Site Occupancy by Mexican Spotted Owls (*Strix occidentalis lucida*) in the US Forest Service Southwestern Region, 2016

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Technical Report SC-MSO-USFS-03

The Bird Conservancy of the Rockies

Connecting people, birds and land

Mission: Conserving birds and their habitats through science, education and land stewardship

Vision: Native bird populations are sustained in healthy ecosystems

Bird Conservancy of the Rockies conserves birds and their habitats through an integrated approach of science, education and land stewardship. Our work radiates from the Rockies to the Great Plains, Mexico and beyond. Our mission is advanced through sound science, achieved through empowering people, realized through stewardship and sustained through partnerships. Together, we are improving native bird populations, the land and the lives of people.

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2. **Education** is critical to the success of bird conservation.
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1. Guide conservation action where it is needed most by conducting scientifically rigorous monitoring and research on birds and their habitats within the context of their full annual cycle.
2. Inspire conservation action in people by developing relationships through community outreach and science-based, experiential education programs.
3. Contribute to bird population viability and help sustain working lands by partnering with landowners and managers to enhance wildlife habitat.
4. Promote conservation and inform land management decisions by disseminating scientific knowledge and developing tools and recommendations.

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Cover Photo:

Mexican Spotted Owl Pair in Ponderosa Pine Near Flagstaff, AZ by Wendy Lanier

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Executive Summary

The Mexican Spotted Owl (MSO) was listed as threatened under the Endangered Species Act in 1993. A revised recovery plan for MSO was completed in 2012, recommending that the population be monitored via estimating the rate of site occupancy. In August 2013, the US Forest Service Southwestern Region contracted with the Bird Conservancy of the Rockies (formerly the Rocky Mountain Bird Observatory) to refine the site occupancy monitoring protocol recommended in the revised recovery plan, to pilot test the protocol in 2014, and continue monitoring in subsequent years on Forest Service lands in Arizona and New Mexico.

As part of this continued monitoring, we surveyed 200 sites in 2016. These sites were a random subset of sites initially surveyed in 2014 and the same sites surveyed in 2015.

We analyzed the data using single species multistate and multistate robust design occupancy modeling frameworks. Using these models we were able to estimate the site occupancy probabilities for the three occupancy states (i.e., unoccupied, occupied by a single owl, or occupied by a pair) in 2014, 2015, and 2016 as well as the overall occupancy of the study area. In addition, we were able to estimate transition probabilities that describe colonization and local extinction events that result in changes in occupancy of sites. In the future, this framework will be useful to understand the climatic and environmental covariates that cause variation in local colonization and extinction probabilities.

The probabilities for general occupancy and occupancy by pairs of Mexican Spotted Owls show a positive trend. Both increased from 2014 to 2015 then held stable from 2015 to 2016. This was reflected in the estimated state transition probabilities between these three years.

These models also account for imperfect detection. Detection probability was influenced by the factors of ordinal data, wind, and noise level. Unsurprisingly, wind and noise had a negative impact on detection probability. Detection improved as the season progressed either from different behavioral responses of the owls during different periods of the breeding season or because of increasing technician ability. We also found that detection probability was higher for pairs than for single owls.

In summary the sampling frame and survey methods used in 2014 provided the framework needed to continue to monitor site occupancy by Mexican Spotted Owls in the Southwestern Region of the US Forest Service in 2015 and 2016. This framework may be expanded or adapted for monitoring Mexican Spotted Owls in additional areas of their range. Additional years of data collection will allow us to expand the analysis to answer pertinent questions about what factors drive the occupancy dynamics which will inform management of this sensitive species.

Acknowledgements

The implementation of the 2016 field season and the subsequent analysis of the data would not have been possible without the support and assistance of numerous people.

Karl Malcolm of the US Forest Service Southwest Region was instrumental in securing the funding as well as making sure we had the support we needed throughout the field season. In addition, Karl and the USFS Southwest Region supported our survey efforts in 2014 and 2015.

Numerous Forest Service Forest and District Biologists provided logistical support and invaluable local knowledge and made sure our crew remained safe during the fire season.

Our colleague Brittany Woiderski of Bird Conservancy of the Rockies provided essential GIS support. We are also grateful to another colleague, David Pavlacky, who helped flesh out potential approaches for analyses.

The 2014, 2015, and 2016 Bird Conservancy Spotted Owl crew successfully collected a tremendous amount of data, often in rugged and remote terrain, while staying safe.

This project would not exist without the vision of the MSO Recovery Team. Current Recovery Team members Bill Block and Joe Ganey of the US Forest Service Rocky Mountain Research Station, and Shaula Hedwall of the US Fish and Wildlife Service provided critical guidance in designing and executing this project, as did Karl Malcolm.

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Introduction

The Mexican Spotted Owl (hereafter "MSO" or "owl") is one of three subspecies of Spotted Owl. It was listed as threatened under the Endangered Species Act in 1993. In 1995, the MSO recovery team recommended that the population be monitored via multiple demographic studies randomly located throughout the range of the subspecies (USDI FWS 1995). However, this undertaking proved to be logistically impractical and too expensive. A revised recovery plan was completed in 2012 (USDI FWS 2012), which recommended that the population be monitored by estimating the rate of site occupancy across its range within the United States.

The revised MSO recovery plan outlines two criteria for delisting the subspecies: one pertaining to the owl population trend and the other pertaining to the owl's habitat (USDI FWS 2012). This study addresses the first criterion:

> *"Owl occupancy rates must show a stable or increasing trend after 10 years of monitoring*. The study design to verify this criterion must have a power of 90% (Type II error rate $\beta = 0.10$) to detect a 25% decline in occupancy rate over the 10-year period with a Type I error rate (α) of 0.10."

Occupancy monitoring tracks the proportion of sites occupied by one or more species across a region of interest. It is especially useful because it does not involve capturing/banding of individuals and is much easier to implement. In addition it accounts for imperfect detection. Very rarely are organisms detected perfectly; they are often not observed by researchers even when present in the sampling area. Accounting for imperfect detection requires repeated visits to survey locations but it improves the accuracy and precision of site occupancy estimates (MacKenzie et al. 2002).

The vast majority of the owls in Arizona and New Mexico inhabit land administered by the US Forest Service. In 2013, the Forest Service contracted Bird Conservancy of the Rockies (formerly Rocky Mountain Bird Observatory) to refine and implement the site occupancy monitoring protocol recommended by the recovery plan. A pilot study was conducted in 2014. Based on our experiences and results from that pilot study, we adjusted our sample size and field logistics for subsequent years. We currently have three years of data and are able to estimate occupancy, occupancy state transition, and detection probabilities under single season multistate and multistate robust design occupancy modeling frameworks.

Objectives

The primary objectives were to:

1. Conduct MSO surveys at 200 randomly located sites throughout the US Forest Service Southwestern Region

2. Analyze the 2014 – 2016 data in a single season multistate framework to
    a. Estimate site occupancy for each year
    b. Estimate the occupancy rates for pairs of MSO's
    c. Estimate detection probabilities and understand the factors that influence our ability to detect owls when they are present
3. Analyze the 2014 -2016 data in a multistate robust design framework to estimate the transition probabilities in order to understand processes of extinction and colonization of sites
4. Provide recommendations for long-term monitoring of the MSO in the Southwestern Region

Methods

<u>Sampling Area and Design</u>

The geographic area that we sampled in 2016 remained the same as previous years. For details about how we selected our 1 km^2 survey sites, see the 2014 report (Blakesley 2015). Based on results from 2014, we concluded that surveying 200 sites annually would meet the Recovery Plan's owl monitoring objectives. Those 200 sites were a random subsample of the sites that were surveyed in 2014 and were each surveyed in 2015 (Figure 1). We intended to survey each site twice.

