FINAL REPORT: DISTRIBUTION AND HABITAT ASSOCIATIONS OF THE FEDERALLY THREATENED MEXICAN SPOTTED OWL (STRIX OCCIDENTALIS LUCIDA) IN TEXAS



Photograph courtesy of Steve Howe and the US National Park Service.

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Introduction

The Mexican spotted owl (*Strix occidentalis lucida*) is distributed across the southwestern United States and the Sierra Madre Occidental into northern and central states of Mexico (Gutiérrez et al. 2020). Whereas northern spotted owls (*S. o. caurina*) and California spotted owls (*S. o. occidentalis*) are exclusively forest species, the Mexican spotted owl will occupy relatively treeless rocky canyons in addition to more forested mountain canyons and higher elevation late seral forests (USFWS 2012). These areas are patchy and naturally fragmented across the arid southwest U.S. and northern Mexico, rendering a disjunct distribution of Mexican spotted owls in association with these features (USFWS 2012). While other spotted owl subspecies are clearly tied to late seral forests, habitat modeling indicated topography and climate were more influential in Mexican spotted owl habitat selection than were vegetation metrics (Jones et al. 2023). In addition to different landscapes used as habitat, Mexican spotted owls will use a wider array of nest substrates than other spotted owl species; these include cliff ledges and potholes in narrow canyons, mistletoe clumps, and nests of other species (Tweit 2006).

Legal Status

Mexican spotted owls occur at low densities within habitat patches across their highly fragmented distribution, a pattern that makes them at relatively greater extinction risk due to habitat loss (Davies et al. 2004). The species gained protection as a federally threatened species under the Endangered Species Act in 1993 (58 FR 14248; 3/16/1993). In Texas it is listed by Texas Parks and Wildlife Department as threatened and considered a S1B species, which indicates it is critically imperiled in the state because of extreme rarity or because of other factors making it especially vulnerable to extirpation from the state. Listing of the Mexican spotted owl as threatened was based primarily on loss of habitat due to timber harvest practices and wildfires across the majority of its distribution, increased predation due to habitat alteration, and a lack of protective regulations (58 FR 14248; 3/16/1993). Wildfires are also a concern and in Texas, where timber harvesting does not occur within the presumed range of Mexican spotted owls, large wildfires are considered the primary threat to the species (USFWS 1993, 2012).

Since federal listing of the Mexican spotted owl as threatened in 1993, conservation efforts have been focused on the species distributions in Arizona, Colorado, New Mexico, and Utah (USFWS 2012). The developed recovery plan recommended protection of a minimum of 243 ha around owl nest sites; changes to logging patterns; and restoration of riparian zones (USFWS 2012). Although some components of the recovery plan have been adopted by the US Forest Service in New Mexico and Arizona, the recovery plan has not resulted in any regulatory rules (Gutiérrez et al. 2020).

Natural History

The Mexican spotted owl is relatively well-studied in the mountains and canyon

lands of New Mexico, Arizona, and Utah (see Gutiérrez et al. 2020 for comprehensive review). In contrast, the species' status and occurrence across its purported distribution in the Trans-Pecos region of Texas, which is geographically quite different from the rest of its range in the United States, is poorly understood. The species' known distribution in Texas is based on limited documented observations at isolated locations in the Davis Mountains and the Guadalupe Mountains (Bryan and Karges 2001, Mullet and Ward 2010). No systematic survey effort has yet been attempted for the species in Texas. This is primarily due to lack of funding, the challenges of nocturnal surveys in the expansive and rugged landscape, and limited access to a landscape that is primarily in private ownership. Thus, compared to other states, there are no rigorous quantitative data for the species' distribution in Texas. This hampers development of meaningful informed decisions and conservation planning for Mexican spotted owls in Texas.

Due to their habitat requirements across the arid landscapes of the southwestern United States, Mexican spotted owls are not uniformly distributed; rather, they are found among disjunct areas in isolated mountain systems and canyons, which are typical of the Trans-Pecos region of Texas. Mexican spotted owls will hold territories in coniferous forests and pine-oak woodlands (Ganey and Balda 1989, Zwank et al. 1994) but will also occupy narrow canyons with small groves of trees (Rinkevich 1991, Willey 1998). Mexican spotted owls typically nest in the oldest and largest trees within coniferous forest stands (Ganey and Balda 1989, Ganey and Balda 1994, Zwank et al. 1994, Seamans and Gutiérrez 1995). Wooded areas used by the owls consist of a large number of tree species in both the canopy and understory. Stands of three types of woodlands are thought to be important to Mexican spotted owls: mixed-conifer dominated by Douglas-fir (*Pseudotsuga menziesii*),

pine (Pinaceae)-oak (*Quercus* spp.) woodland, and riparian forests with high tree diversity (Gutiérrez et al. 2020).

Mexican spotted owls will also use canyon areas for nesting habitat. Canyons used by the owls usually consist of vertical-walled rocky cliffs and tributary side canyons, with small caves, ledges, and potholes that provide nesting and roosting sites (Gutiérrez and Rinkevich 1991). Occupied canyons usually have patches of wooded vegetation and sources of permanent or ephemeral water. Home range sizes are positively correlated with elevation and amount of old growth forest (i.e., unlogged areas >200 years old) in forested areas (Ganey and Balda 1989), and with the geophysical features in canyon areas (Willey 1998).

Mexican spotted owls typically forage in woodlands but in canyon areas, such as much of the Trans-Pecos, the species appears to have distinct centers of activity (Willey 1998). In Utah, Willey (1998) found 75% Adaptive Kernel estimations of Mexican spotted owl home ranges consisted of small areas in which radio-telemetry derived relocations were densely packed. These centers of activity averaged 279 ha and were less variable among owls than were the 95% Adaptive Kernel estimated home ranges (Willey 1998). They are a nocturnally active species, normally roosting during the daylight hours and then hunting from dusk to dawn. Their primary prey is reported to be woodrats (*Neotoma* spp.), but use of prey varies among years and locations, and includes small rodents (e.g., *Peromyscus* spp., *Microtus* spp.), rabbits (*Sylvilagus* spp.), and bats (*Chiroptera*) (Gutiérrez et al. 2020).

Mexican spotted owls do not build their own nests; rather, they use an existing structure such as an old hawk nest, the flattened top area of a mistletoe clump, or ledges

and cavities of cliff walls (Gutiérrez et al. 2020). Areas with high canopy or overhead cover and cooler temperatures than ambient conditions are selected. Mexican spotted owls may use the same nest site repeatedly or may use alternate sites (Forsman et al. 1984). Spotted owls generally do not breed until three years of age or older; only 14.6% breed before three years (Gutiérrez et al. 2020). Little information is known on clutch sizes due to inaccessibility of nests. Museum collections of 11 Mexican spotted owl clutches averaged 2.1 eggs (Gutiérrez et al. 2020). The species will only produce one brood of nestlings per year (Gutiérrez et al. 2020). The number of young fledged from nests in Arizona and New Mexico ranged from 0.0 to 2.0 depending on age of the breeding female, location, and year (see Gutiérrez et al. 2020).

Although juvenile survival appears to be low, adult survival is high and over a decade of mark-recapture data may be required to determine turnover rates. The U.S. Fish and Wildlife Service (1995) estimated a minimum of 777– 1,554 Mexican spotted owls in the southwest U.S. and 38 in Mexico between 1990 and 1993, but data were imprecise due to lack of consistent surveys. Rough density estimates for Arizona and New Mexico ranged from 0.076 to 0.120 owls/km^2 and from 0.147 to 0.180 owls/km^2, respectively (Gutiérrez et al. 2020). There are no similar data or estimates for Texas.

Mexican Spotted Owls in Texas

Despite substantial research focused on Mexican spotted owls over the last decades, Texas has been largely overlooked. There are two primary reasons for this. First is the perception that the species is only present in widely scattered, low-density populations. This may be accurate, but rigorous surveys validating the presumption have not been conducted. Alternatively, given the unique habitat requirements of the owls, the

sparse distribution of areas that would provide those habitat patches across an expansive arid landscape may suggest more owls are present but that the nesting areas simply have not been accessed and assessed. The second reason that has precluded much research in the Trans-Pecos is that most of the region is in private ownership, whereas the expanses of state and federal lands in the other states within the owl's distribution make on-the-ground management and regulation easier to undertake.

