).
3) Illumination and period of breeding season were ignored. Evidence gathered during this study was not sufficiently clear to indicate whether any particular illumination regime would contribute to increased responsiveness. The data did suggest that responsiveness might be higher in the early season, but we chose not to dilute sample size by including this factor.

Because the sample size for the idealized survey parameters was very low (n = 7) we also defined "semi-ideal" parameters, which were identical to ideal parameters except they also included the 250 m distance, which doubled the sample size. Results of these comparisons are given in Tables 12 and 13. Ideal parameters produced significantly better responsiveness than other parameter combinations using all tests (p = 0.036), and a less significant improvement using only confirmed owls (p = 0.062). For semi-ideal parameters versus all other parameter combinations, the difference in responsiveness was significant for both sample sets (p = 0.011 for all tests, p = 0.030 for confirmed tests).

Table 12. Comparison of responsiveness under ideal call broadcast survey parameters (100 m distance, dusk time period) to all other combinations of survey parameters, shown as # positive responses / # tests (percent positive responses), for unobstructed conditions only. Lines designated as "all tests" include the tests for which the observer could not confirm presence of the target owl at the expected location. Lines with "confirmed owls only" exclude these tests.

	Ideal	*Not ideal*
All tests (p=0.036)	7/7 (100%)	34/57 (60%)
Confirmed owls only (p=0.062)	7/7 (100%)	34/52 (65%)

Table 13. Comparison of responsiveness under semi-ideal call broadcast survey parameters (100 m or 250 m distance, dusk time period) to all other combinations of survey parameters, shown as # positive responses / # tests (percent positive responses), for unobstructed conditions only. Lines designated as "all tests" include the tests for which the observer could not confirm presence of the target owl at the expected location. Lines with "confirmed owls only" exclude these tests.

	Semi-ideal	*Not semi-ideal*
All tests (p=0.011)	13/14 (93%)	28/50 (56%)
Confirmed owls only (p=0.30)	13/14 (93%)	28/45 (62%)

Finally, during tests in which a response was recorded by the surveyor as a result of call broadcasts, the average amount of elapsed time from the beginning of the broadcast until the first response was 1 minute, 9 seconds. Of the 41 unobstructed tests with a positive response, one or two broadcast iterations (out of the four performed) was sufficient to elicit the response in all but five cases. Only four positive responses were obtained in the obstructed tests; two on the first iteration, one on the second, and one on the third. Table 14 summarizes these results as a function of distance.

Table 14. For tests where a positive response was obtained, number of broadcast iterations (out of the four performed) required to elicit the response. Number of iterations was not recorded for one of the 45 tests for which positive responses were obtained, and that test is omitted from the totals.

	1 iteration	*2 iterations*	*3 iterations*	*4 iterations*
Unobstructed, 100 m	8 cases	6 cases	0 cases	0 cases
Unobstructed, 250 m	6 cases	7 cases	2 cases	0 cases
Unobstructed, 450 m	5 cases	3 cases	1 case	2 cases
Obstructed, 100 m	1 case	0 cases	0 cases	0 cases
Obstructed, 250 m	1 case	1 case	0 cases	0 cases
Obstructed, 450 m	0 cases	0 cases	1 case	0 cases

It was difficult to identify a stereotypical pattern for owl movements that occurred during the call broadcast tests, other than to note that movements usually occurred in some form. Of the 45 positive responses recorded, we had sufficient data for 39 owls to estimate maximum linear distance moved during the broadcast test. Of these, 17 moved more than 100 m, 13 moved between 50 – 100 m, five moved between 10 – 50 m, and four either did not move or moved less than 10 m. The most common pattern was for the owl to initially respond from a location in vicinity of the cavity, and then to move closer to the surveyor as the vocal response continued intermittently.

Capture, Radio-Telemetry, and Sexing

In 2010, six owls were captured and radio-tagged over the course of seven nights of mist-netting attempts. Although owls typically began responding to call broadcasts quickly, it sometimes required an extended broadcast period before they could be lured into the net. Two nights of netting were unsuccessful, presumably because the nets were too visible in the relatively bright conditions prevailing. In these cases, owls approached the speakers and nets, but avoided the nets themselves. Two owls were captured on both the SG and CS territories, and one owl each was captured on the SS and SH territories. All owls that were captured and radio-tagged flew strongly after release and were confirmed to be alive and active on subsequent days.

Telemetry observations in 2010 were made on an *ad hoc* basis depending upon other field work priorities. We used telemetry primarily to locate or confirm the location of nest cavities and male roost sites. Telemetry data for 2010 were not sufficient to compute average home ranges, but we usually detected birds within 100 m of the nest site or activity center, although more extended forays (up to 400 m) were also noted. We also

made an attempt to assign the sex of all radio-tagged birds based on what we assumed to be sex-specific behaviors and vocalizations, as described in literature (Ligon 1968, Henry and Gehlbach 1999). These include the following:

1) Females were expected to remain in the cavity the great majority of the time, whereas males were often away from the cavity for extended periods.
2) Males were expected to be responsible for issuing what Ligon (1968) described as Calls A and B, what we more informally termed the "chatter" call.
3) Females are expected to be responsible for issuing what Ligon (1968) termed Call C, what we more informally termed the "peeu" call.
4) Other calls within the Elf Owl repertoire described by Ligon (1968) or Henry and Gehlbach (1999) were reported to be less sex-specific, and were not used as a basis for making assumptions about sex of the bird.

We also assumed that for both the SG and CS territories, the two captured owls represented a mated pair. Given our observations of the radio-tagged birds, we provisionally determined that four were males, and two females. Chromosomal examination later confirmed these sex assignments (Table 15).

Table 15. List of owls captured and radio-tagged, radio frequency numbers, territories, assumed sex based on vocal and behavioral observations, and actual sex as determined by chromosomal analysis. No sex determinations were made for the 2011 SG owl because it lost its radio tag soon after capture.

Frequency	Territory	Capture Date	Assumed Sex	Confirmed Sex
151.320	SH	4/1/10	M	M
151.381	SS	4/2/10	M	M
151.261	CS	4/16/10	M	M
151.141	CS	4/16/10	F	F
151.111	SG	4/22/10	F	F
151.060	SG	4/22/10	M	M
151.080	CS	5/19/11	M	M
151.290	SG	5/25/11	n/a	n/a
151.441	CM	5/30/11	M	M

In 2011, we experimented with the use of net poles as described in the Methods section. These attempts, however, were unsuccessful, as owls proved to be adept at avoiding the nets even when exiting or entering their cavities. We reverted therefore to mist-netting, and succeeded in capturing three owls, one each from the CS, SG, and CM territories. Of these, two birds were provisionally identified as males based on subsequent observations (as described above), while the third bird lost its tag too soon to allow for observations or a corresponding sex assignment to be made. As was the case in 2010, chromosomal examination later confirmed these sex assignments (Table 15). The CS and CM birds retained their tags long enough to allow for telemetry observations to be conducted over three different nights or more. Total retention time of tags was at least three days for the CM bird (no observations were made beyond this time frame due to the end of our field

season), and at least eight days for the CS bird. The SG owl lost its transmitter within 36 hours of attachment, prior to collection of any substantial telemetry data.

Figures 22 - 28 show telemetry revealed locations for the two male birds that were successfully tracked over multiple nights in 2011. It should be noted that telemetry-based locations for owls are in many cases approximate. Birds cannot be closely approached without altering their behaviors, and thus position must be estimated using some combination of one or more signal bearings and/or estimated distances from a reference point. The amount of error inherent in this process was not precisely determined, but when conducting mock telemetry exercises with a unmounted transmitter, a telemetry operator was routinely able to estimate the true position within 25 m, without approaching closer than 100 m to the actual transmitter location.

Although there were unique features of each bird's activity pattern, some commonalities were observed. Both male birds spent the daylight hours in a day-roost site located close to the occupied cavity. The CS day-roost site was located in a dense mesquite thicket approximately 75 m from the nest cavity. The CM day roost site was located very close (< 15 m) to the nest cavity, and may have been using another cavity within the same saguaro. It was not possible to be certain of this, however, as there were two other mature saguaros located within ~ 15 m of the nest cavity saguaro, and because radio signals emanating from inside cavities can be difficult to locate precisely. Emergence from the day roost occurred during the dusk period, after the sun had set but before full darkness occurred. During the early portion of the night, both tagged birds were often active, with frequent movements and vocalizations. Nest cavity visits occurred occasionally during this period, alternating with forays away from the nest site. The middle part of the night was characterized by more extended, episodic forays that lasted for periods of up to one hour and sometimes led the birds deep into the riparian woodlands. These forays took birds their farthest observed distance from nest cavity, with distances ranging up to 600 m. In between the forays, the birds were usually located within 50 m of the nest cavity. Again, nest exchanges were sometimes observed during the middle part of the night, although less frequently than in the earlier part of the night. The later part of the night was relatively inactive. The CM bird remained relatively close to the nest cavity / day-roost site. The CS bird spent a large part of this period in uplands above the nest cavity, more specifically within a small narrow canyon containing a mature mesquite tree. Nest exchanges during the late night period were not observed. Both owls were in their day-roost sites prior to sunrise. Although little telemetry data was returned from the third radio-tagged male (from the SG territory), we note that its tag was lost in the vicinity of a large cottonwood tree located about 120 m away from the nest cavity, toward the river, within riparian woodland habitat.

Figure 22. Telemetry revealed locations for the Cassie's Marsh male, night of 5/31 – 6/1, 2011. Early night = 1931 – 2330 hours, Middle night = 2331 – 0230 hours, and Late night = 0231 – 0530 hours. The nest cavity and day roost sites are superimposed in this map.

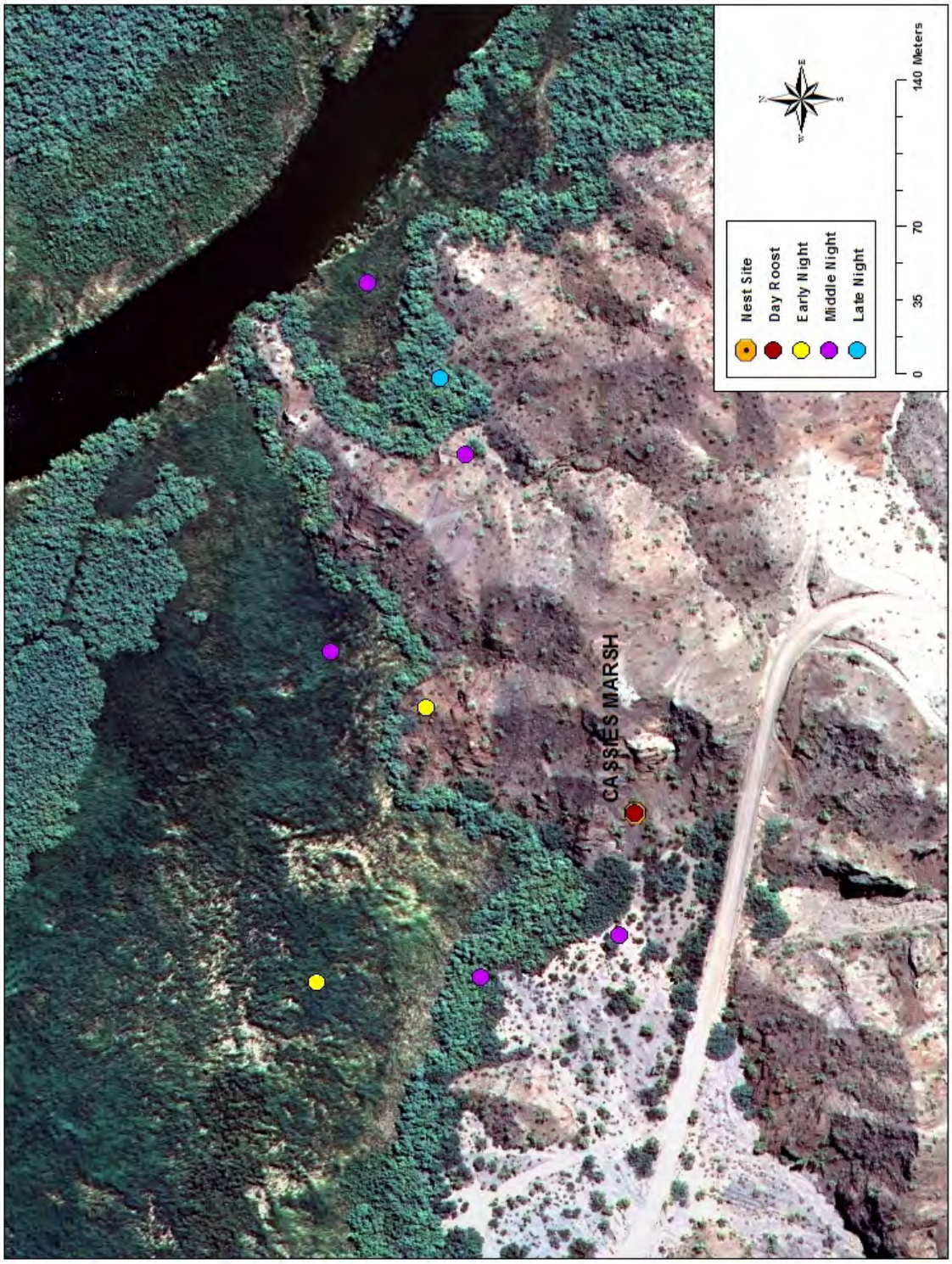


Figure 23. Telemetry revealed locations for the Cassie's Marsh male, night of 6/1 – 6/2, 2011. Early night = 1931 – 2330 hours, Middle night = 2331 – 0230 hours, and Late night = 0231 – 0530 hours. The nest cavity and day roost sites are superimposed in this map.