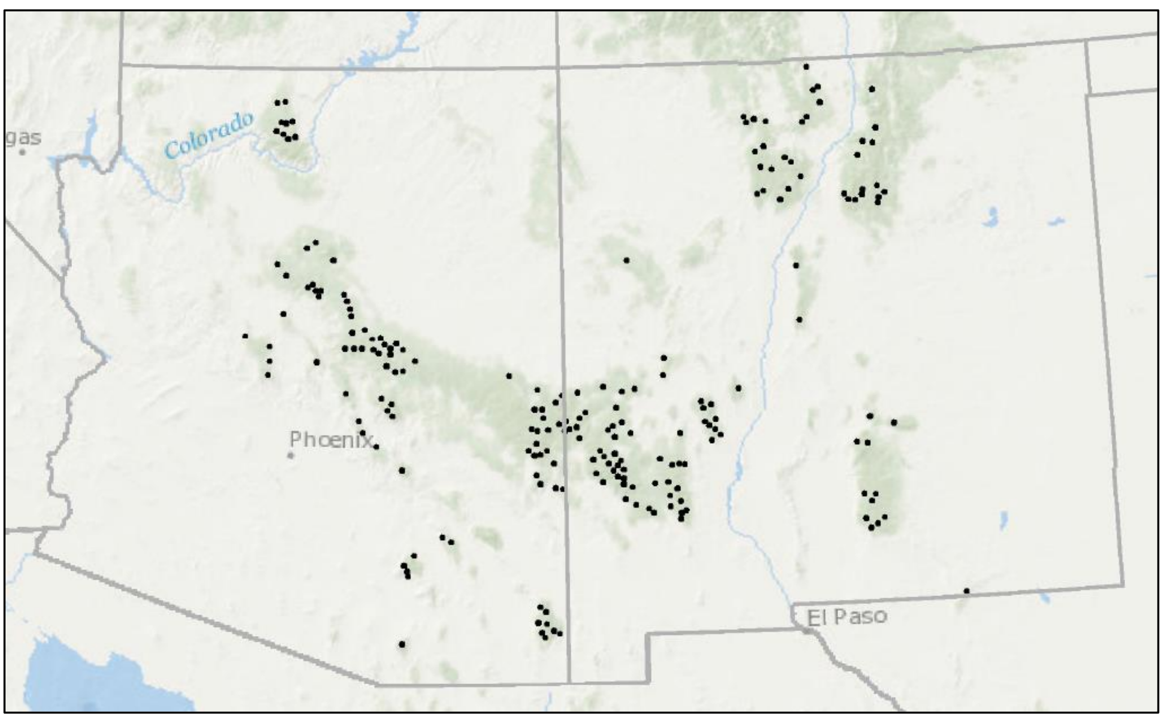

Figure 1. The distribution of sampling units (*n = 200*) surveyed for Mexican Spotted Owl occupancy in 2016 in the US Forest Southwestern Region.

Each site contained five predetermined survey points. These points were distributed within the site such that there was one point in the center of the site and one point in each of the four quadrants (Figure 2). This ensured full coverage of the site, assuming that conditions allowed the technician to hear owls 250-300 m away. We encouraged technicians to use their discretion to move the survey points to locations that would improve the reach of their calls (i.e. calling from a ridge top rather than the side of a ridge) or to improve their ability to hear any owls (i.e. moving off of the top of a ridge if conditions were windy). However, our technicians did not move points more than 100 m from their original location in order to maintain full coverage of the site.

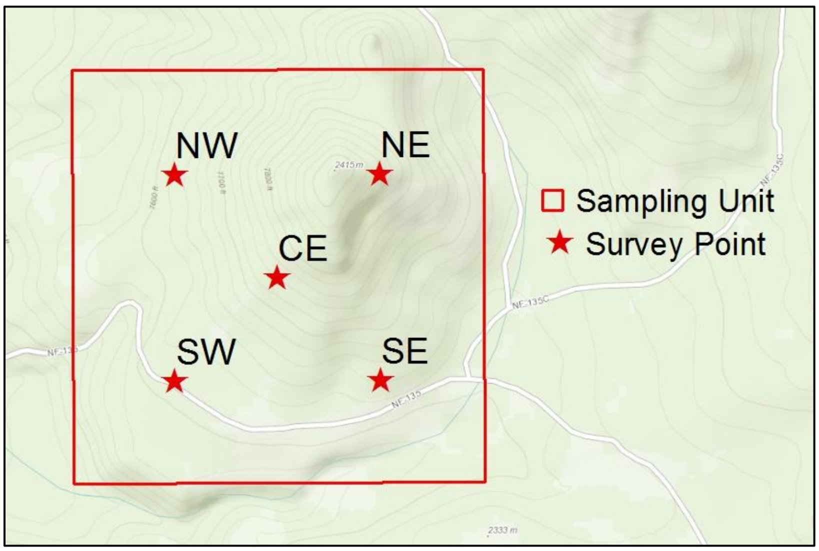

Figure 2. 1-km^2 Mexican Spotted Owl sample site containing the five survey points within the site.

Survey Protocol

Survey techniques for Spotted Owls are well-established (Forsman 1983). Spotted Owls are territorial and readily respond to vocalizations of other Spotted Owls, whether they are actual owls calling, recordings of owl calls, or human imitations of owl calls.

Technicians navigated to the survey points using a Garmin eTrex 20 Global Positioning System (GPS) and the geographical coordinates of the survey points. Surveys were conducted no earlier than 30 minutes after sunset. At each survey point within a site, technicians broadcasted prerecorded Spotted Owl calls using a FoxPro NX4. Each prerecorded call file contained 10 minutes of calls with a frequency of about 20 seconds of calling and 20 seconds of silence. Following the 10 minutes of calls, technicians listened in silence for five minutes. We used three different call files: one with a mixture of male and female calls, one with female calls only, and one with male calls only. We began surveying a site with the mixed male and female calls. If a MSO was detected, the technician switched to the recordings of the opposite sex owl for the remainder of that survey and all subsequent surveys within that site. Technicians continued to call all points within a site until they detected both a male and female MSO within the site. Occasionally one or two points within a site were not called due to safety concerns, high noise levels, or private property. We required a minimum of three points surveyed to consider a site effectively surveyed.

Once a technician detected an owl, that technician recorded the sex, age class, species, and time of detection of the owl. Adult MSO's have a wide variety of calls whereas juveniles only make a begging call. Adult female MSO's have a higher pitched call and this difference in pitch can be used to determine the sex of the calling owl. For other owl species, age and sex were not so easily determined and were recorded as "unknown." The technician then took a compass bearing towards the owl and estimated the distance to the owl. The technician plotted the bearing and distance on a map and used that to estimate the location in Universal Transverse Mercator (UTM) coordinates of the owl. Occasionally, the technicians were able to walk to where the owl was and then use their GPS units to record more precise coordinates of the owl.

Technicians also collect data on wind (using the Beaufort scale) and noise levels at each call point. For more details regarding our survey protocol and data collection, see Appendix A and Appendix B.

<u>Analysis</u>

Per the MSO recovery plan (USDI FWS 2012), we collected and analyzed our data in an occupancy framework (MacKenzie et al. 2006). In this occupancy framework, the main focus is determining presence or absence of owls in the sample sites.

We analyzed the 2014-2016 data using two different occupancy modeling approaches: a single season multistate model and a multistate robust design model. The single season multistate model affords a straightforward way to estimate the rate of occupancy across multiple years as well as analyze a trend in those estimates. This directly supports the goals of the MSO recovery plan. The multistate robust design model describes the dynamics that drive change in occupancy probabilities. This approach allows us to better understand the ecological processes that influence colonization or abandonment of sites.

Single Season Multistate Occupancy Model

Single season multistate occupancy models estimate the probability of site occupancy as well as the probability that an occupied site is characterized by additional state variable (e.g. reproductive or social status, Nichols et al. 2007). In addition, by grouping the data by year, we can analyze the overall trend in occupancy as mandated by the recovery plan.