Regardless, the Mexican spotted owl is a resident of Texas, is a state threatened species, and is in need of a better understanding of its state presence and habitat requirements. Such information is not intended for protection from human activities, but rather to understand the risks from a changing climate that is making habitat hotter and increasing the risk of wildfire. The importance of this cannot be understated: Mexican spotted owls are long-lived and generally nonmigratory with year-round occupancy of home ranges (Zwank et al. 1994), so even a temporary loss of their habitat in an isolated area could be a permanent loss of the species at that local scale. There is an economic/ecotourism component for local communities as well. Ecotourism is popular in the Trans-Pecos, and birding in particular is a big attraction to the region. Mexican spotted owls are a high priority species for birding enthusiasts, so understanding where the species occurs, what risks are posed by observation, and how to balance conservation and economics is an important issue.

None of these issues can currently be addressed, simply due to a complete lack of meaningful information for management and conservation efforts. In birding guides the species is listed as a rare but permanent resident to the mountains of the Trans-Pecos and Guadalupe Mountains (Rappole and Blacklock 1994, Peterson and Zimmer 1998). The only

descriptions for the species in Texas are from only three locations in the Davis Mountains (Bryan and Karges 2001) and for a sample of sites in the Guadalupe Mountains (Oberholser 1974, Mullet and Ward 2010), but Lockwood and Freeman (2014) suggested they may be more widespread. As Gutiérrez et al. (2020) point out, critical information needs include understanding the relationships between habitat and demography, survival, and reproduction, and details on juvenile dispersal in relation to dispersal habitat availability for well-informed management and conservation plans. However, collecting data on those components of information cannot be considered until valid information on species distribution and population structure across the landscape is known.

This Study

Data for Mexican spotted owls are primarily from Arizona, Utah, New Mexico, and Colorado. The species' estimated distribution in Texas was based primarily on a few documented observations at isolated locations. However, until this study there had been no focused effort to assess the true distribution and habitat associations of Mexican spotted owls in Texas. The landscapes and habitat used by this species, and the fact that conventional surveys must be done at night, render conventional surveys time consuming, expensive, and a personnel safety risk in the Trans-Pecos region.

We attempted to develop a better understanding of Mexican spotted owl presence and habitat use in Texas. We developed a naïve preliminary habitat model suggesting areas in the Trans Pecos region that may potentially harbor Mexican spotted owls. We then deployed automated recording units (ARU) among accessible areas to passively record during pre-programmed listening periods. Following retrieval of these units, we assessed each for spotted owl detections. We used detections and lack of detections to build an

informed probability model of potential presence of spotted owl across the Trans-Pecos region. From this we attempted to estimate population size or density of the species in Texas.

METHODS

Preliminary Model

We developed a predictive model of Mexican spotted owl habitat suitability in the Trans-Pecos region of Texas. Based on known habitat associations for Mexican spotted owls, the primary components used in the preliminary predictive model were canopy cover and the linearity and directionality of canyons. In constructing this model, we used a vegetation model and a topographic model. The vegetation model was constructed from the National Land Cover Database (NLCD) for forested areas and the LandFire Forest Canopy Cover (LFCC) database. The topographic model was constructed using a multi-scale topographic position index (TPI; Guisan et al. 1999) to identify deep, narrow canyons and then further refined to identify areas with the lowest insolation (i.e., minimal sun exposure). Two scales, 300 and 2000 meters, were used to create the TPI layer that identified canyons. TPI was used to classify topography into 3 categories of no canyon, wide shallow canyon, and deep narrow canyon. Solar radiation was calculated for midday at midsummer and the resulting insolation raster was classified into a binary category indicating areas having shade during this time. The insolation and TPI layers were combined into a topographic model. The topographic and vegetation models were combined into a full model using ranks of 0 – 8, with areas with the highest ranking consisting of a vegetation component of >50% canopy combined with deep shade and narrow canyons. Deep shade was converted to a binary variable using a cutoff of solar radiation at solar noon at solstice ≤ 0.1 kWh/m^2. 0 indicates insolation level > 0.1 kWh/m^2 at solar noon on summer

solstice. From this map we intersected highly ranked areas with areas that were either public or where access permission could be obtained. Within these selected areas we allocated sampling points spaced 400 m (1/4 mile) apart for deployment of ARUs. All spatial analysis was conducted using ArcGIS Pro 3.2.2 (Environmental Systems Research Institute, Redlands, CA, USA).

Automated Recording Unit Deployment

We used Wildlife Acoustics Song Meter Mini 2 ARUs for passive recording of owl vocalizations. These units were programmed to record for 3 continuous hours starting at sunset and then for 1 continuous hour prior to sunrise. The ARUs were georeferenced so that sunset and sunrise times were automatically adjusted with date. We deployed 85 ARUs between 19 March and 11 April 2024 among 4 mountain ranges: the Chisos Mountains (n=29) in Big Bend National Park, the Guadalupe Mountains (n=19) in Guadalupe Mountains National Park, the Sierra Vieja (n=11) on the Chilicote Ranch, and the Davis Mountains (n=26) on property owned by The Nature Conservancy and several private ranches (Table 1).

ARU Data Analysis

Upon retrieval of ARUs in August and September, we downloaded all recorded data to back-up hard drives for archiving. We then submitted sound files to automated screening in BirdNET Analyzer V1.3.1 (Cornell Lab of Ornithology, see Kahl et al. 2021). We conducted the sound file analysis in R (R Core Team 2024) using the NSNSDAcoustics package (National Park Service Natural Sounds and Night Skies Division 2024). We set a confidence threshold for Mexican spotted owl identification at 0.7; thus, initial screening identified sound clips within sound files that the program has a ≥70% confidence of being a

Mexican spotted owl. This allowed filtering out of all other species calls and noises. We then used R to manually verify calls identified from each ARU as being Mexican spotted owls. For a given ARU, we terminated manual screening once a Mexican spotted owl call was verified at that ARU and the status of that location was considered 'present.' If all calls were screened and we determined that none were verifiable as being Mexican spotted owls, the ARU location was considered 'absent.' Two of the ARUs had storage cards that were corrupted and were not able to be analyzed; thus, we completed analysis on 83 ARU locations.

Habitat Model Refinement

We developed a new habitat model based on ARU detections using the same layers, plus elevation, that were used to develop our preliminary model. All ARU locations were buffered by 200 m (to prevent overlap of buffers) and the mean value of each of the model variables within each buffer was calculated from the relevant raster (Table 2, 3). Six variables were considered for the new model: Shade, NLCD Forest classes (NLCDFor), insolation (Solar), Canyon, LandFire 50+ (LF50), and Elevation (Elev). Elevation was derived from the 10-Meter Digital Elevation Model. We evaluated collinearity using Pearson correlation coefficients. No pairwise correlation (r) greater than 0.7 occurred so all covariates were considered further. All covariates were scaled and centered for further analysis.

We developed a candidate model set of 26 models ranging from a null model (intercept-only) to a global, fully interactive model consisting of all six covariates (Table 4). We ran logistic regressions using the detection or non-detection of a Mexican spotted owl at an ARU as the response variable. Fit of models was assessed by examining the Receiver

Operating Characteristic (ROC) and Area Under Curve (AUC) of the global model. Models were compared against each other using Corrected Akaike Information Criterion (AICc). Because multiple models appeared competitive with each other, we created a confidence set of 7 models containing 95% of the model weights and used these to assess the meaningful variables (based on number of models in which the variable was present and whether the 95% confidence interval on the coefficient overlapped 0) to determine what covariates to use in the predictive model. We used model averaging of the confidence set of models to calculate the coefficients used in the refined habitat model.

Once a regression model was identified, we used ArcGIS Pro to apply the regression equation to the Trans-Pecos region. We then used the ARU buffers to look at the 90% prediction intervals on the mean values of the predicted model at ARU locations. A threshold of 0.27, representing the upper 90% prediction limit of sites where owls were absent, was used to classify the predicted habitat model into a binary 'habitat' and 'nonhabitat' layer. We applied a hexagonal tessellation to identify areas that were majority 'habitat' with the area of hexagons being equal in size (12.6 ha) to the 200 m buffered ARU polygons. These hexagonal areas were then grouped into regions and any region having less than the 36 ha (equivalent of 3 hexagons) of 'habitat' were eliminated to produce the final habitat model.