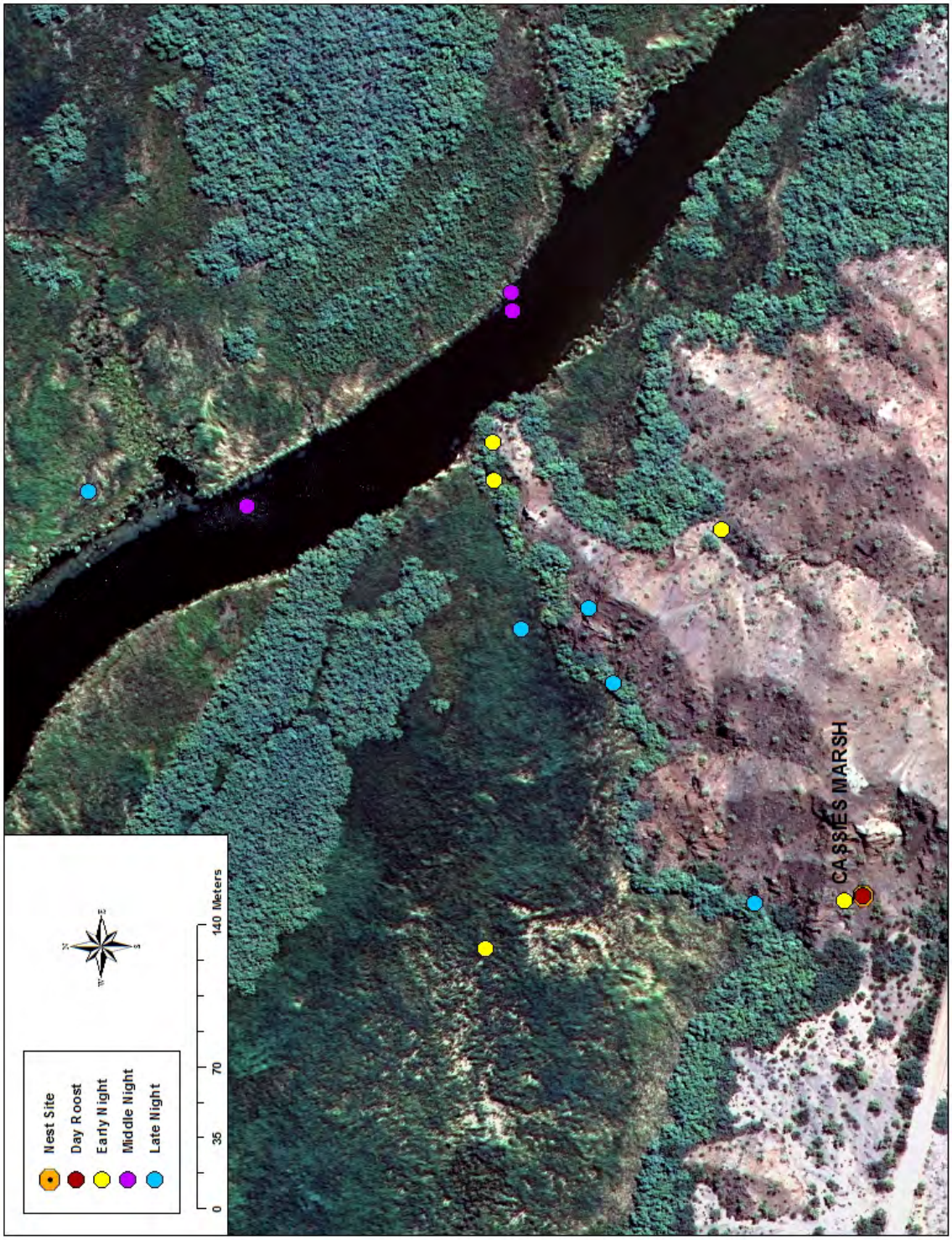


Figure 24. Telemetry revealed locations for the Cassie's Marsh male, night of 6/2 – 6/3, 2011. Early night = 1931 – 2330 hours, Middle night = 2331 – 0230 hours, and Late night = 0231 – 0530 hours.

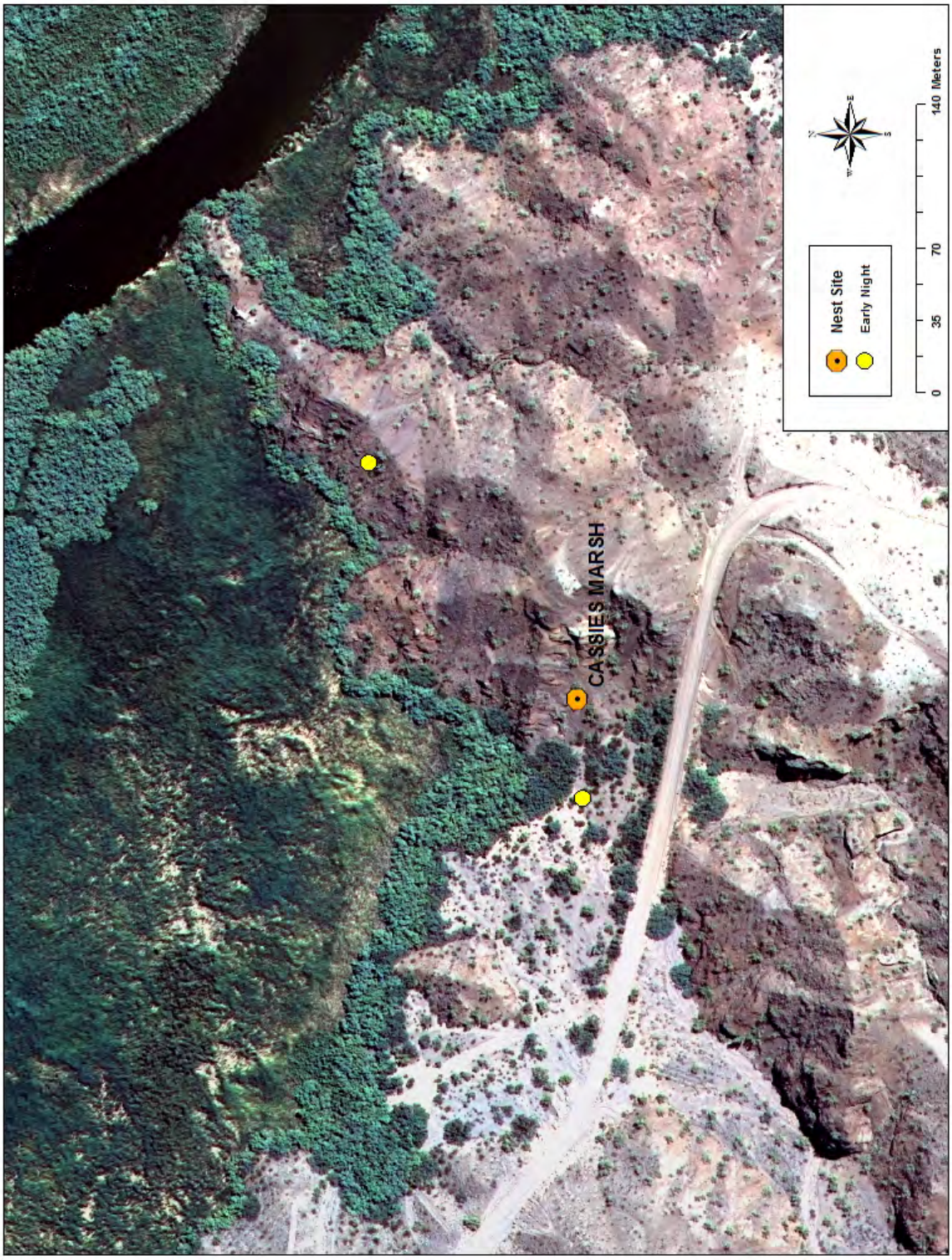


Figure 25. Telemetry revealed locations for the Cliff Side male, night of 5/19 – 5/20, 2011. Early night = 1931 – 2330 hours, Middle night = 2331 – 0230 hours, and Late night = 0231 – 0530 hours.

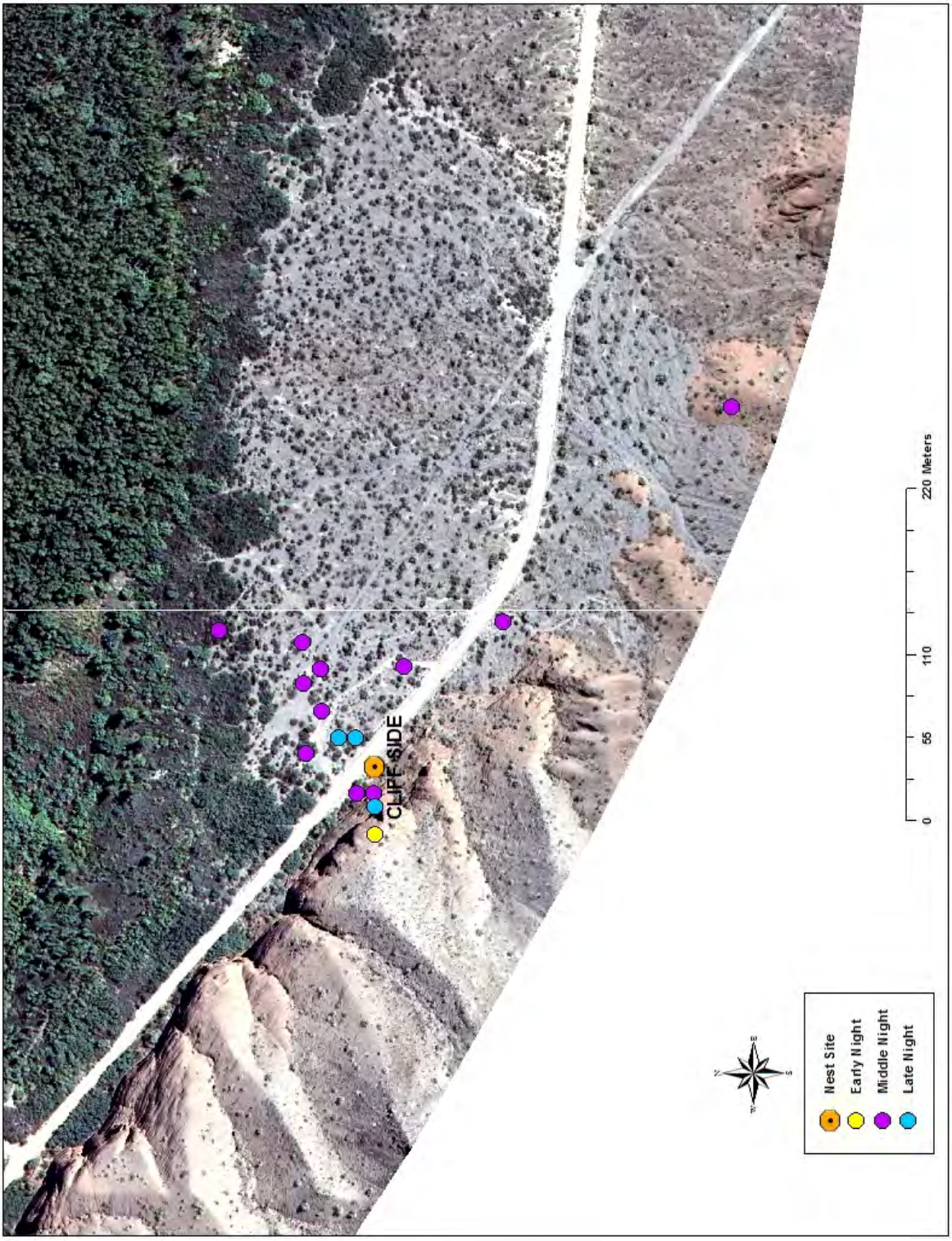


Figure 26. Telemetry revealed locations for the Cliff Side male, night of 5/20 – 5/21, 2011. Early night = 1931 – 2330 hours, Middle night = 2331 – 0230 hours, and Late night = 0231 – 0530 hours.

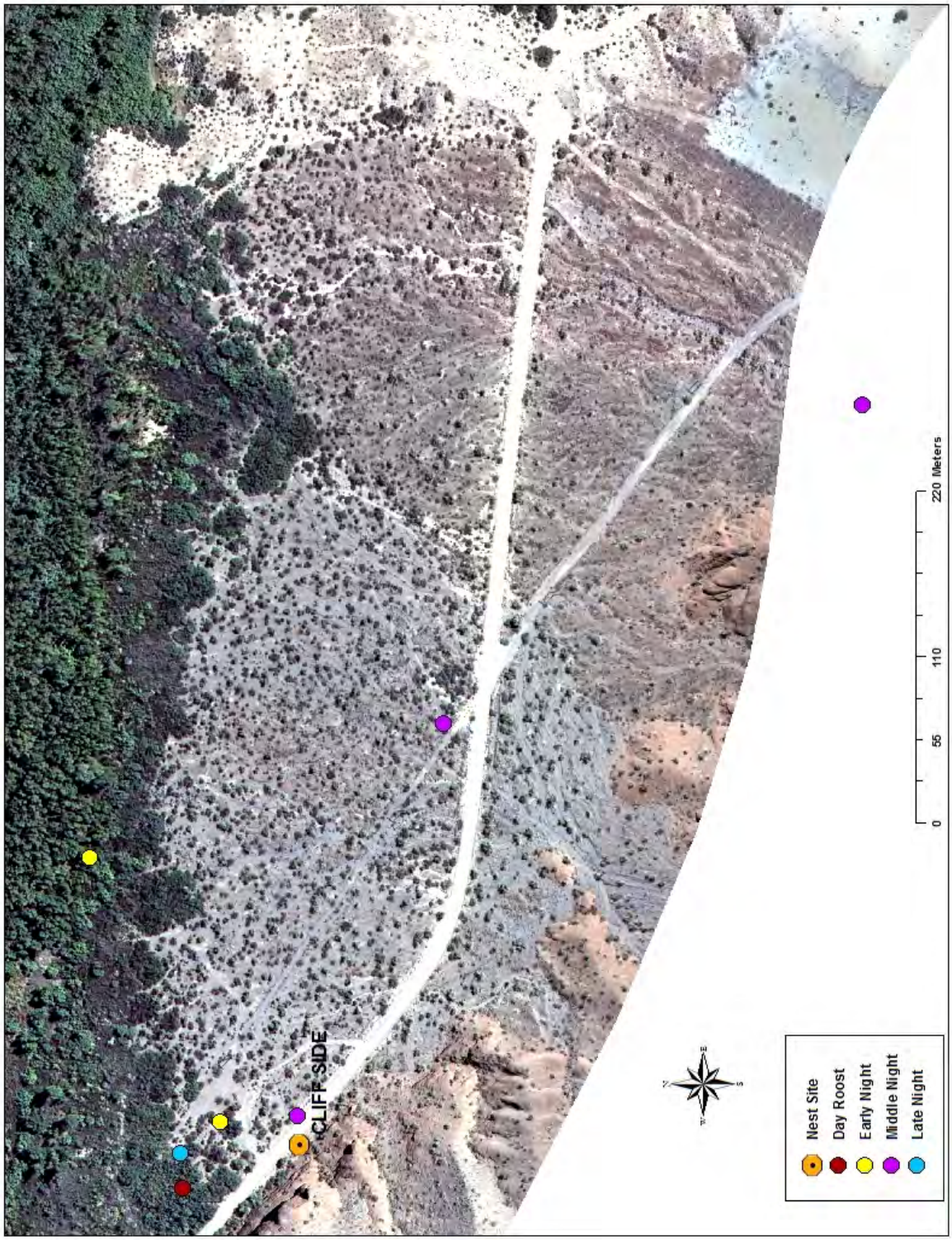


Figure 27. Telemetry revealed locations for the Cliff Side male, night of 5/21 – 5/22, 2011. Early night = 1931 – 2330 hours, Middle night = 2331 – 0230 hours, and Late night = 0231 – 0530 hours.