We applied this model to our MSO data to estimate the overall probability of occupancy as well as the probability that an occupied site contains a pair of owls, which has strong implications for potential population growth. These probabilities are described by the parameters ϕ_{it}^{1} and ϕ_{it}^{2} (Table 1, following notation of MacKenzie et al. 2009).

Like most current occupancy models, this model also accounts for imperfect detection. The probability of detection is described by two parameters, p_{ij}^{1} and p_{ij}^{2}, differentiated by the occupancy state of the site (Table 1). In addition, the model allows for misclassification of the state variable of interest (in our case, pair occupancy). This probability that an observer would correctly classify the occupancy state (i.e. detect both owls in a pair) is defined by the parameter δ_{ij} (Table 1).

Table 1. Parameters estimated by the single season multistate model and their definitions.

Parameter	Definition
$\boldsymbol{\phi_{it}^{1}}$	Probability that site *i* is occupied in year *t* regardless of whether or not there is a pair present
$\boldsymbol{\phi_{it}^{2}}$	Conditional probability that site *i* contains a pair, given that is occupied in year *t*
$\boldsymbol{p_{ij}^{1}}$	Probability that occupancy is detected for site *i* during survey *j*, given that the site does not contain a pair
$\boldsymbol{p_{ij}^{2}}$	Probability that occupancy is detected for site *i* during survey *j*, given that the site contains a pair
$\boldsymbol{\delta_{ij}}$	Probability that the pair is detected in site *i* during survey *j*

We can also use the parameters estimated by the model to derive other occupancy parameters of interest such as site occupancy probability for pairs not contingent on occupancy status and site occupancy probability for single owls. The unconditional probability that a site is occupied by a pair of owls for a given year is calculated as:

$$\phi_i^{pair} = \phi_i^1 * \phi_i^2.$$

The probability that a site is occupied by only a single owl is:

$$\phi_i^{single} = \phi_i^1 - (\phi_i^1 * \phi_i^2).$$

Even though this model is structured for data from a single season, we can get year-specific estimates by treating year as a group in the analysis. Therefore the data contained one “season” but three “groups” for each of the three years from 2014-2016. Because a third survey was conducted in several sites in 2015, the data contained three sampling periods within a season. For sites in which a third survey was not conducted in a given year, which was often the case, a “.” denoted the lack of the survey for that period. The model is capable of handling such missing data.

Multistate Robust Design Occupancy Model

We also analyzed the data from 2014 to 2016 using multistate robust design occupancy models (MacKenzie et al. 2009) in order to estimate the dynamics that drive changes in site occupancy. These models divide time in to primary periods and secondary periods that occur within the primary periods. In fitting our data to these models, we treated year as a primary period and the individual surveys as the secondary periods within each primary period (Figure 3).

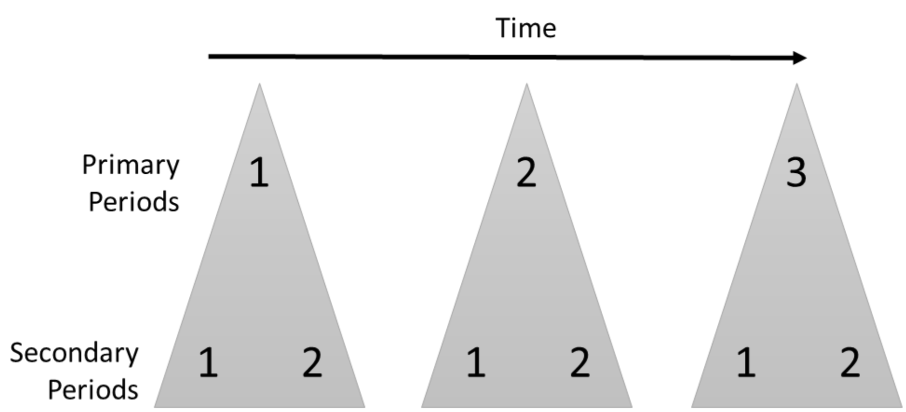

Figure 3. Diagram of the robust design framework. Secondary periods are nested within primary periods. Here, the primary periods are the years of surveys, 2014, 2015 and 2016, and the secondary periods are the surveys that occurred in those years.

These models are useful because they allow for multiple occupancy states and transitions between those states. In our analysis, we defined three possible states: unoccupied, occupied by a single MSO, and occupied by a pair of MSO’s. This model assumes that the state of a site can only change between primary periods. Further, due to the ordered nature of these states, the model assumes that a site’s true state is the “most occupied” state that was observed. For example, if we observed a single male in the first survey but observed a pair in the second survey of one site, then the model assumes that a pair occupied the site for the entire season and the female was not detected in the first survey.

Occupancy is defined in this model by the parameter ϕ_{it}^{x}, where *x* is the state (*U* for "unoccupied", *S* for "single", *P* for "pair", Table 2). The model directly estimates the occupancy probability for each occupied state for the first primary period (year 2014 in our analysis).

Table 2. Parameters estimated by the multistate robust design model and their definitions.

Parameter	Definition
$\boldsymbol{\phi_{it}^{x}}$	Probability that site *i* is occupied by state *x* in year *t*, where *x* = unoccupied, single, or pair
$\boldsymbol{\psi_{it}^{rx}}$	Probability that site *i* will transition between occupancy states following year *t*, where *r* denotes the initial state and *x* denotes the final state.
$\boldsymbol{p_{ij}^{x,x}}$	Probability of observing an occupancy state given the true state of the site *i* during survey *j*. The observed occupancy state is denoted as the first *x* and the true state is denoted as the second *x*.

This model allows sites to transition among states between years (Tables 2 and 3; Figure 4). The probability of transitioning among states is denoted as ψ_{it}^{rx}, where *rx* represents the nine possible transitions (i.e. from unoccupied to single "*US*", from unoccupied to pair "*UP*", from pair to single "*PS*", etc.). These transition probabilities describe reductions in occupancy status, increases in occupancy status (colonization), and stasis in occupancy, which is derived by subtraction (Table 3). This model assumes occupancy closure within a primary period and that any transitions between states only occur between primary periods.

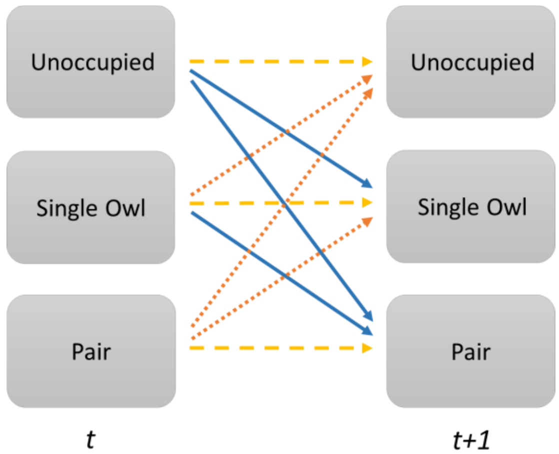

Figure 4. The three occupancy states and possible transitions among states by Mexican Spotted Owls. Dashed yellow lines represent stasis in occupancy status, solid blue lines represent increases in occupancy, and dotted red lines represent decreases in occupancy.

Table 3. Transition probability parameters (ψ_{it}^{rx}) for the Mexican Spotted Owl multistate robust design occupancy model. The probability of remaining in the same state (highlighted in yellow) is found by subtraction. The probabilities corresponding to an increase in occupancy states are highlighted in blue. The probabilities corresponding to a decrease in occupancy states are highlighted in red.

		State in year *t+1*		
		Unoccupied (U)	Single (S)	Pair (P)
State in year *t*	Unoccupied	$1 - \psi_{it}^{US} - \psi_{it}^{UP}$	ψ_{it}^{US}	ψ_{it}^{UP}
	Single	ψ_{it}^{SU}	$1 - \psi_{it}^{SU} - \psi_{it}^{SP}$	ψ_{it}^{SP}
	Pair	ψ_{it}^{PU}	ψ_{it}^{PS}	$1 - \psi_{it}^{PU} - \psi_{it}^{PS}$

The model does not directly estimate occupancy probabilities for primary periods following the first one. While these can be derived using the initial occupancy probabilities and the transition probabilities (see Lanier and Blakesley 2015), we can get those estimate more simply from the single season multistate model.