RESULTS

Our preliminary model suggested areas within 7 mountain ranges potentially held suitable habitat for Mexican spotted owls. From north to south, these were the Guadalupe Mountains, the Eagle Mountains, the Sierra Vieja, the Davis Mountains, the Del Norte Mountains, and the Chisos Mountains. Between 18 March and 12 April we deployed 19

ARUs in the Guadalupe Mountains, 11 in the Sierra Vieja, 26 in the Davis Mountains, and 29 in the Chisos Mountains. We were not able to gain land access to target areas in the Eagle Mountains, Chinati Mountains, or Del Norte Mountains. Access to the Chinati and Del Norte Mountains may be forthcoming but was not available in time for this study. The ARUs were deployed across a mix of public (Guadalupe and Chisos mountains) and private (Sierra Vieja and Davis Mountains) lands. Of note is that while deploying ARUs in the Guadalupe Mountains we found evidence of Mexican spotted owls at multiple locations. These included white-wash (i.e., excrement) and regurgitated pellets at roost/hunting perches, and as many as three individuals calling at our backcountry campsite.

With the recording schedule we programmed, each ARU should have collected data for at least two months. We found most ARUs had recorded from the deployment dates well into June or July. When running the sound files through the automated classification system, possible detections of Mexican spotted owls were found at 57 of the 83 (69%) recording locations. Unfortunately, manual verification revealed most of these were misclassifications of other species, especially of dove (Columbidae) species.

Based on manual verification of audio clips, we confirmed Mexican spotted owls were present in three of the mountain ranges (Table 3). We recorded the species presence at 17 of the 19 (89.5%) ARU location in the Guadalupe Mountains, at 1 of the 29 (3.4%) locations in the Chisos, and at 1 of the 26 (3.8%) locations in the Davis Mountains. Additionally, 3 ARUs in the Davis recorded calls that we could not conclusively verify as Mexican spotted owls but were not clearly belonging to another species.

All 7 models in the confidence set contained the Canyon covariate, and the Canyon coefficients never had confidence intervals overlapping zero. The Elevation covariate was

present in 3 of the 7 models and in 2 cases had confidence intervals not overlapping zero. Shade was present in only 1 model and with a confidence interval that barely overlapped zero. All remaining variables had confidence intervals strongly overlapping zero in all cases. This indicated that Mexican spotted owl presence was positively associated with presence of TPI-identified deep narrow canyons, higher elevations, and, surprisingly, a negative association of deep shade. The final model was:

$$logit(Owlpresence) = -1.6855 + 2.031Canyon + 0.8448Elevation - 0.7809Shade$$

Using this model, we identified 26 blocks of likely Mexican spotted owl habitat among 6 mountain ranges of the Trans-Pecos (Table 5, Fig. 1). The habitat model suggests that there are only approximately 63.8 km^2 of habitat in the region, with the largest block in the Guadalupe Mountains (Fig. 2), followed by the Davis Mountains (Fig. 3). Small blocks of habitat, probably able to support a single pair of owls, exist in the Chisos (Fig. 4), Sierra Vieja (Fig. 5), Chinati, and Sierra Diablo Mountains. Due to the isolated nature of these latter blocks, full occupancy is unlikely, but it is reasonable to assume that there are approximately 11 pairs of Mexican spotted owls in the Guadalupe Mountains, 2-3 pairs in the Davis Mountains, and no more than 2 pairs in the remaining ranges for approximately 15-16 pairs possible in the Trans-Pecos region of Texas.

Another approach to estimate the potential number of Mexican spotted owl pairs present is by dividing the area of predicted habitat from our model (i.e., 63.8 km^2) by the average area of Protected Activity Centers (PACs) for known pairs of owls in Guadalupe Mountains National Park (i.e., 4.7 km^2). This results in a similar estimate of approximately 14 pairs of Mexican spotted owls present in the Trans-Pecos region.

We obtained Mexican spotted owl detections at 22.9% of our 83 sampled locations.

These low numbers make it difficult to develop a rigorous estimate of the number of breeding owl pairs in Texas. Given these constraints, the two admittedly coarse approaches we took to estimating the number of breeding Mexican spotted owls were similar in their results. We believe it is reasonable that 14 – 16 pairs of breeding Mexican spotted owls may be present in suitable patches of habitat across the Trans-Pecos region of Texas.

DISCUSSION

Although widely but sparsely distributed across the southwestern United States and the northern and central states of Mexico (Gutiérrez et al. 2020), the Mexican spotted owl remains a poorly studied and understood subspecies compared to northern and California spotted owls. This may be partially due to the research focus placed upon the latter two forest-occupying species and the conflicts with timber harvesting practices and invasive barred owls. Within their range, the body of knowledge for Mexican spotted owls comes from the Four Corners states of the United States; our study is the first effort to estimate distribution and population size of the species within Texas.

Based on our survey data and landcover/land type assessments, our informed model identified 26 blocks of likely suitable habitat for Mexican spotted owls in Texas. These spatial blocks were located in 6 mountain ranges, four of which we sampled. Additional areas with blocks of habitat were in the Sierra Diablo Mountains and the Chinati Mountains. These six mountain ranges are spaced an approximate average of 84 km apart (range = 48.3 – 133.6), with the Guadalupe Mountains being the northernmost and the Chisos Mountains laying at the southern end of the Trans-Pecos. Although greater than the distances reported for Mexican spotted owls dispersing from natal sites to eventual

breeding sites, these distances are well within observed total dispersal distances and observed intermountain movements for Mexican spotted owls (Gutiérrez et al. 1996, Willey and van Riper 2000). We detected Mexican spotted owls in the Guadalupe Mountains and the Davis Mountains (approximately 123 km direct flight apart). The Sierra Diablo Mountains lay between these two mountain ranges, and our model indicates there may be suitable habitat for Mexican spotted owls in this range (Figure 3). Although there were no large blocks of owl habitat in the Sierra Diablos, which may preclude occupancy by breeding pairs, the mountain range may be important for dispersal and be occupied by non-breeding owls.

The Davis and Chisos Mountains, both with spotted owl detections, lay approximately 171 km apart, with the Sierra Vieja Mountains and the Chinati Mountains laying between them to the west. We sampled but did not detect spotted owls in the Sierra Viejas, but this may have been due to not having sufficient ARUs deployed, or access to properties that would have allowed comprehensive sampling. Additionally, we were not able to obtain access to sample the Chinati Mountains.

Although the habitat patches within individual ranges, as identified by our informed model, are small, we suspect owls may occur within them. Mexican spotted owls frequently occupy habit that is patchy and naturally fragmented (USFWS 2012). At the very least, it is likely that the areas we have identified are important for dispersal and connectivity across the Trans-Pecos. We suggest that, if access can be obtained for identified habitat blocks in the Sierra Diablo and Chinati Mountains, and additional areas in the Sierra Vieja, additional sampling could better inform the baseline data of Mexican spotted owl distribution in Texas.

Given the scarcity of modeled habitat (i.e., ~ 63.8 km^2), it is unsurprising that our population estimates are very low at only 14-16 breeding pairs across the region. However, Mexican spotted owls naturally occur at low density within a highly fragmented distribution of habitat patches (Davies et al. 2004) and appear to be adapted to a metapopulation structure that involves interchange across sky islands. Although this diffuse distribution can put the population at risk of habitat loss (e.g., wildfire, drought), the distribution among distant ranges suggests some security from complete loss of the species in the event of habitat disturbance.

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Table 1. Audio recording unit (ARU) locations, deployment and retrieval dates, and presence – absence of Mexican spotted owls (MSOW) in four mountain ranges in the Trans-Pecos region of Texas, 2024. Presence-absence: 1 = presence detected, 0 = no detection, P = possible but unconfirmed detection (e.g., low quality recording due to ambient conditions or distance), and U = unreadable memory card. Location data for private lands not reportable.

