Short-eared Owl (*Asio flammeus*) surveys in the North American Intermountain West

2016 Annual Report

Storm clouds over survey route Idaho-032.
Photo by project volunteer Wallace Keck, March 22, 2016.

Robert A. Miller[1], Neil Paprocki[2], Jay D. Carlisle[1]

[1]Intermountain Bird Observatory, Boise State University
[2]Hawkwatch International

Author Contacts

Robert A. Miller	Neil Paprocki	Jay D. Carlisle
1910 University Drive. MS1515 Boise, Idaho 83725 208-860-4944 RobertMiller7@boisestate.edu	2240 S 900 E Salt Lake City, UT 84106 801-484-6808 x106 npaprocki@hawkwatch.org	1910 University Drive. MS1515 Boise, Idaho 83725 208-426-5203 jaycarlisle@boisestate.edu

ABSTRACT. The Short-eared Owl is an open-country species breeding in the northern United States and Canada, and has likely experienced a long-term, range-wide, and substantial decline. However, the cause and magnitude of the decline is not well understood. Booms et al. (2014) proposed six conservation priorities to be addressed for this species. We set forth to address the first two: 1) better define habitat use and 2) improve population monitoring. We recruited 204 volunteers to survey over 9.5 million ha within the state of Idaho and 7.8 million ha within the state of Utah for Short-eared Owls during the 2016 breeding season. We surveyed 98 transects, 94 of which were surveyed twice, and detected Short-eared Owls on 20 transects. We performed multi-scale occupancy modeling to identify habitat associations, and performed multi-scale abundance modeling to generate state-wide population estimates. Our results suggest that within the Intermountain West, Short-eared Owls are more often found in areas with greater amounts of sagebrush habitat and lesser amounts of grassland habitat at the 1750ha transect scale. At the 50ha point scale, Short-eared Owls tend to associate positively with stubble agriculture and negatively with bare dirt (plowed) agriculture. Cropland was not chosen at the broader transect scale suggesting that Short-eared Owls may prefer more heterogeneous landscapes. On the surface our results may seem contradictory to the presumed land use by a “grassland” species; however, many of the grasslands of the Intermountain West, consisting largely of invasive cheatgrass, lack the complex structure shown to be preferred by these owls. We suggest the local adaptation to agriculture represents the next best habitat to their historical native habitat preferences. Regardless, we have confirmed regional differences which should be considered in conservation planning for this species. Importantly, our results demonstrate the feasibility, efficiency, and effectiveness of utilizing public participation in scientific research (i.e., citizen scientists) to achieve a robust sampling methodology across the broad geography of the Intermountain West.

Key Words: abundance; habitat; Idaho; land use; road survey; occupancy; population trend, Utah

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INTRODUCTION

The Short-eared Owl (*Asio flammeus*) is a global open-country species often occupying tundra, marshes, grasslands, and shrublands (Holt et al. 1999, Wiggins et al. 2006). In North America, the Short-eared Owl breeds in the northern United States and Canada, mostly wintering in the United States and Mexico (Wiggins et al. 2006). Swengel and Swengel (2014) surveyed seven midwestern states, finding Short-eared Owls breeding in larger intact patches of grassland (>500ha) with heavy plant litter accumulation, and little association with shrub cover. Within Idaho, Miller et al. (2016) found a positive association with shrubland, marshland and riparian areas at a transect scale (1750ha), and a positive association with certain types of agriculture (fallow and bare dirt) and a negative association with grassland at a point scale (50ha). However, habitat use has not been thoroughly explored within the Intermountain West of North America.

Booms et al. (2014) argued that the Short-eared Owl has experienced a long-term, range-wide, substantial decline in North America. To support their claim, they summarized Breeding Bird Survey and Christmas Birds Count results from across North America (National Audubon Society 2012, Sauer et al. 2014). Figure 1 illustrates the general downward trend in Short-eared Owl populations in western North America between 1966 and 2013, as estimated from the Breeding Bird Survey; however only California and Saskatchewan had sufficient sample size for a significant result (Sauer et al. 2014). Booms et al. (2014) acknowledge that neither the Breeding Bird Survey nor Christmas Bird Count adequately sample the Short-eared Owl population in North America as the species is not highly vocal and is most active during crepuscular periods and at night, resulting in very few detections.

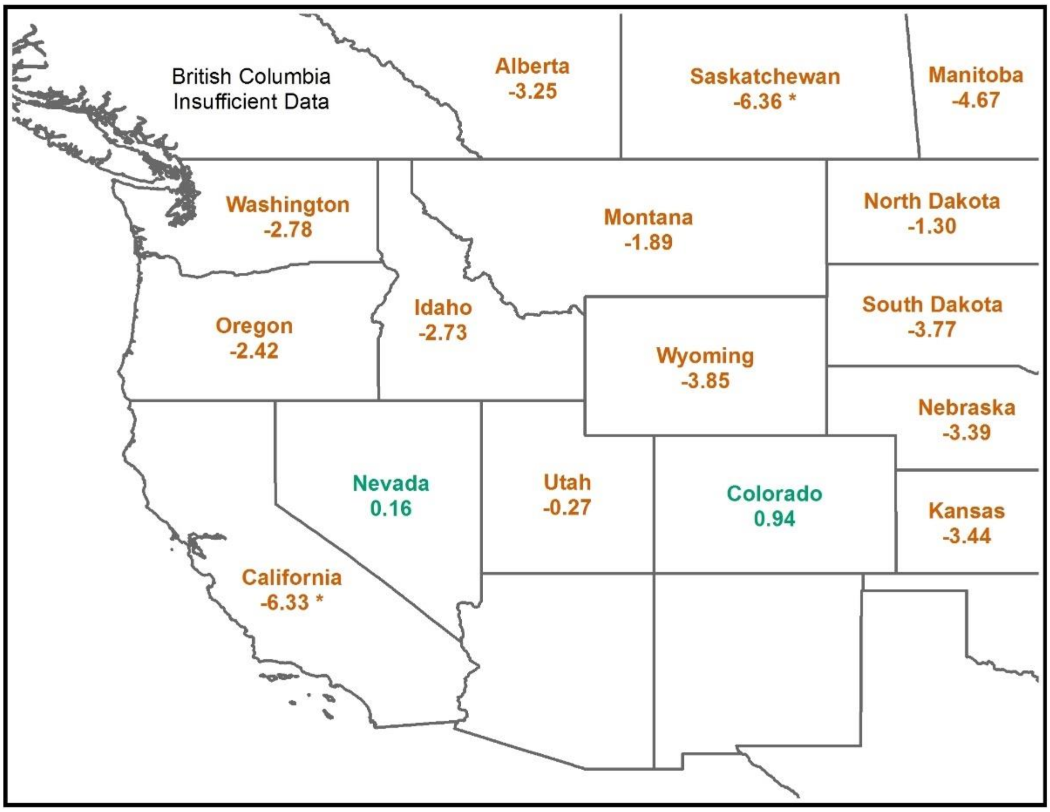

Figure 1. State and province estimated annual trends in Short-eared Owl populations from 1966 – 2013 from the Breeding Bird Surveys within the United States and Canada (Sauer et al. 2014). California and Saskatchewan are the only samples whose 95% confidence interval failed to overlap zero.