This model also accounts for imperfect detection within each secondary period. These detection probabilities describe the probability of observing a certain state given the true state of the site. However, we will interpret the detection probability estimates from the single season multistate occupancy model, to avoid redundancy. More information about detection probability estimates for this multistate robust design occupancy model can be found in our previous report (Lanier and Blakesley 2015).

Model Formation and Selection

For both modeling frameworks, we considered models that had varying structures for the occupancy, transition, and detection probabilities. We allowed occupancy probabilities to vary by occupancy state and year (Table 4). The interaction between state and year was the only structure we considered for this parameter. Because the multistate robust design model only estimates occupancy for the initial year, year was dropped from the structure in this modeling framework.

Table 4. Candidate structures for each parameter in the multistate robust design and single season multistate analyses of the Mexican Spotted Owl occupancy data. State refers to the occupancy state. Date refers to the ordinal date of the survey. Wind and noise relate to the conditions during the survey.

Occupancy ϕ_{it}^{x}	**Transition** ψ_{t}^{rx}	**Detection** p_{ij}^{x} and δ_{ij}
state * year	transition transition * year	null state date wind noise

The candidate structures for transition probability allowed for separate estimation for each transition type as well as an interaction between transition type and year (Table 4).

We thought that the occupancy state, date of the survey (Blakesley 2015), wind, and noise levels would affect the detection probability (Table 4). Wind and noise are both an average of the conditions at each call point within a site during a given survey. We modeled all additive combinations of these four covariates. In addition, we considered a null structure in which detection probability was the same across all surveys.

We fit models with all possible combinations of these parameter structures to the MSO data from 2014 - 2016 using Program MARK (White and Burnham 1999). We then used Akaike Information Criterion adjusted for sample size (AIC_c) to rank the models (Burnham and Anderson 2002).

Results

2016 Summary

We conducted 399 surveys in 200 sites. A third survey was conducted in three sites towards the end of the season. However, we did not include these third surveys in 2016 in the analysis because the sites surveyed a third time were not selected randomly. Four sites did not receive a second survey. This was due to fire in or near three of the sites and extreme heat and lack of available water in one site. We detected owls during 191 surveys in 111 sites.

Single Season Multistate

Model Selection

Of the 512 models we fit to the data, 19 of those had a ΔAICc less than two and were considered the top models (Table 5). The structures for the detection parameters in the most parsimonious (AICc weight = 0.0496) contained an effect of wind on p^1, wind and date on p^2, and date and noise on δ. The second most supported model, which carried a similar weight (AICc weight = 0.0493), contained the same structures for the detection parameters with the added covariate of date for p^1. The structure for the occupancy probabilities did not vary across this model set. Date refers to the ordinal date of the survey.

Table 5. The top models and their model selection results for the single season multistate model. Only models with ΔAICc < 2 are presented.

Model	**AICc**	**Delta AICc**	**AICc Weights**	**Deviance**
ϕ^1 (year), ϕ^2 (year), p^1(wind), p^2(date+wind), δ(date+noise)	1872.560	0	0.0496	1843.926
ϕ^1 (year), ϕ^2 (year), p^1(date+wind), p^2(date+wind), δ(date+noise)	1872.572	0.012	0.0493	1841.846
ϕ^1 (year), ϕ^2 (year), p^1(noise+wind), p^2(date+wind), δ(date+noise)	1873.485	0.925	0.0312	1842.759
ϕ^1 (year), ϕ^2 (year), p^1(wind), p^2(date+noise+wind), δ(date+noise)	1873.572	1.012	0.0299	1842.846
ϕ^1 (year), ϕ^2 (year), p^1(wind), p^2(date+noise), δ(date+noise)	1873.658	1.097	0.0286	1845.023
ϕ^1 (year), ϕ^2 (year), p^1(date+wind), p^2(date+noise+wind), δ(date+noise)	1873.724	1.163	0.0277	1840.900
ϕ^1 (year), ϕ^2 (year), p^1(date+noise+wind), p^2(date+wind), δ(date+noise)	1873.805	1.245	0.0266	1840.981
ϕ^1 (year), ϕ^2 (year), p^1(noise+wind), p^2(date+wind), δ(date+wind)	1873.836	1.276	0.0260	1843.110
ϕ^1 (year), ϕ^2 (year), p^1(wind), p^2(date+wind), δ(date+noise+wind)	1873.869	1.308	0.0258	1843.142
ϕ^1 (year), ϕ^2 (year), p^1(wind), p^2(date+wind), δ(date+wind)	1873.909	1.349	0.0253	1845.275
ϕ^1 (year), ϕ^2 (year), p^1(date+wind), p^2(date+wind), δ(date+wind)	1873.916	1.355	0.0252	1843.189
ϕ^1 (year), ϕ^2 (year), p^1(date+wind), p^2(date+wind), δ(date+noise+wind)	1873.956	1.395	0.0247	1841.131
ϕ^1 (year), ϕ^2 (year), p^1(date+wind), p^2(date+noise), δ(date+noise)	1873.989	1.429	0.0243	1843.263
ϕ^1 (year), ϕ^2 (year), p^1(noise+wind), p^2(date+noise), δ(date+noise)	1874.075	1.514	0.0233	1843.349
ϕ^1 (year), ϕ^2 (year), p^1(noise+wind), p^2(date+noise), δ(date+wind)	1874.180	1.620	0.0221	1843.454
ϕ^1 (year), ϕ^2 (year), p^1(noise+wind), p^2(date+noise+wind), δ(date+noise)	1874.197	1.636	0.0219	1841.373
ϕ^1 (year), ϕ^2 (year), p^1(date+noise+wind), p^2(date+wind), δ(date+wind)	1874.312	1.752	0.0207	1841.488
ϕ^1 (year), ϕ^2 (year), p^1(noise+wind), p^2(date+noise+wind), δ(date+wind)	1874.405	1.844	0.0197	1841.580
ϕ^1 (year), ϕ^2 (year), p^1(noise+wind), p^2(date+wind), δ(date+noise+wind)	1874.492	1.931	0.0189	1841.668

The factor of wind greatly influenced p^1. This factor was in the structure for all the top models for this particular detection probability parameter. Noise and date had less influence on this parameter and were present in nine and seven models, respectively, and are not present in the most parsimonious model.

The model selection results showed that wind also influenced p^2 and appeared in 15 of the top models. Date showed a stronger influence on this parameter, appearing in all model structures for this detection probability. Noise had less of an impact. It was present in eight models and absent from the most parsimonious model.

The detection probability associated with correctly classifying state, δ, was strongly influenced by date, which appeared in all the top models. It was also affected by noise (12 of the top models) but less affected by wind (only 9 of the top models).

Parameter Estimates

Due to the high degree of model uncertainty expected from fitting 512 models, we present model averaged parameter estimates. Overall site occupancy (ϕ^1) increased from 2014 (ϕ^1_{2014}= 0.421, SE=0.048) to 2015 (ϕ^1_{2015}= 0.615, SE=0.043) but remained largely the same between 2015 and 2016 (ϕ^1_{2016}= 0.609, SE=0.043; Figure 5).