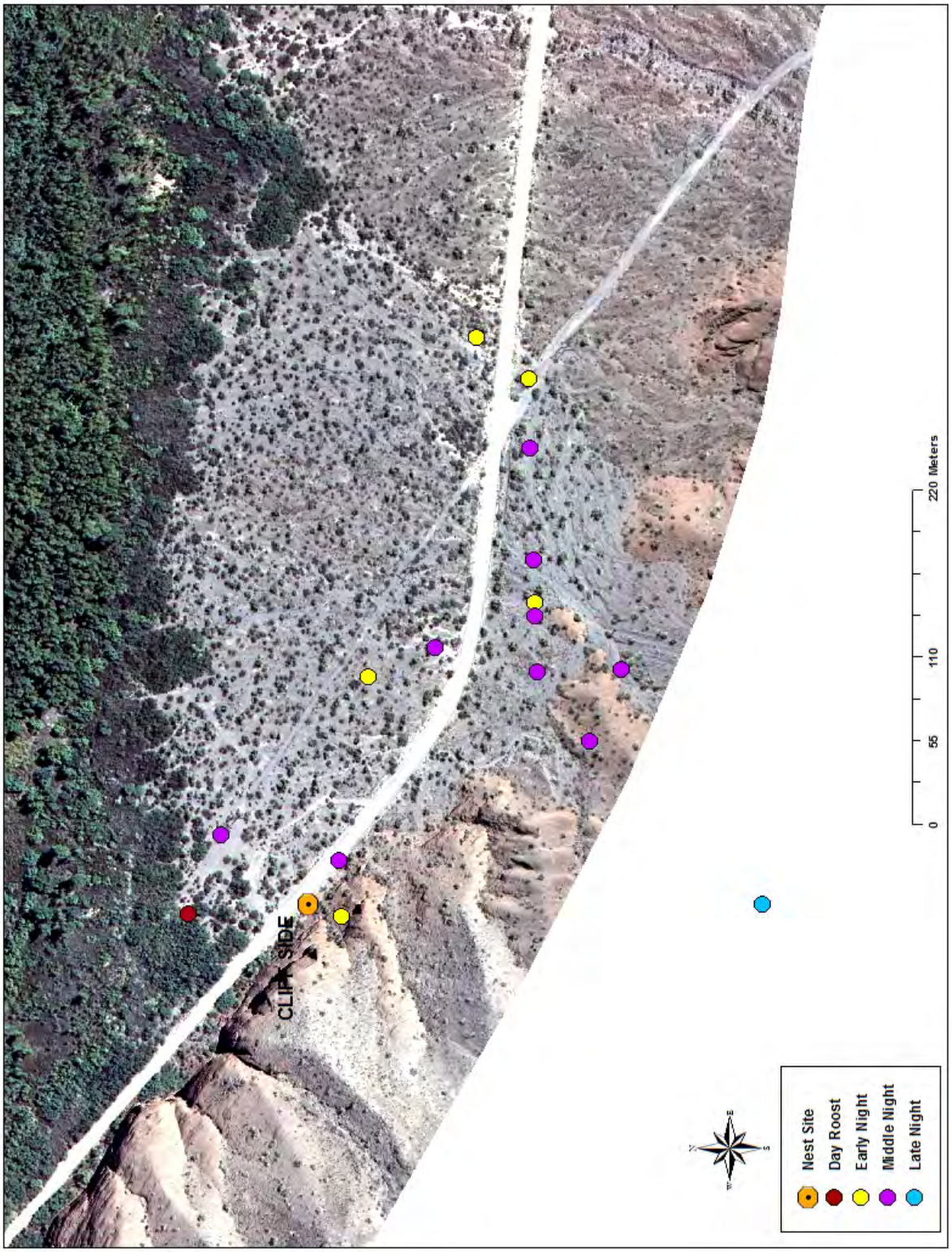
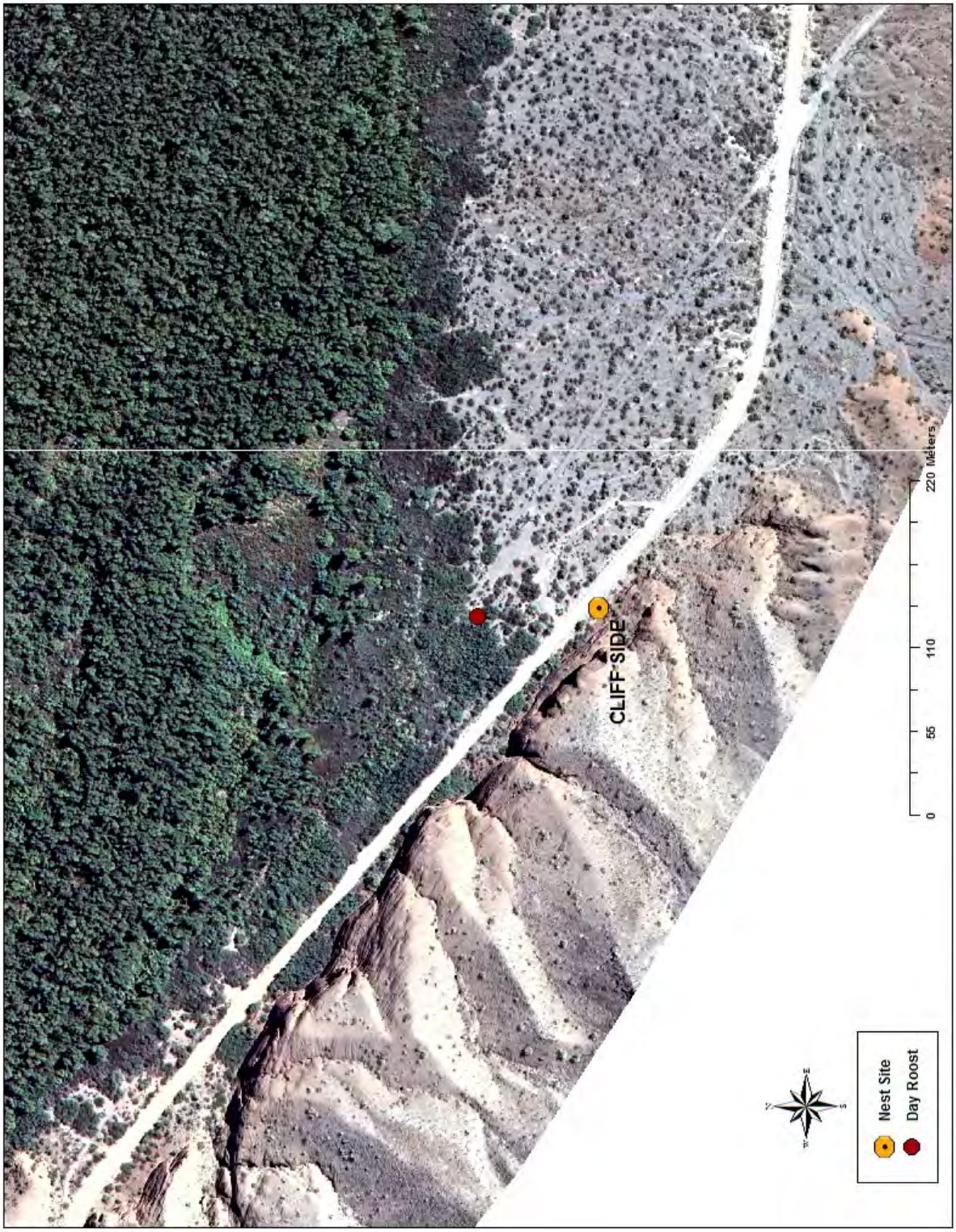


Figure 28. Telemetry revealed locations for the Cliff Side male, night of 5/27 – 5/28, 2011. Early night = 1931 – 2330 hours, Middle night = 2331 – 0230 hours, and Late night = 0231 – 0530 hours.



Home Range and Territory Spacing

By plotting all telemetry-based bird locations, a home range estimate could be generated for both the CM and CS territories in 2011 (Figures 29 – 30), which were 7.9 ha for CM, and 13.9 ha for CS. Territory spacing may also provide some insight into the area requirements of Elf Owls, especially along the riparian edge habitat in our study area, where saguaro cavities are abundant. Within the area where our survey coverage was most thorough (i.e. south of the river, in the eastern part of the refuge; Figures 3 and 5), we calculated for each confirmed territory the distance from its nest cavity or activity center to its nearest neighboring nest cavity or activity center (Table 16). We used the 2010 territories for this exercise, because they included all of the 2011 territories in this area, along with two additional territories. Within the area collectively defined by these territories, we have relatively high confidence that all territories were detected. The closest spacing observed was 214 m, ranging up to 695 m for the territories located along the southern edge of the riparian zone. The nearest-neighbor distance was even farther for the FT territory, but it was located on the opposite (north) side of the river, where our survey coverage was more limited.

Table 16. Distance from each cavity (or activity center) to its nearest known neighboring cavity, within the thoroughly-surveyed portion of the study area in 2010.

Territory	*Nearest Neighbor*	*Distance (m)*
CM	SG	642
SG	SS	214
SS	SG	214
KS	SS	402
CS	SH	695
SH	CS	695
FT	SH	1058

Additional Day Roost Site Observations

Partial information was collected on an *ad hoc* basis in 2010 regarding the location of day roost sites among the territories that were confirmed, as follows:

1) SH: The male from this territory was radio-tagged, and daytime locations for this bird came from within or very near to the nest saguaro, suggesting that the day roost location may have been another cavity in the same saguaro.
2) SS: The male of the pair was captured and radio-tagged. Its daytime signal was detected on multiple occasions in a dense willow/tamarisk thicket located within the riparian corridor, at a distance of ~ 30 m from the nest site in a saguaro.
3) SG: Both the male and female were radio-tagged. The male's day roost site was located within 15 m of the saguaro nest cavity in dense riparian transitional vegetation.

Figure 29. All telemetry revealed locations in the Cassie's Marsh territory, 2011, and home range estimation.