Langham et al. (2015) used Breeding Bird Survey data, Christmas Bird Count data and correlative distribution modeling with various future emission scenarios to predict distribution shifts of North American bird species in response to future climate change. Their results predict that 90% of the winter range of Short-eared Owls in the year 2000 may no longer be occupied by 2080 and, even with a northward shift in winter range, the total area of winter range is expected to reduce in size by 34% (National Audubon Society 2014).

Booms et al. (2014) and Langham et al. (2015) have highlighted the apparent disconnect of current and predicted population trends of Short-eared Owls and current conservation priorities. Booms et al. (2014) proposed six measures to better understand and prioritize actions associated with the conservation of this species. We have chosen to focus on the first two of those measures: 1) better define and protect important habitats; and 2) improve population monitoring (Booms et al. 2014).

Public participation in scientific research, sometimes referred to as citizen science, can take many forms ranging from contributory to contractual (Shirk et al. 2012). Public participation in scientific research has a long history of contributing data critical to the monitoring of wildlife (e.g., Breeding Bird Surveys [Sauer et al. 2014], Christmas Birds Counts [National Audubon Society 2012], eBird data for conservation [Callaghan and Gawlik 2015], and Monarch Butterfly monitoring [Ries and Oberhauser 2015]). Public participation projects can deliver benefits to multiple constituents including the volunteers and the lead researchers. For a contributory project, the volunteer gains increased content knowledge, improved science inquiry skills, appreciation of the complexity of ecosystems and ecosystem monitoring, and increased technical monitoring skills (Shirk et al. 2012). The primary advantage to the researcher for a contributory project is at the project scale (decreased cost, increased sample size and geographical spread; Shirk et al. 2012). Researchers must structure programs appropriately to achieve desired results, as unstructured citizen science data collection may not provide sufficient resolution to meet the program objectives (Kamp et al. 2016).

Short-eared Owl near Market Lake, Idaho.
Photo by project volunteers Sheri and Don Weber, March 12, 2016.

With an expansion of our 2015 efforts (Miller et al. 2016), we set forth to address the first two conservation actions for Short-eared Owls as promoted by Booms et al (2014), specifically defining habitat needs and improving population monitoring in the Intermountain West. Our program objectives include: 1) to identify the habitat use by Short-eared Owls during the breeding season in the Intermountain West; 2) to establish a baseline population estimate to be used to evaluate population trends; 3) to develop a monitoring framework to evaluate population trends over time; and 4) evaluate if these objectives can be met by using a large network of citizen science volunteers through contributory public participation in a scientific research framework as described by Shirk et al. (2012).

METHODS

Study area

Our study area included the states of Idaho and Utah within the Intermountain West of the United States. We stratified this region by first laying a 10km by 10km grid over the two states. We quantified presumed Short-eared Owl habitat within our study area using Landfire data (US Geological Survey 2012). Grassland, shrubland, marshland/riparian, and agriculture land cover classes were considered to be potential Short-eared Owl habitat (Wiggins et al. 2006). Grids with at least 70% land cover consisting of any of these four classes were considered in our survey stratum. All other grids were removed. The result consisted of 9,460,000ha within the Idaho stratum, primarily in southern and west-central Idaho, and 7,760,000ha within Utah (Fig. 2).

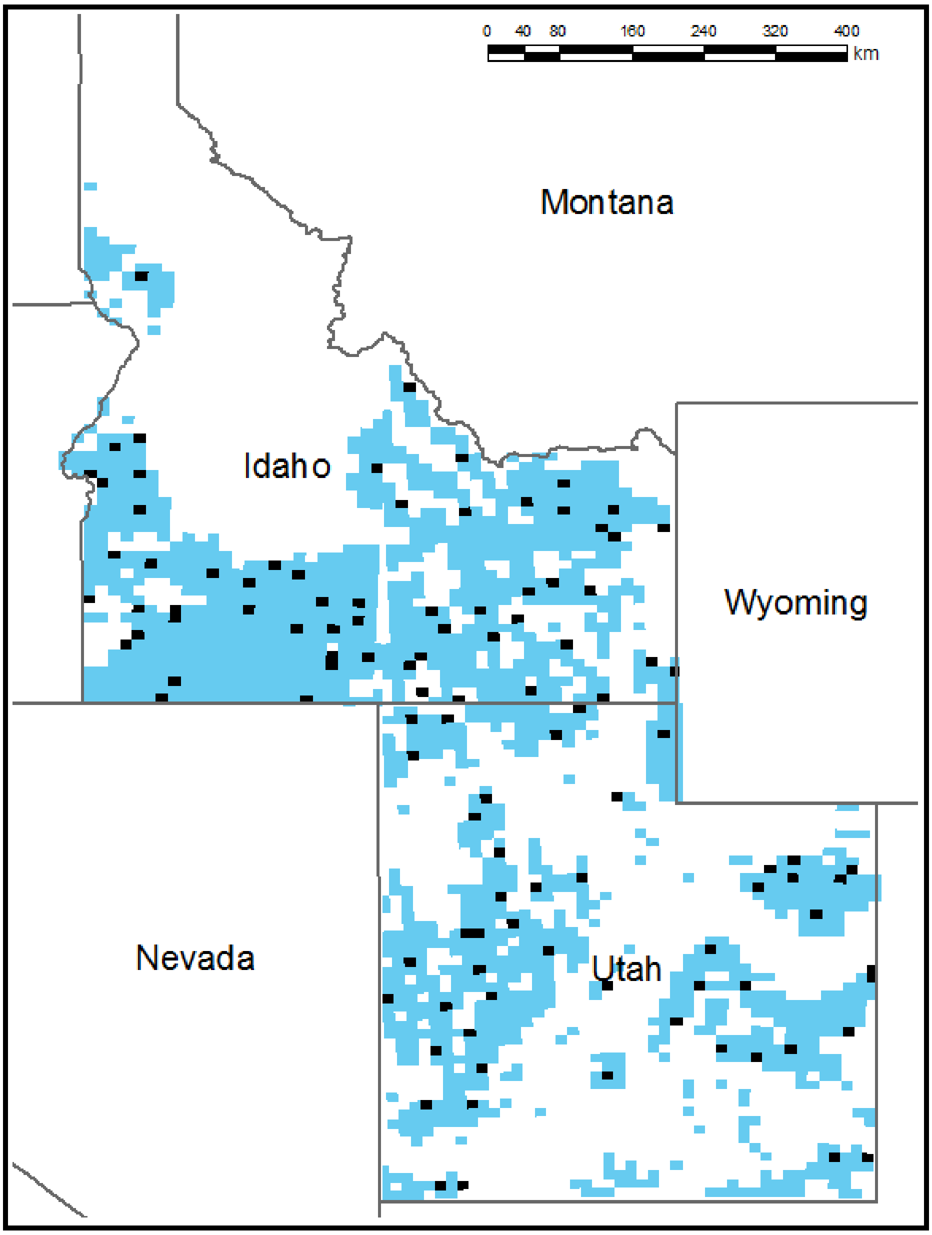

Figure 2. Distribution of strata (blue squares) and spatially-balanced survey transects (black squares) for Short-eared Owl surveys during the 2016 breeding season across the states of Idaho and Utah within the Intermountain West.

