# Site Occupancy by Mexican Spotted Owls (*Strix occidentalis lucida*) in the US Forest Service Southwestern Region, 2015



**16 November 2015**

# The Bird Conservancy of the Rockies

*Connecting people, birds and land*

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**Vision**: Native bird populations are sustained in healthy ecosystems

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2. **Education** is critical to the success of bird conservation.
3. **Stewardship** of birds and their habitats is a shared responsibility.

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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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**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 seasons on Forest Service lands in Arizona and New Mexico.

We surveyed 201 sites at least twice in 2015.  These sites were a random subset of sites surveyed in 2014.

We analyzed the data in a Multistate Robust Design framework. This analysis method not only allows for estimation of site occupancy for separate states (in our case: unoccupied, occupied by a single owl, or occupied by a pair) but it also estimates the transition probabilities between those states. Using this model we were able to estimate the site occupancies for the three states in 2014 and 2015 and the transition probabilities that describe colonization events. In the future, this framework will be useful to understand the habitat and environmental covariates that cause variation in local colonization and extinction probabilities.

The probability that a pair occupied a site was higher in 2015 than in 2014 indicating a positive trend in the population in the last year. Similarly, the probability that a site was unoccupied decreased from 2014 to 2015.

The estimates of the transition probabilities provided insight about the occupancy dynamics in the region. Our analysis also showed that there was very little downgrading in occupancy status (i.e. transition from being occupied by a pair or single owl in 2014 to being unoccupied in 2015). One of the more interesting findings from the estimates of the transition probabilities was that a site that was not occupied by a pair in 2014 was more likely to be occupied by a pair in 2015 if the site was occupied by a single owl in 2014, than if it was unoccupied in 2014.  It appeared that site occupancy by a single owl can serve as a "stepping stone" to site occupancy by a pair.

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.  This framework may be expanded or adapted for monitoring Mexican Spotted Owls in additional areas of their range. Additional seasons of data collection will allow us to expand the analysis to answer pertinent questions about what factors drive the occupancy dynamics.

**Acknowledgements**

**Table of Contents**

**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. This new monitoring framework does not involve capturing/banding of owls and is much easier to implement.

Occupancy monitoring requires repeated visits to sampling locations in order to estimate the probability of detecting the organism of interest (MacKenzie et al. 2002). Very rarely are organisms detected perfectly; they are often not observed by researchers even when present in the sampling area. By accounting for imperfect detection, we are able to improve the accuracy and precision of site occupancy estimates.

The 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 β = 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."

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 season was conducted in 2014. Based on our experiences and results from that pilot season, we adjusted our sample size and field logistics for 2015. With two seasons of data we were able to model the site occupancy dynamics in a multistate robust design framework.

*Objectives*

The primary objectives were to:

1. Conduct fieldwork to
   a. Improve the logistics of conducting MSO surveys at hundreds of randomly located sites throughout the US Forest Service Southwestern Region

> b. Collect data necessary to monitor the site occupancy of the MSO and evaluate the quantitative/analytical aspects of the sampling design
2. Analyze the 2014 and 2015 data in a multistate robust design framework to
>> a. Highlight any variation in occupancy in these two years
>> b. Explore the transition probabilities to understand processes of extinction and colonization of sites
>> c. Provide recommendations for long-term monitoring of the MSO in the Southwestern Region

## Methods

*Sampling Area and Design*

The geographic area that we sampled remained the same in 2014 and 2015. For details about how we selected our 1 km² 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. We attempted to survey 205 sites in 2015, knowing that some sites may be inaccessible. The 205 sites were a random subset of the sites we surveyed in 2014 (Figure 1). Each site was sampled at least twice in 2015.