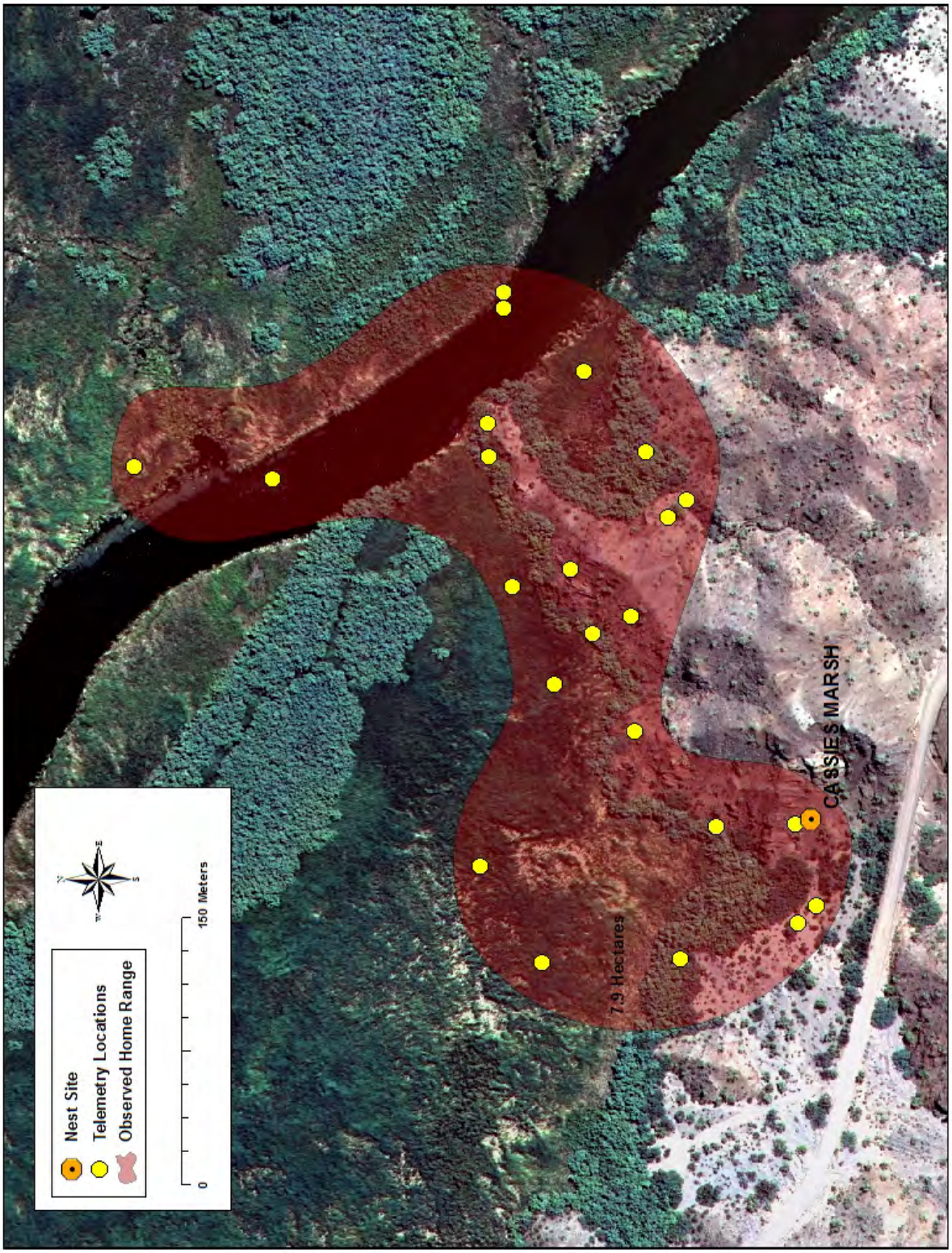
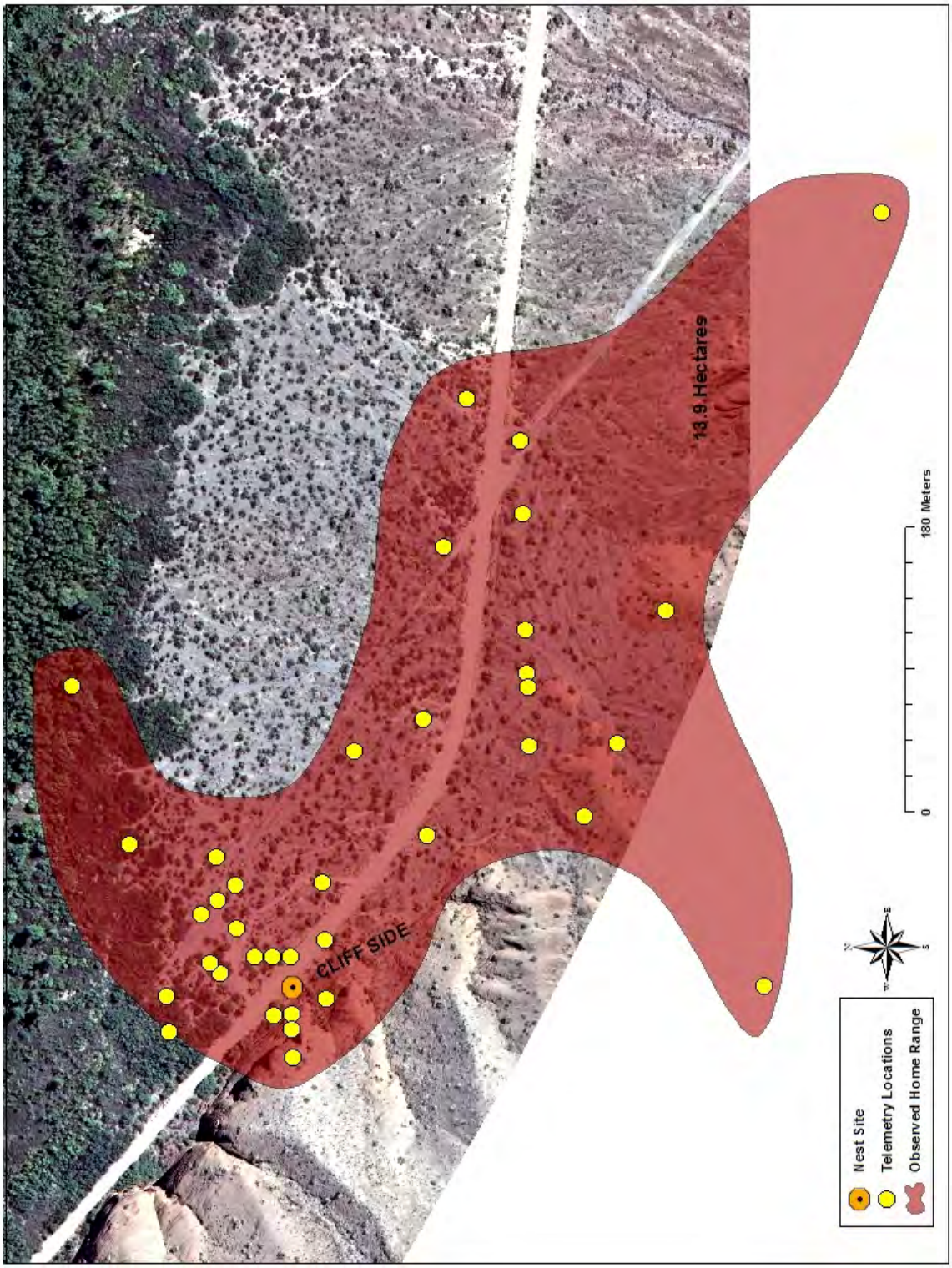


Figure 30. All telemetry revealed locations in the Cliff Side territory, 2011, and home range estimation.



4) CS: Both the male and female were radio-tagged after being captured near the nest saguaro during an apparent nest attendance exchange. The day roost site of the tagged male was subsequently located by telemetry in mesquite patch 50 m from the nest site, in the riparian transition zone (use of the same day roost site was confirmed by telemetry in 2011, see above). The female was usually located in the nest saguaro during telemetry observations.
5) CM: Vocalizations were heard from a mesquite patch near the road in the early dusk, which was a possible day roost site. Neither bird was radio-tagged.

Territory Fidelity

Five of the seven territories identified in 2010 were reoccupied in 2011; CM, SG, SS, CS, and SH. Nest cavities were either located in the same saguaro in both years, or in a different saguaro within 5 m of the original one. Although the six birds captured in 2010 were leg banded, none of these birds were recaptured in 2011. Confirmed males were captured on the CS and SG territories in both 2010 and 2011, and we are therefore able to confirm that the same male did not occupy either of these two territories in subsequent years. We can make no determination about possible returns for females, or for the other territories.

Habituation

Three confirmed or possible territories in 2011 were exclusively designated for habituation testing. These were intentionally selected from territories on the north side of the river, away from the responsiveness-testing territories on the south side of the river, to avoid interfering with responsiveness tests. One possible territory (North Sandy Wash) had to be eliminated because it was never confirmed. Habituation testing was conducted on the other two territories that were confirmed. On one (Fox Wash S), no response was heard on any of the three sequential nights of call broadcast surveys. It is possible that this territory had been abandoned by this time, although we could not confirm this because the site was not revisited after the habituation tests. On the North Burn territory, responses were obtained to call broadcasts on all three nights of testing. The response occurred after the second broadcast iteration on the first night, after the first iteration on the second night, and not until the fourth iteration on the third night. Because of the very limited extent of habituation data, we can draw no conclusions as to whether or not habituation is a factor influencing responsiveness.

Peeper Cam Nest Cavity Examination

In 2011, we had access to a pole-mounted peeper camera during the latter part of the field season. We used this apparatus to attempt to confirm specific nest cavities within each of the five territories being used for responsiveness tests, and succeeded in finding the occupied cavity in three of the territories (Figure 31). On the other two territories, terrain geometry and cactus configuration rendered it difficult to obtain interior views of all likely candidate cavities on saguaros. When a cavity was confirmed to be occupied by Elf

Owls, we took several measurements and assessed the breeding stage. Results are presented in Table 17. Of special interest was that on the same date, breeding stage was distinctly different among the three territories, ranging from presence of eggs to presence of feathered nestlings.

Table 17. Measurements obtained on confirmed Elf Owl nest cavities in 2011.

Territory	*Date*	*Height of Cavity (m)*	*Aspect of Cavity (deg)*	*Location on Cactus*	*Young Stage*	*Number of Young / Eggs*
CS	5/29/11	4.18	130	Arm	Nestlings – downy	2
SH	5/29/11	4.74	80	Main stem	Nestlings - feathered	2
SS	5/29/11	7.11	0	Main stem	Eggs	?

Cavity opening size for the three occupied cavities ranged from 7.5 – 9.0 cm, and cavity depth ranged from 7.52 – 15.0 cm. All occupied cavities had substantial "drop", i.e. the nest itself was located in an excavation that was lower than the cavity entrance. This drop could not be measured directly, but was estimated to be approximately 7 cm in all three cavities.

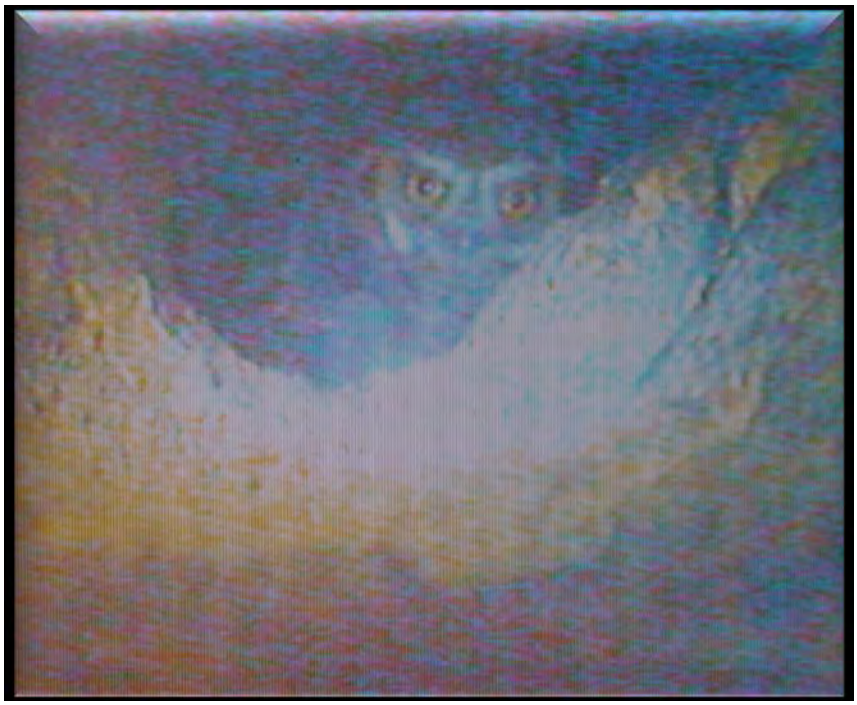


Figure 31. Elf Owl photographed inside a nest cavity.

DISCUSSION

Responsiveness

The most pronounced contrast in Elf Owl responsiveness occurred between unobstructed and obstructed broadcast conditions, which has important ramifications for Elf Owl discovery surveys and population monitoring along the Lower Colorado River. However, because obstruction was not incorporated into the study design until 2011, and because most owl territories in the study area were in edge habitat, we were able to generate substantially more insight about optimized survey parameters in unobstructed conditions than in obstructed conditions. Therefore, except where explicitly noted otherwise, the remainder of this section applies to unobstructed conditions.

As expected, distance was negatively correlated with responsiveness, with the most pronounced drop in responsiveness occurring somewhere between the 250 m and 450 m distance. Our results suggested that time of night was a less important factor than initially hypothesized, but there was a slightly higher responsiveness at dusk than other times of night. This result, as well as published findings that owls are more vocal and active in the early part of the evening (Ligon 1968, Henry and Gehlbach 1999) and our own telemetry data confirming this activity pattern, leads us to recommend using the dusk period as a standardized time of night for implementing our recommended survey protocol (see below).

Within the breeding season, there appeared to be an effect of seasonality on responsiveness, although that effect was not statistically significant. Specifically, responsiveness was somewhat higher in the April – mid May period than in the mid-May – early June period. This corresponds to published findings that vocalization frequency and responsiveness to call broadcast surveys are highest during the pair formation and nest site selection periods (Henry and Gehlbach 1999), including the "late advertising" period in mid to late April (Hardy and Morrison 2000). Given that Ligon (1968) reported a 26 day incubation period for Elf Owls, and that our peeper cam observations (see above) showed that hatching in our study area occurred around late May or early June, it is reasonable to conclude that most owls were incubating by early May (at least during years that are comparable to the period of the study). This, in turn, suggests that the pair formation, nest site selection, and late advertising periods conclude no later than mid-May. In our study, we could not begin to implement our responsiveness tests until territories had been identified and confirmed, but future discovery surveys will not be subject to this constraint. Therefore, we conclude that discovery surveys should begin as soon as possible after the migratory arrival period is largely complete (late March), but before incubation begins (mid May). Furthermore, if the goal of a discovery survey effort is to detect only owls that have established a territory (as opposed to earlier transients), we recommend avoiding surveys during the first week of April. This leaves a period of approximately five weeks (2nd week of April – mid-May) as a preferred survey window.

We found no significant effect of illumination on responsiveness, but we did record our lowest responsiveness rates at the brightest illumination levels. This contrasts with other

studies suggesting that vocalization frequency and responsiveness was higher in brighter conditions (Henry and Gehlbach 1999, Hardy and Morrison 2000). We have no compelling explanation for this inconsistency, which could have been a quirk of limited sample size or the result of a co-varying factor that was not measured. One field crew member suggested that owls may become more agitated by the observer during responsiveness tests when illumination is high, although we have no basis for assessing this hypothesis. Minimally, however, our findings demonstrated that high responsiveness rates did occur during low illumination periods. Considering our results in light of previous studies, we see currently no reason to specify illumination in our recommended survey protocol. Ideally, illumination would be standardized or randomized to avoid any potential effects, but given the reality that the recommended time window for surveys (approximately three weeks, as described above) is less than one lunar cycle, limiting surveys to specific illumination conditions could greatly limit the feasibility of the implementing the protocol. That said, if USBR determines that all required survey work within a given field season can be conducted in two weeks or less, a cautious approach would be to survey only during nights with intermediate illumination (i.e. avoid new moon, a set moon, or a full moon).

In terms of the causality of responsiveness, our findings suggest that a non-response can occur for one of two main reasons. The first involves the hearing limitations of a human surveyor. We recorded many instances where owls responded to broadcasts (as noted by the observer), but where even a well-trained surveyor with good hearing did not detect the response. This phenomenon appeared to be the most common reason for recorded non-responses in obstructed conditions. The second reason for non-responses relates to the activities and behaviors that owls are exhibiting at the time when the broadcast survey is conducted. When owls (as noted by the observer) are relatively active prior to the initiation of the survey, they nearly always generated a response that was detected by the surveyor (except at longer distances and/or obstructed conditions). In contrast, when owls were involved in what appeared to be sheltering behavior, or seemed otherwise inactive, they were less likely to generate a response detectable by the surveyor.

Sample Size Constraints

Among 87 responsiveness tests, we examined obstruction, time of night, distance, seasonality, and illumination. By themselves, the major factors identified in the experimental design (time of night, distance, and obstruction) produced 18 different permutations (=2x3x3). This increased to 36 permutations when two levels of seasonality were considered, and to 108 permutations when three levels of illumination were considered. Clearly, good replication could not be achieved for all of these permutations, and choices were required regarding the prioritization of factors. One of these choices, based on results collected during the first part of the 2010 field season, was to de-emphasize testing at the shortest distance (100 m) because responsiveness at this distance had proven to be very high. However, at that point in time, most tests had been conducted in the unobstructed conditions that characterized the occupied territories, and the concept of indirectly assessing the effects of obstruction had not yet been formulated. Given the results obtained in 2011, it is clear that additional testing is warranted in obstructed

conditions at shorter distances (perhaps 50 m, 100 m, and 200 m) in order to determine effective call broadcast range within riparian woodland habitat, particularly given that a goal of the LCR MSCP is to recover riparian habitat to benefit covered species, including the Elf Owl. If and when riparian-nesting Elf Owls are found during discovery surveys in the LCR MSCP project area (as described below), they should be subject to additional testing of this sort to further refine and validate the survey protocol.