Transect selection

We selected survey transects within the stratum using a spatially-balanced sample of 10km by 10km grids using a Generalized Random-Tessellation Stratified (GRTS) process (Stevens Jr. and Olsen 2004). We eliminated grids with no secondary roads, a requirement of our road-based protocol. We selected a spatially-balanced sample of 50 grids per state (Fig. 2). We selected additional surveys in each state in blocks of ten that could be offered up to additional volunteers only if the original 50 grids, were all committed. Only one additional group of surveys were offered to volunteers, in Idaho. We delineated a survey route within each grid along a 9km stretch of secondary road, the maximum survey length feasible using the protocol and our justification for choosing a 10km by 10km grid structure (Larson and Holt 2016). If multiple possible routes were available within a single grid, we chose routes expected to have the least traffic, routes on the edge of the greatest amount of roadless habitat, or routes with the highest likelihood of detecting Short-eared Owls (a potential source of bias discussed later). Larson and Holt (2016) report that in favorable conditions Short-eared Owls can be correctly identified up to 1600m away, with high detectability up to 800m. Calladine et al. (2010) had a mean initial detection distance of 500 - 700m, with a maximum recorded value of 2500m. As our analysis method is robust for false negative detections, but less so for false positive detections, we chose to assume a larger average initial detection distance of 1km. Therefore, we considered all land within 1km of the surveyed points as sampled habitat.

Public participation recruitment

We recruited citizen science volunteers to complete survey routes. We used a combination of partnerships, listservs, social media, and personal contacts to complete our roster. Our most successful recruiting tool was to reach out to existing volunteer organizations such as naturalist groups and birding groups, electronically, through submitted newsletter articles, and in person. In some cases we reached out to professional biologists to cover remote grids or grids on restricted lands (e.g., reservation lands or national laboratory lands closed to the public).

We began recruiting volunteers two months prior to the beginning of the survey window. Roughly ⅔ of our volunteers were true citizen scientists, whereas ⅓ were professional biologists either volunteering to survey routes or assigned to complete the route (e.g., restricted lands). We originally offered 50 grids in each state. After we recruited volunteers for all 50 grids in Idaho, we offered 10 additional grids. We successfully recruited volunteers for 55 grids in Idaho and 50 in Utah. The difference between the originally selected number of grids (55 in Idaho and 50 in Utah) and those successfully surveyed (50 and 48 respectively) was the result of volunteers failing to complete the survey (essentially a random sample of missed surveys).

We provided training materials (e.g., owl identification), a procedure manual, maps, civil twilight schedules and datasheets to volunteers to help ensure survey quality. One formal training session was held for volunteers in Utah, which was attended by 35 volunteers. We also provided volunteers who could not make the formal training session with a freely accessible YouTube training video, which has been viewed 135 times. We asked volunteers to submit data via an online portal utilizing Google Forms.

Owl surveys

Observers attempted to complete two surveys per transect. Each survey window was three weeks long for the first visit and another three weeks for the second visit. Survey windows were adjusted for each route based upon elevation. For low elevation routes (below 4000ft elevation in Idaho and below 5000ft in Utah), the survey windows extended from March 1 to March 21st for the first visit and March 22nd to April 15th for the second visit. For mid-elevation routes (between 4000 and 6000ft in Idaho, and 5000 and 6000ft in Utah), the survey windows were March 16th to April 7th and April 8th to April 30th. For higher elevation routes (above 6000ft elevation in both states), the survey windows extended from April 1st to April 21st and April 22nd to May 15th. Volunteers could choose any day within their survey window to perform their survey, however we asked volunteers to separate the two visits by at least one week.

Observers surveyed points separated by approximately ½ mile (800m) along secondary roads from 100 to 10 minutes prior to the end of local civil twilight, completing as many points as possible (8 – 11 points) during the 90-minute span (Larson and Holt 2016). The multi-scale analyses methods we used relax the assumption of point independence enabling the intermediate point spacing with overlapping area surveyed (i.e., 800m spacing instead of 2000m).

At each point observers performed a five-minute point count, noting each individual bird minute-by-minute (i.e., with replacement). For each observation of a Short-eared Owl, observers recorded whether the bird was seen, heard (hoots, barks, screams, wing clip, bill snap), or both, and what behaviors were observed (perched, foraging, direct flight, agonistic, courtship).

Habitat data

At each point observers collected basic habitat data during each visit as we expected some land cover to change during the period (e.g., agricultural field may have been plowed from stubble to dirt between visits). Observers noted the proportion of habitat within 400m of the point (half the distance between points) that consisted of tall shrubland (above knee height), low shrubland (below knee height), tall grassland (above knee height), low grassland (below knee height), marshland, fallow agriculture, retained stubble agriculture, plowed dirt agriculture, and green agriculture (new green plant growth visible; Table 1). Mixed grassland and shrubland was classified as shrubland if there were at least shrubs regularly distributed through the area. We also had volunteers count the number of visible livestock and estimate the proportion of the point radius open to livestock grazing.

Table 1. Definition, variable name used in models, mean, standard deviation (SD), range, position within multi-scale hierarchy, and source of covariates evaluated for influence in occupancy and abundance analysis of Short-eared Owls within Idaho and Utah during the 2016 breeding season.

Variable	**Name in Models**	**Mean ± SD**	**Range**	**Hierarchy**	**Source**
Day-of-year	julian	97 ± 18	61 – 136	Detection	Survey
Minutes before civil twilight	minCiv	54 ± 34	-12 – 214	Detection	Survey
Low shrub 400m	lShr	28 ± 36	0 – 100	Point-scale Availability	Survey
High shrub 400m	hShr	13 ± 23	0 – 100	Point-scale Availability	Survey
Low grass 400m	lGr	16 ± 26	0 – 100	Point-scale Availability	Survey
High grass 400m	hGr	2 ± 9	0 – 100	Point-scale Availability	Survey
Marsh 400m	marsh	2 ± 7	0 – 70	Point-scale Availability	Survey
Fallow ag 400m	fallow	2 ± 9	0 – 90	Point-scale Availability	Survey
Stubble ag 400m	stubble	5 ± 17	0 – 100	Point-scale Availability	Survey
Dirt ag 400m	dirt	4 ± 15	0 – 100	Point-scale Availability	Survey
Green ag 400m	green	8 ± 20	0 – 100	Point-scale Availability	Survey
Grazing 400m	graze	30 ± 42	0 – 100	Point-scale Availability	Survey
Livestock 400m	ls	9 ± 40	0 – 1000	Point-scale Availability	Survey
Sagebrush 1km	Sageland	0.25 ± 0.27	0.00 – 0.96	Occupancy/Abundance	GIS
Shrubland 1km	Shrubland	0.31 ± 0.25	0.00 – 0.95	Occupancy/Abundance	GIS
Grassland 1km	Grassland	0.07 ± 0.11	0.00 – 0.56	Occupancy/Abundance	GIS
Cropland 1km	Cropland	0.14 ± 0.19	0.00 – 0.78	Occupancy/Abundance	GIS
Marshland 1km	Marshland	0.02 ± 0.04	0.00 – 0.20	Occupancy/Abundance	GIS

We collected transect level data using Geographic Information System (GIS) analysis by buffering all surveyed points by 1km, the presumed average maximum detection distance, and quantifying the proportion of each habitat type from the 2012 Landfire dataset (Table 1; US Geological Survey 2012).

