

Short-eared Owl Population Size, Distribution, Habitat Use, and Modelled Response to a Changing Climate: 2020 Annual and Comprehensive Report

Version 1.0



Short-eared Owl, Bob Tregilus (four-year Project WAfLS volunteer).

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1 ABSTRACT

The Short-eared Owl (*Asio flammeus*) is an open-country species that breeds in the northern United States and Canada, and has likely experienced a long-term, range-wide population decline. However, the cause and magnitude of the decline are not well understood. Several conservation actions have been proposed for this species (Booms et al. 2014), including: 1) better define and protect important habitats; 2) improve population monitoring; 3) determine seasonal and annual movements; 4) re-evaluate NatureServe's National Conservation Classifications; and 5) develop management plans and tools. Our program has been largely motivated by these conservation actions. Population monitoring of Short-eared Owls is complicated by the fact that the species is an irruptive breeder with low site fidelity, resulting in annual shifts in local breeding densities, often tied to fluctuations in prey density. It is therefore critical to implement monitoring at a scale needed to detect regional changes in distribution that likely occur annually. We recruited more than 1,200 participants, mostly community-science volunteers to implement a survey of Short-eared Owls across eight western states over the past six years. The study sites were distributed across over 87 million hectares within the states of California, Idaho, Montana, Nevada, Oregon, Utah, Washington, and Wyoming. We found that grazing negatively influenced Short-eared Owl occupancy, but grazing and Short-eared Owls are not mutually exclusive. By managing the grazing utilization rate across the pasture, the negative effect can be at least partially mitigated. Short-eared Owls favor native shrublands and grassland and avoid anthropogenic landscapes. We see no evidence that the steep decline in the species that was suspected to have occurred over the past 40 years has continued. Short-eared Owl occupancy rates were highly variable across the eight states within the program, and from year-to-year. However, overall weighted mean occupancy rates were relatively stable. We are unable to answer if these spatial and temporal shifts in occupancy were the result of movement or birth/death rates. Short-eared Owls were more often found in natural versus anthropogenic landscapes, in sagebrush/hay/pasture versus marsh and row crops, and in more grass versus structured land covers. While we regularly detected owls on anthropogenic landscapes, populations in native shrubland and grasslands were more stable; possibly due to more stable prey resources, although other hypotheses exist. As expected, we more often found Short-eared Owls in less rugged areas at lower elevations. Lastly, Short-eared Owls occupied areas that were intermediate, but not too hot during the summer period, and in areas that received more precipitation in the driest season. Our modelling results indicated Short-eared Owls are under extreme threat from common projections of climate change effects. We conservatively predicted that average future viability of Short-eared Owls across our study area will decrease by 59% in the next 50 years. We predicted that the amount of "good" habitat would decrease by 76%, and the amount of "great" habitat would decrease by 60% over that period. Our results demonstrated the feasibility, efficiency, and effectiveness of utilizing public participation in scientific research (i.e., community scientists) to achieve a robust sampling methodology across the broad geography of the western United States.

Key Words: community-science | conservation | habitat use | monitoring | occupancy | population trend | Short-eared Owl

Significance Statement

Our project, which we entitled the Western *Asio flammeus* Landscape Study (WAfLS), was the largest geographic survey of Short-eared Owls in the world. The abundance estimates and habitat associations from this effort provides critical insight to land managers across western North America to influence species-specific and general conservation actions.



1.1 ACKNOWLEDGMENTS:

We are deeply grateful for the more than 1,200 participants/volunteers that invested their time and money to complete the surveys described in this report. This program would not exist without their continued dedication and commitment. Travel restrictions imposed due to the 2020 Covid-19 pandemic presented participatory challenges for many volunteers across the study sites and we are thankful for those that could still participate safely and responsibly following their individual state's health guidelines.

We thank the following organizations that provided support to the Grouse & Grazing Project: U.S. Bureau of Land Management, Idaho Department of Fish and Game, Idaho Governor's Office of Species Conservation, U.S. Fish and Wildlife Service, and the Public Lands Council. We also thank the permittees and local grazing associations affiliated with the Grouse & Grazing Project in Idaho.

We thank the U.S. Fish and Wildlife Service Wildlife and Sport Fish Restoration Program (WSFR) for funding this program through the Competitive State Wildlife Grant Program (C-SWG). We could not have maintained the program for all eight western states without their support. We thank the Western Association of Fish and Wildlife Agencies (WAFWA) for their coordination and management of funding for this project and the Pacific Flyway Council Nongame Technical Committee for their support in the development of the grant proposal.

We thank the California Department of Fish and Wildlife, Hawkwatch International, Idaho Department of Fish and Game, Intermountain Bird Observatory, Klamath Bird Observatory, Nevada Department of Wildlife, Owl Research Institute, Teton Raptor Center, Utah Division of Wildlife Resources, Washington Department of Fish and Wildlife, Wyoming Biodiversity Institute, and Wyoming Game and Fish Department for their in-kind support to keep this program on-track.

We thank the Idaho Bird Conservation Partnership for providing a forum to begin the project and the continued endorsement of the work. We thank Matt Stuber for his efforts to help get this program started back in 2015. We thank Denver Holt of the Owl Research Institute for consultation on the survey protocol. We thank Rob Sparks and David Pavlacky of the Bird Conservancy of the Rockies for their consultation on the study design and statistical analysis.

2 INTRODUCTION

The Short-eared Owl (*Asio flammeus*) is a near-global open-country species that often occupies 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 over-wintering in the United States and Mexico (Wiggins et al. 2006). Swengel and Swengel (2014) conducted surveys for this species in seven midwestern states, finding Short-eared Owls breeding in large intact patches of grassland (>500 hectares) with heavy plant litter accumulation, and little association with shrub cover. Within Idaho, Miller et al. (2016) found positive associations with shrubland, marshland, and riparian areas at a transect scale (1750ha), and with certain types of agriculture (fallow and bare soil) at the point scale (50ha), and a negative association with grassland at a point scale. However, until now habitat use has not been broadly explored within western North America.

Booms et al. (2014) argued that the Short-eared Owl has experienced a long-term, range-wide, substantial decline in North America. They based this claim on a summary of Breeding Bird Survey and Christmas Birds Count results from across North America (National Audubon Society 2012, Sauer et al. 2017). Booms et al. (2014) acknowledged 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.

A complicating factor in monitoring the abundance or population trends in a species like the Short-eared Owl is its response to prey populations that undergo large fluctuations (for review, see Newton 2008). Prey species fluctuations vary in their synchronization, with populations being variously in or out of phase through both time and across space in ways that are only generally predictable. Furthermore, the timing and amplitude of fluctuations tend to vary between temperate and more northerly regions. Consequently, Short-eared Owls respond to these complex changes by adopting an irruptive or nomadic strategy whereby they regularly move across landscapes and regions – sometimes involving great distances – to settle in areas with suitable food resources, and as a result they often have low site fidelity. This dramatic variability in movement means that local monitoring of abundance, although potentially informative about local patterns of use, provides little knowledge about the status or performance of regional populations. Such an effort requires a survey designed to cover a regional spatial scale.

Relative to winter range, 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 several measures to better understand and prioritize actions associated with the conservation of this species: 1) better define and protect important habitats; 2) improve population monitoring; 3) determine seasonal and annual movements; 4) re-evaluate NatureServe's National Conservation Classifications; and 5) develop management plans and tools. Our program has been largely motivated by these proposals.

Public participation in scientific research, sometimes referred to as citizen science or community 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 Bird 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 themselves, the lead researchers, the conservation community, and the general public. 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 scale; Shirk et al. 2012). Researchers must structure programs appropriately to achieve desired results, as unstructured community science data collection may not provide sufficient resolution to meet program objectives (Kamp et al. 2016).

The Western Asio flammeus Landscape Study (as we have labeled it; hereafter WAfLS) began in 2015 with an Idaho state-wide effort and a limited pilot in northern Utah (Miller et al. 2016). In 2016, we restructured and expanded to an Idaho and Utah state-wide program. In 2017, we once again expanded, this time into the neighboring states of Nevada and Wyoming. After securing dedicated funding in 2018, we were able to add California, Montana, Oregon, and Washington to encompass all of the western states in the lower-48 with significant presence of Short-eared Owl habitat. As a result of the restructuring of the program in 2016, and the growth of the program between 2016 and 2018, we were able to integrate varying amounts of data in each component of the analysis, always using as much as possible that still met the requirements and assumptions of the statistical procedures we used. We sometimes used data from all six years, sometimes just the most recent five years (stable sampling in participating states), and sometimes just the last three years (full eight-state program).

Our program objectives include:

- Objective #1: Identify impacts of various grazing practices on occupancy rates by Short-eared Owls through direct manipulation on the landscape.
- Objective #2: Quantify Short-eared Owl population size in each participating state to enable SWAP managers to assess and refine conservation priorities, threats, and actions.
- Objective #3: Quantify how Short-eared Owl populations fluctuate spatially and temporally at state and flyway scales so that land and wildlife managers can contextualize local changes within the broader regional variation.
- Objective #4: Identify their distribution, and how habitat use, grazing, and climate influences Short-eared Owls in the West such that managers can target and prioritize specific open-land landscapes to retain important areas and connect disjunct landscapes.
- Objective #5: Generate statistically-rigorous, region-wide projections of Short-eared Owl viability based upon ensemble climate models to focus management actions for maximum conservation return for owls and other open-land species.
- Objective #6: Implement high-value conservation actions prioritized by future population projections focused on most at-risk and core populations of Short-eared Owls by engaging flyway councils, AFWA committees, state personnel, and other agencies to facilitate science delivery that effectively links results to priority state conservation opportunities.

3 RESULTS AND DISCUSSION (NOTE: METHODS LOCATED AT THE END OF THIS REPORT)

Note: Our 2020 program was significantly affected by the Covid-19 pandemic and various restrictions that were implemented inconsistently across our study area. However, we were successful in completing a critical mass of effort needed to address all objectives, and about half of our states completed an implementation in 2020 on par with previous years.

Project WAfLS has been a tremendously successful, largely community-science driven initiative. The vast majority of project participants were community-science volunteers (see Table 1 for summary of field effort); their participation was critical to the implementation of our statistically-rigorous survey of Short-eared Owls across eight western states over the past six years. We completed six years of surveys in Idaho, five years in Utah, four years in Nevada and Wyoming, and three years each in California, Montana, Oregon, and Washington. The study sites were distributed across over 87 million hectares within these states. Over the most recent five-year study period (years with consistent sampling approach), we surveyed 436 transects, detecting Short-eared Owls on 152 of them (Table 2). We implemented multiple analysis techniques to meet our objectives.

In 2020, we recruited 466 participants, a mixture of community-science volunteers and professional biologists. During the 2020 survey season we completed at least one survey at 335 of our 436 available survey grid cells (Figure 1). Due to the Covid-19 pandemic, this number was down from previous years, but still confirmed a herculean effort. Combined with past participants (131, 204, 330, 622, and 605, in 2015 – 2019 respectively), we estimate at least 1,200 people have participated in the program over the past six years. The program engaged true community-science volunteers, non-federal paid staff, and federal paid staff.

Table 1. Hours and miles invested and value of each contribution for true program volunteers by state 2015 – 2020 (based on standard hourly volunteer rate for each state - California=\$29.95/hr, Idaho=\$22.14/hr, Montana=\$23.09/hr, Nevada=\$22.61/hr, Oregon=\$25.40/hr, Utah=\$24.99/hr, Washington=\$31.72/hr, and Wyoming=\$22.14/hr, and federal mileage rate \$0.535/mile). Varies from official grant reporting as it includes years not funded by grant dollars and does not include eligible and reported non-federal match.

State (years)	Volunteer Hours	Volunteer Hours \$	Volunteer Miles	Volunteer Miles \$	Total \$
California (3)	1,951	\$58,432	32,330	\$17,297	\$75,729
Idaho (6)	6,040	\$133,726	85,618	\$45,806	\$179,532
Montana (3)	1,317	\$30,410	17,316	\$9,264	\$39,674
Nevada (4)	1,145	\$25,888	21,836	\$11,682	\$37,570
Oregon (3)	2,007	\$50,978	29,899	\$15,996	\$66,974
Utah (5)	4,746	\$118,603	81,095	\$43,386	\$161,989
Washington (3)	2,543	\$80,664	47,143	\$25,222	\$105,886
Wyoming (4)	2,379	\$58,523	39,097	\$20,917	\$79,440
Total	22,128	\$557,224	354,324	\$189,570	\$746,794

Table 2. Total number of grid cells surveyed in 2020 and the previous five years pooled with detections of owls by state (In 2015 we used different grids, so those are not represented here but are used in other analyses).

State	2020 Surveyed Grids	2020 w/ Owls	All Surveyed Grids	All w/ Owls at least once
California	43	6	56	10
Idaho	63	15	63	38
Montana	42	11	51	31
Nevada	15	0	52	11
Oregon	32	7	53	14
Utah	54	8	55	16
Washington	45	3	53	19
Wyoming	41	8	53	13
Total	335	64	436	152



Figure 1. Infographic from 2020 season created and distributed to our community-science volunteers. Performance in some states was heavily impacted by Covid-19 regulations.

3.1 OBJECTIVE #1: IDENTIFY IMPACTS OF VARIOUS GRAZING PRACTICES ON THE OCCUPANCY RATES BY SHORT-EARED OWLS THROUGH DIRECT MANIPULATION ON THE LANDSCAPE.

Previous studies have found Short-eared Owls breeding at lower rates on grazed versus ungrazed landscapes (Bock et al. 1993, Dechant et al. 2001, Swengel and Swengel 2014, Larson and Holt 2016). We implemented two approaches to address this objective. We collected grazing data at each survey point across the eight-state region and we collaborated with the pre-existing Grouse & Grazing Project to look at specific grazing treatment effects.