Other factors for which our results were suggestive, but not statistically significant (including seasonality, illumination, and time of night) could potentially be clarified with more testing and greater sample size. We do not consider these to be a critical needs, however, because:

1) Our findings with regard to time of night, although not significant, correspond to published information, and furthermore, there is no compelling reason not to standardize future testing within the dusk time period.
2) Similarly, our seasonality results, although not quite achieving statistical significance, correspond to published information, and in conjunction these provide a good basis for framing the preferred survey season (i.e. April)
3) Although our illumination results do not correspond to other findings, we see no basis for concluding that illumination is a critical factor. Furthermore, it may not be practical to consider illumination in survey scheduling, as discussed previously. These, however, are subjective judgments, and further study might help to clarify whether there is merit in focusing survey efforts within some yet-to-be-defined illumination conditions.

Riparian and Edge Territories

Although we were able to confirm the presence of two Elf Owls in the riparian woodland interior during the course of the study, most birds in the BWRNWR occupy edge territories and choose cavities in saguaro cactuses. It is unclear how soon and how commonly Elf Owls in the LCR MSCP project area would colonize suitable woodland interiors as habitat is recovered. For instance, Rosenberg et al. (1991) reported that Elf Owls in the region were most likely to be found breeding in areas where riparian woodland interfaced with saguaro cactus uplands, a conclusion that corresponds well to our findings at the BWRNWR. However, some historically-occupied sites occur in areas where saguaros are absent (e.g., Fort Mohave), giving credence to the notion that saguaros are not essential if suitable riparian nest substrates are available. Regardless, riparian habitat appears to provide significant value to edge-nesting owls, based on our telemetry data that showed substantial use of riparian woodlands during forays.

Hardy and Morrison's (2001) findings suggest an interesting hypothesis about the distribution of Elf Owl territories in the study area. They state that for saguaro-nesting Elf Owls, the likelihood of choosing a particular saguaro as a nest site increases with both density of cavities on the individual saguaro, and local density of mature saguaro plants. They further noted that occupied territories had multiple, unused cavities, and suggested that territory selection may be related to a high density of unoccupied cavities. Similarly,

Henry and Gehlbach (1999) concluded that Elf Owls tend to choose territories with multiple cavities. Reasons for this preference might include access to possible re-nesting sites, availability of cavities with different microclimates from which to choose, use of additional cavities by males for day roosts or sheltering sites, or mate attraction.

In our study area, saguaros are common along the riparian edge, and most mature saguaros contain several cavities that appear large enough to accommodate Elf Owls. Therefore, it is reasonable to assume that cavity density along the riparian edge is greater than within the riparian woodland interior, possibly explaining the observed distribution of territories. Regardless, the previously-reported preference for high cavity density has important implications for the LCR MSCP project, namely that Elf Owls may not recolonize recovered habitat until cavity density reaches some threshold level. This in turn may suggest useful management actions within the LCR MSCP project area. These might include supplementing natural cavities with nest boxes, creating additional cavities in natural vegetation, or managing vegetation to encourage high cavity density.

Nest Site Availability

In previous publications, Elf Owls were noted to prefer a high density of available cavities and, possibly, a negative effect of nest cavity competitors (Hardy and Morrison 2001). It is curious to us that both Elf Owl and Gilded Flicker (*Colaptes chrysoides*) have been virtually lost from the system of the Lower Colorado River in the past 50 years, the former being a secondary cavity nester and the latter being a cavity excavator. Other cavity excavators that create Elf Owl-sized cavities also exist in the system at present, such as the Gila Woodpecker (*Melanerpes uropygialis*), but we speculate as to whether the declines of the two LCR MSCP covered species are related. This possibility suggests the value of a nest-site-limitation study, testing the assumption of whether or not the availability of suitable nest cavities is currently limiting the Elf Owl population of the Lower Colorado River. Because Elf Owls are known to use artificial nest boxes (Henry and Gehlbach 1999), it would be fairly straightforward and inexpensive to conduct such a study.

Home Ranges

The two home ranges delineated in this study were considerably larger than the average home range size of 1.0 ha measured in the Rio Grande Valley by Gamel (1997). Beyond this observation, however, we have no basis to draw further conclusions.

RECOMMENDATIONS AND CONCLUSIONS

Recommended Call Broadcast Survey Protocol

The main goal of this study was to systematically test the manner in which Elf Owl responsiveness varied with selected call broadcast survey parameters, and to use these findings to produce an optimized Elf Owl survey protocol and an associated detectability estimate. All of the territories we tested were located along the riparian habitat edge (see Figure 32), and most of the tests we conducted involved moderate to low levels of vegetation obstruction between the call broadcast surveyor and the target owl. Therefore, our understanding of responsiveness and detectability in these "unobstructed" conditions (as defined previously) is very good. Additionally, our findings should be applicable not only to unobstructed conditions in our study area, but to the relatively small or narrow riparian zones that characterize much of the LCR MSCP project area, where the potential for vegetation obstruction is limited.

Figure 32. Elf Owl nesting territory in the BWRNWR, showing cavities in a saguaro cactus and nearby transitional vegetation . Photo by USBR, Lower Colorado Region.

The more limited results we obtained for fully obstructed survey conditions (as defined previously) clearly indicated that wide areas of dense, tall vegetation substantially reduced Elf Owl responsiveness. However, the data were insufficient to generate good

estimates of responsiveness across the full range of experimentally-varied survey parameters. Given this, an ideal approach would be to:

1) Create an optimized survey protocol for unobstructed conditions (including riparian edge habitat, and narrow or small riparian zones), using the data collected in this study, and
2) Conduct additional studies to:
    a. develop an optimized survey protocol for obstructed conditions, and
    b. determine the most reasonable "break points" for classifying obstructed versus unobstructed habitat

Given that much of the potential Elf Owl habitat in the LCR MSCP project area is (using our definition) unobstructed, this approach would ensure that the more labor- and time-intensive protocol suitable for obstructed habitat would be used only in the areas where it is needed in order to achieve high detectability.

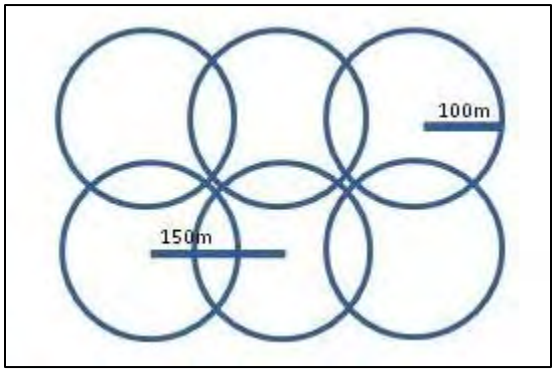
In the absence of sufficient data to generate two distinct protocols, or a clear basis for systematically distinguishing between obstructed and unobstructed conditions throughout the LCR MSCP project area, we have developed a single recommended survey protocol that we know to be sufficient for unobstructed conditions (based on the detectability calculations shown below), and which we believe to be effective for obstructed conditions. This protocol is more intensive than necessary to achieve high detectability in unobstructed conditions. Furthermore, it has an unknown detectability rate in obstructed conditions, although believe it to be in excess of 80%, based on the limited data available.

This recommended protocol follows. For survey parameters that we did not explicitly test (broadcast volume, wind speed, etc.), we recommend maintaining consistency with our established approach. An abbreviated set of instructions, including only the information needed by a surveyor, is provided in Appendix 6.

1) Surveyors should be trained to readily recognize Elf Owl vocalizations, and hearing tests should be conducted to ensure that they can hear recorded vocalizations in windless and obstruction-free conditions at a distance of at least 500 m.
2) We recommend that surveys be conducted in teams of two. It would be very difficult for one person to be responsible for operating call broadcasts, listening, data recording, and keeping track of broadcast station spacing and broadcast timing. Additionally, having a crew of two provides a backup pair of ears.
3) Surveys should be conducted only when wind conditions are favorable (< 12 km per hour on a sustained basis) and there is no precipitation.
4) The preferred seasonal window for conducting surveys begins after the first week of April, and concludes on 15 May.
5) Illumination conditions can be ignored (see Discussion for rationale).
6) Surveys should begin just after dusk and conclude by three hours after dusk. (see Discussion for rationale).

7) The call broadcast apparatus should generate a volume of 65 – 70 db measured at 1 m from the speaker. A call broadcast cycle should consist of 25 seconds of chatter calls (calls A and/or B, as defined by Ligon (1968)), followed by 35 seconds of silent listening time. Our 25 second broadcast period was comprised of six distinct chatter calls separated by ~ 2 – 3seconds. Using locally recorded vocalizations may be advantageous, or alternately the call track that we used in our field work could be used for consistency and convenience.
8) We provisionally assume a 100 m effective survey radius, noting that effective survey radius in obstructed conditions has not yet been adequately determined. Survey routes and stations should therefore be configured to ensure that no point within the survey zone lies farther than 100 m from a call broadcast station. By trigonometric calculation, this dictates a spacing of 141.42 m between broadcast stations, which we round off to 150 m for simplicity (Figure 33). For survey zones that are narrow, a single semi-linear survey route paralleling the drainage may be sufficient. For wider survey zones, multiple routes or winding routes may be required. Each route should include a call broadcast station every 150 m of linear distance, and intermediate listening stations halfway between each broadcast station. Intermediate listening stations provide a safety margin to mitigate against the possible failure of surveyors to hear responses at longer distances. If discovery survey routes are needed inside riparian zones (as opposed to along their edges), they may be constrained to established trails. If so, it should be determined the extent to which the survey zone can be effectively covered with this trail system, based on the assumption of a 100 m effective survey radius.

Figure 33. Schematic diagram showing how the effective survey areas (each with100 m radius) of six call broadcast stations spaced on 150 m centers cover nearly all of the survey zone.



9) A survey of a given area should consist of replicated survey efforts on two different nights within the season window defined above in item #4. Although we have no basis for determining an optim time between the two surveys, separating them by two weeks or more may be advantageous given the possibility of annual variations in breeding phenology. For the second survey, stations previously used for call broadcasts should become intermediate listening stations, and vice versa. This step effectively staggers the broadcast stations by 75 m on the two different

nights, providing additional assurance given the uncertainties regarding effective call broadcast radii in obstructed conditions.

10) The procedure for conducting a survey of a single designated survey area is given below:
    a. Stop at the first call broadcast station.
    b. Use an initial two minute listening period to determine if owls are already vocalizing (during the preferred seasonal window, Elf Owls are expected to be relatively vocal, especially in the early evening). If so, the detection should be recorded.
    c. Play four broadcast cycles (as defined in item #7, above). For each cycle, point the speakers in a different cardinal direction. Our data indicate that nearly every responsive bird was heard within this time frame.
    d. After conclusion of the last call playback cycle, proceed directly to the intermediate listening station 75 m farther along the survey route.
    e. Listen for 2 minutes at the intermediate station.
    f. Proceed 75 m to the next call broadcast station.
    g. Repeat steps b. – f. until the survey is complete.
11) If responses are obtained at sequential call broadcast stations, additional effort may be required to determine whether one or two owls are responsible.
12) In some cases, a researcher may wish to determine whether Elf Owls are present at a site during the migration period, before territories are established. This might be desirable, for instance, in determining where to place nest boxes. In these cases, surveys should be conducted as close as possible to the 15 – 25 March period. It is possible that conducting call broadcasts during this period, before birds are committed to a territory, could interfere with successful territory establishment. However, we have no firm basis for assessing this possibility.
13) Distribution records and anecdotal information provided by biologists familiar with southwestern birds suggest that Elf Owls colonize newly-available breeding habitat slowly. Assuming this to be the case, our recommendation is to conduct call broadcast discovery surveys at a given site every 4 – 5 years. However, USBR may wish to examine particular sites of interest more frequently (for instance, locations where nest boxes are placed).

Detectability

Even optimized survey methods will inevitably "miss" some birds, and for many applications it is either helpful or critical to know the likelihood that this will occur. In avian biology, "detectability" is defined as the percentage of birds, from among those actually present within a defined survey area, that are detected during a standardized survey. Detectability is always specific to a particular survey protocol, always species-specific, and often habitat-specific and sex-specific. Detectability is usually estimated by supplementing standard surveys with intensive surveys at a subset of all survey areas. Detectability is then estimated as the average ratio of the number of birds detected by standard survey methods to the number detected using intensive survey methods.

Estimation of detectability is most efficiently accomplished when a standard survey protocol has been formalized, and is applied in relatively uniform habitat. Otherwise, different detectabilities would have to be estimated for different survey protocols and for different habitat conditions. Much of the field effort in this study was directed towards experimenting with different survey parameters in order to create an optimized protocol for the conditions present at our study area. As such, only a subset of the data we collected was relevant to estimating detectability for that optimized protocol. This data suggests, for example, that if call broadcast surveys are conducted using our methods, in unobstructed conditions, during the dusk time period, and with playback station intervals based on the assumption of a 250 m effective survey distance, there is an estimated 93% chance of detecting a given owl pair that is present within the survey zone (see Table 13). For our recommended protocol in unobstructed conditions (which is based on a 100 m effective survey distance), detectability would be higher. This approach can be extended to answer more complicated questions. For instance, if there are two territories present in the survey zone, that chance of detecting at least one of them (with station spacing based on a 250 m effective distance) is over 99% ((0.93x0.93)+(0.07x0.93)+(0.93x0.07)).

Currently, our data are not sufficient to calculate detectability in obstructed conditions with the same assurance we can attribute to unobstructed conditions. We believe that detectability will be high in obstructed conditions using the protocol recommended above, because of its relatively close call broadcast station intervals, the two nights of replicated surveying, and the staggering of call broadcast stations on those two nights. However, further work is needed before this detectability can be quantified. Preferably, this would involve direct studies of riparian-nesting Elf Owls. Alternately, additional tests of the sort we performed in 2011 (i.e. broadcasting through obstructions to edge territories) would be useful, particularly at an array of shorter distances.