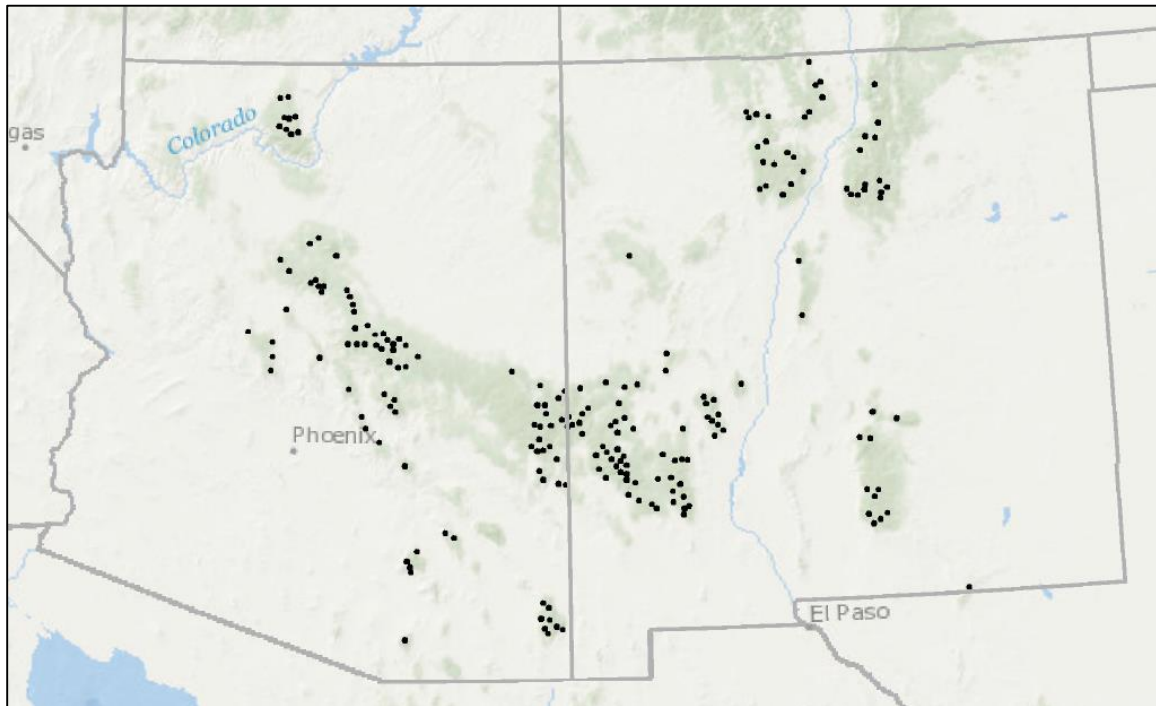
Figure 1. The distribution of sampling units (*n = 201*) surveyed for Mexican Spotted Owl occupancy in 2015 in the US Forest Southwestern Region.

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.
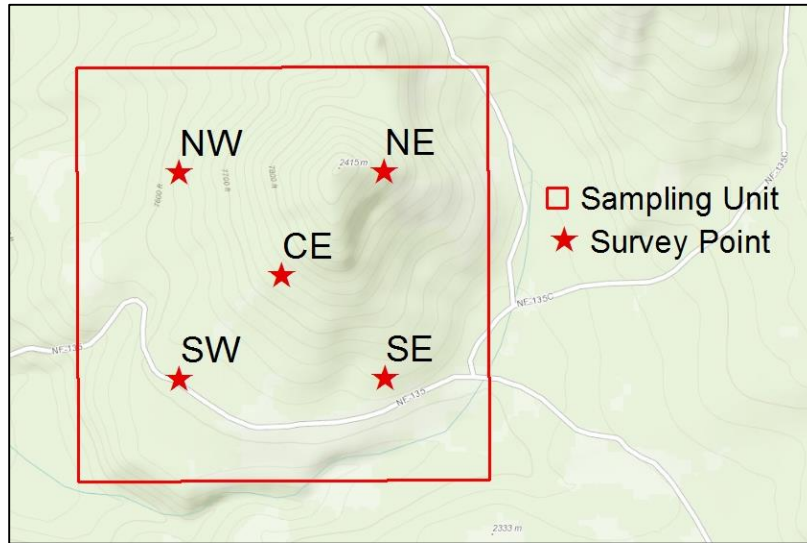


Figure 2. 1-km² Mexican Spotted Owl sample site containing the five survey points within the site.