ARU	Latitude	Longitude	Mountain Range	Location	Deployment	Retrieved	MSOW
CR001	29.2585	103.3087	CHISOS MTS	Oak Creek	3/19/2024	8/5/2024	0
CR002	29.2662	103.3089	CHISOS MTS	Oak Creek	3/19/2024	8/5/2024	0
CR003	29.2552	103.3064	CHISOS MTS	Oak Creek	3/19/2024	8/5/2024	0
CR004	29.2535	103.2995	CHISOS MTS	Boot Canyon Trail	3/20/2024	8/6/2024	0
CR005	29.2715	103.3129	CHISOS MTS	Oak Creek	3/19/2024	8/5/2024	0
CR006	29.2638	103.3083	CHISOS MTS	Oak Creek	3/19/2024	8/5/2024	0
CR007	29.2615	103.3122	CHISOS MTS	Oak Creek Side Drain	3/19/2024	8/5/2024	0
CR008	29.2756	103.3221	CHISOS MTS	Window Trail	3/19/2024	8/5/2024	0
CR009	29.2690	103.3113	CHISOS MTS	Oak Creek	3/19/2024	8/5/2024	0
CR010	29.2709	103.2749	CHISOS MTS	Lost Mine Trail	3/22/2024	8/7/2024	0
CR011	29.2625	103.2563	CHISOS MTS	Pine Canyon Trail	3/21/2024	8/8/2024	0
CR012	29.2629	103.2531	CHISOS MTS	Pine Canyon Trail	3/21/2024	8/8/2024	0
CR013	30.6936	104.1433	DAVIS MTS	TNC - North	3/27/2024	8/25/2024	0
CR014	29.2974	103.2820	CHISOS MTS	Maple Canyon	3/21/2024	8/8/2024	0
CR015	29.2961	103.2788	CHISOS MTS	Maple Canyon	3/21/2024	8/8/2024	0
CR016	29.2440	103.2978	CHISOS MTS	Boot Canyon Trail	3/20/2024	8/6/2024	0
CR017	29.2440	103.3114	CHISOS MTS	Laguna Meadow Trail	3/20/2024	8/6/2024	0
CR018	29.2485	103.2936	CHISOS MTS	Boot Canyon Trail	3/20/2024	8/6/2024	0

CR019	29.2404	103.3087	CHISOS MTS	Blue Creek Trail	3/20/2024	8/6/2024	0
CR020	29.2318	103.3096	CHISOS MTS	Blue Creek Trail	3/20/2024	8/6/2024	1
CR021	29.2527	103.3028	CHISOS MTS	Boot Canyon Trail	3/20/2024	8/6/2024	0
CR022	29.2488	103.3102	CHISOS MTS	Laguna Meadow Trail	3/20/2024	8/6/2024	0
CR023	29.2425	103.3078	CHISOS MTS	Colima Trail	3/20/2024	8/6/2024	0
CR024	30.6517	104.1646	DAVIS MTS	TNC - West	3/27/2024	8/25/2024	0
CR025	Private	Private	DAVIS MTS	Private	3/27/2024	8/25/2024	P
CR026	29.2723	103.2845	CHISOS MTS	Lost Mine Trail	3/22/2024	8/7/2024	0
CR028	29.2650	103.2492	CHISOS MTS	Pine Canyon Trail	3/21/2024	8/8/2024	0
CR029	29.2742	103.2675	CHISOS MTS	Lost Mine Trail - Bushwack	3/22/2024	8/7/2024	0
CR030	29.2714	103.2675	CHISOS MTS	Lost Mine Trail - Bushwack	3/22/2024	8/7/2024	0
CR031	Private	Private	DAVIS MTS	Private	3/27/2024	8/25/2024	U
CR032	29.2745	103.2636	CHISOS MTS	Lost Mine Trail - Bushwack	3/22/2024	8/7/2024	0
CR033	31.9021	104.8486	GUADALUPE MTS	Devil's Hall	4/8/2024	9/15/2024	1
CR034	29.2672	103.2663	CHISOS MTS	Lost Mine Trail	3/22/2024	8/7/2024	0
CR035	29.2777	103.2630	CHISOS MTS	Lost Mine Trail - Bushwack	3/22/2024	8/7/2024	0
CR036	30.7011	104.1491	DAVIS MTS	TNC - North	3/27/2024	8/25/2024	0
CR037	30.6932	104.1552	DAVIS MTS	TNC - North	3/27/2024	8/25/2024	0
CR038	Private	Private	DAVIS MTS	Private	3/28/2024	8/25/2024	0
CR039	30.6968	104.1518	DAVIS MTS	TNC - North	3/27/2024	8/25/2024	0
CR040	Private	Private	DAVIS MTS	Private	3/28/2024	8/25/2024	0
CR041	Private	Private	DAVIS MTS	Private	3/28/2024	8/25/2024	0
CR042	Private	Private	DAVIS MTS	Private	3/28/2024	8/25/2024	0
CR043	Private	Private	DAVIS MTS	Private	3/28/2024	8/25/2024	0
CR044	Private	Private	DAVIS MTS	Private	3/28/2024	8/25/2024	0
CR045	Private	Private	DAVIS MTS	Private	3/28/2024	8/25/2024	0
CR046	Private	Private	DAVIS MTS	Private	3/28/2024	8/25/2024	0
CR047	30.6336	104.1375	DAVIS MTS	TNC - Limpia	3/29/2024	8/25/2024	0
CR048	Private	Private	DAVIS MTS	Private	3/29/2024	8/25/2024	0

CR049	30.6358	104.1462	DAVIS MTS	TNC - Limpia	3/29/2024	8/25/2024	0
CR050	30.6370	104.1410	DAVIS MTS	TNC - Limpia	3/29/2024	8/25/2024	P
CR051	30.6327	104.1498	DAVIS MTS	TNC - Limpia	3/29/2024	8/25/2024	0
CR052	30.6316	104.1544	DAVIS MTS	TNC - Limpia	3/29/2024	8/25/2024	P
CR053	30.6353	104.1568	DAVIS MTS	TNC - Limpia	3/29/2024	8/25/2024	0
CR054	30.6305	104.1339	DAVIS MTS	TNC - Limpia	3/29/2024	8/25/2024	0
CR055	30.6495	104.1378	DAVIS MTS	TNC - Wolfs Den	3/30/2024	8/25/2024	1
CR056	30.6487	104.1352	DAVIS MTS	TNC - Wolfs Den	3/30/2024	8/25/2024	0
CR057	30.6509	104.1299	DAVIS MTS	TNC - Wolfs Den	3/30/2024	8/25/2024	0
CR058	31.9080	104.8490	GUADALUPE MTS	Devil's Hall	4/8/2024	9/15/2024	1
CR059	31.9089	104.8534	GUADALUPE MTS	Devil's Hall	4/8/2024	9/15/2024	1
CR060	31.9127	104.8542	GUADALUPE MTS	Devil's Hall	4/8/2024	9/15/2024	1
CR061	31.9831	104.7847	GUADALUPE MTS	S McKittrick S Side 1	4/10/2024	9/22/2024	1
CR062	31.9936	104.7813	GUADALUPE MTS	N McKittrick	4/9/2024	9/21/2024	1
CR063	31.9828	104.7776	GUADALUPE MTS	N McKittrick	4/9/2024	9/21/2024	1
CR064	31.9751	104.7908	GUADALUPE MTS	S McKittrick S Side 2	4/10/2024	9/22/2024	1
CR065	Private	Private	SIERRA VIEJA	Private	4/11/2024	8/9/2024	0
CR066	31.9725	104.7863	GUADALUPE MTS	S McKittrick Canyon	4/9/2024	9/21/2024	1
CR067	Private	Private	SIERRA VIEJA	Private	4/11/2024	8/9/2024	0
CR068	31.9828	104.7776	GUADALUPE MTS	McKittrick Canyon	4/9/2024	9/21/2024	1
CR069	31.9580	104.7936	GUADALUPE MTS	S McKittrick Canyon	4/9/2024	9/21/2024	1
CR070	31.9641	104.7856	GUADALUPE MTS	S McKittrick Canyon	4/9/2024	9/21/2024	0
CR071	31.9917	104.7844	GUADALUPE MTS	N McKittrick	4/9/2024	9/21/2024	1
CR072	31.9848	104.7666	GUADALUPE MTS	McKittrick Canyon	4/9/2024	9/21/2024	0
CR073	Private	Private	SIERRA VIEJA	Private	4/11/2024	8/9/2024	0
CR074	31.9868	104.7875	GUADALUPE MTS	N McKittrick DD	4/9/2024	9/21/2024	1
CR075	31.9772	104.7831	GUADALUPE MTS	S McKittrick Canyon	4/9/2024	9/21/2024	1
CR076	31.9670	104.7899	GUADALUPE MTS	S McKittrick Canyon	4/9/2024	9/21/2024	1
CR077	31.9641	104.7856	GUADALUPE MTS	S McKittrick Canyon	4/9/2024	9/21/2024	1

CR078	Private	Private	SIERRA VIEJA	Private	4/11/2024	8/9/2024	0
CR079	Private	Private	SIERRA VIEJA	Private	4/11/2024	8/9/2024	0
CR080	31.9578	104.7978	GUADALUPE MTS	S McKittrick Canyon	4/9/2024	9/21/2024	1
CR081	Private	Private	SIERRA VIEJA	Private	4/11/2024	8/9/2024	0
CR082	Private	Private	SIERRA VIEJA	Private	4/11/2024	8/9/2024	0
CR083	Private	Private	SIERRA VIEJA	Private	4/11/2024	8/9/2024	0
CR084	Private	Private	SIERRA VIEJA	Private	4/11/2024	8/9/2024	0
CR085	Private	Private	SIERRA VIEJA	Private	4/11/2024	8/9/2024	U
CR086	Private	Private	SIERRA VIEJA	Private	4/11/2024	8/9/2024	0

Table 2. Descriptions of variables used in habitat suitability modeling for Mexican spotted owls in Texas, 2025.