On the broader surveys, we found evidence that the relationship between grazing and Short-eared Owl occupancy varied among years. In 2018 and 2019, the amount of land surrounding each point that was grazed was negatively associated with Short-eared Owl occupancy. In 2017, we found an intermediate positive effect (positive for some grazing, but negative for high grazing). In all other years we found no relationship between grazing and Short-eared Owl occupancy. In our overall multi-year analysis, the amount of land surrounding a point that was grazed was not associated with point-scale occupancy. The lack of a consistent signal across the years could be a statistical anomaly but is most likely the result of a lack of resolution and accuracy of the estimates. In some cases, grazing animals were present leading to an obvious conclusion on whether the landscape was grazed, but when grazing animals were not present volunteers used their best judgement to decide if the landscape looked as if it had been grazed.

We suspect that there are multiple factors influencing our inconsistent results from the broad surveys along the grazing dimension. The most logical explanations include annual variation in numbers and location of preferred prey relative to grazed landscapes, large variation in the intensity, timing and duration of grazing, and density-dependent factors forcing some owls into less ideal landscapes.

Within the Grouse & Grazing Project, we conducted Short-eared Owl surveys at points overlaid onto pastures that had been assigned to experimental grazing treatments. We detected Short-eared Owls at all five Grouse & Grazing study sites, and at 15 of the 22 pastures surveyed (Table 3). Since all study sites have grazing treatments, we can conclude that Short-eared Owl occupancy is not completely incompatible with grazing. The raw counts of points with owls and pastures with owls did not correlate with the broader Idaho occupancy rates generated from both Multi-scale Occupancy and Colonization/Extinction modeling (subsections 3.2 and 3.3). This lack of correlation was unexpected. We suggest that the characteristics of the Grouse & Grazing study sites are much more homogenous than the broader Project WAfLS survey stratum, and this difference may explain the lack of correlation. For example, we may expect prey density to be more variable as the landscape becomes more heterogenous.

Table 3. Raw survey results from Short-eared Owl surveys on Grouse & Grazing Project pastures using the standard point protocol of the WAfLS program. Incidental observations were recorded only within the dates of the WAfLS surveys, but include observations collected all times of day.

Year	Study Sites	Study Pastures	Pastures w/ Owls	Points Surveyed	Points w/ Owls	Incidental in Study Area	Incidental Adjacent
2018	5	22	13	380	31	33	19
2019	5	20	3	344	3	2	0
2020	5	20	4	316	5	0	0

From a grazing treatment perspective, we detected Short-eared Owls on all four experimental grazing treatments, including those pastures with active grazing (Table 4). The pastures with owls did not vary from expected values based upon availability (i.e., no significant difference by treatment; $\chi^2=2.14$, $df=3$, $P=0.54$). Furthermore, the points with Short-eared Owls also did not vary from expected values based upon availability (i.e., no significant difference by treatment; $\chi^2=1.46$, $df=3$, $P=0.69$). The no-grazing treatment where livestock grazing was excluded for 2+ years did not have higher occupancy of Short-eared Owls than

the other 3 treatments that had livestock grazing (Table 4). We conclude that the presence of grazing animals on a pasture is not a detriment to the area being occupied by Short-eared Owls.

Table 4. Grazing regime on surveyed pastures and whether Short-eared Owls were detected on them.

Treatment	2018				2019				2020			
	Pastures	W/ Owls	Points	W/ Owls	Pastures	W/ Owls	Points	W/ Owls	Pastures	W/ Owls	Points	W/ Owls
No Grazing Prev. Yr.	5	3	31	7	7	0	56	0	6	1	47	2
Grazed Prev. Spr/Sum	7	4	64	12	6	0	57	0	6	1	53	1
Grazed Prev. Fall	4	3	33	6	0	0	0	0	2	0	18	0
Grazed Concurrently	6	3	63	6	7	3	59	3	5	2	40	2

When considering the grazing utilization of the pastures, we found a significant effect on the point-scale occupancy. The model that included grazing utilization fit the data well (AIC_c of 232.7 versus 237.9 for the null model). Cows do not graze pastures evenly and Short-eared Owls were less likely to be found at points where grazing utilization was high, a significant drop in likelihood at points with as little as 10% utilization (Figure 2). Hence, Short-eared Owls occupy grazed sites and grazed pastures, but appear to have an aversion to occupying areas within the pastures that are actively used by grazing animals.

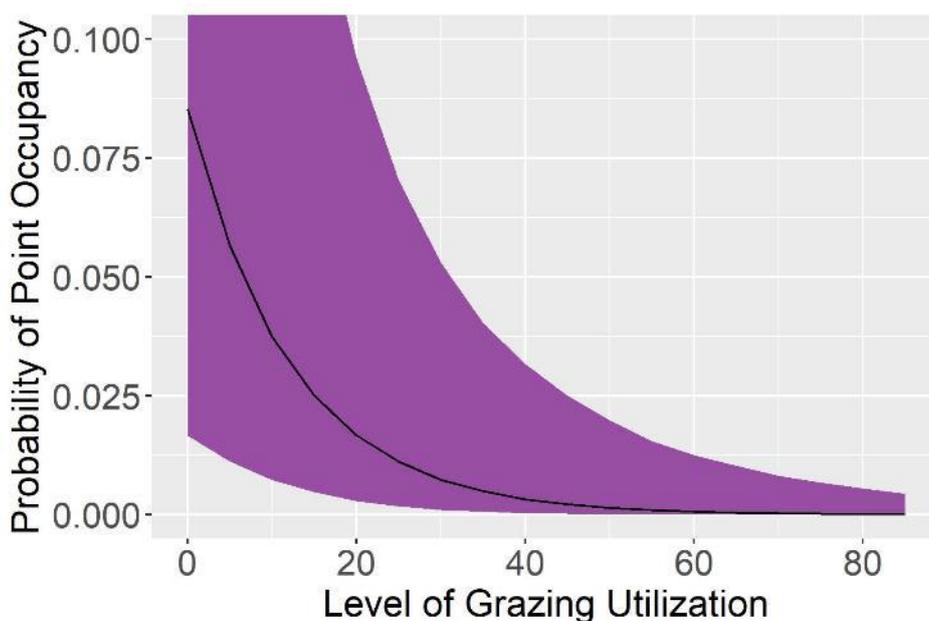


Figure 2. Effect of grazing utilization on the probability of occupancy by Short-eared Owls at the point scale, shown with 95% confidence intervals.

CONCLUSIONS: OBJECTIVE 1

We found that utilization negatively influences Short-eared Owl occupancy, but grazing and Short-eared Owls are not entirely mutually exclusive. By managing the grazing utilization rate across the pasture, the negative effect can be at least partially mitigated.

3.2 OBJECTIVE #2: QUANTIFY SHORT-EARED OWL POPULATION SIZE IN EACH PARTICIPATING STATE TO ENABLE MANAGERS TO ASSESS AND REFINE CONSERVATION PRIORITIES, THREATS, AND ACTIONS.

We implemented multi-scale occupancy modeling as our index of Short-eared Owl population size and density. As many of our collected land cover variables included compositions, we first had to transform our habitat variables using compositional statistics and principal component analysis.

3.2.1 Compositional Statistics

The compositional statistics were not informative in and of themselves but were used for later inference in both the multi-scale occupancy modeling and the boosted regression tree modeling.

3.2.1.1 Point-scale Principal Components

The top three components at the point-scale surpassed the threshold of representing at least 90% of the cumulative proportion of variance (98%; Table 5). All point-scale land cover variables were represented in the top components. Component #1 primarily included cheatgrass versus a combination of tall shrubs and active agriculture. With the weightings, this component can be interpreted primarily as a cheatgrass versus other land cover measures. Component #2 primarily included cheatgrass and active agriculture versus complex grass and stubble/fallow agriculture. This component can be interpreted as low structure versus high structure environments. Lastly, component #3 represented stubble/fallow agriculture versus shrubland, so it is essentially interpreted as agriculture versus shrubland.

Table 5. Loadings from Principal Component Analysis of variables collected by field participants quantifying land cover within 400m of each survey point. Green shading represents the most important factors for each component ($|>0.2|$) used for inference. Gray shading represents components not used in any analyses as previous components cumulatively include greater than 90% of the variance represented by the components.

	Comp. 1	Comp. 2	Comp. 3	Comp. 4	Comp. 5
Cheatgrass	-0.71	-0.54			
Dirt/green Ag	0.50	-0.52	0.25	0.27	0.58
Tall shrubs	0.43		-0.33	-0.60	-0.16
Complex grass	-0.25	0.41	-0.19	-0.31	0.80
Stubble/fallow Ag		0.43	0.75		
Low shrubs		0.29	-0.48	0.68	
Cum. Proportion of Variance	53%	84%	98%	100%	100%

3.2.1.2 Grid-scale Principal Components

The top four components at the grid-scale surpassed the threshold of representing at least 90% of the cumulative proportion of variance (94%; Table 6). All grid-scale land cover variables were represented in the top components. Component #1 primarily included orchards and row-crops versus a combination of shrubland and grassland, essentially non-native versus native. Component #2 primarily included sagebrush and orchards versus row crops, hay, fallow, and pasture agriculture. Component #3 represented marsh/riparian versus hay, fallow, and pasture. Lastly, component #4 combined sagebrush and row crops versus grassland, hay, fallow, and pasture agriculture.

Table 6. Loadings from Principal Component Analysis of variables collected from Landfire dataset for land cover within 1 km of all surveyed points within a survey grid. Green shading represents the most important factors for each component ($|>0.2|$) used for inference. Gray shading represents components not used in any analyses as previous components cumulatively include greater than 90% of the variance represented by the components.

	Comp. 1	Comp. 2	Comp. 3	Comp. 4	Comp. 5	Comp. 6
Orchards	0.76	0.45	-0.14		-0.19	0.15
Sagebrush	-0.46	0.47	-0.23	0.58		-0.18
Grassland	-0.34		-0.14	-0.36	0.20	0.75
Row Crops	0.20	-0.62	0.22	0.58		0.23
Marsh/Riparian	-0.16	0.18	0.82	-0.24	-0.18	-0.19
Hay/Pasture	-0.14	-0.38	-0.41	-0.30	-0.59	-0.31
Development	0.13	-0.13	-0.13	-0.23	0.74	-0.46
Cum. Proportion on Variance	42%	79%	88%	94%	97%	100%

3.2.2 Multi-scale Occupancy Modeling

The selection process for the multi-scale occupancy analysis produced eight models falling within two ΔAIC_c of the top model. However, after accounting for uninformative parameters, only a single model remained. At the point scale, no variables were selected as influencing the probability of detection of at least one Short-eared Owl, given that at least one owl was present at the point, or influencing the probability of the owl occupying the area around the survey point given that there was at least one owl on the survey grid cell.

Influencing the probability that the survey grid cell was occupied by at least one Short-eared Owl, we found two of the cell-scale compositional principal components in the top model. We found that component #1 was negatively associated with occupancy, suggesting the Short-eared Owls were more likely to be found in sagebrush and/or grasslands than in row crops and/or orchards (Figure 3a). We found that component #3 was also negatively associated with occupancy suggesting the Short-eared Owls were more likely to be found in sagebrush and/or hay/fallow/pasture than in marshland and/or row crops (Figure 3b). These findings are compatible with the expected biology of the species, expanding the often mis-applied label of “grassland species” to include native shrublands.

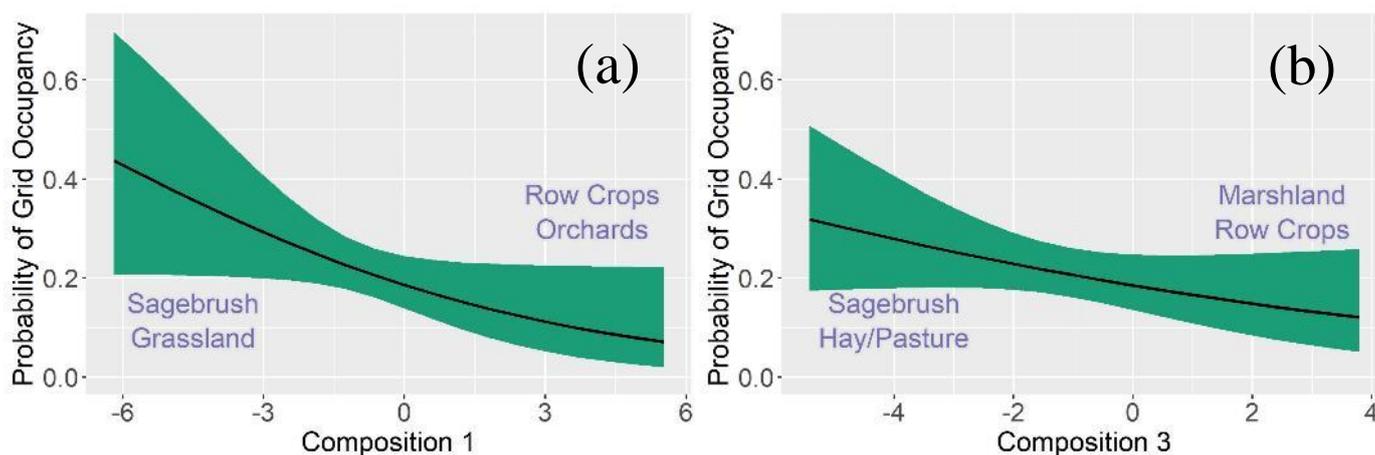


Figure 3. Model predictions generated from multi-scale occupancy top model for the effect size of the proportion of area within 1km of all surveyed points in various habitats influencing the probability of at least one Short-eared Owl occupying the survey area. Black line = model prediction; green area = 95% confidence interval.