*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 surveyed.

Once a technician detected an owl, that technician recorded the sex, age, species, and time of detection of the owl. 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.

For more details regarding our survey protocol and data collection, see Appendix A and Appendix B.

*Multistate Robust Design Occupancy Model*

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 data from 2014 and 2015 using multistate robust design occupancy models (MacKenzie et al. 2009). 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).
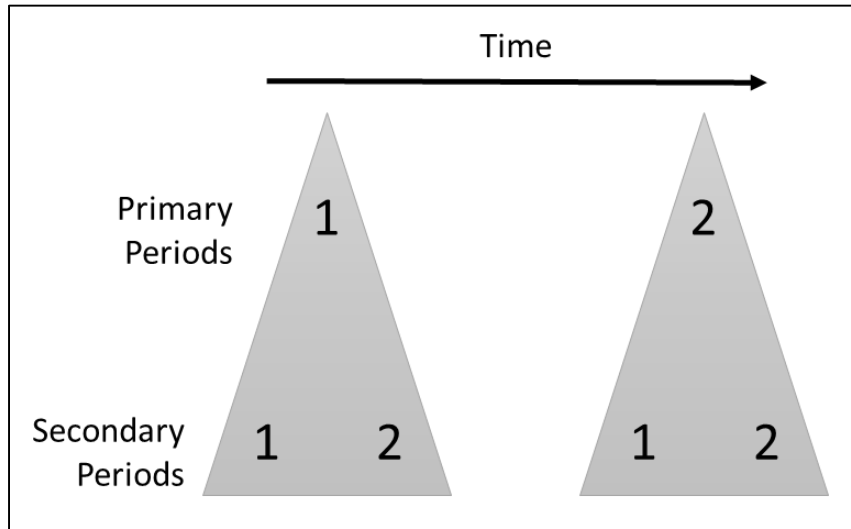
Figure 3. Diagram of the Robust Design framework. Secondary periods are nested within primary periods. Here, the primary periods are the two years of surveys, 2014 and 2015, and the secondary periods are the surveys that occurred in those years.

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 $\phi_i^x$, where *i* is the primary period (2014 or 2015) and *x* is the state (*U* for "unoccupied", *S* for "single", *P* for "pair"). The model directly estimates the occupancy probability for each occupied state for the first primary period (year 2014 in our analysis).

This model allows sites to transition among states between years (Table 1, Figure 4). The probability of transitioning among states is denoted as $\psi^t$, where *t* represents the nine possible transitions (i.e. from unoccupied to single "*US*", from unoccupied to pair "*UP*", from pair to single "*PS*", etc.). Three transition probabilities, $\psi^{US}$, $\psi^{UP}$, and $\psi^{SP}$, can be considered colonization probabilities as they all indicate transitions to higher occupancy states. Reduction in occupancy states is described by the parameters $\psi^{PS}$, $\psi^{PU}$, and $\psi^{SU}$, with the later two indicating local extinction events. Lastly stasis in occupancy status is denoted by the parameters $\psi^{UU}$, $\psi^{SS}$, and $\psi^{PP}$, which are derived by subtraction (Table 1). This model assumes occupancy