The primary changes in field methods from 2015, reported in Miller et al. (2016), were the inclusion of the Utah stratum, the use of Landfire data instead of Shrubmap data at the transect scale, the distinction of low and high shrubs and grasses, and the collection of information on grazing.

Statistical analysis

We performed both multi-scale occupancy modeling (Nichols et al. 2008, Pavlacky Jr. et al. 2012) and multi-scale abundance modeling (Chandler et al. 2011, Sparks et al. *In Review*). For multi-scale occupancy modeling we implemented a minute-by-minute replacement design, allowing for simultaneous evaluation of detection, point-scale occupancy, and transect-scale occupancy (Nichols et al. 2008). Similar to Pavlacky et al. (2012) we used a modified version of Nichols et al. (2008) where the point-scale occupancy uses spatial replicates, but unlike Pavlacky et al. (2012) we also included our temporal replicates (i.e., two visits) essentially producing a model where the Θ parameter represents a combination of point-scale occupancy and point-scale availability. For the occupancy analysis we also evaluated state and latitude as possible predictors for transect level occupancy, but did not allow both to be in the same model because of collinearity.

For the multi-scale abundance analyses we implemented a modified, open population, *N*-mixture model with a Poisson distribution (Chandler et al. 2011, Sparks et al. *In Review*). Similar to the occupancy modeling, we deviated from Chandler et al. (2011) by utilizing spatial replicates for point-scale occupancy (Sparks et al. *In*

Review), along with our temporal replicates producing a model where the Φ parameter represents a combination of point-scale occupancy and point-scale availability. Both analysis methods are robust to missing data, allowing us to include surveys with differing numbers of points (8 – 11) and the four transects which were only surveyed once.

Within each analysis approach (occupancy and abundance) we evaluated variables influencing the probability of detection (day-of-year and minutes-before-civil-twilight), availability at the point scale (vegetation and grazing values collected by observers within 400m of point, ~50ha), and transect occupancy or abundance (habitat types collected through GIS data within 1km of all sampled points; Table 1). The 10km by 10km grid structure was only used to distribute and spatially balance the transects, all analyses only utilized the 1750ha area surrounding the points actually surveyed (1km radius buffer).

We used a sequential, parameter-wise model building strategy (Lebreton et al. 1992, Doherty et al. 2010), ranking models using Akaike Information Criterion adjusted for small sample size (AIC_c) for the occupancy modeling and abundance modeling (Burnham and Anderson 2002). For each type of multi-scale modeling (occupancy and abundance), we first evaluated each variable by assessing the null model, the model with just the variable of interest, and the model with the variable of interest and the square of the variable of interest. We eliminated the variable from further consideration if the null model ranked highest, otherwise we propagated forward the highest ranking of the variable of interest or the variable and it's square. We first selected candidate variables influencing the probability of detection (*p*) by considering all combinations of the retained variables and chose all variables appearing in models within two ΔAIC_c of the top model. We then fixed the variable set for probability of detection and repeated the procedure for variables influencing the occupancy/availability at the point-scale (Θ [for occupancy modeling], Φ [for abundance modeling]). Lastly we repeated the procedure for variables influencing transect occupancy (Ψ) or transect abundance (Λ) to arrive at our final model set for each analysis.

For inference we used model averaging of all models falling within two ΔAIC_c of the top model, that also ranked higher than the null model (Burnham and Anderson 2002). For each variable appearing within this final model set for the occupancy analysis, we created and present model averaged predictions by ranging the variable of interest over its measured range while holding all other variables at their mean value. From the occupancy models we created an occupancy prediction map across our strata using only the transect-scale data (i.e., the only stratum-wide data available). For the state-wide abundance estimate we extrapolated the estimated average transect abundance from our top model, back to the total area of our sampled stratum.

We present graphical representations of estimated effect size with 95% confidence intervals to align with the majority of scientific literature, whereas, we present abundance estimates with 80% confidence intervals to more closely align with local management objectives. We conducted all statistical analyses in Program R and Program Mark (White and Burnham 1999, R Core Team 2013). We used the R package "RMark" to interface between Program R and Program Mark for the multi-scale occupancy modeling (Laake 2014). We used the R package "unmarked" to perform the multi-scale abundance modeling (Fiske and Chandler 2011). We used R package "AICcmodavg" to rank all models (calculating AIC_c), and to perform model averaging (Mazerolle 2015).

RESULTS

A total of 204 volunteers participated in the survey portion of the program, contributing 2619 volunteer hours of their time, and travelling 36,464 miles to complete the surveys. We successfully surveyed 98 grids, 94 of which were surveyed twice. We detected Short-eared Owls on 11 and 16 transects during the first and second round of surveys, respectively, resulting in detections on a total of 20 transects across the two survey visits. We detected Short-eared Owls during both visits on seven of the transects.

The model selection process for the multi-scale occupancy analysis produced nine models falling within two ΔAIC_c of the top model (Table 2). Minutes-before-civil-twilight and wind appeared in four and one model, respectively, influencing the probability of detection of at least one Short-eared Owl, given that at least one owl was present (Table 2, Fig. 3).

The proportion of land within 400m (~50ha) of the survey point covered in stubble agriculture and plowed dirt agriculture were selected as variables influencing the probability of at least one Short-eared Owl at a point, given that at least one owl occupied the transect (Table 2, Fig. 4). Stubble agriculture had a positive relationship whereas plowed dirt agriculture had a negative relationship with availability. Latitude was selected as a predictor in all models predicting the presence of at least one Short-eared Owl on a transect, with northern latitudes having higher likelihood (Table 2; Fig 5). The proportion of land within 1km (~1750ha) of all surveyed points on a transect in sagebrush or grassland habitat were each selected within the top model set, but each appeared in only a subset of the models (Table 2, Fig. 5). The proportion of survey habitat in sagebrush had a positive association whereas grassland had a negative association. Applying the top model set across the full state strata, we created a prediction map illustrating the areas of highest potential for occupancy by Short-eared Owls (Fig. 6).

Table 2. Top model set, and the null model for comparison (shaded), for multi-scale occupancy analysis predicting the occupancy of transects within Idaho and Utah by Short-eared Owls during the 2016 breeding season. k is the number of parameters in the model, AIC_c is Akaike's Information Criterion adjusted for small sample size, ΔAIC_c is the difference in AIC_c values between individual models and the top model, and w_i is the model weight. We only presented models where $\Delta AIC_c \leq$ 2.00, the set used to generate model averaged predictions, and the null model for comparison.