MODEL VARIABLES

Shade – Binary layer with 1 indicated shade at noon during mid-summer, based on the solar level with insolation ≤ 0.1 kWh/m^2. 0 indicates insolation level > 0.1 kWh/m^2 at solar noon on summer solstice.

NLCDFor – Binary level built from reclassified 2021 National Land Cover Database (NLCD) to represent forested areas (1) and non-forested areas (0). The NLCD classes deciduous forest, evergreen forest, and mixed forest were used to define forested areas, all other classes were considered non-forested. The NLCD data are described at https://www.usgs.gov/data/national-land-cover-database-nlcd-2021-products and available from the USGS EROS Earth Explorer website (https://earthexplorer.usgs.gov).

Solar – Raster derived from Digital Elevation Model containing estimated solar radiation energy received per square meter at solar noon at summer solstice. Units are kilowatt hours per square meter (kWh/m^2).

Canyon – A derived layer consisting of three categories indicating canyon topography. Derived from 10-m DEM layer using a multi-scale topographic position index (TPI; Guisan et al. 1999) with two scales, 300 and 2000 meters, used. At the 2000 m TPI level a binary category was created with raster values < 1.62 standard deviation below the mean value indicating a 'wide canyon' (valley), classified as a 1. All values >-1.619 standard deviation were classed as 0. A similar process was used at the 300 m TPI level using a cutoff of <-2 standard deviation to indicate a narrow canyon, classed as a 2, and all other values as 0. These two derived layers were then combined such that narrow canyons found within wide canyons (TPI300=2, TPI2000=1) were classed as deep narrow canyons (2). Narrow canyons not within wide canyons (TPI300=2, TPI2000=0) were classed as 1, and all other locations were classed as 0.

LF50 – Binary layer indicating forested areas with greater than 50% canopy cover. Derived from the LandFire Forest Canopy Cover (LFCC; https://landfire.gov/data) database. All classes 50%/Tree Cover and above were reclassified as 1, all other classes were combined into 0 category.

Elev – Digital Elevation Model (DEM) raster with 10-meter cells and elevation in meters. DEM obtained from the USGS EROS Earth Explorer website (https://earthexplorer.usgs.gov).

Table 3. Model variable parameters for each audio recording unit location, Trans-Pecos region, Texas, 2024.

Unit	Shade	NLCDFor	Solar	Canyon	MSOhab1	FullMod	LF50	Elev(m)
CR001	0	0.8143	0.6321	0.1209	0.7500	1.6806	0.1875	1723
CR002	0.2740	0.4929	0.2749	0.5382	0.1727	1.4676	0.0432	1613
CR003	0	1.0000	0.4457	0.5847	0.4088	1.9416	0.1022	1800
CR004	0	1.0000	0.4471	0.2524	0.0559	1.3147	0.0140	1958
CR005	0.0342	0.8043	0.4802	0.4670	0.5143	1.8286	0.1286	1509
CR006	0.1172	0.6763	0.4930	0.4402	0.4571	1.6643	0.1143	1645
CR007	0.2000	0.5390	0.4234	0.6239	0.1439	1.3669	0.0360	1752
CR008	0.4150	0.6214	0.3960	1.3147	0.5714	2.9429	0.1429	1452
CR009	0.2067	0.6232	0.3219	0.5815	0.2014	1.6115	0.0504	1548
CR010	0.0405	0.7626	0.8667	0.1296	0.0580	1.0145	0.0145	1862
CR011	0.1879	0.6522	0.3441	0.6537	0.3768	1.8696	0.0942	1815
CR012	0.4932	0.7681	0.2844	0.6256	0.4286	2.2857	0.1071	1724
CR013	0.0200	1.0000	0.6883	0.2362	0.1135	1.3830	0.0284	1936
CR014	0.1497	0.7482	0.6258	0.6195	0.1151	1.5540	0.0360	1613
CR015	0	0.8345	1.4544	0	0	0.8129	0	1557
CR016	0	0.6331	1.2131	0.0059	0.0870	0.7464	0.0217	2094
CR017	0	1.0000	1.5417	0	0	1.0000	0	2054
CR018	0	0.4532	0.8060	0.1626	0	0.6071	0	2077
CR019	0	0.8273	1.0828	0	0	0.8403	0	2063
CR020	0.0205	0.8723	0.5799	0.2131	0	1.1232	0	1878
CR021	0	0.9716	0.4458	0	0.0576	1.0288	0.0144	1997
CR022	0	1.0000	0.6209	0	0	1.0000	0	2031
CR023	0	0.9420	1.2801	0	0	0.9429	0	2120
CR024	0	0.7770	0.6306	0	0	0.7737	0	2091
CR025	0.0139	0.7338	0.9607	0.1454	0	0.8986	0	1744
CR026	0	0.9420	0.3768	0	0.0288	0.9712	0.0072	1801
CR028	0.1096	1.0000	0.5773	0.2062	0.4638	1.7391	0.1159	1653
CR029	0	0.9565	1.1213	0.0375	0.1143	1.1143	0.0286	2087
CR030	0	1.0000	1.1850	0.0315	0.2014	1.2302	0.0504	2059
CR032	0.0067	1.0000	0.7181	0.0936	0.2899	1.3768	0.0725	2068
CR033	0.0203	0.5217	0.5686	1.3443	0	1.7554	0	1930
CR034	0	0.7292	0.7607	0.0809	0.0833	0.9306	0.0208	2012
CR035	0.0137	1.0000	0.2705	0.5103	0.2000	1.7357	0.0500	1946
CR036	0	1.0000	0.8783	0	0.0288	1.0288	0.0072	1910
CR037	0	0.9416	0.8385	0	0.0288	0.9712	0.0072	1957
CR038	0.0067	0.7626	0.5740	0.4150	0.0559	1.2238	0.0140	1537
CR039	0	1.0000	1.1240	0	0	1.0000	0	1929
CR040	0	0.7482	0.6124	0.5076	0.0580	1.4058	0.0145	1538
CR041	0.0272	0.2950	0.4845	0.4202	0	0.7305	0	1515
CR042	0.1544	0.9362	0.3203	0.4823	0.1739	1.7319	0.0435	1641