closure within a primary period and that any transitions between states only occur between primary periods.
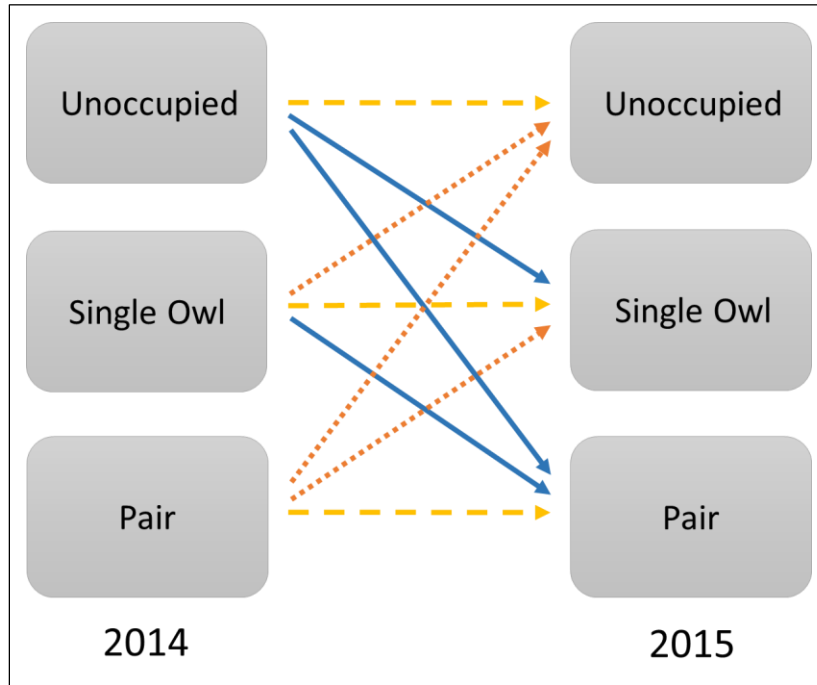


Figure 4. The three Mexican Spotted Owl occupancy states and possible transitions among states. Dashed yellow lines represent stasis in occupancy status, solid blue lines represent increases in occupancy, and dotted red lines represent decreases in occupancy.

Table 1. Transition probability parameters ($\psi$) 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 2015 | | |
|---|---|---|---|---|
| | | Unoccupied (U) | Single (S) | Pair (P) |
| | Unoccupied | $1 - \psi^{US} - \psi^{UP}$ | $\psi^{US}$ | $\psi^{UP}$ |
| State in 2014 | Single | $\psi^{SU}$ | $1 - \psi^{SU} - \psi^{SP}$ | $\psi^{SP}$ |
| | Pair | $\psi^{PU}$ | $\psi^{PS}$ | $1 - \psi^{PU} - \psi^{PS}$ |

The model does not directly estimate occupancy probabilities for primary periods following the first one. However, these can be derived using the initial occupancy probabilities and the transition probabilities. For example, the probability that a pair occupied a site in 2015 can be computed with the following equation:

$$\phi^P_{2015} = (\phi^U_{2014} * \psi^{UP}) + (\phi^S_{2014} * \psi^{SP}) + (\phi^P_{2014} * \psi^{PP}).$$

We then used the delta method to calculate the associated variances with these derived parameters.

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. For example, $p^{S,S}$ is the probability of detecting a single owl given that the site is occupied by a single owl and $p^{S,P}$ is the probability of detecting a single owl given that the site is occupied by a pair. This model assumes that a technician can observe a state that is "less occupied" than the true state (i.e. $p^{S,P}$), but a technician cannot observe a state that is "more occupied" than the true state. Thus $p^{S,U}$, $p^{P,U}$, $p^{P,S}$ are all assumed to be zero and $p^{U,U}$ is assumed to be one. The probability of not observing any owls given that a site is occupied is found by subtraction (Table 2).

Table 2. Detection probability parameters ($p$) for the Mexican Spotted Owl multistate robust design occupancy model.

|  |  | Observed State | | |
|---|---|---|---|---|
|  |  | Unoccupied (U) | Single (S) | Pair (P) |
| **True State** | Unoccupied | 1 | 0 | 0 |
|  | Single | $1 - p^{S,S}$ | $p^{S,S}$ | 0 |
|  | Pair | $1 - p^{S,P} - p^{P,P}$ | $p^{S,P}$ | $p^{P,P}$ |

*Model Formation and Selection*

We considered models that had varying structures for the initial (2014) occupancy probabilities and detection probabilities. We thought that initial occupancy probability, $\phi^x_{2014}$, might vary by occupancy state. We also considered a structure in which all occupied states had the same occupancy probability (constant model, Table 3).