Model	k	AIC_c	ΔAIC_c	w_i
Ψ(lat + LFsage) Θ(stubble + dirt) *p*(.)	7	681.32	0.00	0.18
Ψ(lat) Θ(stubble + dirt) *p*(.)	6	681.85	0.53	0.14
Ψ(lat + LFsage) Θ(stubble + dirt) *p*(minCiv)	8	681.95	0.63	0.13
Ψ(lat + LFsage + LFgrass) Θ(stubble + dirt) *p*(.)	8	682.19	0.87	0.12
Ψ(lat) Θ(stubble + dirt) *p*(minCiv)	7	682.43	1.11	0.11
Ψ(lat + LF grass) Θ(stubble + dirt) *p*(.)	7	682.47	1.15	0.10
Ψ(lat + LFsage + LFgrass) Θ(stubble + dirt) *p*(minCiv)	9	682.87	1.55	0.08
Ψ(lat + LFgrass) Θ(stubble + dirt) *p*(minCiv)	8	683.11	1.79	0.07
Ψ(lat + LFsage) Θ(stubble + dirt) *p*(wind)	8	683.24	1.92	0.07
Ψ(.) Θ(.) *p*(.)	3	696.91	15.59	----

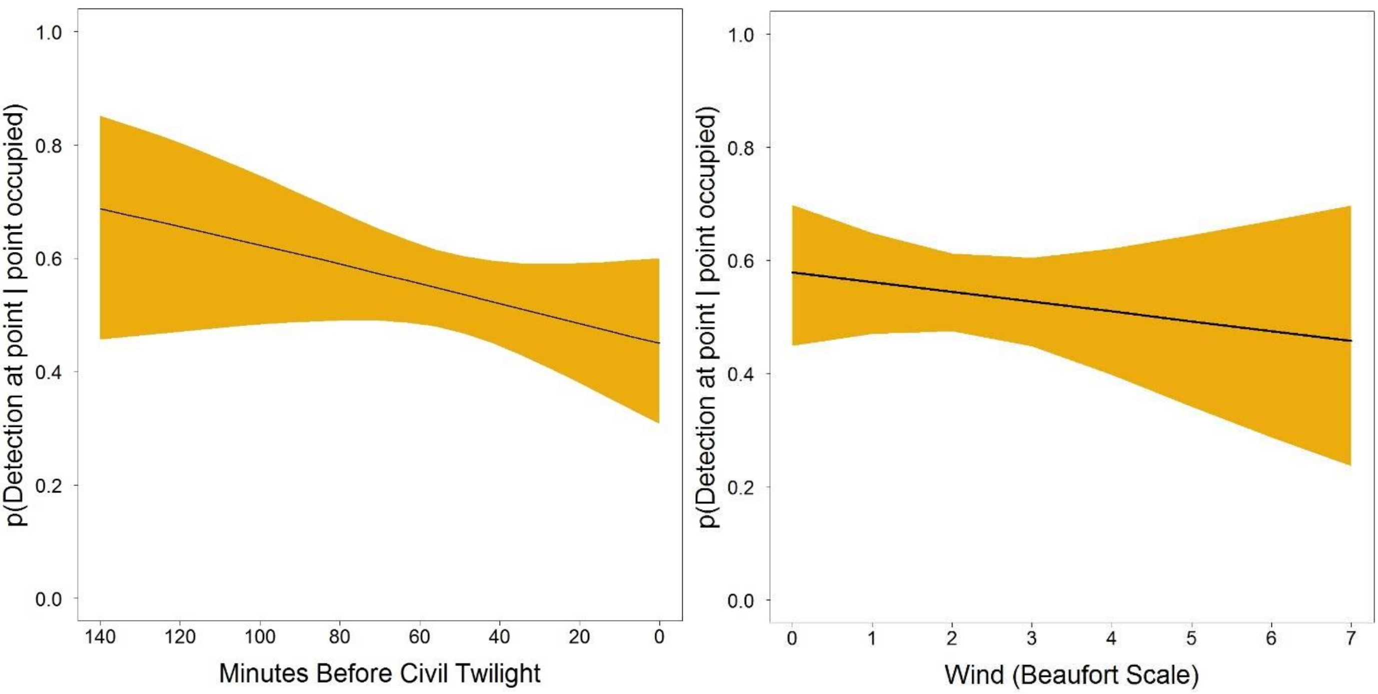

Figure 3. Model averaged prediction generated from multi-scale occupancy top model set for the effect size of a) minutes-before-civil-twilight; and b) wind speed at time of survey on the

probability of detecting at least one Short-eared Owl at a point given that there is at least one Short-eared Owl at the point during the 2016 breeding season. Black line = model prediction; orange area = 95% confidence interval.

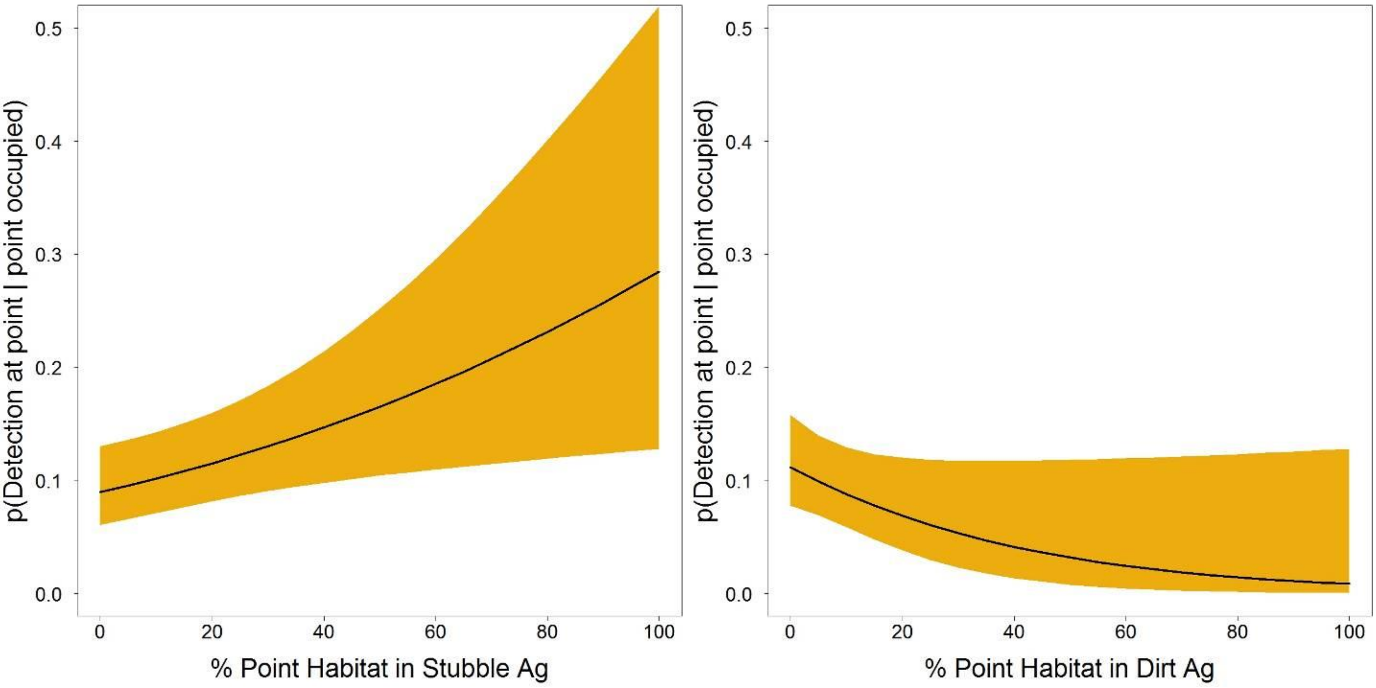

Figure 4. Model averaged predictions generated from multi-scale occupancy top model set for the effect size of the proportion of area within 400m of surveyed point in a) stubble agriculture; and b) plowed dirt agriculture, influencing the availability of at least one Short-eared Owl at the point to be sampled given that the transect was occupied by at least one Short-eared Owl during the 2016 breeding season. Black line = model prediction; orange area = 95% confidence interval.