Recommendations for Future Actions and Research

We assume that discovery surveys will be conducted in appropriate portions of the LCR MSCP project area, particularly in habitat creation sites as they mature, and in historically occupied areas where remnant habitat exists. We suggest that some of these discovery surveys, be conducted during the migrant arrival period (item # 13 in Recommended Call Broadcast Survey Protocol section, above), in addition to the April time frame (item # 4 in the same section). This would allow researchers to determine whether owls are passing through these locations even if they are not yet breeding in them, a notable possibility given that Elf Owls appear to prefer late-successional habitats with abundant cavities.

In terms of direct follow-up to this study, the greatest need is additional responsiveness testing at shorter distances in obstructed conditions. This would allow further optimization of the recommended call broadcast survey protocol for obstructed conditions. Although it would be ideal to conduct such studies with riparian-nesting owls, it would (at least in the shorter term) more practical to take the approach we used in this study. We would recommend that distance be the focal variable, with testing at 50 m, 100 m, 150 m, and 250 m. The other factors that were varied in our study should be

standardized, including time of night (at dusk) and seasonality (all tests conducted in April, possibly into the first week of May if necessary). Illumination would necessarily vary during the testing period. We recommend that testing distances be evenly distributed, to the extent possible, among low, intermediate, and high illumination conditions, and that this additional data be used to gain more insight in illumination's possible effects on responsiveness.

Nest boxes could be used to artificially increase the cavity density of selected areas, thus potentially encouraging Elf Owls to colonize habitat creation sites. They could also be used to study the effect of nest cavity density on territory establishment. Ideally, nest boxes should be located in areas where Elf Owls have been heard during early-season exploratory surveys, especially if territories are not yet being naturally established in these locations. If nest boxes are deployed, an appropriate pre- and post-treatment monitoring program would have to be developed.

Nest-centered habitat assessments in the Bill Williams River NWR would be very valuable in terms of both management insight and the LCR MSCP habitat credit system. These assessments could be conducted on both edge territories, and on as many riparian territories as can be discovered, although the latter would be very labor-intensive. The standard LCR MSCP vegetation assessment protocol could be utilized, modified to generate additional data regarding cavity density in the vicinity of the nest.

Additional telemetry work to delineate home ranges and activity budgets would be very informative. With sufficient time investment and preparation, it might be possible (though challenging) to conduct telemetry on some riparian nesting birds. Home ranges thus identified could be subsequently assessed using the vegetation protocol discussed above.

An annual program of early-season surveys in the BWRNWR over a period of years would be useful in determining the consistency of first arrival dates. This program could be more streamlined than the recommended discovery survey protocol, and might involve a single night of surveying along two or three of our previously-established routes, repeated at intervals of 5 – 7 days beginning in early March until first detections occur. If first arrival dates vary considerably over a period of years, then the recommended seasonal survey window may need to be reconsidered.

Recommendations Regarding Field Study Techniques

The field methods used in this study were generally effective, and they required little or no modification during the course of the field work. Owls responding to surveys in April, or later, are likely to have established territories, and if identifying the location of nest cavities is a goal in any future studies, we stress that dusk emergence observations are critical.

One technique that was not effective involved our use of net poles to attempt to capture owls, as described above. Mist-netting, although time-consuming, was the more effective alternative.

We also noted that retention of glue-on radio-tags appeared to be improved by: 1) placing the tag as high as possible in the interscapular region (i.e. nearer to the neck) without interfering with movement, and 2) gluing the base of the tag directly to the feather stubble, rather than using the intermediate gauze layer recommended in some glue-on transmitter protocols. We speculated that owls found that the gauze layer provided an easy "grasping point" that facilitated tag removal. Furthermore, the tag must be held firmly in place on the owl, with no movement, for at least one minute in order for the adhesive to fully set.

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Appendix 1. All data sheets used during the Elf Owl detectability study at the Bill Williams River National Wildlife Refuge.

Data Sheet Definitions

Surveyor(s): should include only the individual(s) who is/are doing the survey part for that survey (telemetry people not included)

Site Name: should include overall site (Bill Will) as well as route location (i.e. Mosquito Flats)

Date: self-explanatory

Time of Night: dusk, mid-night, and predawn

Moon Phase: **N**ew (0-5%), **Q**uarter (6-25%), **H**alf (26-50%), **G**ibbous (51-90%), **F**ull (91-100%)

Temp/humidity/wind/cloud cover (start and stop): taken from Kestrel; cloud will be in estimated percentages

Moon Position (start and stop): the level/location that the moon is sitting in the sky at the time of starting and stopping the survey (i.e. at horizon, not visible, 35-70 deg, or directly overhead)

UTM: same once established for survey route

Time: time of stop/playback

Set point #: name of survey route plus point # (same once established)

Distance (between points): Default 50m unless detection occurs on or between points.

Playback: yes or no if played/not played. Minimal playback will be used in early season while birds are still arriving and pair bonding is occurring to avoid disturbance. Playback at other times is yet to be determined, as most owls can (so far) easily be found by listening for them.

Number of elf owls detected: per stop; if owl calls consecutively within +/- 20˚, then same owl

Tape Repetitions: the number of 1 min segments played until an owl response is heard (loop of 4 calls with 50 second silences in between); if no response then all 3 repetitions of the tape loop should be recorded.

Detection Type: Audio, visual, or both

Response Type: divided into moving, call, both, and neither. This will be backed up with notes, and is general because we don't know what to expect as far as behavioral response. Only filled in if response observed after playback (to put neither would mean that you saw the owl and it neither called nor moved).

Call Response Type: the type of call the owl responds with which we will define more concretely once we have the Ligon paper (he breaks down/ defines/ explains the different call types in his research)

Bearing: the direction written as a compass bearing that the owl was seen or heard taken from the surveyor's location at time of detection

Distance: the estimated distance you think the responding owl is from you as the surveyor

Notes: any extra pertinent information

We have defined "**incidental**" as a detection of an owl while not on your survey route. If an owl is heard on your way from one 50 m stop to the next the distance can be crossed out and changed, though we think that the likelihood of this is low since its only 50m.

Elf Owl Exploratory Survey Form					**Page of**
Surveyor(s):	Site Name:		Date:	Time of Night:	
Start: Temp(˚F)	Wind:	Humidity(%)	Cloud Cover(%)	Moon position:	
End: Temp(˚F)	Wind:	Humidity(%)	Cloud Cover(%)	Moon position:	Moon Phase:
Total Elf Owls Detected:					

Datum	UTM E/ UTM N	Time	Set Point #	Distance btw pts.	Playback	# Elf Owls Detected	# Tape Reps	Detection Type (A, V, B)	Response Type (M,C, B, N)	Call Type (C, P, S, O)	Bearing	Distance	Note #
NAD83				50m									
NAD83				50m									
NAD83				50m									
NAD83				50m									
NAD83				50m									
NAD83				50m									
NAD83				50m									
NAD83				50m									
NAD83				50m									
NAD83				50m									
NAD83				50m									
NAD83				50m									

Notes:

Responsiveness Test Data Sheet

Date: _____ Telemetry: yes or no

Territory Name	Surveyor	Dist and Bearing	Observer	Dist and Bearing

Time Period:	Distance:
Dusk	100 meters
Mid-Night	250 meters
Pre-Dawn	450 meters

Time into territory	Wind (mph)	Temperature °F	Moon Phase
Time left territory	% Clouds	% Humidity	Moon Position

Surveyor Notes: Broadcast start: Observer Notes: Broadcast heard: Y, N

_____
_____
_____
_____
_____
_____

Plays before Response	Response: Mo, Ca, B, N	Detection: Vi, Au, B, N	Number of Owls Heard	Farthest Distance from Saguaro	Obstructions: owl to speaker

Elf Owl Responsiveness Test Data Sheet (Great Basin Bird Observatory 2010)

Owl Transmitter #_____ USFWS
Band#_____
Territory Center Site Name and UTM (NAD83):
_____
_____

Sex:	Wing Chord:	Blood Sample #
Weight:	Tail Length:	Breeding: confirmed/ not confirmed

Incubation start:	Nestling start:
Incubation end:	Nestling end:

Time Period: **Dusk**	**Distance: 100m** Date: Moon Phase: Response: Vocalized Moved Closer Moved Away None Response Time:_____	**Distance: 250m** Date: Moon Phase: Response: Vocalized Moved Closer Moved Away None Response Time:_____	**Distance: 450m** Date: Moon Phase: Response: Vocalized Moved Closer Moved Away None Response Time:_____
Time Period: **Mid-Night**	**Distance: 100m** Date: Moon Phase: Response: Vocalized Moved Closer Moved Away None Response Time:_____	**Distance: 250m** Date: Moon Phase: Response: Vocalized Moved Closer Moved Away None Response Time:_____	**Distance: 450m** Date: Moon Phase: Response: Vocalized Moved Closer Moved Away None Response Time:_____
Time Period: **Pre-Dawn**	**Distance: 100m** Date: Moon Phase: Response: Vocalized Moved Closer Moved Away None Response Time:_____	**Distance: 250m** Date: Moon Phase: Response: Vocalized Moved Closer Moved Away None Response Time:_____	**Distance: 450m** Date: Moon Phase: Response: Vocalized Moved Closer Moved Away None Response Time:_____

Notes:_____
_____
_____
_____

Banding Data Sheet

CODE	
New Band	N
Band Destroyed	D
Band Lost	L
Band Changed*	C
Band Added*	A
*old band # in NOTES	

SEX	
Male	M
Female	F
Indeterminate	U
Not Attempted	X

AGE	
Local	L
HY, AHY, SY, ASY, TY, ATY	
Indeterminate	U
Not Attempted	X

HOW AGED / SEXED			
Skull	S	Feather Wear	F
CP	C	Mouth/Bill	I
BP	B	Eye Color	E
Juv. Pluma	J	Wing Length	W
Plumage	P	Tail Length	T
Molt	M	Other (NOTE)	O

CP	
None	0
Small	1
Mediu	2
Large	3
N/A	X

BP	
None	0
Smooth	1
Vasculariz	2
Heavy	3
Wrinkled	4
Molting	5
N/A	X

FAT SCORE
0 - 7

BODY MOLT
0 - 4

FF MOLT	
None	0
Adventitious	A
Symmetric	S
Juv. Growth	J

FF WEAR
0 - 5

DISPOSITION CODE	
OK	BLANK
Injured	I
Predation	P
Dead	D
Band Remc	X

STATUS	
banded & released	300
color banded & released	301

date	banders	alpha sp. code	capture time	band #	trans. freq.	age	how det.	sex	how det.	cp	bp	fat	B molt	FF molt	tarsus depth	hallux claw	retrices	exposed culmen	wing chord	flat wing	weight	dispo-sition	release time

Notes:

Telemetry Data Sheet

Date	Time	Telemetry Person	Survey Person	E Owl Band #	Territory UTM

Time Period:	Distance:
Dusk	100 meters
Mid-Night	300 meters
Pre-Dawn	500 meters

Time in territory	Moon Phase	Response: M, C
#plays	# owls resp.	Detection: V, A

Notes:_____

_____

_____

_____

Date	Time	Telemetry Person	Survey Person	E Owl Band #	Territory UTM

Time Period:	Distance:
Dusk	100 meters
Mid-Night	300 meters
Pre-Dawn	500 meters

Time in territory	Moon Phase	Response: M, C
#plays	# owls resp.	Detection: V, A

Notes:_____

_____

Date	Time	Telemetry Person	Survey Person	E Owl Band #	Territory UTM

Time Period:	Distance:
Dusk	100 meters
Mid-Night	300 meters
Pre-Dawn	500 meters

Time in territory	Moon Phase	Response: M, C
#plays	# owls resp.	Detection: V, A

Notes:_____

_____

_____

Appendix 2. Assignment of illumination ratings (0 – 5) to different combinations of moon phase and moon position during responsiveness tests. Regarding moon phase, N = New, Q = Quarter, H = Half, G = Gibbous, and F = Full. Moon position was estimated to the nearest 5 degrees, with 0 degrees corresponding to the horizon and 90 degrees corresponding to straight overhead.

Illumination Rating	Corresponding Moon Phase and Position
0	N moon, or below horizon
1	Q or H moon, at or near horizon (> 5°)
2	Q moon 10 - 45°, H moon 10 - 25°
3	Q moon 50 - 90°, H moon 30 - 90°, G moon 5 – 35°, F moon 5 - 10°
4	F moon 15 – 30° , G moon 40 - 90°
5	F moon 35 - 90°

Appendix 3. Condensed data set showing locations of Elf Owl detections during exploratory surveys in 2010 and 2011. Values of peripheral relevance are omitted, though the full data set is provided to USBR electronically. All UTMs are in NAD 83, and Zone is shown below. For "Playback", Y = a response obtained from a call broadcast, N = detection made by passive listening.