Table 3. Candidate structures for each parameter in the multistate robust design analysis of the Mexican Spotted Owl occupancy data. $\phi$ = Occupancy; $\psi$ = Transition probability; $p$ = Detection probability. Dots indicate a constant structure. State refers to the occupancy state. Date refers to the Julian date of the survey.

| $\phi^x_{2014}$ | $\psi^t$ | $p$ |
|---|---|---|
| . | transition | . |
| state |  | state |
|  |  | date |
|  |  | state +date |

We did not think that the estimates of the different transition probabilities would be the same so we did not consider any constant model structure for the transition parameter. The only structure we considered was one in which the probabilities were estimated separately for each transition type (Table 3).

We thought that the occupancy state of the site as well as the date of the survey (Blakesley 2015) would affect the detection probability. Based upon these two variables, we created four candidate structures for detection probability: an additive effect of state and date, an effect of state but not date, an effect of date but not state, and a constant structure in which there was no effect of state or date (Table 3).

We fit models with the eight possible combinations of these parameter structures to the MSO data from 2014 and 2015 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**

*2015 Season Summary*

Four sites were not sampled because we determined that the terrain made accessing the points too dangerous. We conducted 406 surveys in 201 sites. A third survey was conducted in four sites towards the end of the season. We detected owls during 184 surveys in 112 sites.

*Model Selection*

Of the eight models we fit to the data, only four carried any weight (*w* > 0; Table 4). The most parsimonious model with 93% of the weight indicated that initial occupancy was different for each occupied state, transition probabilities were different for each type of transition, and detection probability was a function of the occupancy state and date (Table 4). We present estimates from this highly supported model.

Table 4. The most parsimonious models with any weight ($w$ > 0) from the multistate robust design occupancy analysis of the 2014 and 2015 Mexican Spotted Owl data. . $\phi$ = Occupancy; $\psi$ = Transition probability; $p$ = Detection probability.

| Model | AICc | Delta AICc | AICc Weight | Num. Par. | Deviance |
|---|---|---|---|---|---|
| $\phi$(state), $\psi$ (transition), $p$ (state+date) | 1200.836 | 0 | 0.925 | 12 | 1176.164 |
| $\phi$(.), $\psi$ (transition), $p$ (state+date) | 1206.477 | 5.641 | 0.055 | 11 | 1183.910 |
| $\phi$(state), $\psi$ (transition), $p$ (state) | 1208.828 | 7.992 | 0.017 | 11 | 1186.261 |
| $\phi$(.), $\psi$ (transition), $p$ (state) | 1212.340 | 11.504 | 0.003 | 10 | 1191.868 |

*Occupancy Probability Estimates*

The estimates of occupancy rates for the occupied states increased between 2014 and 2015 with the proportion of sites occupied by a pair of owls showing the greatest increase (Table 5).

Table 5. The estimated occupancy probabilities ($\phi$) and standard errors (in parentheses) by the Mexican Spotted Owl in Region 3 of the US Forest Service for each occupancy state in 2014 and 2015 from the most parsimonious model. Percent change between categories for each of the three occupancy probabilities= $(\phi^x_{2015}/\phi^x_{2014}) * 100$.

| | Occupancy State[a] | | |
|---|---|---|---|
| | $\phi^U$ | $\phi^S$ | $\phi^P$ |
| **2014** | 0.613 (0.038) | 0.108 (0.033) | 0.279 (0.032) |
| **2015** | 0.402 (0.044) | 0.125 (0.039) | 0.473 (0.045) |
| **Percent Change** | 66 | 116 | 170 |

[a]U = Unoccupied; S = occupied by a single owl; P = occupied by a pair of owls.