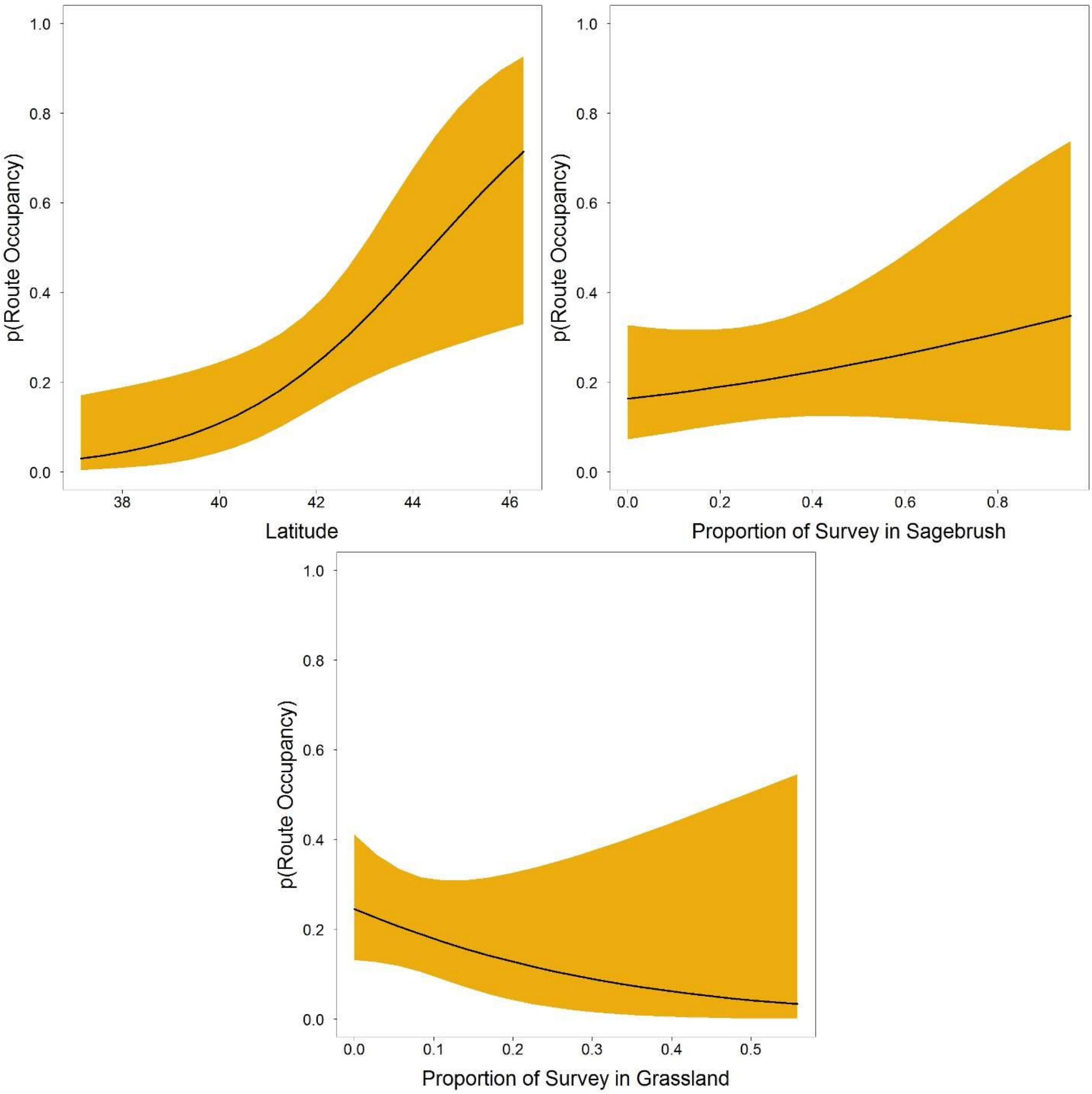

Figure 5. Model averaged predictions generated from multi-scale occupancy top model set for the effect size of the proportion of the area within 1km of surveyed points by a) latitude; b) in sageland; and c) in grassland, influencing the probability of occupancy of the full transect by at least one Short-eared Owl during the 2016 breeding season. Black line = model prediction; orange area = 95% confidence interval.