CR043	0.1800	0.2609	0.7046	0.4203	0	0.7986	0	1512
CR044	0	0.6835	0.6010	0.8603	0.0284	1.5177	0.0071	1535
CR045	0.0662	0.4130	0.4967	0.4156	0.0290	0.8986	0.0072	1499
CR046	0.0270	0.0286	0.5782	0.4827	0	0.5255	0	1487
CR047	0	1	0.8134	0.4258	0.2878	1.6763	0.0719	1909
CR048	0.0068	1	0.6267	0.2480	0.2319	1.4855	0.0580	1995
CR049	0.0265	0.9784	0.6091	0.1203	0	1.0797	0	2010
CR050	0.0069	0.9500	0.9244	0.0608	0.0870	1.0797	0.0217	1940
CR051	0.0068	1.0000	0.4019	0	0	1.0072	0	2120
CR052	0.0139	1.0000	0.6052	0.1434	0	1.1489	0	2148
CR053	0	0.7214	1.0695	0.0051	0	0.7266	0	2166
CR054	0	1.0000	1.0087	0.1318	0.3188	1.4058	0.0797	1887
CR055	0	0.6861	0.5930	0	0	0.6835	0	2018
CR056	0	0.9275	0.5702	0.0500	0	0.9928	0	2036
CR057	0	0.9441	0.6275	0.4356	0	1.3071	0	2050
CR058	0.1141	0.4710	0.4802	0.7857	0.0863	1.4173	0.0216	2007
CR059	0.1103	0.6014	0.5398	0.9181	0.0288	1.6906	0.0072	2041
CR060	0.0405	0.6667	0.7402	0.4149	0.1135	1.2482	0.0284	2102
CR061	0.1192	0.7842	0.4642	0.4109	0.4539	1.7518	0.1135	1666
CR062	0.0068	0.9203	0.5604	1.0129	0.3714	2.3286	0.0929	1677
CR063	0.1192	0.7571	0.6438	1.2961	0.8227	2.9220	0.2057	1611
CR064	0.0927	0.7482	0.4651	1.0521	0.1714	2.1000	0.0429	1712
CR065	0	0.4326	0.7054	0.3084	0.0870	0.8116	0.0217	1558
CR066	0	0.9353	0.7308	0.2771	0.2286	1.5071	0.0571	1631
CR067	0	0.3453	0.8571	0.2611	0.0290	0.6522	0.0072	1585
CR068	0.1192	0.7571	0.6438	1.2961	0.8227	2.9220	0.2057	1611
CR069	0.2534	0.9197	0.2513	1.3066	0.5390	3.0071	0.1348	1767
CR070	0.4200	0.9786	0.2319	1.4319	1.3143	3.9357	0.3286	1741
CR071	0.0789	0.7826	0.6266	1.0407	0.2286	2.0714	0.0571	1657
CR072	0.2267	0.8643	0.7629	0.8962	0.1714	2.1571	0.0429	1587
CR073	0.0608	0.3188	0.7937	0.2148	0.2029	0.8406	0.0507	1595
CR074	0.3793	0.9855	0.3541	0.9635	0.4892	2.8417	0.1223	1669
CR075	0	0.8768	0.7688	0.6566	0.3188	1.8551	0.0797	1620
CR076	0.1800	0.9583	0.4036	0.8653	0.3741	2.4532	0.0935	1664
CR077	0.4200	0.9786	0.2319	1.4319	1.3143	3.9357	0.3286	1741
CR078	0	0.2448	1.2923	0.1310	0.1449	0.4855	0.0362	1549
CR079	0	0.4786	1.2605	0.4840	0.1449	1.0145	0.0362	1566
CR080	0.1879	0.8714	0.3469	0.9506	0.4604	2.4173	0.1151	1827
CR081	0	0.4000	1.2440	0.2431	0.2857	0.8571	0.0714	1567
CR082	0.0940	0.5985	0.9868	0.6417	0.1135	1.4539	0.0284	1568
CR083	0	0.2143	1.5428	0.2854	0.0580	0.6159	0.0145	1602
CR084	0	0.5000	1.4458	0.4390	0.1739	1.1449	0.0435	1621
CR086	0	0	1.3650	0	0	0	0	1709

Table 4. Candidate model set considered for refined Mexican spotted owl habitat model, derived from passive audio survey data and remotely sensed landcover data in Texas, 2025.

Model
mod.null: MSO~1
mod.global: MSO~Shade * NLCDFor * Solar * Canyon * LF50 * Elev
mod.1: MSO~Shade + NLCDFor + Solar + Canyon + LF50 + Elev
mod.2: MSO~Shade + NLCDFor + Elev
mod.3: MSO~Solar + NLCDFor + Elev
mod.4: MSO~Canyon + NLCDFor + Elev
mod.5: MSO~Shade + LF50 + Elev
mod.6: MSO~Solar + LF50 + Elev
mod.7: MSO~Canyon + LF50 + Elev
mod.8: MSO~Canyon + NLCDFor + Solar
mod.9: MSO~Canyon + NLCDFor + Shade
mod.10: MSO~Shade + NLCDFor
mod.11: MSO~Solar + NLCDFor
mod.12: MSO~Canyon + NLCDFor
mod.13: MSO~Shade + LF50
mod.14: MSO~Solar +LF50
mod.15: MSO~Canyon + LF50
mod.16: MSO~Shade + Elev
mod.17: MSO~Solar + Elev
mod.18: MSO~Canyon + Elev
mod.19: MSO~NLCDFor + Elev
mod.20: MSO~LF50 + Elev
mod.21 MSO~Shade
mod.22: MSO~NLCDFor
mod.23: MSO~Solar
mod.24: MSO~Canyon
mod.25: MSO~LF50
mod.26: MSO~Elev

Table 5. Spatial extent of estimated Mexican spotted owl habitat in the Trans-Pecos region, Texas, 2025.

Mountain Range	km^2 of habitat
Chinati Mts	0.4
Chisos Mts	0.6
Davis Mts	9.9
Guadalupe Mts	51.7
Sierra Diablo Mts	0.4
Sierra Vieja Mts	0.8
Total	63.8

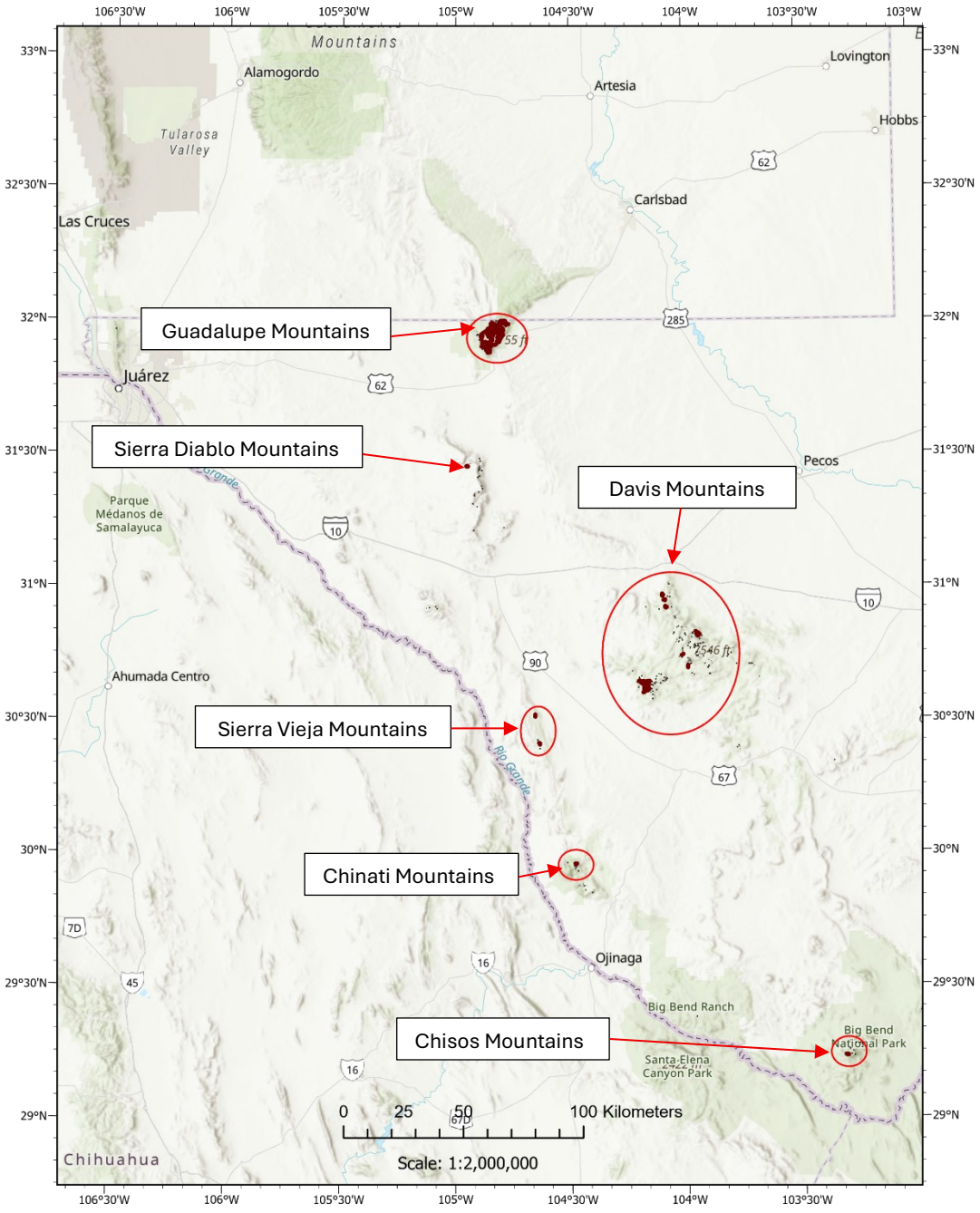


Figure 1. Distribution of modeled Mexican spotted owl potential habitat across the Trans-Pecos region of Texas, 2024.