The various states have participated in Project WAfLS for differing lengths of time, with Idaho being the longest. Calculated grid cell occupancy, a surrogate for abundance, shows highly variable occupancy rates, but a reasonably stable weighted mean rate across the region (Figure 4). Estimated occupancy rates were

higher than average in 2020 in California, Idaho, Oregon, and Wyoming. Occupancy rates were lower in Montana and Washington (Figure 4).

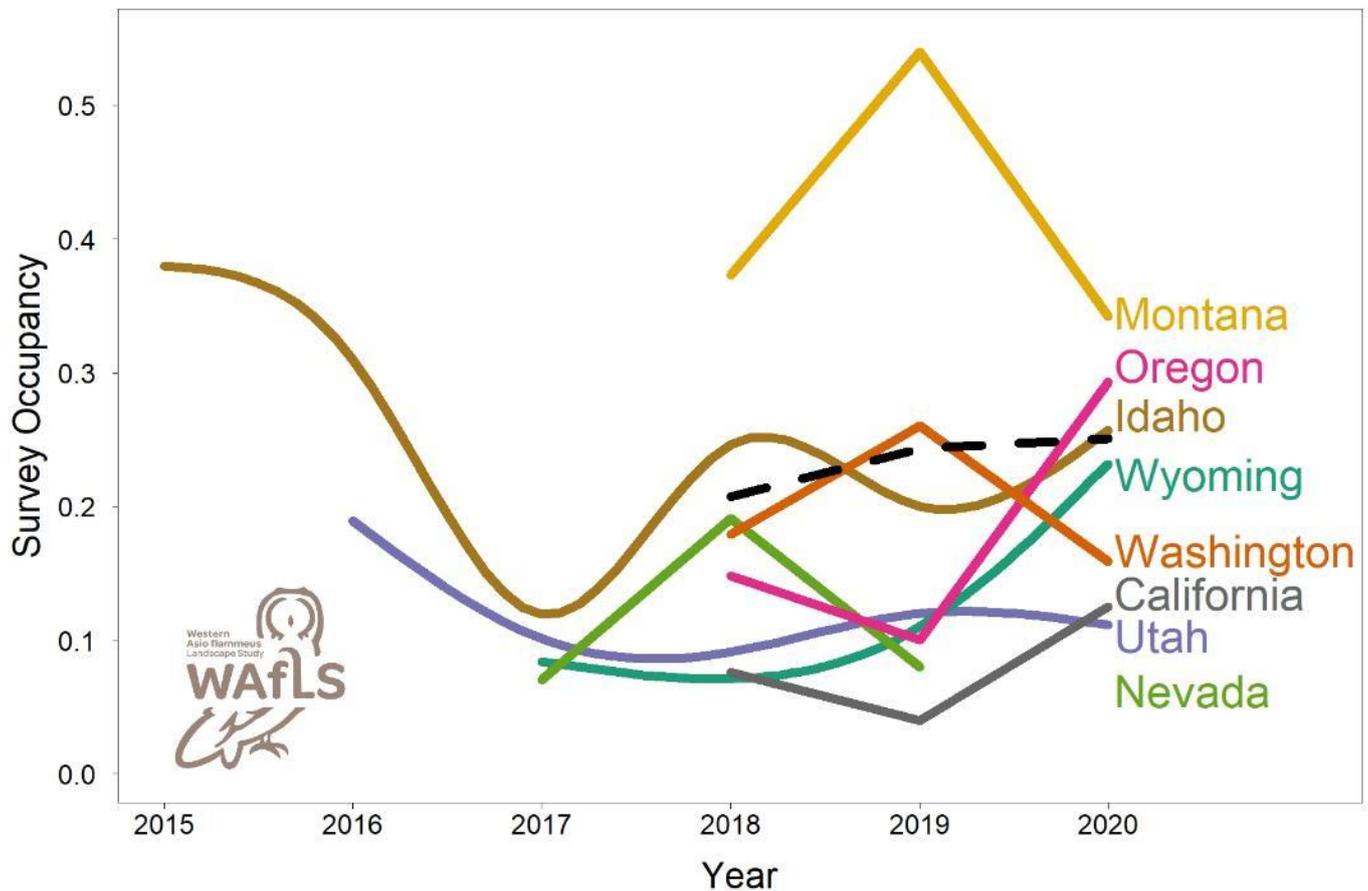


Figure 4. Estimated survey occupancy rates (surrogate for abundance) among the eight states with varying levels of historical participation. Black dashed line represents the weighted mean occupancy rate. Note possible sampling bias from Covid-19 restrictions for Nevada, Oregon, and Washington (Nevada estimates for 2020 could not be calculated due to low route completion).

The weighted mean occupancy rates in the western States has been flat to slightly increasing over the recent three years (Figure 4). Our more limited results from 2017 suggest that the population was very low in that year. However, our review of eBird data (see Appendix I), suggests that Montana may have had a high occupancy rate in 2017, similar to their rate in 2019. If so, the actual weighted occupancy rate across the eight states, may have been near the average of recent years. This reinforces our original belief that to properly assess the population of Short-eared Owls in the West, the broad geography of the eight states, and potentially beyond, must be included. Regardless, with the data we have available, we have no evidence that the suspected steep decline in the species over the past 40 years is continuing.

CONCLUSIONS: OBJECTIVE 2

Short-eared Owls favor native shrublands and grassland to more anthropogenic landscapes. Short-eared Owl occupancy rates are highly variable across the eight states within the program, and from year-to-year. However, overall weighted mean occupancy rates were relatively stable. We see no evidence that the steep decline that was suspected to have occurred over the past 40 years has continued.

3.3 OBJECTIVE #3: QUANTIFY HOW SHORT-EARED OWL POPULATIONS FLUCTUATE SPATIALLY AND TEMPORALLY AT STATE AND FLYWAY SCALES SO THAT LAND AND WILDLIFE MANAGERS CAN CONTEXTUALIZE LOCAL CHANGES WITHIN THE BROADER REGIONAL VARIATION.

The occupancy rates established in Objective #2 illustrate the broad geographic shifts in breeding densities of the Short-eared Owls (Figure 4). For example, between 2018 and 2019, the breeding density shifted to the north and east with densities increasing in Washington, Montana, and Wyoming. Between 2019 and 2020, the population shifted south and west, with densities increasing in California, Idaho, Oregon, and Wyoming. Despite these shifts, the overall weighted density across the eight states remained fairly stable.

Unfortunately, we have not yet been able to ascertain if these large shifts in densities are the result of birds moving from one state to another, as would generally be expected for a nomadic species (Newton 2008), or if they are the result of intrinsic population birth and death rates. The stability of the weighted mean breeding density could support either alternative. In other studies, Short-eared Owls have been shown to exhibit low breeding site fidelity, some individuals breeding in three geographic parts of Europe (F. Mougeot, pers. comm.; J. Calladine, pers. comm.), so it is conceivable that the shift in density represents individual birds moving. Short-eared Owls often exhibit irruptive numerical response to prey fluctuations (Korpimäki and Norrdahl 1991) and are less likely to return to breeding areas when vole numbers are lower (Village 1987).

To further explore population fluctuations, we implemented colonization/extinction modeling. We trust the occupancy rates from the Multi-scale Occupancy analyses over those presented here for the Colonization/Extinction modeling (includes more data), although colonization/extinction provides other unique and valuable insight into population dynamics.

3.3.1 State-specific Colonization/Extinction

Occupancy rates of our survey grid cells varied year-to-year and state-to-state (Table 7). In California we observed a complete turnover of occupied grid cells between 2018 and 2019 (100% site extinction) but observed much more moderate colonization and extinction between 2019 and 2020. In Idaho, we observed some wide swings in population dynamics with zero observed colonization in 2017, driving a significant decline in occupancy rates. The high extinction rates in 2018 and 2019, coupled with moderate colonization rates suggest the population was relatively unstable (via movement or birth/death rates) even though occupancy rates remained stable. In Montana, we observed a high colonization rate between 2018 and 2019. With nearly 70% of Montana's grid cells having been occupied previously, it was not surprising that the colonization rate in 2020 was low. The Nevada and Oregon results were significantly influenced by Covid-19 policies that constrained field effort in 2020; however, we observed relatively high extinction rates in both states in previous years. We observed a more stable population structure in Utah with relatively lower colonization and extinction rates. In Washington, even though the 2020 results were affected by the Covid-19 shutdown, the results were a bit more trustworthy as Washington did complete a first round of statewide surveys. The Washington turnover rates were a little above average. In Wyoming we observed above average extinction rates, but colonization ramped up relative to recent years resulting in reasonable occupancy rates.

Table 7. Grid cell colonization and extinction model results by state. Colonization is the proportion of un-occupied grid cells that were subsequently occupied. Extinction is the rate of occupied grids that were unoccupied in the subsequent year. Probability of detection was calculated from repeat visits only, not by minute-by-minute protocol used in multi-scale occupancy modeling.

		2016	2017	2018	2019	2020
CA	Colonization			0.14	0.15	
CA	Occupancy			0.13	0.13	0.22
CA	Extinction			1.00	0.26	
CA	Detection			0.30	0.30	0.30
ID	Colonization	0.00	0.18	0.29	0.33	
ID	Occupancy	0.35	0.11	0.27	0.24	0.30
ID	Extinction	0.67	0.00	0.90	0.80	
ID	Detection	0.57	0.57	0.57	0.57	0.57
MT	Colonization			0.53	0.00	
MT	Occupancy			0.44	0.69	0.38
MT	Extinction			0.11	0.45	
MT	Detection			0.49	0.49	0.49
NV	Colonization		0.31	0.02	0.00 ^①	
NV	Occupancy		0.09	0.28	0.11	0.00 ^①
NV	Extinction		1.00	0.65	1.00 ^①	
NV	Detection		0.39	0.39	0.39	0.39
OR	Colonization			0.18	0.31 ^②	
OR	Occupancy			0.27	0.27	0.45 ^②
OR	Extinction			0.49	0.17 ^②	
OR	Detection			0.29	0.29	0.29
UT	Colonization	0.06	0.00	0.09	0.08	
UT	Occupancy	0.17	0.15	0.11	0.17	0.23
UT	Extinction	0.40	0.27	0.16	0.04	
UT	Detection	0.44	0.44	0.44	0.44	0.44
WA	Colonization			0.37	0.15 ^②	
WA	Occupancy			0.29	0.39	0.23 ^②
WA	Extinction			0.57	0.64 ^②	
WA	Detection			0.34	0.34	0.34
WY	Colonization		0.05	0.13	0.21	
WY	Occupancy		0.09	0.09	0.12	0.25
WY	Extinction		0.66	1.00	0.41	
WY	Detection		0.51	0.51	0.51	0.51

① Result heavily influenced by sampling bias as a result of Covid-19 restrictions placed upon our participants.

② Results moderately influenced by sampling bias as a result of Covid-19 restrictions placed upon our participants.

3.3.2 Overall Colonization/Extinction

We analyzed colonization/extinction by land cover with all eight states combined. We had hoped to perform this state-by-state but lacked the sample size for a quality analysis. We found that compositional principal component #1 influenced colonization rates, whereas both components #1 and #4 influenced grid cell extinction rates. We found that sagebrush and/or grassland was more likely to be colonized than row crops and/or orchards (Figure 5a). We found that sagebrush and/or grassland, when occupied, had a lower rate of extinction than row crops and orchards when they were occupied (Figure 5b), and that grassland/hay/fallow/pasture had a lower chance of extinction than row crops and/or sagebrush (Figure 5c). These results may seem contradictory, but we interpret component #1 as native versus anthropogenic landscapes, and component #4 as a structure representing a grassy type of land cover versus more structured land covers. In combining Figure 5b and Figure 5c, we can conclude that orchards and row crops have the highest extinction, sagebrush somewhat in the middle with grassland/hay/pasture/marshland had the lowest.