*Transition Probability Estimates*

Between 2014 and 2015 very few sites experienced a reduction in occupancy (i.e. $\psi^{PS}$, $\psi^{PU}$, and $\psi^{SU}$). Thus, there was very little data for these transitions and Program MARK had difficulty in estimating those transition probabilities. It is a fair assumption that, given the relative few sites that experienced reduction in occupancy (seven in total), these estimates were very close to zero.

The transition probabilities we were able to estimate indicate a high probability that an unoccupied site will remain unoccupied ($\psi^{UU} = 0.650$, $SE = 0.053$) and a site occupied by a pair will be occupied by a pair in the following year ($\psi^{PP} = 1.000$,

$SE = 0.000$; Table 6). Further, these estimates demonstrate that sites unoccupied by a pair in 2014 were more likely to be occupied by a pair in 2015 if the site was occupied by a single owl in 2014 ($\psi^{SP} > \psi^{UP}$) than if the site was unoccupied in 2014. That is, it was uncommon for a site to transition from being unoccupied to being occupied by a pair in one season. It appeared that site occupancy by a single owl can serve as a "stepping stone" to site occupancy by a pair.

Table 6. Estimates and standard errors (in parentheses) for transition probabilities of Mexican Spotted Owls in Region 3 of the US Forest Service. An asterisk indicates transition probabilities for which there was not enough data to estimate the parameter.

|  |  | State in 2015 | | |
|---|---|---|---|---|
|  |  | Unoccupied | Single | Pair |
| **State in 2014** | Unoccupied | 0.650 (0.053) | 0.133 (0.045) | 0.217 (0.047) |
|  | Single | * | 0.405 (0.207) | 0.559 (0.163) |
|  | Pair | * | * | 1.000 (0.000) |

*Detection Probability Estimates*

Detection probability improved slightly later on in the survey season ($\beta_{date} = 0.015, SE = 0.005$). This was evident with the estimates of detection reported for each class of detection probability for the first and second surveys (Table 7).

Table 7. Estimates and standard errors (in parentheses) for the detection probabilities of Mexican Spotted Owls in Region 3 of the US Forest Service. The estimates reported for each secondary period correspond to the average dates of our first and second surveys in 2015 which were April 25th and June 11th.

|  | Survey 1 | Survey 2 |
|---|---|---|
| $p^{S,S}$ | 0.403 (0.100) | 0.576 (0.106) |
| $p^{S,P}$ | 0.116 (0.021) | 0.132 (0.024) |
| $p^{P,P}$ | 0.640 (0.038) | 0.730 (0.034) |

The probability of detecting a pair given that the site was occupied by a pair, $p^{P,P}$, was relatively high (Table 7), indicating a small probability of not detecting a pair in both surveys if the site was truly occupied by a pair. Similarly, there was a relatively small probability of detecting just a single owl given the site was occupied by a pair, $p^{S,P}$ (Table 7). The probability of detecting a single owl in sites occupied by a single owl was lower ($p^{S,S}$, Table 7), indicating that single owls were less willing or available to respond to our surveys.

## Discussion

The data indicate a higher rate of occupancy in 2015 than 2014. Correspondingly, the transition probabilities from "less occupied" states to "more occupied" states

were much greater than their inverse. Whether these differences reflect an increasing trend in occupancy on Forest Service lands in Arizona and New Mexico or random variation in demographic processes is unknown.  This annual variation could be caused by several different factors. For example, good weather in 2014 could have resulted in higher adult survival as well as higher reproductive output (Seamans et al. 2002), thus increasing the number of owls on the landscape to colonize previously unoccupied sites. Additional years of data will allow us to incorporate weather and reproductive data in analyses to better understand the annual variation in site occupancy, including transition probabilities.

The lower probability of detecting a single owl given that the site was occupied by a single owl could be due to 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. Lastly, without a breeding territory to defend, a single owl may have been less likely to respond to our calls.