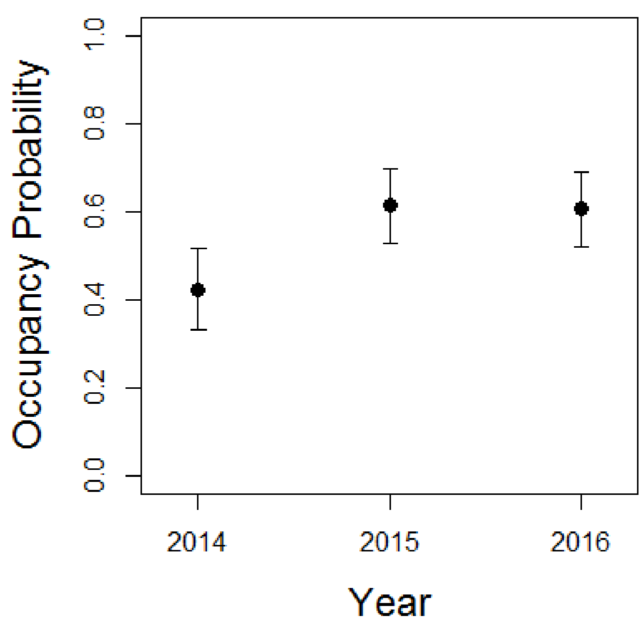

Figure 5. Occupancy rates (ϕ^1) for 2014-2016 with 95% confidence intervals.

The probability that an occupied site contained a pair of owls showed a similar pattern. It increased from 2014 (ϕ^2_{2014}= 0.654, SE=0.080) to 2015 (ϕ^2_{2015}= 0.771, SE=0.055) then held stable from 2015 to 2016 (ϕ^2_{2016}= 0.786, SE=0.056; Figure 6).

This pattern also appeared in the unconditional probability that sites was occupied by a pair of owls (Table 6). The unconditional probability that a site was occupied by a single owl remained largely the same across the three years.

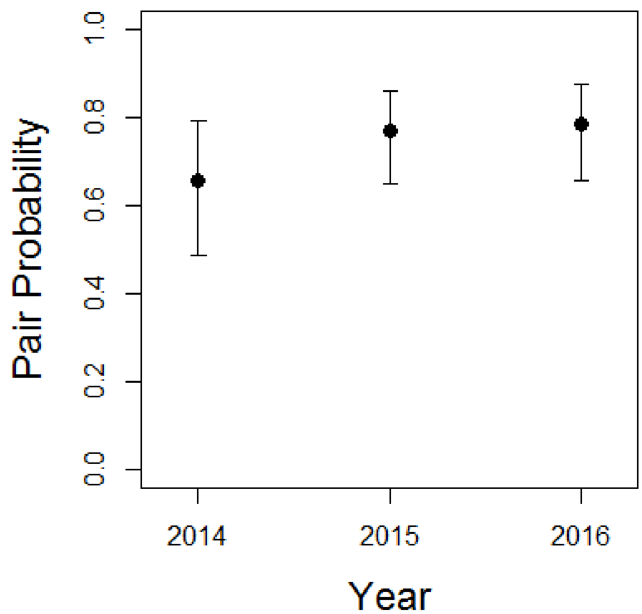

Figure 6. Probability that an occupied site contains a pair of owls (ϕ^2) for 2014-2016 with 95% confidence intervals.

Table 6. Derived unconditional probabilities of site occupancy by single owls or pairs of owls. Standard errors in parentheses.

	2014	**2015**	**2016**
$\boldsymbol{\phi_i^{single}}$	0.146 (0.043)	0.141 (0.038)	0.130 (0.038)
$\boldsymbol{\phi_i^{pair}}$	0.276 (0.036)	0.474 (0.040)	0.479 (0.040)

Detection probabilities increased with increasing date and decreased with increasing wind and noise (Figures 7, 8 and 9; Table 7). Detection in sites occupied by a pair, p^2, was considerably higher than in sites occupied by single owls, p^1. However there was little difference between p^2 and δ (Table 7).

Table 7. Model averaged parameter estimates for the different detection probabilities estimated by the single season multistate model. Estimates are presented for the average values of the covariates date, wind, and noise. Standard errors are presented in parentheses.

	Survey 1	**Survey 2**	**Survey 3**
$\boldsymbol{p^1}$	0.369 (0.091)	0.466 (0.108)	0.643 (0.125)
$\boldsymbol{p^2}$	0.811 (0.026)	0.905 (0.023)	0.938 (0.023)
$\boldsymbol{\delta}$	0.816 (0.027)	0.934 (0.022)	0.962 (0.019)

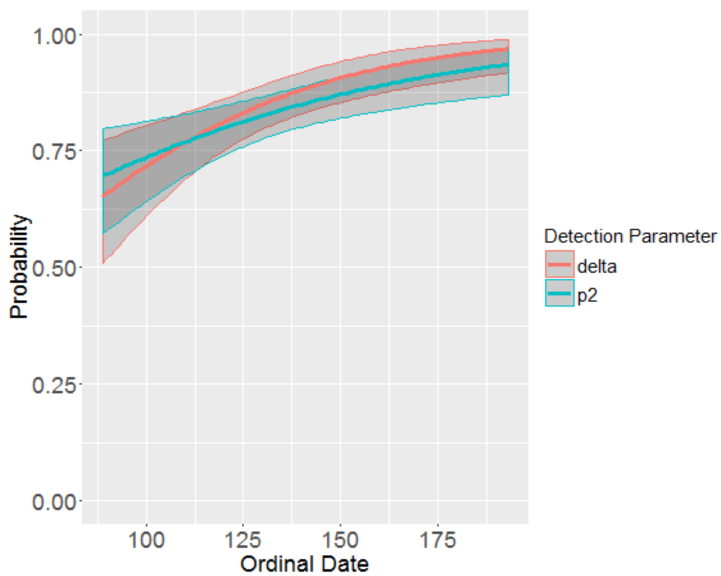

Figure 7. The relationship between date and p^2 and δ as estimated by the most parsimonious model. The shaded regions represent 95% confidence intervals around the estimate. The ordinal date of April 1 is 100. A date effect on p^1 was not included in the most parsimonious model and is not presented here.

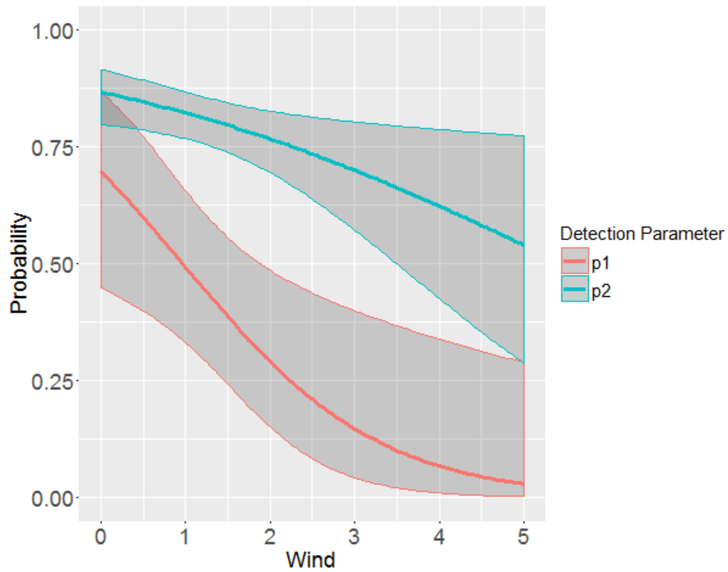

Figure 8. The relationship between wind and p^1 and p^2 as estimated by the most parsimonious model. The shaded regions represent 95% confidence intervals around the estimate. A wind effect on δ was not included in the most parsimonious model and is not presented here.