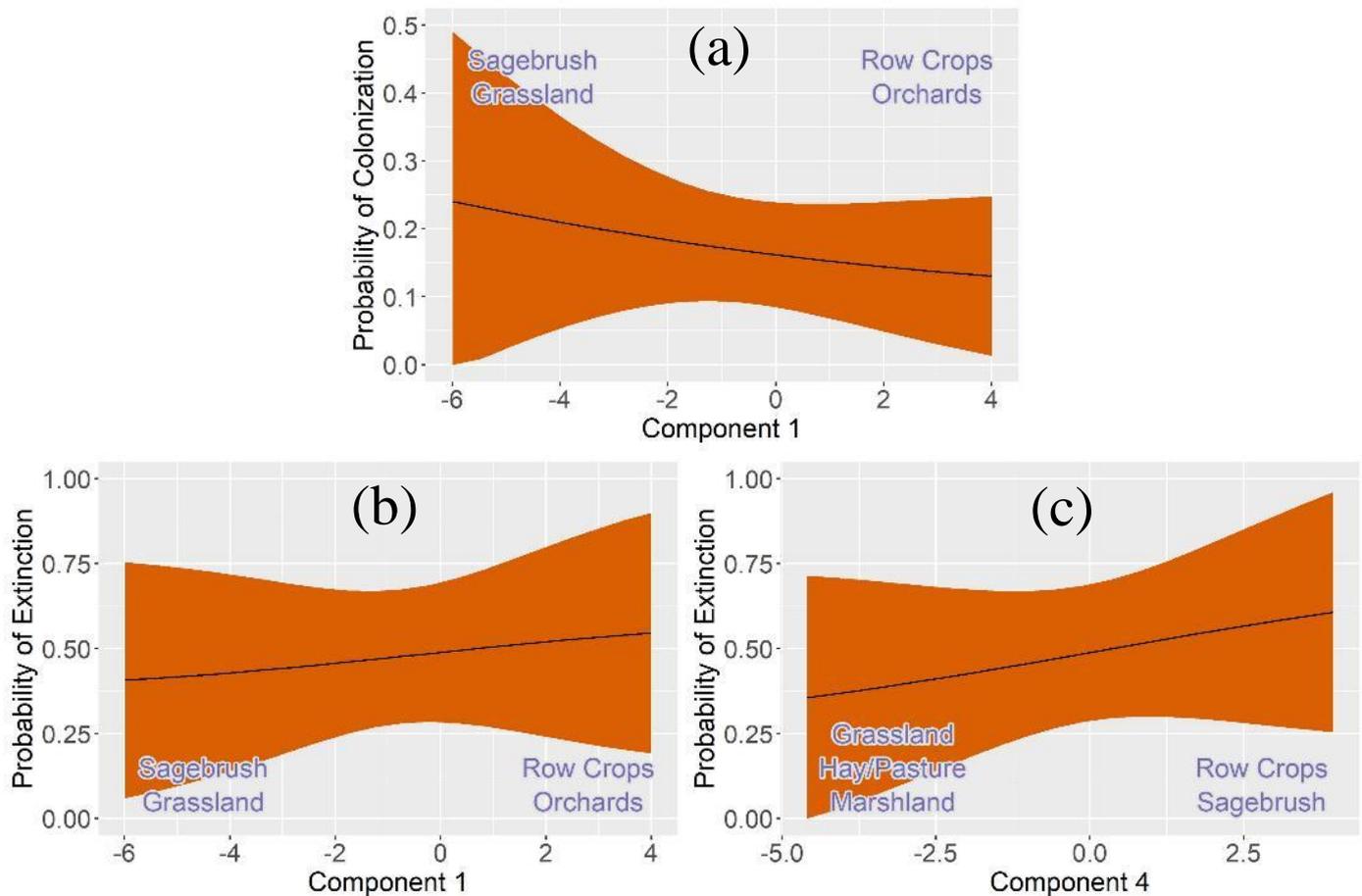


Figure 5. Probability of grid cell colonization and extinction as influenced by principal components representing land cover variables, shown with 95% confidence intervals (orange).

These results show that the native landscape, both shrubland and grassland, have higher stability for Short-eared Owl occupation than other landscapes. These landscapes are more often colonized and less often abandoned by breeding Short-eared Owls.

CONCLUSIONS: OBJECTIVE 3

Annual breeding densities of Short-eared Owls shifted across our study area, as reflected in the state comparisons, but the overall weighted mean density was relatively stable. We are unable to answer if these shifts in density were definitively the result of movement or birth/death rates. While we regularly detected owls on anthropogenic landscapes, the populations in native shrubland and grassland were more stable, possibly the result of more stable prey populations, but other hypotheses exist.

3.4 OBJECTIVE #4: IDENTIFY THEIR DISTRIBUTION, AND HOW HABITAT USE, GRAZING, AND CLIMATE INFLUENCES SHORT-EARED OWLS IN THE WEST, SUCH THAT MANAGERS CAN TARGET AND PRIORITIZE SPECIFIC OPEN-LAND LANDSCAPES TO RETAIN IMPORTANT AREAS AND CONNECT DISJUNCT LANDSCAPES.

We had originally expected to accomplish this objective with the multi-scale occupancy modeling performed for Objective #2. However, that tool resulted in choosing only the most important cover types which we found to be important but not sufficient to adequately address this objective. We therefore shifted to a boosted regression tree (BRT) framework for this objective (Ridgeway 1999, 2020).

Our final BRT model was built using a tree complexity of 10 and a learning rate of 0.001. The result was a fixed model with 1500 regression trees. The models mean total deviance was 1.29 and mean residual deviance was 0.84, and the Area Under the Curve (AUC) was 0.95 suggesting a very good fit, possibly an overfitted result. However, Elith et al. (2008) suggested that overfitting of BRT models is rarely a problem when applying the resulting model to independent data sets.

Our top optimized model had seven variables, including three land cover composition variables, elevation, slope, and two climate variables (Figure 6). The land cover compositions were mostly consistent with the multi-scale occupancy models with Short-eared Owls more often found in natural versus anthropogenic landscapes (Composition #1; Figure 6a), in sagebrush/hay/pasture versus marsh and row crops (Composition #3; Figure 6b), and in more grass versus structured land covers (Composition #4; Figure 6e). As expected, we more often found Short-eared Owls in less rugged areas at lower elevations (Figure 6c,g). Lastly, the climate variables suggest that Short-eared Owls occupy areas that are intermediate, but not too hot during the summer period, and in areas that receive more precipitation in the driest season (Figure 6d,f). The percent contribution of each variable to the overall result shows that land cover compositions 1 and 3 were most influential, but the contribution of all seven variables were between 10 – 18% (Figure 6).

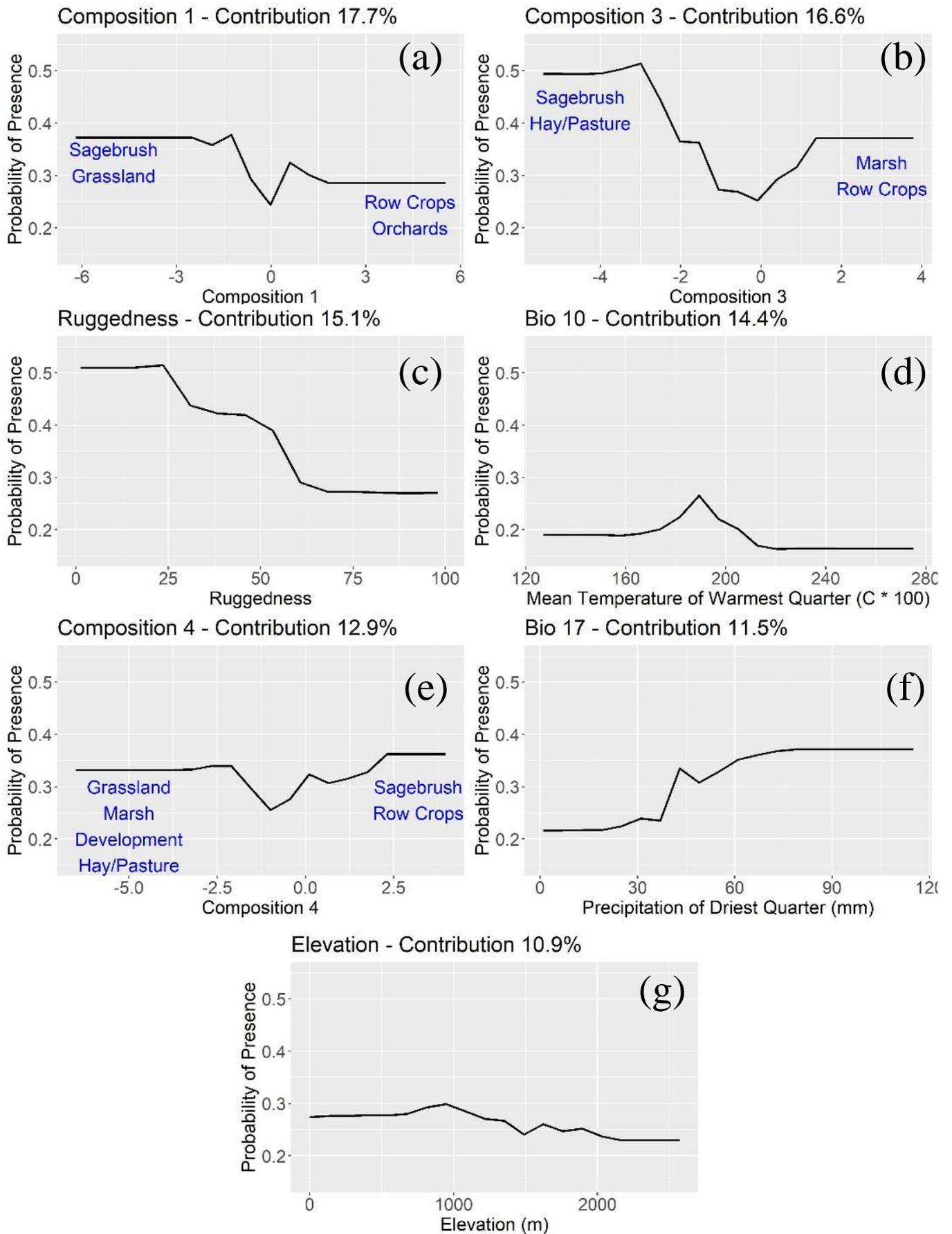


Figure 6. Plots of predicted influence of seven co-variables on the probability of Short-eared Owl presence across eight western states generated from our top BRT model set. Each variable shown with estimated contribution to the overall BRT models. See methods for explanation.

CONCLUSIONS: OBJECTIVE 4

Short-eared Owls were more often found in natural versus anthropogenic landscapes, in sagebrush/hay/pasture versus marsh and row crops, and in more grass versus structured land covers. As expected, we more often found Short-eared Owls in less rugged areas at lower elevations. Lastly, the climate variables suggested that Short-eared Owls occupied areas that were intermediate, but not too hot during the summer period, and in areas that received more precipitation in the driest season.

3.5 OBJECTIVE #5: GENERATE STATISTICALLY-RIGOROUS, REGION-WIDE PROJECTIONS OF SHORT-EARED OWL VIABILITY BASED UPON ENSEMBLE CLIMATE MODELS TO FOCUS MANAGEMENT ACTIONS FOR MAXIMUM CONSERVATION RETURN FOR OWLS AND OTHER OPEN-LAND SPECIES.

We implemented a Maximum Entropy (MaxEnt) modelling analysis to predict future region-wide population viability for Short-eared Owls. The top MaxEnt model as evaluated with AIC_c was a linear-quadratic-hinge model (LQH). The regularized training gain for the LQH model built with all presence records was 0.53, and the Area Under the Curve of the receiver operating characteristic plot (AUC) was 0.82. From the jackknife test of variable importance, the single most important predictor variable, in terms of the gain produced by a one-variable model, was Precipitation of Wettest Month (positive association; worldclim.org bio_13), followed by Mean Diurnal Temperature Range (negative; worldclim.org bio_2), and Mean Temperature of Warmest Quarter (intermediate association; worldclim.org bio_10). Slope (negative), Precipitation Seasonality (Coefficient of Variation; positive; worldclim.org bio_15), grassland (positive), and orchards (negative hinge near zero; i.e., never found when orchards present) decreased the gain the most when they were omitted from the full model, suggesting that they contained the most predictive information not present in the other variables.

Using the full combination of climate, geographic, and habitat variables, we were able to plot the likelihood of Short-eared Owl occurrence across the study area (Figure 7). Furthermore, replacing only the climate variables within the model with future climate variable projections for the year 2070, using RCP 4.5 climate models, we were able to project the future likelihood of Short-eared Owl occurrence across the study area (Figure 7). This climate view is considered conservative as it assumes no change in land cover, only in climate. We expect the land cover to also change with a change in climate, which could make the change in likelihood of presence even more dramatic.

The predicted average future viability of Short-eared Owls across our study area was 59% lower than the current view (mean viability decreasing from 23% to 14%). The area ranked above 0.5 viability (“good” habitat) was predicted to decrease by 76%. The area ranked above 0.8 viability (“great” habitat) was predicted to decrease by 60%.

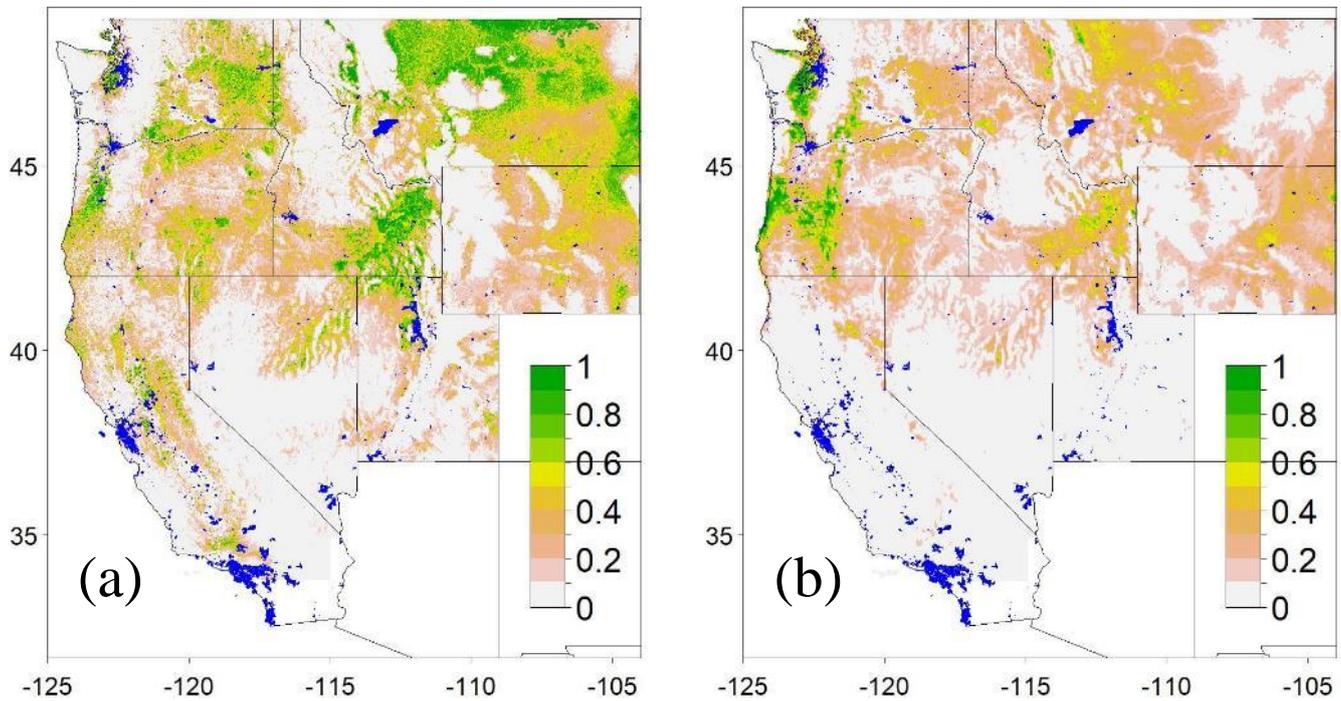


Figure 7. Study-wide predicted occurrence (on scale of 0 to 1) of Short-eared Owls, using current (a) and future (b) climate scenarios, derived from MaxEnt model LQH using presence and pseudo-absence data from project WAFLS 2015-2020. Future climate is projected to the year 2070 using the Representative Conservation Pathway 4.5 assumptions generated by Hadley Centre Global Environment Model version 2. Please use caution in interpreting these models as they project current assessments and future predictions beyond the area sampled by this program. For a more conservative view, the projects should be limited to the stratum area illustrated in Figure 8 (see section 5.2.1).