Having two seasons of data collection allowed us to greatly expand our analysis and include inter-seasonal dynamics. We anticipate being able to further expand our analysis in the following years as we gather even more data. Some potential directions we intend to pursue include:

1. Being able to estimate local extinction rates (previously occupied sampling sites becoming unoccupied) and reduction in occupancy probabilities ($\psi^{PS}$, $\psi^{PU}$, and $\psi^{SU}$).

2. Using habitat and climate covariates to determine what factors contribute to local extinction and colonization of sites.

3. Using MSO reproductive data collected by USFS biologists and others in Region 3 as a covariate in analyses to determine how much variation in site occupancy can be attributed to reproductive output in previous years.

4. Separating the "single" state into "single male" and "single female" to better understand the behavior and ecology of single owls.

5. Using the multi-state, single season occupancy model (Nichols et al. 2007) to analyze trends in occupancy rates over time.

This second year of monitoring demonstrated 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 frame 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.

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 are 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-km2 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).
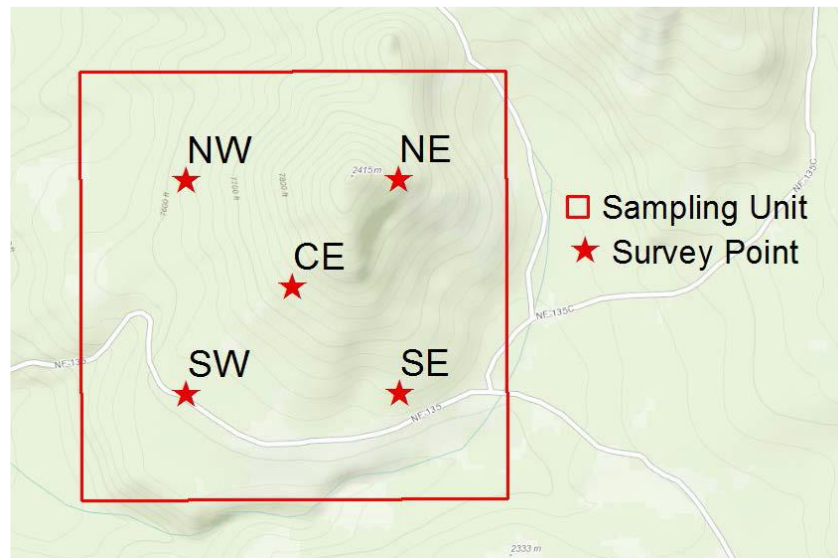


Figure 1. 1-km2 square sample site containing 5 survey points.

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 take advantage of local topography and 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 (see Broadcast Survey Form; Appendix A).

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 within the 1-km2 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 from a survey point, the technician will continue the survey the point, but switch from the recording of both sexes of owls (channel zero) to a recording of the opposite sex of owl. For example, if a male owl is detected, switch to the recording of female calls (channel one); if a female owl is detected, switch to the recording of male calls (channel two). 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 estimated distance from the call point to the owl.

**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 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 from which to survey when winds are not strong, it may be better during windy conditions 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 (TOP/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 at least 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.

**# 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.

### SURVEY INFORMATION (MIDDLE/BLACK PORTION OF THE SURVEY FORM)

**Point:** See Figure 1. Use 2 letter codes. **If you detect an owl while walking between survey points**, stop, record your location on the survey form as Point "99", enter the UTMs of your location and all other information as you would from an established survey point. Enter the "Minutes to detect" as Zero.

**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 minutes:** 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 (BOTTOM/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 lapsed between when you started surveying a point and when you detected 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 has not lapsed.

**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-km2 survey site.

**Appendix B**

## SPOTTED OWL BROADCAST SURVEY FORM

Page _____ of _____

Site: _____    Date: _____/_____/ **2015**    Visit #: _____    Observer 1: _____    **Survey Complete?** _____
e.g., SFE0005    e.g., 01 / APR / 2015     INITIALS

Y Yes; 5 pts surveyed OR SPOW pair in sampling unit
P Partial; 3-4 pts surveyed AND no SPOW pair

Observer 2: _____
INITIALS

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
NSW0 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