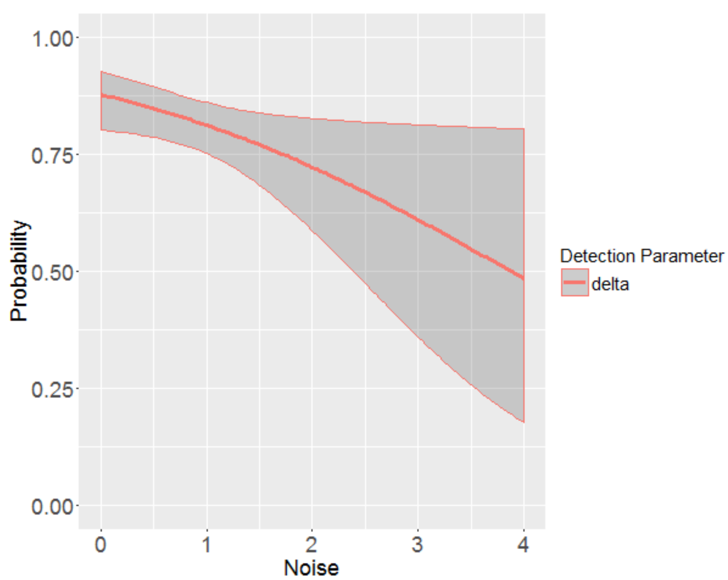

Figure 9. The relationship between noise and δ as estimated by the most parsimonious model. The shaded regions represent 95% confidence intervals around the estimate. Noise effects on p^1 and p^2 were not included in the most parsimonious model and are not presented here.

Multistate Robust Design

Model Selection

Of the 512 models we fit to the data, only three had a ΔAICc less than two (Table 8). These models contain structures that allowed separate estimations of ψ^{UP}, ψ^{PS}, ψ^{PU}, and ψ^{SU} for the period following the 2014 season and the 2015 season. The same structure for the detection probabilities was supported by all three top models and included ordinal date and wind.

Table 8. Model selection results for the top models (ΔAICc < 2) for the multistate robust design analysis. Transitions not listed in the model name are estimated to be the same for 2014 and 2015. Date refers to ordinal date of the survey.

Model	AICc	Delta AICc	AICc Weights	Deviance
ϕ(state), ψ^{UP}(2014≠2015), ψ^{PS}(2014≠2015), p(date+wind)	1702.658	0	0.159	1676.471
ϕ(state), ψ^{UP}(2014≠2015), ψ^{PU}(2014≠2015), p(date+wind)	1703.391	0.733	0.110	1672.665
ϕ(state), ψ^{UP}(2014≠2015), ψ^{PU}(2014≠2015), ψ^{SU}(2014≠2015), p(date+wind)	1703.978	1.320	0.082	1672.119

Parameter Estimates

The transition probability parameter estimates that correspond to a decrease in occupancy status were greater following the 2015 season than they were following the 2014 season (Table 9). However, they still remain very low. Likewise, ψ^{UP} was lower following 2015 than 2014 indicating that fewer sites transitioned from unoccupied to being occupied by a pair following 2015.

Table 9. Parameter estimates for the transition probabilities directly estimated by the multistate robust design model. Shaded cells indicate the transitions that the top models indicated were different between 2014 and 2015. Standard errors are in parentheses.

	Transition Parameter	2014	2015
Increase in occupancy	ψ^{US}	0.128 (0.044)	0.128 (0.052)
	ψ^{UP}	0.188 (0.057)	0.033 (0.043)
	ψ^{SP}	0.565 (0.117)	0.523 (0.106)
Decrease in occupancy	ψ^{SU}	0.020 (0.057)	0.037 (0.084)
	ψ^{PU}	0.015 (0.031)	0.085 (0.046)
	ψ^{PS}	0.059 (0.039)	0.077 (0.050)

Discussion

The data indicate that, while site occupancy by Mexican Spotted Owlsincreased from 2014 to 2015, it remained essentially unchanged from 2015 to 2016. More years of data are needed to determine if this ostensibly positive trend is indicative of continued and true population growth or simply random variation in demographic processes due to stochastic factors such as weather. Favorable weather has been shown to influence adult survival as well as reproductive output of Mexican Spotted Owls (Seamans et al. 2002). The single season multistate occupancy modeling framework will allow us to continue to monitor the site occupancy rates.

As we have shown, the multistate robust design occupancy model is particularly informative because the transition parameters it estimates explain the underlying processes that drive change in occupancy. These parameters explain the stasis in occupancy between 2015 and 2016 that the single season multistate analysis illuminated. The colonization of unoccupied sites (ψ^{US}+ ψ^{UP}) was slightly less for 2015 than 2014 but it was still greater than zero indicating that colonization of sites occurred. This colonization was balanced by the increase in local extinction (ψ^{SU}+ ψ^{PU}), which resulted in the stasis in overall occupancy.

Similarly, the unconditional probability that a pair occupied a site remained the same between 2015 and 2016. The transition probabilities $\psi^{UP}$and ψ^{SP} drive increases in this value while $\psi^{PU}$and ψ^{PS} explain decreases in this value. Even though ψ^{SP} is relatively large and indicates that about half of sites that were occupied by a single owl supported a pair in the subsequent year, the proportion of sites occupied by single owls was small. Thus this transition probability has a reduced impact on fluctuations in the occupancy rates of pairs. The small impact that ψ^{SP} had between 2015 and 2016 was balanced by the combined effects of $\psi^{PU}$and ψ^{PS}, resulting in the stasis in pair occupancy that the single season multistate analysis revealed. In addition the multistate robust design models will allow us to model colonization and downgrades in occupancy as a function of environmental, climatic, and reproductive variables, which could explain the variation in occupancy from year to year and help managers on the ground.

The estimates for the different detection probabilities highlight the different behaviors of single owls verses paired owls. The detection probability for sites with single owls, p^1, was lower than for sites with a pair, p^2. This follows a similar pattern we found in the 2015 report and is likely caused by one or more of the following factors. First, a single owl detected in one survey may have been a transient that was unavailable for detection in the other survey. In this case, the owl's presence could be considered "use" rather than "occupancy" because occupancy assumes that the owl was available for detection in both surveys. Secondly, nonbreeding owls might have larger home ranges (Willey 2007) and therefore an owl might not be spatially available for detection during both surveys even if its home range encompassed the survey site. Also, without a breeding territory to defend, a single owl may be less likely to respond to our calls. Lastly, sites occupied by a single owl, by definition, have fewer owls available to respond and be detected than sites with a pair. Therefore, the opportunities for technicians to hear an owl are greater in sites occupied by a pair.

Also, the single season multistate analysis showed that the probability of detection for site with a pair, p^2, was very similar to the probability that both member of that pair were detected, δ. Therefore, when we detected owls in sites occupied by a pair, we were highly likely to detect both members of that pair. There was a low probability of nondetection in sites occupied by a pair (1-p^2) and a similarly low probability of missing one member of a pair (1- δ).

The decrease in detection probability with increasing wind and noise is intuitive. Noise, which can be caused by running water, wind, other wildlife, or, sometimes, traffic, can make it difficult for the observers to hear the owls or for the owls to hear us. Wind could have a similar effect but there could also be a behavioral reason for the low detection during higher winds. Owls might be less likely to respond and exert energy if the wind is coupled with cold temperatures. The increase in detection probability with increasing date could be due to differential response rates during different stages of the breeding season or from the increase in the technicians' ability as the season progressed.

Three years of data allowed us to expand our analysis and estimate parameters that were inestimable before (e.g. probabilities of transitioning to lower occupancy states). We anticipate being able to further expand our analysis in the following years as we gather even more data. Some potential directions we would like to pursue include:

1. Using habitat and climate covariates to determine what factors contribute to
    a. occupancy of sites, and
    b. local extinction and colonization of sites.
2. Using MSO reproductive data collected by USFS biologists and others in Region 3 as a covariate in analyses to determine
    a. how much variation in site occupancy can be attributed to reproductive output in previous years, and
    b. whether annual reproductive rates influence detection probability.
3. Separating the "single" state into "single male" and "single female" to better understand the behavior and ecology of single owls.
4. Using the data we collect on other owl species during surveys to look at interspecific influences on occupancy and detection of MSO's. We are especially interested in the influence of Great Horned Owl presence on MSO's.

5. Using passive audio recorders deployed at the existing survey sites to determine whether audio recording data will be useful in supplementing or replacing data collected during broadcast surveys.

This third year of monitoring continued to demonstrate the ability of the current sampling design and methods to achieve the monitoring goals of the 2012 MSO Recovery Plan. We recommend that the Forest Service continue monitoring under the current framework so that we can continue to gain more knowledge about the annual variation in site occupancy by Mexican Spotted Owls. This framework can be expanded to include other areas of the Mexican Spotted Owl's range.