CONCLUSIONS: OBJECTIVE 5

Short-eared Owls are under extreme threat from projected climate change. We conservatively predict that average future viability of Short-eared Owls across our study area will decrease by 59% in the next 50 years. The amount of “good” habitat is predicted to decrease by 76%, and the amount of “great” habitat is predicted to decrease by 60% over the same period.

3.6 OBJECTIVE #6: IMPLEMENT HIGH-VALUE CONSERVATION ACTIONS PRIORITIZED BY FUTURE POPULATION PROJECTIONS FOCUSED ON MOST AT-RISK AND CORE POPULATIONS OF SHORT-EARED OWLS BY ENGAGING FLYWAY COUNCILS, AFWA COMMITTEES, STATE PERSONNEL, AND OTHER AGENCIES TO FACILITATE SCIENCE DELIVERY THAT EFFECTIVELY LINKS RESULTS TO PRIORITY STATE CONSERVATION OPPORTUNITIES.

We have implemented a variety of actions moving toward greater conservation of the species. Our work can be categorized into identification of conservation issues, building outreach and education capability, integrating with state wildlife action plan activities/revisions, and developing a network of individuals and organizations to implement further conservation.

3.6.1 Identified Conservation Threats

Our study has primarily focused on the landscape and land cover aspects of Short-eared Owl presence. However, Short-eared Owls face numerous threats, some of which our participants have observed directly during the period of our study, although typically not in association with surveys. This is not a comprehensive list of threats and has not been prioritized.

Agricultural practices. Our data indicate a positive association between Short-eared Owls and hay and fallow agriculture fields. Field observations have confirmed an association with alfalfa. These fields are often harvested during the nesting season for Short-eared Owls. We know of multiple instances of fields with known nests being harvested. We have not quantified this threat but believe it to be widespread, although it is unknown if these practices impact the population (additive mortality). It is conceivable that agricultural practices are one of the drivers of higher owl turnover in anthropogenic landscapes (as illustrated by our colonization/ extinction modeling). In communication with our European counterparts, they have observed large-scale nest destruction due to mowing (R. Kleefstra, pers. comm.).

Vehicle strikes. Vehicle strikes are potentially a substantial concern for the conservation of this species. Our participants have documented more than 140 such collisions over the past few years. These collisions often occur on straight, flat backroads with little traffic. Some of our mortality hotspots include northern Utah around the Promontory, Howell, Faust Valley, and Snowville areas, and in southern and eastern Idaho northwest of Mud Lake and south of Malta. We have other reports from Wyoming and Montana. In a long-term study of Barn Owl mortality along I-84 in southern Idaho, very few Short-eared Owl carcasses were found suggesting that Short-eared Owls may avoid higher traffic areas (J. Belthoff pers. comm.). Our qualitative observations suggest that most mortalities are young birds killed shortly after they become independent (June and July). We have successfully launched a pilot road survey process in Idaho (Project PROwl), to quantify population level effects. The next step is to scale that project to achieve statistical objectives.



One of 33 dead Short-eared Owls documented in June of 2016 by six-year Project WAfLS volunteers Don and Sheri Weber, northwest of Mud Lake, Idaho

Airplane collisions. Linnell and Washburn (2018) found that Short-eared Owls were disproportionately impacted by aircraft collisions, with many of their reported observations occurring in our study area (Table 8). The association of Short-eared Owls with grasslands and vole populations help explain the association with airfields.

Table 8. Number of owl strikes with US civil (1 January 1990 – 30 June 2014) and US Air Force (USAF) aircraft (1 January 1994 – 30 June 2014), by species, within the USA.

SPECIES	USA	
	NUMBER OF STRIKES WITH AIRCRAFT	% OF TOTAL
Barn Owl (<i>Tyto alba</i>)	1043	42.5
Short-eared Owl (<i>Asio flammeus</i>)	467	19.0
Long-eared Owl (<i>Asio otus</i>)	20	0.8
Snowy Owl (<i>Bubo scandiacus</i>)	114	4.6
Great Horned Owl (<i>Bubo virginianus</i>)	261	10.6

Solar farm mortalities. Mortalities of Short-eared Owls from solar farms have been reported to the US Fish and Wildlife Service (J. Pagel, pers. comm.), occurring within our study area, but details are not available. We have little information of the magnitude of this source of mortality.

Fence collisions. Collision with barbed-wire fences is a known threat for Short-eared Owls and other shrubland species. Our teams have documented two mortalities, one in Utah and one in Wyoming, and one injury resulting in a non-releasable rehabilitated bird. We suspect collisions with fences occur more often than reported, as substantial areas of fencing are not in close proximity to major road systems. As Short-eared Owls often occupy the same landscapes as Greater Sage-grouse (*Centrocercus urophasianus*), any flagging of fences underway to reduce impacts for that species would likely also benefit Short-eared Owls.



Short-eared Owl caught on barbed-wire fence, Wyoming (photo by four-year Project WAfLS volunteer, Tina Toth)

Stock tanks. At least four Short-eared Owl mortalities have been reported due to stock tank drownings in southern Idaho. This has been a pressing issue for the Idaho Bird Conservation Partnership, with good progress on surveys for and mitigating tanks lacking bird ladders. Short-eared Owls and many other bird and bat species would likely benefit from similar actions in other states.



Short-eared Owl carcasses in stock tanks without bird ladders in southern Idaho (Photo: Paul Mascuch).

Rodenticide. A possible additional source of direct mortality, or indirect mortality contributing to fence or vehicle collisions, is poisoning, particularly by rodenticides. In a California study of raptor mortalities, Kelly et al. (2014) found high levels of ingested rodenticide even when the final cause of death was the result of collisions. In a similar study in Massachusetts, Murray (2017) found a high proportion of raptors had ingested rodenticide. Abernathy et al. (2018) found rodenticide in the blood of migrating raptors in California. The Pacific Flyway Council identified addressing rodenticide impacts on raptors as a priority for their Nongame Technical Committee (Pacific Flyway Council 2015) and generated a report on the subject (Pacific Flyway Council 2018). So far, we have tested two Short-eared Owl carcasses collected along roadways (one from Idaho and one from Utah) for rodenticide and both have tested negative. We will look to test additional carcasses.

Our partners will hopefully continue to monitor these threats, as opportunity allows, to continue to document and learn from observed mortality events.

3.6.2 Outreach and Education Capability

The community-science nature of our broad survey initiative was a natural connection to public outreach. Engaging over 600 people per year (and at least 1,200 people over the past six years) to actively contribute to project implementation directly resulted in a natural network of informed and often passionate citizens. The list of conservation issues and threats we have identified have largely been reported by our community-science participants. We provided an annual webinar to our participants to emphasize the results and conservation needs, with each viewed more than 100 times. One-on-one interactions between project coordinators and volunteers also provided opportunities to further share information about Short-eared Owls, conservation, and the importance of scientific field methodology. Lastly, we developed and used platforms to share information among participants (a Facebook site) and between project managers and participants (annual reports), which further strengthened participant engagement and overall project success. We think all these interactions were productive components of outreach and education.

Our outreach and engagement efforts extended beyond the volunteers to the broader public community. We made a number of presentations at local chapters of the Audubon Society and other wildlife-oriented groups (e.g., Idaho Master Naturalists). The WAfLS program was highlighted in local newspapers and Audubon society newsletters and webpages. The project was also featured in the International Owl Center's Owl Conservation & Research News. Our technical lead was interviewed for an education program broadcast by KBSU public radio emphasizing our community-science focus. Last, it's impossible to quantify the number of informal discussions had between our volunteers and their friends and family about Short-eared Owls and their conservation. Though hard to estimate, we suspect benefits from peer-to-peer information sharing sparked by participants' personal experiences with this project may be just as or possibly more valuable than information provided to the public by agency or conservation groups.

From a science outreach perspective, we have published one paper to date (Miller et al. 2016), have presented our results each year at the Raptor Research Foundation conference. We have presented at the World Owl conference and have given both poster and oral presentations at the national Wildlife Society conference and at many regional and state chapter meetings of The Wildlife Society. We directly participated in the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Draft Short-eared Owl Threats Assessment process and on the Short-eared Owl conservation planning process for the province of Québec. We have further consulted on research studies in Hawaii and Argentina.

3.6.3 Integrating with State Wildlife Action Planning Activities

One of the most impactful methods to support conservation actions at the state level is by providing targeted information, by state, that will be useful to updating State Wildlife Action Plans (SWAP) for species being



considered for designation as a species of greatest conservation need. Our 2015 program results were directly integrated into Idaho’s State Wildlife Action Plan (SWAP), influencing the content of plan sections that addressed population size estimates, status, and recommended actions. The 2015 SWAP planning cycle for the other seven states was not in synchrony with our program roll out, but all states have communicated their interest and commitment to integrating our results in their revision process and all states are due to revise their SWAP by 2025 or before.

Here are a few examples of integration work that has been completed to date influenced by the results of this project:

- Wyoming has used Project WAfLS results to update their species account for Short-eared Owl in preparation for the next SWAP revision.
- Utah, a state where Short-eared Owls are not currently listed as Species of Greatest Conservation Need, has launched an effort to re-evaluate the species for their next SWAP revision.
- Montana, had previously classified Short-eared Owls as Species of Information Priority, but are now using our data to re-evaluate the ranking.

We expect similar actions in all remaining states.

3.6.4 Building a Network of Individuals and Organizations

We initially developed a project website to facilitate development of a network of individuals and organizations to implement surveys. Following the accomplishment of the survey components this project, the site is now in transition, being re-focused to support project science delivery needs and facilitate development of a diverse group of individuals and organizations to participate in science-driven conservation planning and implementation.

We convened two focus groups including Pacific Flyway partners and Nongame Technical Committee members who discussed key threats to Short-eared Owls and opportunities to engage a variety of stakeholders who can implement actions designed to reduce threats in the project area. The focus group identified a need for audience specific decision support tools (DSTs) including mapping tools and targeted, science-based conservation opportunity documents. Target audiences include state, Natural Resources Conservation Service, and Joint Ventures conservationists who work with private landowners and agricultural trade groups. Next steps for developing DSTs are now focused on using Project WAfLS to describe key ecological attributes that describe desired conditions in target Short-eared Owl habitats. An interactive map of Short-eared Owl occupancy will be developed, along with a series of science briefs and management guides that identify priority threat-reducing conservation actions and opportunities.

CONCLUSIONS: OBJECTIVE 6

We have identified specific conservation threats for this species, each of which has been observed within our study area. These threats, along with our core research findings, have been integrated into our various outreach and education efforts and with each state’s SWAP process. Targeted science delivery tools including an interactive occupancy map and science and conservation opportunity briefs are now being developed. Priority implementation partners include state, Natural Resources Conservation Service, and Join Ventures conservationists who work with private land owners and agricultural trade groups.



3.7 AREAS OF FUTURE RESEARCH

3.7.1 Continued Monitoring of Populations through eBird and IMBCR

With the completion of the Project WAfLS grant period, we must establish how monitoring Short-eared Owl populations can continue moving forward. Project WAfLS has been very successful and reasonably cost effective but continuing the project will require funding to address project needs (e.g., project management, coordination of volunteers, data management, data analysis, information outreach and dissemination). Our structured monitoring protocol has been operationalized in the Avian Knowledge Network and is freely available for use by states and other partners. We have investigated the option of using eBird as a basis of this monitoring (see Appendix I). The results are encouraging, but not as accurate in many states as we would like. Without additional funding, eBird may be the best option available, although it does not address all aspects of project needs.

3.7.2 Short-eared Owl Mortality Mitigation in Agricultural Landscapes

With our handful of incidental mortality observations and reports of extremely high agricultural harvest-related mortality in Europe (R. Kleefstra, pers. comm.), we believe that agricultural practices associated with harvest, particularly with the growth of alfalfa production, could be an additive source of mortality for Short-eared Owls. Thus, we plan to launch a program to simultaneously quantify potential mortality factors and identify options to address those factors. This effort would likely involve a partnership with the agricultural community. We believe this action may have the greatest possible return on conservation investment due to its potential feasibility of achieving conservation, availability of partners to carry conservation forward (e.g., National Resource Conservation Service), and availability of new technology to help scale conservation (e.g., thermal imaging drones).