Date	Survey Trail	Zone	Playback	Easting	Northing
3/21/2010	Mosquito Flats Interior 2010	11	N	769899	3797027
3/21/2010	Mosquito Flats Interior 2010	11	N	769952	3797118
3/22/2010	Mosquito Flats Road	11	N	769937	3797006
3/22/2010	Mosquito Flats Road	11	N	770101	3797044
3/22/2010	Mosquito Flats Road	11	N	769932	3796840
3/22/2010	Mosquito Flats Road	11	N	770577	3796847
3/22/2010	Mosquito Flats Road	11	N	770603	3796914
3/22/2010	Mosquito Flats Road	11	N	770527	3796979
3/23/2010	Mosquito Flats Edge	11	N	770722	3796940
3/23/2010	Mosquito Flats Edge	11	N	770059	3796921
3/23/2010	Mosquito Flats Edge	11	N	770098	3796844
3/23/2010	Mosquito Flats Edge	11	N	770040	3796931
4/11/2010	Borrow Pit Exterior	11	Y	771107	3796707
4/11/2010	Borrow Pit Exterior	11	N	771180	3796709
4/11/2010	Borrow Pit Exterior	11	Y	770686	3796917
4/18/2010	Fox Wash Center	11	N	771622	3796722
4/18/2010	Fox Wash Center	11	N	771774	3796904
4/18/2010	Fox Wash Center	11	N	771640	3797055
4/18/2010	Fox Wash Center	11	N	771714	3797380
4/18/2010	Fox Wash Center	11	N	771316	3797757
5/3/2010	Fox Wash E	11	Y	771605	3797632
5/3/2010	Fox Wash E	11	N	771711	3796824
5/7/2010	Mosquito Flats Interior 2010	11	Y	770026	3797420
3/19/2011	North Sandy Wash	11	N	771680	3795991
3/22/2011	Saguaro Slot	11	N	769035	3797924
3/25/2011	Cross River	11	N	770587	3797458
3/27/2011	Mineral Wash (Planet Ranch) 2011	12	N	224456	3794383
3/28/2011	Middle Delta	11	N	769586	3797962
3/28/2011	North Burn	11	N	770419	3798186
3/28/2011	North Burn	11	N	770604	3798136

Date	Survey Trail	Zone	Playback	Easting	Northing
3/28/2011	North Burn	11	N	770252	3798203
3/28/2011	North Burn	11	N	770294	3798338
4/1/2011	Borrow Pit Exterior	11	Y	770663	3796761
4/1/2011	Borrow Pit Exterior	11	N	770549	3796880
4/1/2011	Borrow Pit Exterior	11	N	770567	3796880
4/1/2011	Mosquito Flats Road	11	Y	770285	3797072
4/1/2011	Mosquito Flats Road	11	Y	770228	3796815
4/1/2011	Mosquito Flats Road	11	N	770003	3796930
4/1/2011	Mosquito Flats Road	11	N	770271	3796905
4/1/2011	Mosquito Flats Road	11	N	770269	3796971
4/1/2011	Mosquito Flats Road	11	N	770425	3797020
4/1/2011	Mosquito Flats Road	11	N	770605	3796848
4/4/2011	North Sandy Wash	11	N	771939	3796609
4/5/2011	Sandy Wash	11	Y	771789	3796394
4/9/2011	Cross River	11	Y	770248	3798037
4/9/2011	Cross River	11	Y	770806	3797553
4/10/2011	North Burn	11	Y	770234	3798203
4/11/2011	Fox Wash S	11	Y	770928	3797157
4/11/2011	Fox Wash S	11	Y	771075	3797150
4/11/2011	Fox Wash S	11	N	771576	3797054
4/14/2011	Esquera Ranch (Planet Ranch)	11	N	774605	3795288
4/14/2011	Esquera Ranch (Planet Ranch)	11	N	774926	3795342
4/14/2011	Esquera Ranch (Planet Ranch)	11	N	774898	3795352
4/14/2011	Esquera Ranch (Planet Ranch)	11	Y	774780	3795526
4/14/2011	Mineral Wash (Planet Ranch) 2011	12	N	224628	3794267
4/15/2011	Borrow Pit Interior 2011	11	N	770812	3797009
4/15/2011	Borrow Pit Interior 2011	11	Y	770726	3797118
4/15/2011	Mosquito Flats Interior 2011	11	N	770587	3797147
4/16/2011	Fox Wash N	11	Y	771657	3797733
4/16/2011	Fox Wash N	11	Y	771602	3797410
4/20/2011	Mosquito Flats Road	11	N	769839	3797181
4/20/2011	Mosquito Flats Road	11	y	769979	3796819

Appendix 4. Condensed data set for Elf Owl responsiveness tests, 2010 – 2011. Variables of peripheral relevance are omitted from this appendix, although they are included in the full data set submitted to USBR electronically. "Distance", "Night Segment", "Obstructed", "Illumination Code", and "Season" are the independent variables analyzed in this study (for Season, e = 12 May or earlier, l = later than 12 May). Remaining variables represent data collected during each test. "Response per Surveyor" indicates whether the surveyor noted a response to call broadcasts. "Response per Observer" indicates whether the observer noted a response to call broadcasts. "Confirm Owl Present?" refers to whether or not the observer was able to confirm that an owl was present in the expected location, regardless of whether the surveyor noted a response. "Time to Response" and "Broadcast Iterations" were recorded by the surveyor, and denote the time and the number of iterations that elapsed before the first response was noted. "Movements" were determined by referring to both the surveyor's and observer's data, and indicate the estimated distance moved by the owl during the course of the responsiveness test. For multiple field, y = yes; n = no; m = probably, but not confirmed; u = unknown / not recorded; and N/A = not applicable to this observation.

Territory	Date	Year	Distance (m)	Night Segment	Obstructed	Illumination Code	Season	Response per Surveyor	Response per Observer	Confirm Owl Present?	Time to Response	Broadcast Iterations	Movements
Cassie's Marsh	6/2/2010	2010	250	dusk	n	0	l	y	y	y	2:15	3	> 100 m
Cassie's Marsh	5/28/2010	2010	450	dusk	n	0	l	y	y	y	0:40	1	> 100 m
Cassie's Marsh	5/5/2010	2010	250	midnight	n	0	e	n	n	y	N/A	N/A	20 m
Cassie's Marsh	5/8/2010	2010	450	midnight	n	0	e	n	n	y	N/A	N/A	N/A
Cassie's Marsh	5/2/2010	2010	100	predawn	n	4	e	y	y	y	0:15	1	20 m
Cassie's Marsh	5/12/2010	2010	250	predawn	n	0	e	y	y	y	1:30	2	> 100 m

Territory	Date	Year	Distance (m)	Night Segment	Obstructed	Illumination Code	Season	Response per Surveyor	Response per Observer	Confirm Owl Present?	Time to Response	Broadcast Iterations	Movements
Cassie's Marsh	6/2/2010	2010	250	dusk	n	0	l	y	y	y	2:15	3	> 100 m
Cassie's Marsh	5/28/2010	2010	450	dusk	n	0	l	y	y	y	0:40	1	> 100 m
Cassie's Marsh	5/5/2010	2010	250	midnight	n	0	e	n	n	y	N/A	N/A	20 m
Cassie's Marsh	5/19/2010	2010	450	predawn	n	0	l	y	y	y	1:05	2	> 100 m
Cliff Side	5/29/2010	2010	250	dusk	n	0	l	n	y	y	N/A	N/A	20 m
Cliff Side	5/7/2010	2010	450	dusk	y	0	e	n	n	y	N/A	N/A	N/A
Cliff Side	4/26/2010	2010	100	dusk	n	5	e	y	u	y	1:50	1	N/A
Cliff Side	5/11/2010	2010	250	midnight	n	0	e	y	y	y	0:20	1	100 m
Cliff Side	5/4/2010	2010	450	midnight	n	0	e	y	y	y	0:15	1	10 m
Cliff Side	5/23/2010	2010	450	predawn	n	0	l	n	n	n	N/A	N/A	N/A
Cliff Side	5/2/2010	2010	100	predawn	n	4	e	y	y	y	0:55	1	80 m
Cliff Side	5/19/2010	2010	250	predawn	n	0	l	y	y	y	1:02	2	10 m
Fox Tunnel	5/30/2010	2010	250	dusk	y	0	l	n	m	y	N/A	N/A	N/A
Fox Tunnel	6/2/2010	2010	450	dusk	y	0	l	n	n	n	N/A	N/A	N/A
Fox Tunnel	5/6/2010	2010	100	dusk	y	0	e	y	y	y	0:50	1	40 m
Fox Tunnel	5/11/2010	2010	250	midnight	y	0	e	n	n	y	N/A	N/A	N/A

Territory	Date	Year	Distance (m)	Night Segment	Obstructed	Illumination Code	Season	Response per Surveyor	Response per Observer	Confirm Owl Present?	Time to Response	Broadcast Iterations	Movements
Cassie's Marsh	6/2/2010	2010	250	dusk	n	0	l	y	y	y	2:15	3	> 100 m
Cassie's Marsh	5/28/2010	2010	450	dusk	n	0	l	y	y	y	0:40	1	> 100 m
Cassie's Marsh	5/5/2010	2010	250	midnight	n	0	e	n	n	y	N/A	N/A	20 m
Fox Tunnel	5/19/2010	2010	450	midnight	y	1	l	y	n	y	2:30	3	N/A
Fox Tunnel	5/28/2010	2010	450	predawn	y	5	l	n	m	y	N/A	N/A	N/A
Fox Tunnel	5/23/2010	2010	250	predawn	y	0	l	n	n	n	N/A	N/A	N/A
Kryptonite Saguaro	5/19/2010	2010	100	dusk	n	0	l	y	y	y	0:05	1	80 m
Kryptonite Saguaro	5/12/2010	2010	250	dusk	n	0	e	y	y	y	1:05	2	> 100 m
Kryptonite Saguaro	5/28/2010	2010	250	midnight	n	5	l	n	n	y	N/A	N/A	N/A
Kryptonite Saguaro	5/5/2010	2010	100	midnight	n	0	e	y	y	y	0:50	1	50 m
Kryptonite Saguaro	5/1/2010	2010	100	predawn	n	4	e	n	n	n	N/A	N/A	N/A
Kryptonite Saguaro	5/9/2010	2010	250	predawn	n	0	e	n	y	y	N/A	N/A	N/A
Saguaro Hill	5/13/2010	2010	250	dusk	n	0	l	y	y	y	1:25	2	> 100 m
Saguaro Hill	5/20/2010	2010	450	dusk	n	3	l	y	y	y	1:30	2	> 100 m
Saguaro Hill	5/27/2010	2010	450	midnight	n	5	l	n	m	y	N/A	N/A	N/A
Saguaro Hill	5/10/2010	2010	250	midnight	n	0	e	y	y	y	0:15	1	> 100 m

Territory	Date	Year	Distance (m)	Night Segment	Obstructed	Illumination Code	Season	Response per Surveyor	Response per Observer	Confirm Owl Present?	Time to Response	Broadcast Iterations	Movements
Cassie's Marsh	6/2/2010	2010	250	dusk	n	0	l	y	y	y	2:15	3	> 100 m
Cassie's Marsh	5/28/2010	2010	450	dusk	n	0	l	y	y	y	0:40	1	> 100 m
Cassie's Marsh	5/5/2010	2010	250	midnight	n	0	e	n	n	y	N/A	N/A	20 m
Saguaro Hill	5/31/2010	2010	100	midnight	n	0	l	y	y	y	2:40	2	50 m
Saguaro Hill	5/1/2010	2010	100	predawn	n	4	e	n	n	n	N/A	N/A	N/A
Saguaro Hill	5/18/2010	2010	250	predawn	n	0	l	y	y	y	0:20	1	> 100 m
Saguaro Hill	5/6/2010	2010	450	predawn	n	3	e	y	y	y	0:10	1	70 m
Saguaro Slot	5/4/2010	2010	250	dusk	n	0	e	y	y	y	0:25	1	100 m
Saguaro Slot	5/20/2010	2010	450	dusk	n	3	l	n	y	y	N/A	N/A	100 m
Saguaro Slot	4/9/2010	2010	100	dusk	n	0	e	y	u	y	0:45	1	
Saguaro Slot	5/27/2010	2010	450	midnight	n	5	l	n	y	y	N/A	N/A	N /A
Saguaro Slot	5/8/2010	2010	250	midnight	n	0	e	y	y	y	2:45	3	> 100 m
Saguaro Slot	4/19/2010	2010	100	midnight	n	2	e	y	u	y			
Saguaro Slot	5/12/2010	2010	450	predawn	n	0	e	y	n	y	0:25	1	> 100 m
Saguaro Slot	5/18/2010	2010	250	predawn	n	0	l	y	y	y	1:25	2	> 100 m
Saguaro Slot	4/12/2010	2010	100	predawn	n	2	e	y	u	y	2:20	2	

Territory	Date	Year	Distance (m)	Night Segment	Obstructed	Illumination Code	Season	Response per Surveyor	Response per Observer	Confirm Owl Present?	Time to Response	Broadcast Iterations	Movements
Cassie's Marsh	6/2/2010	2010	250	dusk	n	0	l	y	y	y	2:15	3	> 100 m
Cassie's Marsh	5/28/2010	2010	450	dusk	n	0	l	y	y	y	0:40	1	> 100 m
Cassie's Marsh	5/5/2010	2010	250	midnight	n	0	e	n	n	y	N/A	N/A	20 m
Secret Garden	5/13/2010	2010	250	dusk	n	0	l	y	y	y	1:15	2	50 m
Secret Garden	5/28/2010	2010	450	dusk	n	3	l	y	y	y	0:05	1	> 100 m
Secret Garden	4/26/2010	2010	100	dusk	n	5	e	y	u	y	1:25	1	
Secret Garden	5/31/2010	2010	100	midnight	n	3	l	n	n	y	N/A	N/A	N/A
Secret Garden	5/18/2010	2010	250	midnight	n	1	l	y	y	y	1:15	2	40 m
Secret Garden	5/10/2010	2010	450	midnight	n	0	e	y	y	y	2:10	3	15 m
Secret Garden	5/1/2010	2010	250	predawn	n	4	e	n	n	y	N/A	N/A	N/A
Secret Garden	5/6/2010	2010	450	predawn	n	3	e	y	y	y	4:00	4	20 m
Cassie's Marsh	4/28/2011	2011	100	dusk	n	0	e	y	y	y	1:40	2	95 m
Cassie's Marsh	5/13/2011	2011	450	dusk	y	4	l	n	m	y	N/A	N/A	0 m
Cassie's Marsh	5/6/2011	2011	250	midnight	n	0	e	n	n	y	N/A	N/A	N/A
Cassie's Marsh	5/21/2011	2011	450	midnight	n	3	l	y	y	y	1:10	2	> 100 m
Cassie's Marsh	5/17/2011	2011	100	predawn	y	3	l	n	y	y	N/A	N/A	80 m