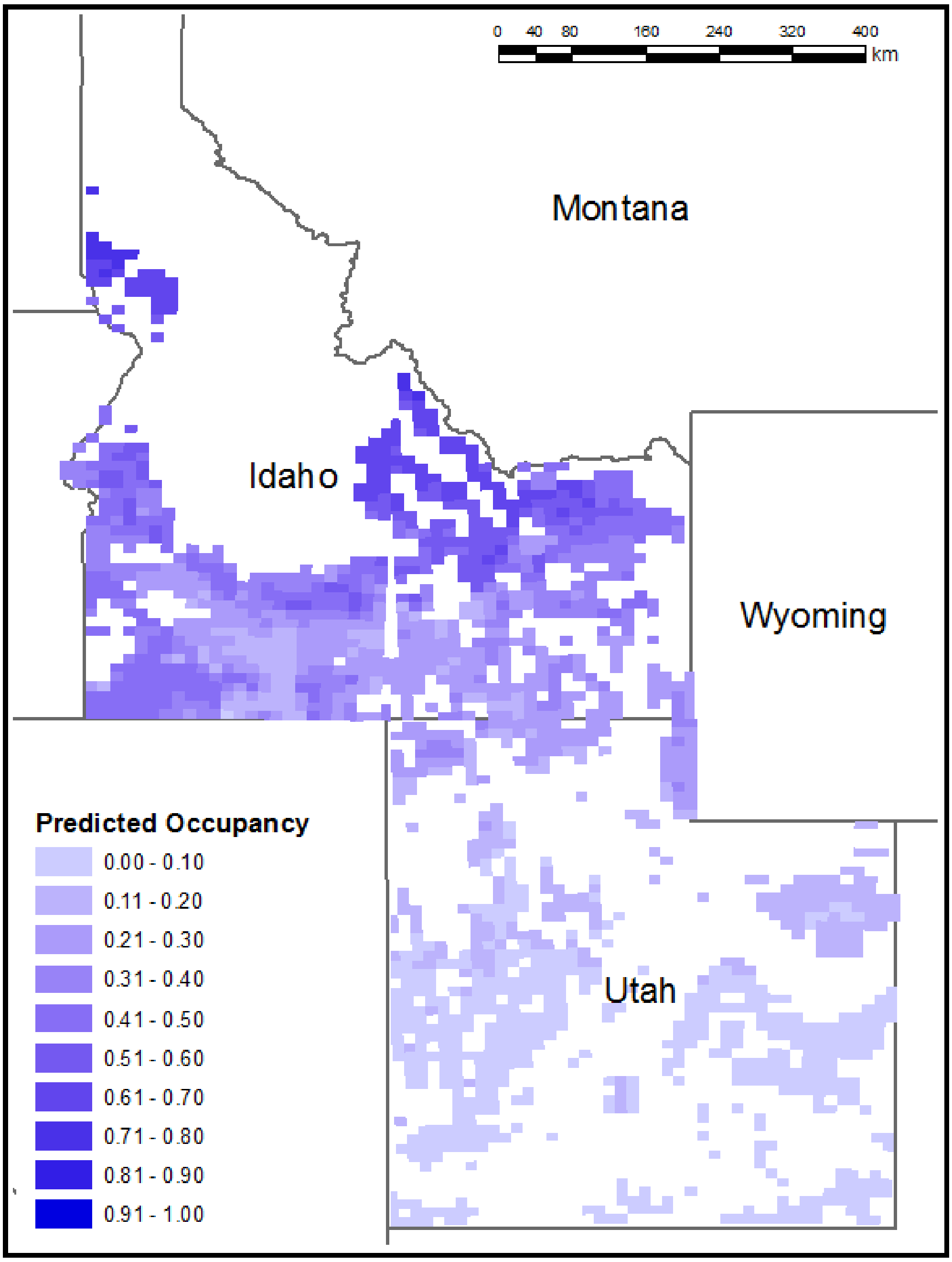

Figure 6. Model averaged prediction generated from multi-scale occupancy top model set based on latitude and the proportion of original 10km x 10km grids in sageland and grassland habitat influencing the probability of occupancy by at least one Short-eared Owl during the 2016 breeding season. Color scales represent (Ψ) from light purple to dark purple.

The model selection process for the multi-scale abundance analysis produced a single top model, with no others falling within two ΔAIC_c of the top model (Table 3). As abundance analysis is generally less reliable in predicting habitat associations than occupancy analysis, we do not present variable-by-variable effect sizes within this document. The probability of detection (p) for the abundance model was 0.39 (95% confidence interval: 0.29 – 0.50). The probability of point-scale availability (Φ) was 0.05 (95% confidence interval: 0.03 – 0.08). The calculated abundance per transect (Λ) from the top model for Idaho was 0.46 (95% confidence interval: 0.24 – 0.87) and for Utah was 0.31 (95% confidence interval: 0.14 – 0.71). Using the top model from the multi-scale abundance modeling, we extrapolated estimated transect abundance using mean covariate values back to the area of the state strata to estimate a total of 2195 adult Short-eared Owls in Idaho (80% confidence interval: 1433 – 3355) and of 1241 adult Short-eared Owls in Utah (80% confidence interval: 729 – 2113; Fig. 7).

Table 3. Top model set, and the null model for comparison (shaded), for multi-scale abundance analysis predicting the abundance of Short-eared Owls on grids within Idaho and Utah during the

2016 breeding season. k is the number of parameters in the model, AIC_c is Akaike's Information Criterion adjusted for small sample size, ΔAIC_c is the difference in AIC_c values between individual models and the top model, and w_i is the model weight. We only presented models where $\Delta AIC_c \leq$ 2.00 and the null model for comparison.

Model	k	AIC_c	ΔAIC_c	w_i
Λ (state + LFsage + LFcrop) Φ(stubble) *p*(minCiv)	8	698.37	0.00	1.00
Λ (.) Φ(.) *p*(.)	3	736.88	38.51	----

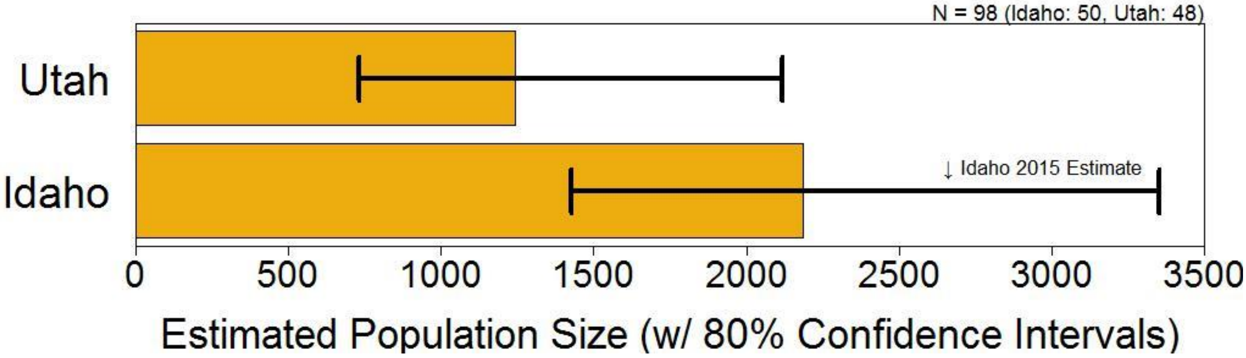

Figure 7. State-by-state abundance estimates with 80% confidence intervals of adult (second-year and above) Short-eared Owls during the 2016 breeding season, calculated using multi-scale abundance modeling.

Short-eared Owl volunteer Matt Howard surveying for owls on grid Utah -018 near Vernon, Utah.
Photo by project volunteer Mary Pendergast, April 4, 2016.

DISCUSSION

We successfully engaged a large group of volunteers to survey for Short-eared Owls across a broad geographic region in the Intermountain West. The analysis identified important Short-eared Owl habitat associations, providing insight into which habitats in the region may be most important for conservation and further study. The large scale over which we were able to survey helped us to produce the first rigorous state-wide population estimates for the species in Utah, and provides more specificity to the state-wide population estimates generated in 2015 for Idaho. The results of this survey effort will directly inform the State Wildlife Action Planning (SWAP) process for both Idaho and Utah.

The Idaho state-wide abundance of Short-eared Owls as predicted from this study is down 16% as compared to the 2015 results (Miller et al. 2016). This is certainly an issue to keep an eye on. However, the goodness of fit metrics for the abundance model this year was much stronger than in 2015, suggesting the model fit and subsequent prediction is of higher quality. As the Short-eared Owl is nomadic and subject to annual fluctuations in breeding densities, trends based on a limited number of years should be used with caution (Wiggins et al. 2006). It is therefore too early to conclude that we witnessed a population decline between 2015 and 2016 as more data is needed.

The multi-scale occupancy analysis enabled us to explore the factors influencing the occupancy of the transect as a whole, and if the transect was occupied, in which point habitats the birds were present (Pavlacky et al. 2012). With this study we found that transects with increased amounts of sagebrush as the primary habitat type had higher likelihood of Short-eared Owl presence, and those transects with a higher amount of grassland had a lower likelihood of being occupied by Short-eared Owls. During the 2015 study in Idaho, we found higher likelihood in sagebrush and marshland/riparian, however, the confidence intervals with marsh and riparian were very wide (Miller et al. 2016). The replacement in the top model set of marshland/riparian (positive association) by grassland (negative association) may be the result of the broader geographic region sampled or better resolution provided by a larger overall sample size. Regardless, both year's findings are consistent with our expectations for this species within the Intermountain West.

Habitat on transect Utah-049. Photo by project volunteer Leah Waldner Lewis, April 3, 2016.