3.7.3 Short-eared Owl Movement

As identified in WAfLS objectives #2 and #3, we documented large scale changes in local breeding densities, but were not able to answer the question as to whether the changes were driven by movement or intrinsic birth/death rates. We seek to establish this through further study of Short-eared Owl movement. We have some historical movement data from Alaska, Montana, and Hawaii, and have built a global network of Short-eared Owl researchers for collaboration – Argentina, Czechia, Netherlands, Scotland, Slovenia, and Spain. We are planning to deploy a few more trackers on birds across our study area and work on a collaborative analysis of results with others around the world.

3.7.4 Analysis of Additive versus Compensatory Mortality

Relative to identified sources of mortality, we have not established if the mortality was additive or compensatory, although we suspect that much of it is additive. This is an important question to answer as we work to acquire or influence investment in the conservation of this species.

4 CONCLUSIONS

Project WAfLS was very successful in completing our assessment of Short-eared Owl populations in the western United States utilizing a largely volunteer-driven network of community-science volunteers. We found that grazing negatively influences Short-eared Owl occupancy, but that grazing and the presence of Short-eared Owls were not mutually exclusive. Results of the grazing study indicated that managing the grazing utilization rate across the pasture could reduce the negative effects of grazing.

Short-eared Owls favor native shrublands and grassland to more anthropogenic landscapes. We see no evidence that the suspected steep decline in the species over the past 40 years has continued. Short-eared Owl occupancy rates were highly variable across the eight states within the program, and from year-to-year.



However, overall weighted mean occupancy rates were relatively stable. We were unable to ascertain if the shifts in abundance were the result of movement, as might be expected for an irruptive or nomadic species, or birth/death rates. Short-eared Owls were more often found in natural versus anthropogenic landscapes, in sagebrush/hay/pasture versus marsh and row crops, and in more grass versus structured land covers. We found that while we regularly detected owls on anthropogenic landscapes, the populations in native shrubland and grassland were more stable, possibly the result of more stable prey populations, but other hypotheses exist. As expected, we more often found Short-eared Owls in less rugged areas at lower elevations. Lastly, the climate variables suggested that Short-eared Owls occupied areas that were intermediate, but not too hot during the summer period, and in areas that received more precipitation in the driest season.

Short-eared Owls are under extreme threat from projected climate change. We conservatively predicted that average future viability of Short-eared Owls across our study area would decrease by 59% in the next 50 years. The amount of “good” habitat was predicted to decrease by 76%, and the amount of “great” habitat was predicted to decrease by 60% over the same time period.

5 METHODS

5.1 GROUSE & GRAZING PROJECT

Livestock grazing is a common land use across much of the western U.S. and has a high amount of overlap with the Short-eared Owl’s distribution. In 2018 – 2020, the Grouse & Grazing Project, led out of the University of Idaho, conducted Short-eared Owl surveys in pastures that were part of a large-scale grazing experiment that was designed to assess effects of grazing on Greater Sage-grouse. The objective of these surveys was to examine if owl occupancy or abundance are affected by cattle grazing.

5.1.1 Grouse & Grazing Study Areas

Short-eared Owl surveys were conducted on public lands at five study sites in southern Idaho. These five sites include Sheep Creek, Browns Bench, Jim Sage, Big Butte, and Pahsimeroi Valley. Sheep Creek is located roughly 80 miles south of Bruneau on the eastern edge of the Owyhee Mountains and just northwest of the Jarbidge Mountains. This site was dominated by Wyoming sagebrush and had very low levels of anthropogenic disturbance due to its remote location. Browns Bench is located on the western edge of Salmon Falls Reservoir near Rogerson. The study pastures at this site were sandwiched between Monument Springs Mountain that rises ~300 m above the study pastures and the reservoir to the east. This site was dominated by black sagebrush with pockets of Wyoming and mountain big sagebrush as well. Jim Sage was located on the eastern edge of the Jim Sage Mountains roughly 5 miles south of Malta. This site was on a gently sloping east facing aspect and was dominated by low sagebrush with pockets of Wyoming and basin big sagebrush. Big Butte is located in the big desert region roughly 20 miles southeast of Arco. This site was a maze of historical lava flows in a very remote area that largely lacked anthropogenic disturbance. It was dominated by a mix of three tip sagebrush and basin big sagebrush. Pahsimeroi Valley was located on the southern end of the Pahsimeroi Valley near the town of May. This site was surrounded by the Big Lost Mountain Range to the west and the Lemhi Mountain Range to the east. The site was dominated by a mix of low sagebrush in the river valley and Wyoming big sagebrush on the toe slopes. Agricultural lands (primarily alfalfa) were directly adjacent to several of the study pastures.

5.1.2 Grouse & Grazing Owl Surveys

We established survey locations in each pasture by placing a grid of points 1000 m from one another. If the pasture had an irregular shape, we moved or placed additional survey points to ensure that placement of

survey locations would give us a reasonable probability of detecting all Short-eared Owls in the pasture. We followed the point protocol developed by the broader WAfLS program (see below; e.g., 2 visits, survey timing, time of day, 5-minute protocol, land cover data collection, etc.; see Appendix II).

5.1.3 Grouse and Grazing Utilization Surveys

5.1.3.1 *Landscape Appearance*

We used the landscape appearance method (Coulloudon et al. 1999) to estimate utilization in experimental pastures. We used ArcGIS to randomly place a grid of north-south transects in experimental. If the pasture was grazed by livestock during spring/summer, we placed transects 300 m apart and sampled at 200-m intervals along each transect. If the pasture was not grazed by livestock during spring/summer that year, we instead placed transects 500 m apart and sampled at 200-m intervals (because we were expecting only minimal utilization by native ungulates in pastures that did not have cows in them). At 200-m intervals along each transect, the observer stopped walking and estimated utilization according to the utilization classes in Coulloudon et al. (1999; Table 9) within a 15-m radius half-circle in front of them.

5.1.3.2 *Shapefile Methods*

For utilization via landscape appearance transects, we obtained pasture-level estimates by taking the mean of all points sampled within that pasture. We used the mid-point of the ranges outlined in Table 9 to represent each of the 6 categories (i.e., the “slight” category was the mid-point between 6 and 20, or 13).

We created maps of pattern use by herbivores in each pasture based on our visual estimates of utilization from the landscape appearance transects. We used the Inverse Distance Weighted (IDW) tool in ArcGIS (version 10.4) to interpolate utilization in areas between sampling points. IDW interpolation is based on the assumption that points closer together are more alike than those further apart. An advantage of using IDW interpolation is that it is an exact interpolator (i.e., the interpolated value at each point where a measurement was taken will line up directly with what was actually measured at that point). We used the 12 nearest neighbors to interpolate each pixel of the resulting raster surface. The resulting maps were then classified into the 6 utilization categories to help visualize the spatial variation in utilization (see categories in Table 9).

Table 9. Utilization classes that we used to estimate percent utilization along landscape appearance transects (based on Coulloudon et al. 1999).

Utilization Class	Description
0-5%	The rangeland shows no evidence of grazing or negligible use.
6-20%	The rangeland has the appearance of very light grazing. The herbaceous forage plants may be topped or slightly used. Current seed stalks and young plants are little disturbed.
21-40%	The rangeland may be topped, skimmed, or grazed in patches. The low value herbaceous plants are ungrazed and 60 to 80 percent of the number of current seed stalks of herbaceous plants remain intact. Most young plants are undamaged.
41-60%	The rangeland appears entirely covered ^① as uniformly as natural features and facilities will allow. Fifteen to 25 percent of the number of current seed stalks of herbaceous species remain intact. No more than 10 percent of the number of low-value herbaceous forage plants are utilized.
61-80%	The rangeland has the appearance of complete search ^② . Herbaceous species are almost completely utilized, with less than 10 percent of the current seed stalks remaining. Shoots of rhizomatous grasses are missing. More than 10 percent of the number of low-value herbaceous forage plants have been utilized.
81-94%	The rangeland has a mown appearance and there are indications of repeated coverage. There is no evidence of reproduction or current seed stalks of herbaceous species. Herbaceous forage species are completely utilized. The remaining stubble of preferred grasses is grazed to the soil surface.
95-100%	The rangeland appears to have been completely utilized. More than 50 percent of the low-value herbaceous plants have been utilized.

① “covered” means that foraging ungulates have passed through the area.

② “complete search” means that foraging cattle have spent considerable time foraging in the area and were not just passing through.

5.1.4 Grouse & Grazing Owl Analysis

5.1.4.1 By Treatment

We evaluated if grazing treatment at both the pasture and point scale was related to Short-eared Owl detections. We categorized pastures and points into four treatment classes including no grazing in the previous or current year, grazing only the previous spring, grazing only the previous fall, and grazing concurrent with the surveys. We used χ^2 analysis to evaluate if the number of owls detected at the pasture level and point level differed significantly from the number of available pastures and points for each treatment. We determined significance using $\alpha = 0.05$.

5.1.4.2 Relationship between Owl Occupancy and Grazing

We analyzed the effect of grazing utilization levels on Short-eared Owl point occupancy using generalized linear mixed models with a binomial distribution (Zuur et al. 2009, 2010). We included study site, pasture, and year as random effects to account for pseudo-replication and spatial autocorrelation (Zuur et al. 2009, 2010). We considered utilization to have an effect if the model that included grazing utilization ranked above the null model when evaluated using Akaike Information Criterion adjusted for sample size (AICc; Burnham and Anderson 2002). We created and presented model predictions by ranging utilization over its measured range and plotting the model result.

5.2 REGION-WIDE SHORT-EARED OWL SURVEYS.

5.2.1 Study area

Our 2018 – 2020 study area included eight western states of the contiguous lower 48 of the United States. We stratified this region by placing a 10 km-by-10 km grid over the states, and within these grid cells, we quantified presumed Short-eared Owl habitat within our study area using Landfire data (US Geological Survey 2012), or in the case of California, we used the State’s Vegetation Classification and Mapping Program (VegCAMP) data. We used the VegCAMP data in California because of its superior quality as compared with Landfire. The VegCAMP data were only used for grid cell selection and not in the data analysis. Grassland, shrubland, marshland/riparian, and agriculture land cover classes were considered potential Short-eared Owl habitat (Wiggins et al. 2006). Grids with at least 70% land cover consisting of any combination of these four classes (60% in California) were included in our survey stratum. All other grid cells were then removed from further consideration. The result consisted of 6,040,000 hectares within California, 9,460,000 hectares within Idaho, 25,220,000 hectares within Montana, 10,260,000 hectares within Nevada, 9,740,000 hectares within Oregon, 7,760,000 hectares within Utah, 5,530,000 hectares within Washington, and 13,810,000 hectares within Wyoming (Figure 8).

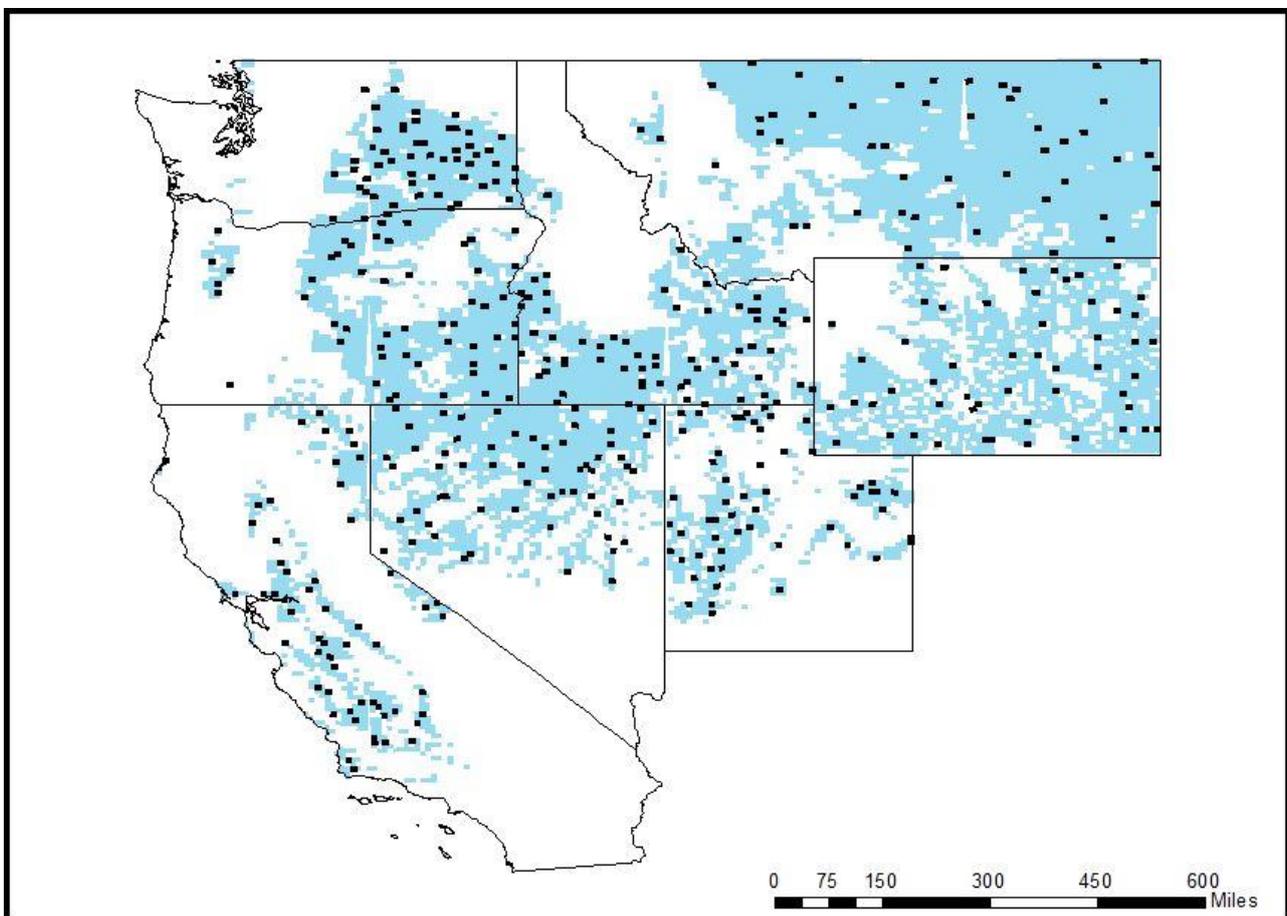


Figure 8. Distribution of cover types that potential supported habitat (blue area) and spatially-balanced survey transects (black squares) for Short-eared Owl surveys during the 2018 – 2020 breeding season across the states of California, Idaho, Montana, Nevada, Oregon, Utah, Washington, and Wyoming.