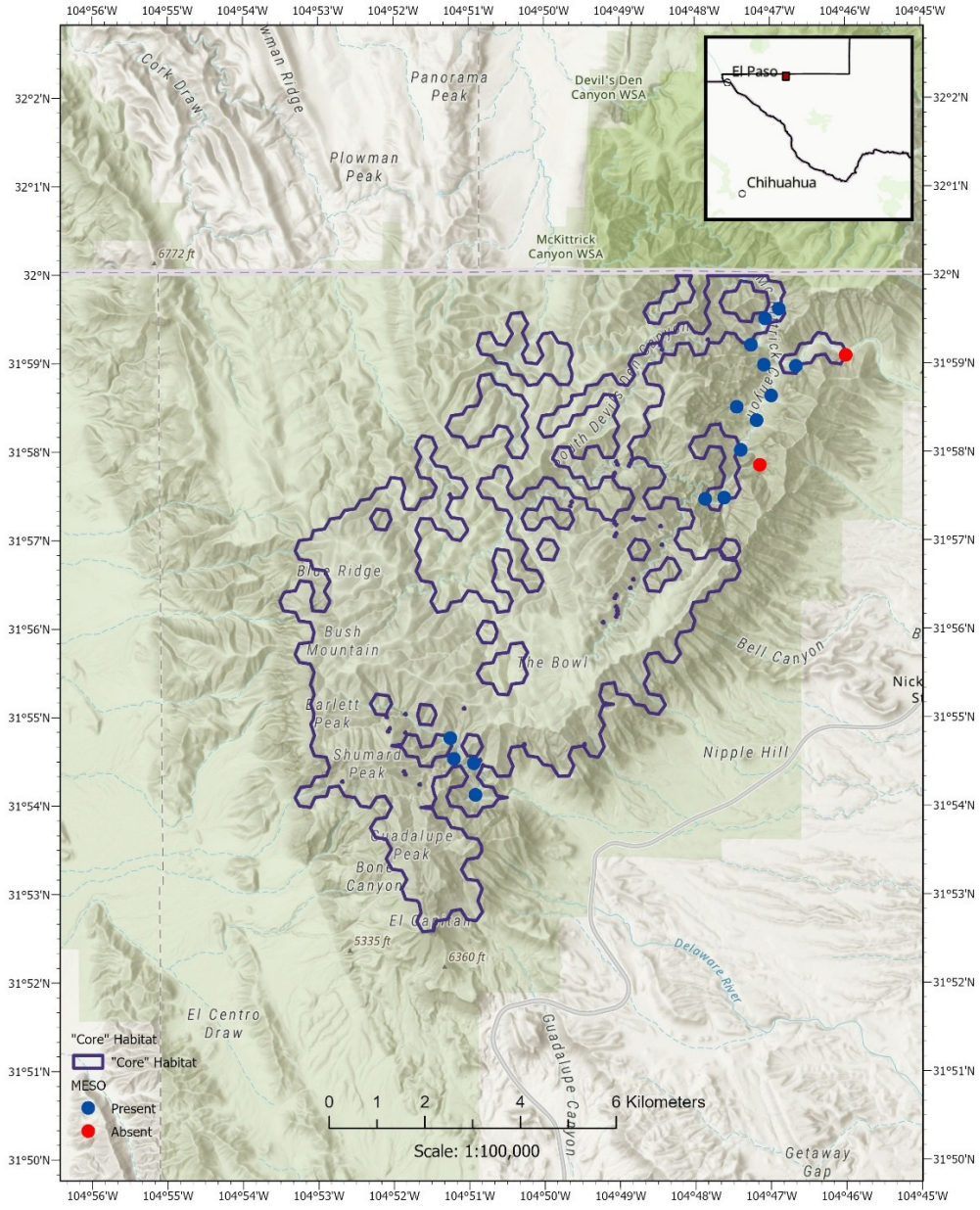


Figure 2. Locations of deployed automated recording units, and modeled estimation of core habitat for Mexican spotted owls (MSO) in the Guadalupe Mountains, Texas, 2024. Red indicated no detection of target species, blue indicates confirmed detection of Mexican spotted owl.

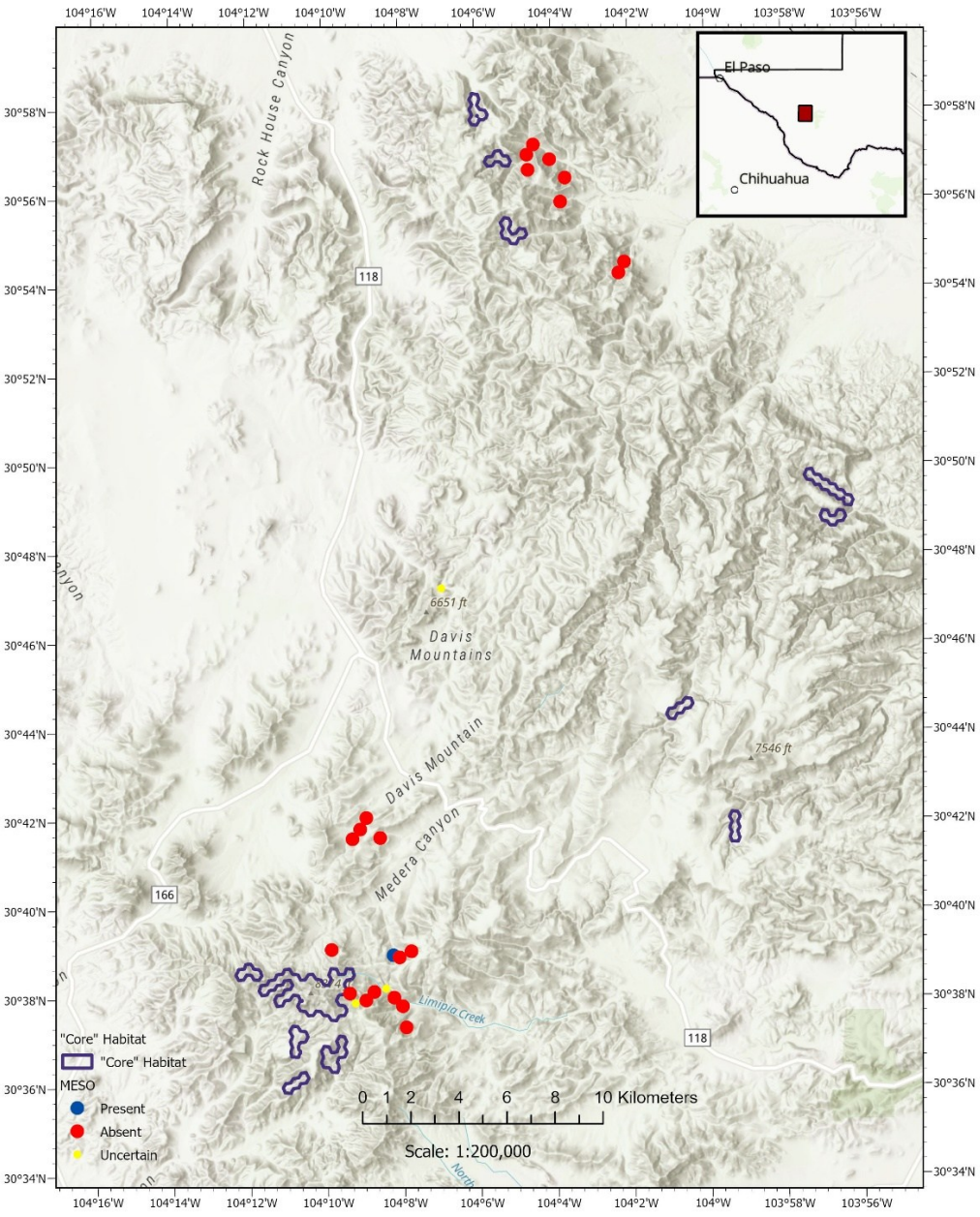


Figure 3. Locations of deployed automated recording units, and modeled estimation of core habitat for Mexican spotted owls (MSO) in the Davis Mountains, Texas, 2024. Red indicated no detection of target species, blue indicates confirmed detection, yellow indicates possible but unconfirmed detection of Mexican spotted owl.