Territory	Date	Year	Distance (m)	Night Segment	Obstructed	Illumination Code	Season	Response per Surveyor	Response per Observer	Confirm Owl Present?	Time to Response	Broadcast Iterations	Movements
Cassie's Marsh	6/2/2010	2010	250	dusk	n	0	l	y	y	y	2:15	3	> 100 m
Cassie's Marsh	5/28/2010	2010	450	dusk	n	0	l	y	y	y	0:40	1	> 100 m
Cassie's Marsh	5/5/2010	2010	250	midnight	n	0	e	n	n	y	N/A	N/A	20 m
Cassie's Marsh	5/2/2011	2011	250	predawn	n	0	e	n	n	y	N/A	N/A	N/A
Cassie's Marsh	5/27/2011	2011	450	predawn	n	3	l	y	y	y	5:00	4	20 m
Cliff Side	4/24/2011	2011	100	dusk	n	0	e	y	y	y	1:05	2	10 m
Cliff Side	5/10/2011	2011	250	dusk	y	3	e	y	y	y	2:00	2	5 m
Cliff Side	5/30/2011	2011	450	dusk	n	0	l	n	y	y	N/A	N/A	60 m
Cliff Side	5/6/2011	2011	250	midnight	y	0	e	n	y	y	N/A	N/A	0 m
Cliff Side	5/1/2011	2011	450	midnight	y	0	e	n	n	y	N/A	N/A	N/A
Cliff Side	5/17/2011	2011	250	predawn	n	4	l	y	y	y	0:30	1	> 100 m
Cliff Side	5/24/2011	2011	450	predawn	y	3	l	n	n	unk	N/A	N/A	N/A
Saguaro Hill	6/1/2011	2011	250	dusk	n	0	l	n	y	y	N/A	N/A	25 m
Saguaro Hill	5/5/2011	2011	450	dusk	y	3	e	n	y	y	N/A	N/A	80 m
Saguaro Hill	5/1/2011	2011	250	midnight	n	0	e	y	u	y	0:10	1	> 100 m
Saguaro Hill	5/28/2011	2011	100	predawn	n	0	l	y	y	y	1:30	2	60 m

Territory	Date	Year	Distance (m)	Night Segment	Obstructed	Illumination Code	Season	Response per Surveyor	Response per Observer	Confirm Owl Present?	Time to Response	Broadcast Iterations	Movements
Cassie's Marsh	6/2/2010	2010	250	dusk	n	0	l	y	y	y	2:15	3	> 100 m
Cassie's Marsh	5/28/2010	2010	450	dusk	n	0	l	y	y	y	0:40	1	> 100 m
Cassie's Marsh	5/5/2010	2010	250	midnight	n	0	e	n	n	y	N/A	N/A	20 m
Saguaro Hill	5/13/2011	2011	250	predawn	y	4	l	n	n	y	N/A	N/A	N/A
Saguaro Hill	5/24/2011	2011	450	predawn	y	3	l	n	m	y	N/A	N/A	N/A
Saguaro Slot	4/28/2011	2011	100	dusk	n	0	e	y	y	y	1:05	2	65 m
Saguaro Slot	5/16/2011	2011	250	dusk	y	5	l	y	y	y	0:50	1	60 m
Saguaro Slot	5/11/2011	2011	450	dusk	y	3	e	n	y	y	N/A	N/A	30 m
Saguaro Slot	5/2/2011	2011	250	midnight	y	0	e	n	m	y	N/A	N/A	N/A
Saguaro Slot	5/22/2011	2011	450	midnight	y	3	l	n	m	y	N/A	N/A	N/A
Saguaro Slot	6/1/2011	2011	250	predawn	n	0	l	n	n	y	N/A	N/A	N/A
Saguaro Slot	5/27/2011	2011	450	predawn	n	3	l	n	y	y	N/A	N/A	20 m
Secret Garden	5/5/2011	2011	250	dusk	y	2	e	n	y	y	N/A	N/A	6 m
Secret Garden	5/16/2011	2011	450	dusk	n	3	l	n	m	y	N/A	N/A	N/A
Secret Garden	6/1/2011	2011	250	midnight	n	0	l	n	n	n	N/A	N/A	N/A
Secret Garden	5/25/2011	2011	450	midnight	n	0	l	n	n	n	N/A	N/A	N/A

Territory	Date	Year	Distance (m)	Night Segment	Obstructed	Illumination Code	Season	Response per Surveyor	Response per Observer	Confirm Owl Present?	Time to Response	Broadcast Iterations	Movements
Cassie's Marsh	6/2/2010	2010	250	dusk	n	0	l	y	y	y	2:15	3	> 100 m
Cassie's Marsh	5/28/2010	2010	450	dusk	n	0	l	y	y	y	0:40	1	> 100 m
Cassie's Marsh	5/5/2010	2010	250	midnight	n	0	e	n	n	y	N/A	N/A	20 m
Secret Garden	5/1/2011	2011	100	predawn	n	0	e	y	y	y	0:10	1	> 100 m
Secret Garden	5/10/2011	2011	250	predawn	y	0	e	n	y	y	N/A	N/A	100 m
Secret Garden	5/22/2011	2011	450	predawn	n	3	l	n	m	y	N/A	N/A	N/A

Appendix 5. Results of two-way Chi-Square tests on data from responsiveness tests, conducted in MiniTab ver 14. For all results, R = response, NR = no response. Additionally, AT = all responsiveness tests were used in the analysis, and CT = only responsiveness tests where owl presence was confirmed by the observer were used in the analysis. For all Chi-square results, expected counts are printed below observed counts and Chi-Square contributions are printed below expected counts.

Test for Obstruction (AT)
No obstruction = 1, obstruction = 2

```
           R     NR  Total
    1     41     23     64
       33.10  30.90
       1.884  2.018

    2      4     19     23
       11.90  11.10
       5.241  5.616

Total     45     42     87
Chi-Sq = 14.759, DF = 1, P-Value = 0.000
```

Test for Obstruction (CT)
No obstruction = 1, obstruction = 2

```
           R     NR  Total
    1     41     18     59
       33.61  25.39
       1.626  2.152

    2      4     16     20
       11.39   8.61
       4.797  6.349

Total     45     34     79
Chi-Sq = 14.924, DF = 1, P-Value = 0.000
```

Test for Time of Night (AT), unobstructed conditions
Dusk = 1, midnight = 2, predawn = 3

```
     R     NR  Total
    1     15      5     20
       12.81   7.19
       0.373  0.666

    2     11      9     20
       12.81   7.19
       0.256  0.457

    3     15      9     24
       15.38   8.63
       0.009  0.016

Total     41     23     64
Chi-Sq = 1.778, DF = 2, P-Value = 0.411
```

Test for Time of Night (CT), unobstructed conditions
Dusk = 1, midnight = 2, predawn = 3

```
           R     NR  Total
    1     15      5     20
       13.90   6.10
       0.087  0.199
    2     11      7     18
       12.51   5.49
       0.182  0.414
    3     15      6     21
       14.59   6.41
       0.011  0.026

Total     41     18     59
Chi-Sq = 0.920, DF = 2, P-Value = 0.631
```

Test for Time of Night (AT or CT), obstructed conditions: `Not tested due to sample size (multiple cells with expected counts less than 5).`

Test for Distance to Bird (AT), unobstructed conditions
100m = 1, 250m = 2, 450m = 3

```
          R     NR  Total
    1     15      3     18
       11.53   6.47
       1.043  1.860
     2     15     10     25
       16.02   8.98
       0.064  0.115
    3     11     10     21
       13.45   7.55
       0.447  0.797

Total     41     23     64
Chi-Sq = 4.327, DF = 2, P-Value = 0.115
```

Test for Distance to bird (CT), unobstructed conditions
100m = 1, 250m = 2, 450m = 3

```
      R     NR  Total
    1     15      1     16
       11.12   4.88
       1.355  3.086
    2     15      9     24
       16.68   7.32
       0.169  0.385
    3     11      8     19
       13.20   5.80
       0.368  0.838

Total     41     18     59
Chi-Sq = 6.200, DF = 2, P-Value = 0.045
1 cells with expected counts less than 5.
```

Test for Distance to Bird (AT), unobstructed conditions
100m = 1, 250m and 450m (combined) = 2

```
       R     NR  Total
    1     15      3     18
       11.53   6.47
       1.043  1.860

    2     26     20     46
       29.47  16.53
       0.408  0.728

Total     41     23     64
Chi-Sq = 4.040, DF = 1, P-Value = 0.044
```

Test for Distance to Bird (CT), unobstructed conditions
100m = 1, 250m and 450m (combined) = 2

```
        R     NR  Total
    1     15      1     16
       11.12   4.88
       1.355  3.086

    2     26     17     43
       29.88  13.12
       0.504  1.148

Total     41     18     59

Chi-Sq = 6.094, DF = 1, P-Value = 0.014
1 cells with expected counts less than 5.
```

Test for Distance to Bird (AT or CT), obstructed conditions:
Not tested due to sample size (multiple cells have expected counts less than 5).

Test for Illumination (AT), unobstructed conditions
Low = 1, Intermediate = 2, High = 3

```
  R     NR  Total
    1     27     12     39
       24.98  14.02
       0.163  0.290

    2      9      5     14
        8.97   5.03
       0.000  0.000

    3      5      6     11
        7.05   3.95
       0.595  1.060

Total     41     23     64
Chi-Sq = 2.107, DF = 2, P-Value = 0.349
1 cells with expected counts less than 5.
```

Test for Illumination (CT), unobstructed conditions
Low = 1, Intermediate = 2, High = 3

```
      R     NR  Total
    1     27      9     36
       25.02  10.98
       0.157  0.358

    2      9      5     14
        9.73   4.27
       0.055  0.124

    3      5      4      9
        6.25   2.75
       0.252  0.573

Total     41     18     59
Chi-Sq = 1.519, DF = 2, P-Value = 0.468
2 cells with expected counts less than 5.
```

Test for Illumination (AT), unobstructed conditions
Low or Intermediate (combined) = 1, High = 2

```
   R     NR  Total
    1     36     17     53
       33.95  19.05
       0.123  0.220

    2      5      6     11
        7.05   3.95
       0.595  1.060

Total     41     23     64

Chi-Sq = 1.998, DF = 1, P-Value = 0.158
1 cells with expected counts less than 5.
```

Test for Illumination (CT), unobstructed conditions
Low or Intermediate (combined) = 1, High = 2

```
   R     NR  Total
    1     36     14     50
       34.75  15.25
       0.045  0.103

    2      5      4      9
        6.25   2.75
       0.252  0.573

Total     41     18     59

Chi-Sq = 0.973, DF = 1, P-Value = 0.324
1 cells with expected counts less than 5.
```

Test for Season (AT), unobstructed conditions
Early (12 May or before) = 1, Late = 2

```
           R     NR  Total
    1     26     17     43
       22.24  20.76
       0.635  0.681

    2     19     25     44
       22.76  21.24
       0.621  0.665

Total     45     42     87

Chi-Sq = 2.602, DF = 1, P-Value = 0.107
```

Test for Season (CT), unobstructed conditions
Early (12 May or before) = 1, Late = 2

```
           R     NR  Total
    1     26     15     41
       23.35  17.65
       0.300  0.397

    2     19     19     38
       21.65  16.35
       0.323  0.428

Total     45     34     79

Chi-Sq = 1.448, DF = 1, P-Value = 0.229
```

Test for Combined Factors (AT), unobstructed conditions
Ideal = 1, Not ideal = 2

```
         R     NR  Total
    1     7      0      7
       4.48   2.52
       1.411  2.516

    2     34     23     57
       36.52  20.48
       0.173  0.309

Total     41     23     64

Chi-Sq = 4.409, DF = 1, P-Value = 0.036
2 cells with expected counts less than 5.
```

Test for Combined Factors (CT), unobstructed conditions
Ideal = 1, Not ideal = 2

```
    R     NR  Total
    1      7      0      7
        4.86   2.14
       0.938  2.136

    2     34     18     52
       36.14  15.86
       0.126  0.287

Total     41     18     59

Chi-Sq = 3.487, DF = 1, P-Value = 0.062
2 cells with expected counts less than 5.
```

Test for Combined Factors (AT), unobstructed conditions
Semi-ideal = 1, Not semi-ideal = 2

```
     R     NR  Total
    1     13      1     14
        8.97   5.03
       1.812  3.230

    2     28     22     50
       32.03  17.97
       0.507  0.904

Total     41     23     64

Chi-Sq = 6.454, DF = 1, P-Value = 0.011
```

Test for Combined Factors (CT), unobstructed conditions
Semi-ideal = 1, Not semi-ideal = 2

```
      R     NR  Total
    1     13      1     14
        9.73   4.27
       1.100  2.505

    2     28     17     45
       31.27  13.73
       0.342  0.779

Total     41     18     59

Chi-Sq = 4.727, DF = 1, P-Value = 0.030
1 cells with expected counts less than 5.
```

Appendix 6. Instructions for surveyors using the recommended discovery survey protocol in conditions where location of Elf Owl territories (edge vs. riparian interior) is unknown.

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1) Surveyors must be trained to readily recognize Elf Owl vocalizations, and hearing tests should be conducted to ensure that they can hear recorded vocalizations in windless and obstruction-free conditions at a distance of at least 500 m.
2) Surveys are to be conducted in teams of two.
3) Surveys should be conducted only when wind speed is < 12 km per hour on a sustained basis, and there is no precipitation.
4) Unless otherwise directed, surveys should begin just after the first week of April, and conclude by 15 May.
5) Illumination conditions can be ignored, but should be recorded.
6) Surveys should be conducted during a period extending from just after dusk until approximately 3-4 hours after dusk.
7) The call broadcast apparatus should generate a volume of 65 – 70 db measured at 1 m from the speaker. The call broadcast cycle should consist of 25 seconds of chatter calling ((Calls A and / or B, as defined by Ligon (1968)), followed by 35 seconds of silent listening time.
8) Each survey route should include a call broadcast station every 150 m of linear distance, and intermediate listening stations half way between each broadcast station (75 m intervals). To the extent possible, survey routes should be spaced such that no location containing potential habitat is located more than 100 m from a call broadcast station, or at the very least, from an intermediate listening station. If conditions necessitate broader spacing, detectability may be reduced.
9) A survey of a given area should consist of replicated survey efforts on two different nights. The replicate surveys should be offset in time by 30 minutes – 1 hour (i.e., reversing the directionality of the survey route but conducting it during the same time frame would accomplish this goal effectively). Additionally, call broadcast stations and intermediate listening stations should be interchanged during the second survey night. If possible, there should be at least two weeks between the two replicate surveys, but both should occur withinin the seasonal windows described above.
10) The procedure for conducting a single survey along a survey route is as follows:
    a. Stop at the first call broadcast station.
    b. Use an initial two minute listening period to determine if owls are already vocalizing. If so, the detection should be recorded.
    c. Play four broadcast cycles (as defined in #7, above). For each cycle, point the speakers in a different cardinal direction.
    d. After conclusion of the last call playback cycle, proceed directly for 75 m to the next intermediate listening station.
    e. Listen for 2 minutes at the intermediate station.
    f. Proceed 75 m to the next call broadcast station.
    g. Repeat steps b. – f. until the survey route(s) are complete.

11) If responses are obtained at sequential call broadcast stations, additional effort may be required to determine whether one or two owls are responsible.