5.2.2 Transect selection

We selected grid cells within which survey transects would be sited using a sample of 10 km-by-10 km grid cells derived from a Generalized Random-Tessellation Stratified (GRTS) process (Stevens Jr. and Olsen 2004). We eliminated grid cells with no secondary roads, a requirement of our road-based protocol. We selected a spatially-balanced sample of 50 grid cells per state (Figure 8). We selected additional groups of randomly-selected grid cells in each state in groups of ten that could be offered to additional volunteers only

if the original 50 grid cells were all committed. These additional surveys were integrated into the analysis in the same manner as the base 50. Only one additional group of surveys were offered to volunteers, in Idaho.

We delineated a survey route within each grid cell along one or more segments that totaled 9km of secondary road (Figure 9), the maximum survey length feasible using the protocol and our justification for choosing a 10 km-by-10 km grid structure (Larson and Holt 2016). If multiple possible routes were available within a single grid cell, we chose routes expected to have the least traffic, routes on the edge of the greatest amount of roadless landscapes, or routes with the highest likelihood of detecting Short-eared Owls (a potential source of bias discussed later). In limited cases, such as when road access issues arose, the survey routes were allowed to extend outside of the grid cell, but never for the purpose of accessing other or better habitat areas. Larson and Holt (2016) reported that in favorable conditions Short-eared Owls could be correctly identified at distances up to 1600 meters, with high detectability up to 800 meters. Calladine et al. (2010) had a mean initial detection distance of 500 - 700m, with a maximum recorded value of 2500m. As our analysis method was robust against false negative detections, but less so against 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 (Figure 9).

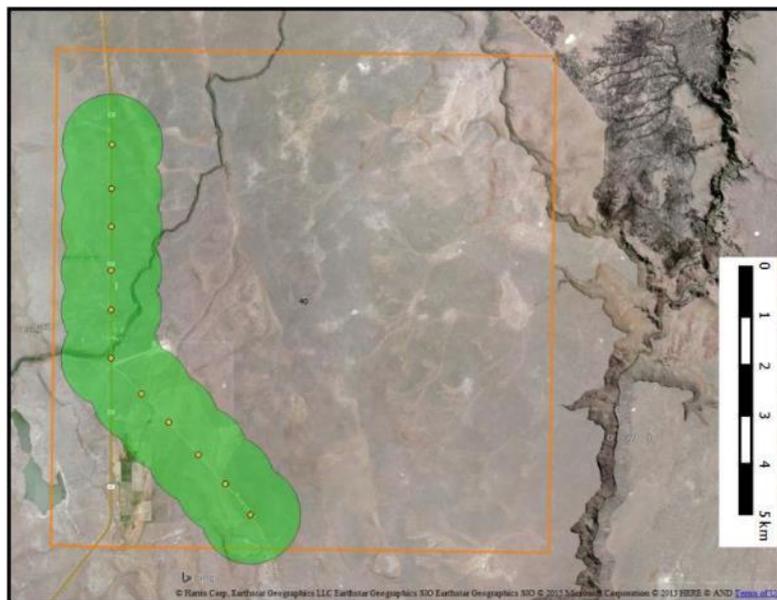


Figure 9. Example illustration of 10km × 10km grid cell (orange), 11 road-based survey points (yellow), and area surveyed within 1km of survey points (green). Green-shaded area was the only area used in the analysis.

5.2.3 Hot-spot Grids

In most states we also sampled a small number of “hot-spot” grid cells. These grid cells (one to eight per state) were subjectively located in places where we expected to find Short-eared Owls, as the sites were intended to be used for drawing comparison of relative abundance among these sites from year to year. We implemented a consistent protocol for sampling these grid cells but did not include the results in the occupancy analyses as they do not meet the assumptions of these analyses and would have biased our results.

5.2.4 Public Participation Recruitment

We identified a coordinator for each state that was responsible for recruiting survey participants for their routes. Most state coordinators relied heavily upon community-science volunteers. For community-science volunteer recruitment 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 and birding groups, electronically, through submitted newsletter articles, and in person. In some cases, we reached out to professional biologists to cover remote grid cells or grid cells on

restricted lands (e.g., reservation lands or national laboratory lands closed to the public). The reliance on professional biologists differed among the states. For example, in addition to recruiting volunteers, coordinators in Nevada invited a network of professional biologists that they had engaged for previous raptor survey routes. This resulted in a larger proportion of paid biologists surveying in Nevada than in other states.

We began recruiting volunteers two months prior to the beginning of the first survey window. Volunteers were asked to register for their survey grid cell online. Across the eight states, roughly $\frac{2}{3}$ of our volunteers were non-professional community science volunteers, whereas $\frac{1}{3}$ were professional biologists either volunteering to survey routes or assigned by their agency or company to complete the route. We completed between 70% and 90% of the assigned surveys in each state. Those surveys not completed were a combination of inability to recruit volunteers for some grid cells, inaccessible survey routes, late snowmelt that prevented access, and some volunteers not completing their surveys. Our historical rate of route non-completion among volunteers is 10 – 15%.

We provided training materials (e.g., owl identification), a procedure manual, maps, civil twilight schedules, and datasheets to volunteers to help ensure survey quality. We provided window signs for participant’s vehicles to help them appear more official and alleviate concerns by local landowners. We provided seven online training videos and held two live launch webinars (with recordings also posted online) prior to the start of the season. We asked volunteers to submit data via an online portal, hosted on the Avian Knowledge Network’s Northwest node since 2019.

5.2.5 Owl Surveys

The survey design involved making two visits to the route during the period of Short-eared Owl courtship flight behavior. 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 (Table 10). Survey timing was chosen to coincide with the period of highest detectability during the courtship period when male owls perform elaborate courtship flights (Figure 10). 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. In northern states we had to adjust these windows to accommodate substantial areas of retained snow on the landscape.

Table 10. Suggested survey timing for each of the two visits derived from mean elevation of the survey grid cell and expected courtship period of Short-eared Owls within each participating state.

CA, ID, OR, WA	Elevation below 4000ft.	Elevation 4000 - 6000ft.	Elevation above 6000ft.	
Visit 1	March 1 - March 21st	March 16 - April 7th	April 1st - April 21st	
Visit 2	March 22nd - April 15th	April 8th - April 30th	April 22nd - May 15th	
MT	Elevation below 4000ft.	Elevation 4000 - 6000ft.	Elevation above 6000ft.	
Visit 1	March 16 - April 7th	April 1st - April 21st	April 15th - May 6th	
Visit 2	April 8th - April 30th	April 22nd - May 15th	May 7th - May 28th	
NV, UT	Elevation below 5000ft.	Elevation 5000 - 6000ft.	Elevation above 6000ft.	
Visit 1	March 1 - March 21st	March 16 - April 7th	April 1st - April 21st	
Visit 2	March 22nd - April 15th	April 8th - April 30th	April 22nd - May 15th	
WY	Elevation below 5000ft.	Elevation 5000 - 6000ft.	Elevation 6000 - 7000ft.	Elevation above 7000ft.
Visit 1	March 10 - March 31st	March 24 - April 14th	April 7th - April 28th	April 14th - May 5th
Visit 2	April 1st - April 22nd	April 15th - May 6th	April 29th - May 20th	May 6th - May 27th

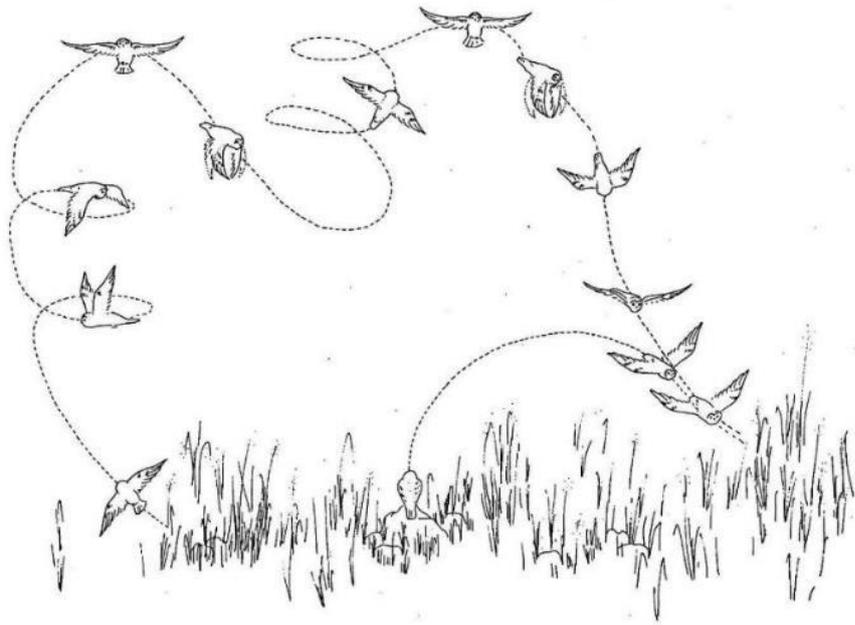


Figure 10. Illustration of male courtship display flight (from Wiggins et al. 2006; included with permission).

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., 800 m spacing instead of 2000 m).

At each survey point observers performed a five-minute point count, noting each individual bird minute-by-minute (e.g., for an owl observed only during minutes 2 and 3 of the five-minute period, we would assign a value of “01100”). 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 the detected behavior noted (perched, foraging, direct flight, agonistic, courtship).

5.2.6 Land Cover Data

At each point observers collected basic land cover data during each visit as we expected some land cover to change during the overall survey period (e.g., an agricultural field may have been plowed and the cover could therefore change from stubble to bare soil between visits). Observers noted the proportion of land cover within 400 m of the point (in general, about half the distance between survey points) that consisted of tall shrubland (above knee height), low shrubland (below knee height), cheatgrass monoculture, complex grassland, marshland, fallow agriculture, retained stubble agriculture, plowed soil agriculture, and green agriculture (new green plant growth visible; see Appendix II for full protocol). Mixed grassland and shrubland was classified as shrubland if there were 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. The grass categories of cheatgrass monoculture and complex grassland represent an evolution from early years of the program where we simply collected grass height. We have assumed that these new categories better represented the attributes that may be used by Short-eared Owls.

5.2.7 Data Entry and Management

We created a Project WAfLS extension in the Avian Knowledge Network (AKN) with a user interface developed for data entry and summary. Existing data previously collected as part of project WAfLS were bulk uploaded into the extension. All project WAfLS data are now available for use by states and partners upon request. The data extension and user interface are available for future monitoring efforts that follow the project WAfLS protocol.

5.2.8 Statistical Analyses

We performed multi-scale occupancy modeling (Nichols et al. 2008, Pavlacky et al. 2012), colonization/extinction modeling (MacKenzie et al. 2003), Generalized Boosted Regression Tree modeling (Ridgeway 1999, 2020), and Maximum Entropy modeling (MaxEnt; Phillips et al. 2006, 2017). We chose multi-scale occupancy modeling for its strength in evaluating fine-scale (point-scale in our case) habitat associations and providing a more refined alternative to abundance estimation. We chose colonization/extinction modeling to evaluate the changes in landscape occupancy year to year. We chose MaxEnt modeling for study-wide habitat mapping, integrating current and future climate scenarios into the predictions. Lastly, we chose Generalized Boosted Regression Tree modeling to bridge the gap between occupancy modeling and MaxEnt, allowing for more refined habitat associations.

5.2.9 Compositional Statistics

New to our analysis in 2020, was the use of compositional statistics. Many of the predictive measures that we used in our modeling were not truly independent. Our land cover variables at both the grid and point scale were compositions, or proportions of a whole. For example, our point land cover categories totaled to 100%. If the amount of sagebrush habitat was 100%, all other habitat values must have been zero. Hence, there was an interdependence between categories. While many analyses and papers have been published using these non-transformed categorical values, it could have significant bias leading to incorrect statistical inference (Aitchison 1986, Pawlowsky-Glahn et al. 2011, R. Miller pers. obs.). The use of compositional statistics complicates the result reporting for each of our analyses, but the result was less biased overall.

To transform our data at the point and grid scale, we first combined the categories at each scale separately into a closed log ratio (Aitchison 1987). We then performed a modified principal component analysis on the resulting data, choosing to propagate forward the most important principal components (on cumulative proportion of variance explained >90%; McCune and Grace 2002, Abdi and Williams 2010). These components at the point scale and at the grid scale were then integrated with other non-compositional values into their respective analyses (e.g., Multi-scale Occupancy or Boosted Regression Tree modeling).

5.2.10 Multi-scale Occupancy Modeling

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 multi-scale occupancy analysis, 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 cover type from the 2012 Landfire dataset (US Geological Survey 2012). We then prepared these data using the compositional statistics approach highlighted in the previous section.