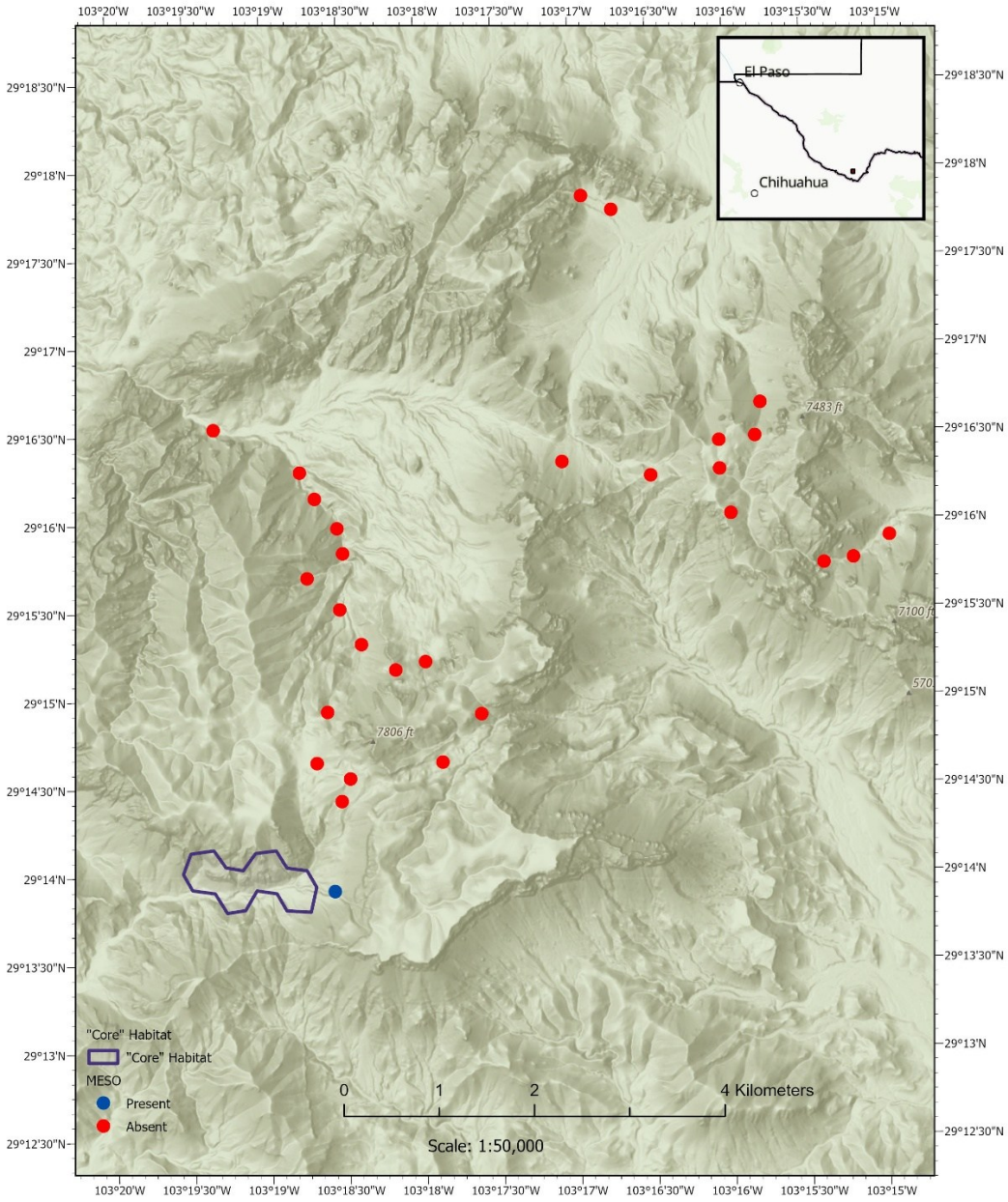


Figure 4. Locations of deployed automated recording units, and modeled estimation of core habitat for Mexican spotted owls (MSO) in the Chisos Mountains, Texas, 2024. Red indicated no detection of target species, blue indicates confirmed detection of Mexican spotted owl.

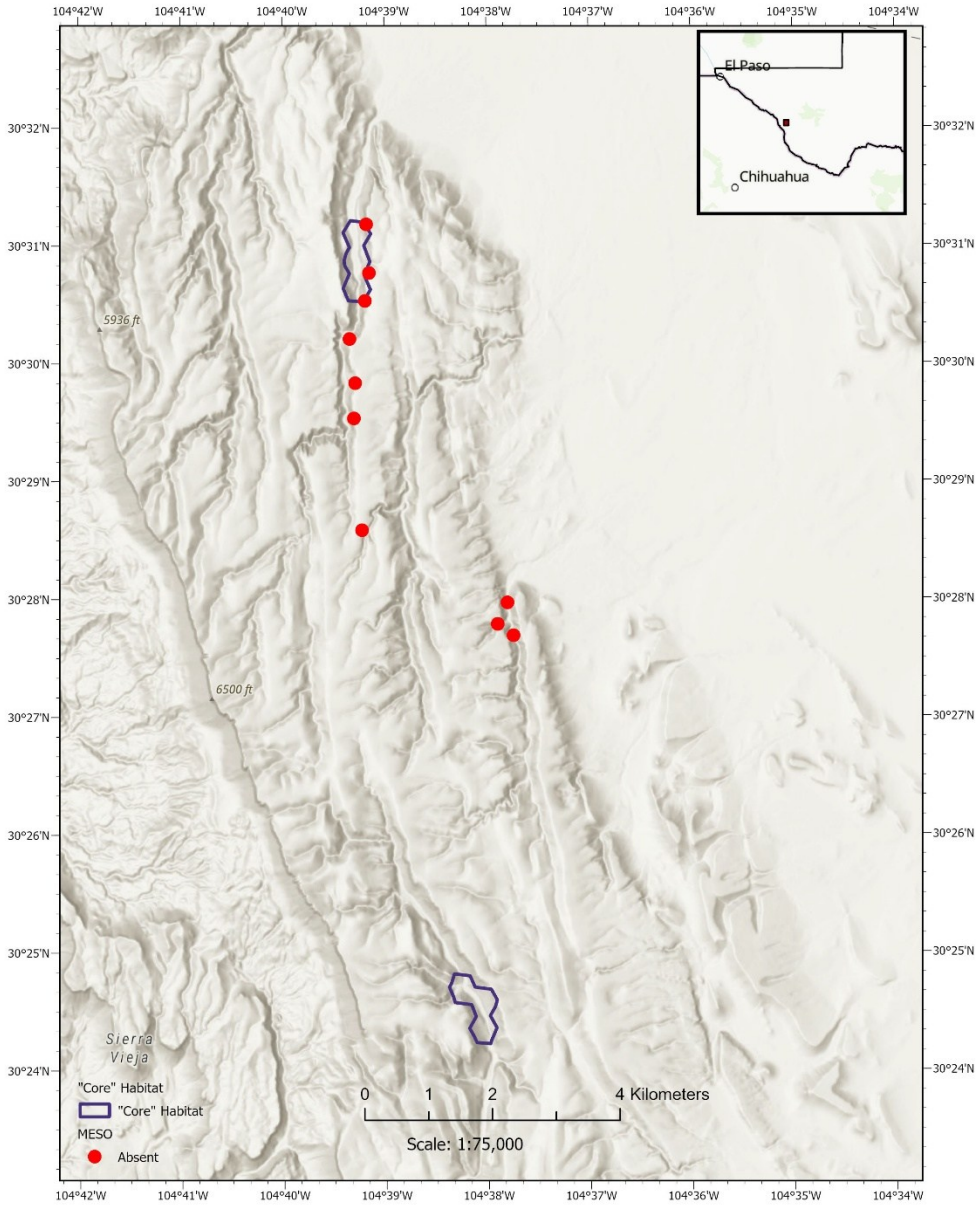


Figure 5. Locations of deployed automated recording units, and modeled estimation of core habitat for Mexican spotted owls (MSO) in the Sierra Vieja Mountains, Texas, 2024. No Mexican spotted owls were detected.