Literature Cited

Blakesley, J.A. 2015. Site Occupancy by Mexican Spotted Owls (*Strix occidentalis lucida*) in the US Forest Service Southwestern Region, 2014. Rocky Mountain Bird Observatory. Brighton, Colorado, USA.

Burnham, K.P. and D.R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Springer-Verlag., New York, New York, USA.

Forsman, E.D. 1983. Methods and materials for locating and studying spotted owls. USDA Forest Service, General Technical Report, PNW-162, Pacific Northwest Research Station, Portland, Oregon, USA.

Lanier, W.E. and J.A. Blakesley. 2015. Site Occupancy by Mexican Spotted Owls (*Strix occidentalis lucida*) in the US Forest Service Southwestern Region, 2015. Bird Conservancy of the Rocies. Brighton, Colorado, USA.

MacKenzie, D.I., J.D. Nichols, G.B. Lachman, S. Droege, J.A. Royle, and C.A. Langtimm. 2002. Estimating site occupancy rates when detection probabilities are less than one. Ecology 83:2248-2255.

MacKenzie D.I., J.D. Nichols, J.A. Royle, K.H. Pollock, L.L. Bailey, and J.E. Hines. 2006. Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence. Academic Press, Burlington, Massachusetts, USA.

MacKenzie D.I., J.D. Nichols, M.E. Seamans, R.J. Gutierrez. 2009. Modeling species occurrence dynamics with multiple states and imperfect detection. Ecology 90:823-835.

Nichols, J.D., J.E. Hines, D.I MacKenzie, M.E. Seamans, and R.J Gutierrez. 2007. Occupancy estimation and modeling with multiple states and state uncertainty. Ecology 88:1395-1400.

Seamans, M.E., R.J. Gutierrez, and C.A. May. 2002. Mexican Spotted Owl (Strix occidentalis) population dynamics: influence of climatic variation on survival and reproduction. The Auk 119:321-334.

U.S. Department of the Interior, Fish and Wildlife Service [USDI FWS]. 1995. Recovery plan for the Mexican spotted owl: vol. I. USDI Fish and Wildlife Service, Albuquerque, New Mexico, USA.

U.S. Department of the Interior, Fish and Wildlife Service [USDI FWS]. 2012. Final Recovery Plan for the Mexican Spotted Owl (*Strix occidentalis lucida*), First Revision. U.S. Fish and Wildlife Service. Albuquerque, New Mexico, USA. 413 pp.

White, G.C., and K.P. Burnham. 1999. Program MARK: survival estimates from populations of marked animals. Bird Study 46:120–138.

Willey, D.W. and C. van Riper. 2007. Home range characteristics of Mexican spotted owls in the canyonlands of Utah. Journal of Raptor Research 41:10-15.

Appendix A

Mexican Spotted Owl Broadcast Survey Protocol
Rocky Mountain Bird Observatory

Rocky Mountain Bird Observatory is conducting broadcast surveys for the purpose of estimating occupancy rates and monitoring trends in occupancy rates of the Mexican Spotted Owl on all National Forests in Arizona and New Mexico (USFS Region 3). This project is required under the Mexican Spotted Owl Recovery Plan, First Revision (2012).

The sampling locations were selected using a spatially-balanced sampling algorithm (Generalized Random-Tessellation Stratification), and were essentially a random sample of locations within a sampling frame of potentially suitable Mexican Spotted Owl habitat. It is essential to the validity of the monitoring program that all selected sites are surveyed unless they are unsafe to survey.

Sampling locations (sites) consist of 1-km^2 areas. Each site contains 5 survey points, with one point in the center of the site and one point in the center of each quarter of the site, named according to their location (Figure 1).

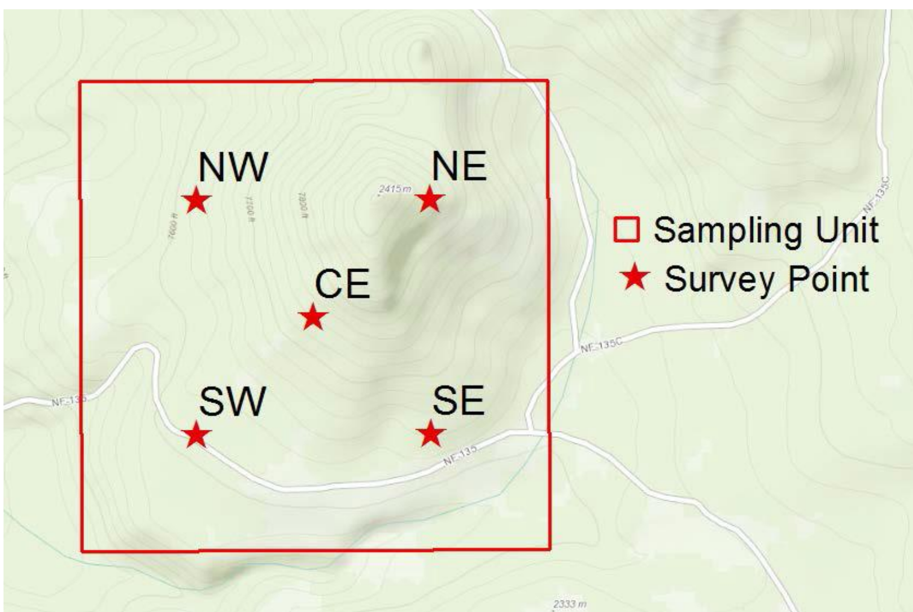

Figure 1. 1-km^2 square sample site containing 5 survey points.

Field technicians will have topographic maps and UTM coordinates of each survey point in their GPS units. Field technicians may use their discretion to move survey points to avoid trespassing on private property, to take advantage of local topography and/or to avoid unsafe terrain; for example, to call from a ridge rather than the side of a slope. In general, call points should not be move more than 100 meters. Field technicians must record the UTMs of the actual location from which they surveyed. A survey point within a site may be skipped if the point lies on private property more than 100 m from Forest Service land or if the technician has concerns about their personal safety (i.e. if the terrain is too dangerous). Safety is of the highest concern; the second highest is conducting thorough and complete surveys.

Surveys are to be conducted no earlier than 30 minutes past sunset (note: the GPS units can be used to determine the exact time of sunset). Each field technician will have a FoxPro NX4 broadcast device to use during surveys. The units contain various recordings of male and female spotted owl calls, with approximately 20 seconds of calls followed by 20 seconds of silence, for 10 minutes. Technicians are to listen for spotted owl responses throughout the survey period. Following the 10 minutes of intermittent calls, the technician will listen for owl responses for 5 additional minutes; the entire time spent at each survey point is 15 minutes (unless a spotted owl responds; see below).

Objectives are to **survey every point until both a male and female spotted owl are detected <u>within</u> the 1-km^2 site, or until all 5 points are surveyed**. If a spotted owl is detected outside of the site, the survey will continue at the remaining survey points. If only one sex of owl is detected within the site from a survey point, the technician will switch from the recording of both sexes of owls (channel zero) to a recording of the opposite sex of owl for the remainder of the 15 minute survey. At this point, it will be up to the technician to turn off the broadcaster at the 10 minute mark and also to keep track of the time during the 5 minutes of silence. For example, if a male owl is detected in survey minute 7, switch to the recording of female calls (channel one) and play this for 3 minutes then listen for 5 minutes; if a female owl is detected in minute 4, switch to the recording of male calls (channel two) for 6 minutes then listen for 5 minutes. All subsequent surveys in the site should use the recordings of the opposite sex. The purpose of this procedure is to avoid excess disturbance to spotted owls detected.

Record the compass bearing from the survey point to the initial location of all owls detected. Plot the bearing on the paper map of the survey site. Use local topography and common sense to estimate the location of the owl (plot on the map) and record the estimate the distance from the call point to the owl.