We found Short-eared Owl occupancy at the transect scale to be positively influenced by sagebrush habitat, and negatively associated with grassland habitat, which may be unexpected as in many parts of its range the Short-eared Owl is considered a grassland species (Clark 1975, Holt et al. 1999, Swengel and Swengel 2014). However, much of the Intermountain West has been converted to invasive cheatgrass (*Bromus tectorum*) and other invasive annual plants (West 2000). Swengel and Swengel (2014) note that in the Midwest Short-eared Owls most often nest in large areas of contiguous grassland, with heavy litter or "rough grassland". The structure of the grassland in their study is quite different from the more homogenous, low litter grass found in invasive grasslands in the Intermountain West. Short-eared Owls in other studies appear to occur less often in landscapes similar to the invasive grasslands of the West (Clark 1975, Fondell and Ball 2004). Sagebrush habitats in the Intermountain West usually provide more structural complexity than local grasslands, which may explain the association of the owls with this primary habitat type in our area. However, because much of the Intermountain West has been converted to invasive grasslands, and these are lumped together with native grasslands within our chosen Landfire classification system, the importance of intact, native grasslands may be masked by the overwhelming presence of invasives within our study area.

Given that a transect was occupied, Short-eared Owls were more likely to occupy points with stubble agriculture, and less likely to occupy points with bare dirt agriculture. Stubble agriculture may provide more of the habitat structure preferred by Short-eared Owls than the invasive grasslands in our study area, and the unique plant composition within stubble agriculture may result in increased prey availability (Moulton et al. 2006). The association with other agricultural stages may be related to prey availability as well, but could also be the result of recent changes in the landscape after the owls settled in the area (i.e., owls settled when fields were stubble, but may have left when plowed to dirt and green plants began to grow). Differing from our 2015 results, our 2016 study found that stubble agriculture instead of fallow agriculture had a positive association and plowed dirt agriculture had a negative association instead of a positive association. The substitution of stubble agriculture for fallow agriculture is understandable as both of these habitat types likely provide the structural characteristics sought out by the owls. The shift of plowed dirt agriculture from a positive to negative association is more difficult to explain, possibly resulting from our shift in survey timing in relation to agricultural schedules within the region or just an anomaly in our modeling. Our model fit was superior in 2016 and we expect a negative association with this species, further building our trust in the 2016 results.

The higher use of agricultural lands in relation to non-agricultural lands within a transect could be the result of local adaptation to agriculture, or the result of habitat degradation occurring in the non-agricultural landscape as a result of cheatgrass invasion or open lands grazing (West 2000, Fondell and Ball 2004). As our surveys were limited to roads and many of the roads were built to support agriculture, we may not have adequately sampled undisturbed natural habitat (Gelbard and Belnap 2003), which is becoming increasingly rare in the region. While stubble agriculture was selected at the point scale, cropland was not chosen at the transect scale suggesting that Short-eared Owls are inhabiting more heterogeneous landscapes within our study area than pure agriculture. This may be the most important finding of our study from a conservation perspective.

Cattle at Short-eared Owl survey point on transect Idaho-028.
Photo by project volunteer Sharon Darling Hayes, April 7, 2016.

We evaluated two separate measures of grazing, the proportion of land around the point that appeared to have been grazed and the number of livestock visible at the time of the survey. Unlike Larson and Holt (2016), in our study grazing was not found to be a predictor of Short-eared Owl occupancy. Early feedback from our volunteers suggest some confusion in the qualitative assessment of the amount of the landscape that was open to grazing, which may have influenced our results. We will refine and clarify the approach for future seasons.

Our abundance modeling found similar, but not identical selection of predictor variables. The similarities (minutes before the end of civil twilight for probability of detection, stubble agriculture for availability, and sagebrush for transect abundance) increases our confidence in both modeling approaches. The differences may be explained by habitat variables influencing occupancy and abundance differently (expected result); the slightly different definitions within the models (e.g., probability of detection at least one owl given that there is at least one owl at a point for occupancy modeling versus probability of detecting each individual owl in the abundance model), or just the fact that abundance models are generally less powerful in evaluating habitat associations. Regardless, all of the variables chosen in each model set were fairly consistent with our expectations for this species.

Our study had a number of potential sources of bias, which was one reason we performed both occupancy and abundance analyses. The abundance analysis is more sensitive to sources of bias than the occupancy analysis, but most of these biases do apply to both analysis types. Potential sources of bias that could have increased our estimates included placement of the survey route along the best habitat within the grid, misidentifying species (e.g., counting a distant Northern Harrier as a Short-eared Owl), and identifying owls further than 1km from the survey point. Potentially biasing our results lower included not detecting birds less than 1km due to obstructions or local landscape relief, not sampling the areas that fell outside of our stratum (e.g., grids with only 68% of target habitat instead of >70% target habitat), and the potential influence of road based surveys. Roads represent fragmented landscapes which have been shown to have a negative association for Short-eared Owls in the Midwest (Swengel and Swengel 2014). Additionally, Short-eared Owls could be negatively affected by road noise, which has been shown for other avian species (e.g., Ware et al. 2015).

This project was only viable with the generous support of our volunteer base. However, the volunteer base was likely the largest variance introduced to our project. The skill set of our volunteers ranged from expert to beginner. We emphasized training during the project, but volunteers were not evaluated on their skills; a process more often performed on professional surveys. However, checking datasheets for quality and completeness confirmed that most of our volunteers were very diligent in completing the assigned tasks. The biggest unknown we had pertained to the correct identification of Short-eared Owls. We provided training materials for proper identification and emphasized to volunteers to only record owls that they were certain were Short-eared Owls, as our methods are robust to false negatives. Within our study area, the Long-eared Owl and Northern Harrier would be the most likely species' to confuse with a Short-eared Owl. We focused on the distinction within our training materials. In an effort to mitigate this, we asked volunteers to record the number of Long-eared Owls and Northern Harriers, and to record the number of birds that they believed to be Short-eared Owls, but could not fully confirm. Our volunteers reported 47 instances of possible Short-eared Owls that could not be fully confirmed, suggesting that we were effective in mitigating this risk. As with most programs, quantifying the magnitude of the bias from each factor is often not feasible. We do believe that these biases have been managed as best as possible within the program and that the actual population size falls well within our confidence intervals.

We were successful in meeting all of our initial objectives utilizing a largely volunteer labor force. We suggest that the use of a distributed volunteer labor force resulted in greater efficiency in survey coverage, resulted in more surveys completed, and ultimately resulted in a higher quality inference than would have occurred using only professional staff. In subsequent years we expect to continue the use of citizen scientist volunteers, and maintain the basic structure of the 2015 and 2016 programs. We expect to expand the surveys to additional states in 2017, by completing at least 40 transects per state and maintaining a state-based stratum within the overall analysis to identify local habitat differences and generate state-by-state estimates of abundance. Lastly, we expect to refine the habitat model to collect more specific habitat data at each point.

CONCLUSION

We successfully recruited a large group of volunteers to sample a broad geography within the Intermountain West for Short-eared Owls during the 2016 breeding season. Our results have identified specific habitat associations, confirming that habitat use may vary regionally. We have established abundance estimates for Idaho and Utah which will act as a baseline for further studies to identify and quantify any trends that may be occurring in the population. We have confirmed that our study design was sufficient to meet our objectives and will only require minor modifications moving forward. We are actively working to expand this successful program to other states within the breeding range of the Short-eared Owl.

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