If you detect an owl while walking between survey points, stop. In the black **Survey Information** section, record your location as Point “99”, enter the UTMs of your location and all other information as you would from an established survey point. Then fill out the red **Detection Information** section for the owl you detected. Enter the “Min. to Detect” as “0”.

When two technicians are surveying separate points at the same site: Do **NOT** conduct broadcast surveys at more than one point at a time, including the 5 minute listening period. Use walkie-talkies or InReach units to communicate with your field partner to ensure that you do not survey within the same 15-minute period. The purpose of broadcasting spotted owl calls is to entice any spotted owls present to respond because they perceive you as an intruder in their territory. If an owl perceives that there are two intruders in their territory, they may remain silent.

Survey conditions: Do not survey during rainfall more than a light drizzle. Do not survey if wind conditions would prevent you from detecting a calling spotted owl within 250 meters of your survey point (generally greater than 18 mph; see Beaufort wind scale on survey form). Although ridges can be good points to survey from when winds are not strong, during windy conditions it may be better to survey downslope from ridge tops.

Safety: Except in very gentle terrain, technicians should arrive at their survey sites during daylight hours to view the landscape and plan how they are going to navigate between survey sites. Technicians will check in with their crew leaders at least once a day, either in person, by cell phone, or via their DeLorme inReach satellite communication device. The crew leader may request twice-per-day check-in. The crew leader will designate one crew member with whom they will check in daily.

Survey Form details:

SUMMARY INFORMATION (BLUE PORTION OF THE SURVEY FORM)

Site: Each site name contains 3 letters and 4 digits. The letters indicate the National Forest of the site; the numbers indicate the order of the site in the GRTS random sample; for example, "SFE0005".

Date: Follow the example format: 2 digit day, 3 letter month; for example, "01 APR".

Visit number: Each site will be visited 2 times within the season.

Observers 1 and 2: Use 3 initials (or 2 initials if you don't have a middle name).

If two people are surveying separate points within a unit, each person should fill out a form in the field, but after the survey is over, the data from one technician should be copied onto the other technician's form so that only one survey form is turned in for the survey. Destroy the duplicate form that you are not turning in to avoid confusion.

 # Pairs, # Single males, # Single females, # Juveniles: This section should be filled out at the end of the survey, after all points are surveyed for the night. **Enter zeros rather than leaving fields blank.**

Survey Complete? See the codes on the survey form. If a survey is incomplete, an additional visit to the site will be required.

Why survey incomplete? Enter a very short explanation, following the examples given on the form. If survey is complete, put a dash in this field.

SURVEY INFORMATION (BLACK PORTION OF THE SURVEY FORM)

Point: See Figure 1. Use 2 letter codes for surveys from the points or "99" if you detect an owl between survey points.

Wind: See codes.

Noise: Use this field for non-wind noise, such as a creek or traffic. Enter the type of noise in the "Notes" box of the survey form.

Start time: The time you start broadcasting, or the time you heard an owl if you are walking between points or hear the owl before you start broadcasting from a point. Record as 24-hour time; For example, 8:15 PM = 2015. Exact midnight = 2400. 15 minutes after midnight = 0015, NOT 2415.

End time: The time you stop listening for owls.

Survey time: Fill this out after you enter Start Time and End Time. If you do not detect any owls, this will usually be 15 minutes. If you detect a male and female owl, it may be less than 15 minutes. If you need extra time to confirm a detection (or location of a detection), it is ok to spend more than 15 minutes at a point.

UTME and UTMN: Use your GPS unit.

DETECTION INFORMATION (RED PORTION OF THE SURVEY FORM)

Only fill out this section if owls are detected. Most of these fields are obvious and/or have codes on the form.

Min. to Detect: This is the number of minutes that lapse between when you started surveying a point and when you detect the owl. If you detect an owl before you begin broadcasting, enter "0" for Min to Detect. If you detect an owl within a minute of broadcasting, enter "1" even though an entire minute had not lapsed.

Owl Location UTM's: Estimated from where you plotted it on the printed topo maps. Alternatively, if you can see the owl, then walk to where it is and use your GPS to get more accurate UTM's (note: a bearing and distance are still needed in this case).

Bearing and Distance: Unless the owl is perched on top of your head, record a bearing and distance for all owls observed, even the ones that are very close and you can see. Use your compass to take a bearing to the detected owl. Use your common sense to estimate a distance to it.

Unique Bird ID: This field is used to keep track of the same owl detected from multiple points. Use the same code to indicate the same individual spotted owl detected from more than one point. Start with M1, F1, U1. For example, if you hear the same male owl from NE and NW points, record its location and data for each detection on separate lines, and enter "M1" as the ID on both lines. If you then hear a second male owl from the NW point, record its location on a new line and enter "M2". If only one owl of each sex is detected, there is no need to use the Unique Bird ID field. Example:

Point	Species (see codes)	Sex (M,F,U)	Age (A,J,U)	How (see codes)	Time Detected				Min. to Detect	Bearing (degrees)	Distance (meters)	Unique Bird ID	Inside/ Outside*
NE	SPOW	M	A	HO	2	1	3	5	5	225	300	M1	I
NW	SPOW	M	A	HO	2	2	0	7	2	135	250	M1	I
NW	SPOW	M	A	HS	2	2	1	2	7	352	75	M2	I

Inside/Outside: Enter I or O to indicate whether the owl is inside or outside of the 1-km^2 survey site.

Appendix B

SPOTTED OWL BROADCAST SURVEY FORM

Page ____ of ____

Site: ______________ e.g., SFE0005

Date: ____/_____/ 2016 e.g., 01 / APR / 2015

Visit #: _____

Observer 1: __________ INITIALS

Observer 2: __________ INITIALS

Survey Complete? ______

Y Yes; 5 pts surveyed OR SPOW pair in sampling unit
P Partial; 3-4 pts surveyed AND no SPOW pair
N No; < 3 points surveyed AND no SPOW detected

MSO Summary:

\# Pairs ____ # Single Males ____ # Single Females ____ # Unk. Sex ____ # Juveniles ______

Why Survey Incomplete? __________

Bear, Fire, Mt Lion, People, Priv Prop, Rain, Snow, Space Aliens, Tech Error, Terrain, Wind

Survey Information:

Point	Wind (see codes)	Noise (see codes)	Start Time	End Time	Survey Minutes	Observer Location UTME	Observer Location UTMN

Beaufort Wind Scale

Code:	mph	Description
0	0	smoke rises vertically
1	1-3	smoke drifts
2	4-7	wind felt on face
3	8-12	leaves in constant motion
4	13-18	raises dust; branches sway
5	18-24	small trees sway

Noise codes

0 – no noise
1 – some noise, but can hear very well
2 – moderate noise; can still hear to 200 m
3 – loud noise; affecting ability to detect owls
4 – very loud stream or other noise (move!)

Detection Information:

Point	Species (see codes)	Sex (M,F,U)	Age (A,J,U)	How (see codes)	Time Detected	Min. to Detect	Owl Location UTME	Owl Location UTMN	Bearing (degrees)	Distance (meters)	Unique Bird ID	Inside/ Outside*

Notes:

Species codes

BDOW	Barred Owl
BNOW	Barn Owl
ELOW	Elf Owl
FEPO	Ferruginous Pygmy-Owl
FLOW	Flammulated Owl
GHOW	Great Horned Owl
LEOW	Long-eared Owl
NOPO	Northern Pygmy-Owl
NSWO	Northern Saw-whet Owl
SPOW	Spotted Owl
WESO	Western Screech-Owl
WHSO	Whiskered Screech-Owl

How detected codes

HO Heard Only
HS Heard, then Seen
SO Seen Only
SH Seen, then Heard

*Inside (I) or Outside (O) sampling unit

4/26/2015

IF FOUND, PLEASE RETURN TO: Rocky Mountain Bird Observatory; 230 Cherry Street; Fort Collins, CO 80521