We evaluated variables influencing the probability of detection (day-of-year, minutes-before-civil-twilight, wind, sky cover, etc.), availability at the point scale (point-scale land cover principal components and grazing values collected by observers within 400 m of point, ~50 ha), and transect occupancy (land cover principal components generated from data collected through GIS data within 1 km of all sampled points). The 10 km by 10 km grid structure was only used to distribute and spatially balance the transects, as all analyses utilized the 1750 ha area surrounding the points actually surveyed (1 km 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 ; Burnham and Anderson 2002). 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 its 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 at the point-scale (Θ). Lastly, we repeated the procedure for variables influencing transect occupancy (Ψ) to arrive at our final model set for each analysis.

For inference we first removed all models with uninformative parameters (Arnold 2010), then used model averaging of all remaining 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 presented model averaged predictions by ranging the variable of interest over its measured range while holding all other variables at their mean value.

5.2.11 Colonization/Extinction Modeling

We performed colonization/extinction modeling (MacKenzie et al. 2003) to explore site fidelity and nomadism of Short-eared Owls across our study area. Because the owls in our study area were not marked and individually identifiable, measures of site fidelity and nomadism were not intended to reflect the behavior of individuals. We analyzed our multiple year data on a state-by-state basis to provide better insight into how occupancy rates varied year to year across the region. We analyzed the overall results by land cover (compositional land cover) to see if some land cover classes were more susceptible to colonization and extinction.

5.2.12 Boosted Regression Tree Modeling

We chose to implement a new analysis in 2020 based upon Generalized Boosted Regression Tree modeling (Ridgeway 1999, 2020). We chose boosted regression trees to bridge the gap between our multi-scale occupancy models that tend to select only the few most important predictor variables and MaxEnt which has a tendency to be overly optimistic and uses many variables. Boosted regression trees have been shown to outperform both other approaches (Shafizadeh-Moghadam et al. 2018).

As both our grid scale land cover and climate data were based upon long-term datasets and not yearly measures, we did not analyze across study years. Instead, we merged the last five years of survey data together generating a list of grid cells where Short-eared Owls had and had not been detected on our formal surveys. We then integrated the grid-scale compositional principal components for land cover, geographic features (elevation, slope, ruggedness), and the 19 worldclim (Fick and Hijmans 2017) climate variables as predictors into the modeling.

We followed the general procedure recommended by Elith et al. (2008) to balance model fitting and predictive performance. We set tree complexity to 10 and lowered the learning rate until we settled on a

model with more than 1000 trees being chosen. While not required, we simplified the predictor set by removing variables until the average change in deviance exceeded the original standard error of deviance. We presented the resulting variable's impact by predicting owl occupancy by ranging each variable value over the measured range while holding all others at their median values. We presented the estimated contribution of each variable as suggested by Friedman (2001).

5.2.13 Maximum Entropy Modeling

For the MaxEnt analyses, we used the same base Landfire dataset (US Geological Survey 2012), integrated in a different way. We produced study-wide raster maps of the proportion of each cover type (e.g., shrubs, sage, grass, etc.) within 150 m of each 30 m × 30 m pixel on the landscape. Similarly, we created study-wide maps of elevation and an ecological relevant sample of the 19 standard climate variables derived from 1970 – 2000 (worldclim.org; Fick and Hijmans 2017). All values were then resampled down to 30-second blocks (~1 km; the resolution of the climate data) using bilinear interpolation.

We used all presence and pseudo-absence (locations that we failed to detect owls but cannot be certain that they were absent) observations from the past five years in the analysis (2016 – 2020). The result is that the model best represents Idaho and Utah with five years of data, Nevada and Wyoming each with four years of data, and the other four western states with only three years of data. We evaluated the MaxEnt model feature classes (linear, quadratic, hinge) using AIC_c (Shcheglovitova and Anderson 2013). Some caution should be applied in the interpretation of MaxEnt output particularly as the models project conditions beyond the areas and beyond the cover types specifically sampled by our program.

For future climate projections, we used the same top MaxEnt model, but applied future climate model data instead of recent climate data. Future climate data were derived from the Fifth Assessment of the Intergovernmental Panel on Climate Change (IPCC AR5) using the Hadley Centre Global Environment Model version 2 and Representative Conservation Pathway 4.5 projected to the year 2070 (RCP4.5; Moss et al. 2008). This dataset assumes a radiative forcing value of +4.5 in the year 2100 relative to pre-industrial values, a conservative model that assumes considerable reductions in the rate of growth in current greenhouse gas emissions. For the future projections, we held the habitat variables at their current level, an assumption that is not likely to hold true as changes in climate will likely result in changes in habitat available.

5.3 STATISTICAL SOFTWARE

We present graphical representations of estimated effect size with 95% confidence intervals to align with the majority of scientific literature. We conducted all statistical analyses in Program R and Program Mark (White and Burnham 1999, R Core Team 2019). We used the R package “RMark” to interface between Program R and Program Mark for the multi-scale occupancy modeling (Laake 2014). We used R package “AICcmodavg” to rank all models (calculating AIC_c), and to perform model averaging (Mazerolle 2015). We used R package “unmarked” for colonization/extinction modeling (Fiske and Chandler 2011). We used R package “dismo” (Hijmans et al. 2017), interfacing with the MaxEnt software engine (Phillips et al. 2017), for all MaxEnt analyses. We used R package “ENMeval” for ranking and evaluating MaxEnt models (Muscarella et al. 2014). We used R package “gbm” for the Generalized Boosted Regression Tree modeling (Ridgeway 2020). We fit generalized linear mixed models by using R package “lme4” (Bates et al. 2020).

6 LITERATURE CITED

- Abernathy, E. V., J. M. Hull, A. M. Fish, and C. W. Briggs. 2018. Secondary anticoagulant rodenticide exposure in migrating juvenile Red-tailed Hawks (*Buteo jamaicensis*) in relationship to body condition. *Journal of Raptor Research* 52:225–230.
- Aitchison, J. 1986. *The Statistical Analysis of Compositional Data*. Monographs on Statistics and Applied Probability. Chapman & Hall Ltd., London. (Reprinted in 2003 with additional material by The Blackburn Press).
- Abdi, H., and L. J. Williams. 2010. Principal component analysis. *Wiley Interdisciplinary Reviews: Computational Statistics* 2:433–459.
- Arnold, T. W. 2010. Uninformative parameters and model selection using Akaike's Information Criterion. *Journal of Wildlife Management* 74:1175–1178.
- Bates, D., M. Maechler, B. Bolker, S. Walker, R. H. B. Christensen, H. Singmann, B. Dai, F. Scheipl, G. Grothendieck, P. Green, and J. Fox. 2020. R Package: lme4. Linear Mixed-Effects Models using 'Eigen' and S4. Version: 1.1-23.
- Bock, C. E., V. A. Saab, T. D. Rich, and D. S. Dobkin. 1993. Effects of livestock grazing on Neotropical migratory landbirds in western North America. Pages 296-309 in D. M. Finch and P. W. Stangel, editors. Status and management of Neotropical migratory birds. U.S.D.A. Forest Service, General Technical Report RM-229.
- Booms, T. L., G. L. Holroyd, M. A. Gahbauer, H. E. Trefry, D. A. Wiggins, D. W. Holt, J. A. Johnson, S. B. Lewis, M. D. Larson, K. L. Keyes, and S. Swengel. 2014. Assessing the status and conservation priorities of the Short-Eared Owl in North America. *Journal of Wildlife Management* 78:772–778.
- Burnham, K., and D. Anderson. 2002. *Model selection and multi-model inference: a practical information-theoretic approach*. Second Edition. Springer-Verlag, New York, New York, USA.
- Calladine, J., G. Garner, C. Wernham, and N. Buxton. 2010. Variation in the diurnal activity of breeding Short-eared Owls *Asio flammeus*: implications for their survey and monitoring. *Bird Study* 57:89–99.
- Callaghan, C. T., and D. E. Gawlik. 2015. Efficacy of eBird data as an aid in conservation planning and monitoring. *Journal of Field Ornithology* 86:298-304.
- Chandler, R. B., J. A. Royle, and D. I. King. 2011. Inference about density and temporary emigration in unmarked populations. *Ecology* 92:1429–1435.
- Clark, R. J. 1975. A field study of the Short-Eared Owl, *Asio flammeus* (Pontoppidan), in North America. *Wildlife Monographs* 47:3–67.
- Coulloudon B., K. Eshelman, J. Gianola, N. Habich, L. Hughes, C. Johnson, M. Pellant, P. Podborny, A. Rasmussen, B. Robles, P. Shaver, J. Spehar, and J. Willoughby. 1999. Sampling vegetation attributes. Interagency Technical Reference/U.S. Department of the Interior, Bureau of Land Management, Denver, Colorado, USA
- Dechant, J. A., M. L. Sondreal, D. H. Johnson, H. Douglas, L. D. Igl, C. M. Goldade, MP. Nenneman, and B. R. Euliss. 2001. Effects of management practices on grassland birds: Short Eared Owl. USGS Northern Prairie Wildlife Research Center.
- Doherty, P. F., G. C. White, and K. P. Burnham. 2010. Comparison of model building and selection strategies. *Journal of Ornithology* 152:317–323.
- eBird Basic Dataset. 2020. Version: EBD_relOct-2020. Cornell Lab of Ornithology, Ithaca, New York. Accessed: Oct 2020.
- Elith, J., J. R. Leathwick, and T. Hastie. 2008. A working guide to boosted regression trees. *Journal of Animal Ecology* 77:802–813.
- Fick, S. E., and R. J. Hijmans. 2017. Worldclim 2: New 1-km spatial resolution climate surfaces for global land areas. *International Journal of Climatology* 37:4302-4315.
- Fiske, I., and R. Chandler. 2011. Unmarked: an R package for fitting hierarchical models of wildlife occurrence and abundance. *Journal of Statistical Software* 43:1–23.
- Fondell, T. F., and I. J. Ball. 2004. Density and success of bird nests relative to grazing on western Montana grasslands. *Biological Conservation* 117:203–213.

- Friedman, J. H. 2001. Greedy function approximation: a gradient boosting machine. *Annals of Statistics* 29:1189–1232.
- Gelbard, J. L., and J. Belnap. 2003. Roads as conduits for exotic plant invasions in a semiarid landscape. *Conservation Biology* 17:420–432.
- Hijmans, R. J., S. E. Cameron, J. L. Parra, P. G. Jones, and A. Jarvis. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25: 1965–1978
- Hijmans, R. J., S. Phillips, J. Leathwick, and J. Elith. 2017. dismo: Species Distribution Modeling. R package version 1.1-4.
- Holt, D. W., R. Berkley, C. Deppe, P. L. Enriquez-Rocha, P. D. Olsen, J. L. Petersen, J. L. Rangel-Salazar, K. P. Segars, and K. L. Wood. 1999. Strigidae species accounts. Pages 153–242 in J. del Hoyo, A. Elliott, and J. Sargatal (Editors). *Handbook of the birds of the world. Volume 5*. Lynx, Barcelona, Spain.
- Johnson, D. H., S. R. Swengel, and A. B. Swengel. 2013. Short-Eared Owl (*Asio flammeus*) occurrence at Buena Vista Grassland, Wisconsin, during 1955–2011. *Journal of Raptor Research* 47:271–281.
- Kamp, J., S. Oppel, H. Heldbjerg, T. Nyegaard, and P. F. Donald. 2016. Unstructured citizen science data fail to detect long-term population declines of common birds in Denmark. *Diversity and Distributions* 22:1024–1035.
- Kelly, T. R., R. H. Poppenga, L. A. Woods, Y. Z. Hernandez, W. M. Boyce, F. J. Samaniego, S. G. Torres, and C. K. Johnson. 2014. Causes of mortality and unintentional poisoning in predatory and scavenging birds in California. *Veterinary Record Open* 1:e000028. <https://doi.org/10.1136/vropen-2014-000028>.
- Korpimäki, E., and K. Norrdahl. 1991. Numerical and functional responses of Kestrels, Short-Eared Owls, and Long-eared Owls to vole densities. *Ecology* 72:814–826.
- Laake, J. L. 2014. RMark: An R interface for analysis of capture-recapture data with MARK. AFSC Processed Rep 2013-01, 25p. Alaska Fisheries Science Center, Seattle, WA.
- Langham, G. M., J. G. Schuetz, T. Distler, C. U. Soykan, and C. Wilsey. 2015. Conservation status of North American birds in the face of future climate change. *PLoS ONE* 10(9):e0135350.
- Larson, M. D., and D. W. Holt. 2016. Using roadside surveys to detect Short-eared Owls: A comparison of visual and audio techniques. *Wildlife Society Bulletin* 40:339–345.
- Lebreton, J. D., K. P. Burnham, J. Clobert, and D. R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. *Ecological Monographs* 62:67–118.
- Linnell, K. E., and B. E. Washburn. 2018. Assessing owl collisions with US Civil and US Air Force aircraft. *Journal of Raptor Research* 52:282–290.
- MacKenzie, D. I., J. D. Nichols, J. E. Hines, M. G. Knutson, and A. B. Franklin. 2003. Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. *Ecology* 84:2200–2207.
- Mazerolle, M. J. 2015. AICcmodavg: Model selection and multimodel inference based on (Q)AIC(c). R package version: 2.0-3. [online] URL: <http://CRAN.R-project.org/package=AICcmodavg>.
- McCune, B., and J. B. Grace. 2002. Analysis of ecological communities. MjM Software Design, Gleneden Beach, OR.
- Miller, R. A., N. Paprocki, M. J. Stuber, C. E. Moulton, and J. D. Carlisle. 2016. Short-Eared Owl (*Asio flammeus*) surveys in the North American Intermountain West: Utilizing citizen scientists to conduct monitoring across a broad geographic scale. *Avian Conservation and Ecology* 11(1):3.
- Moss, R., M. Babiker, S. Brinkman, E. Calvo, T. Carter, J. Edmonds, I. Elgizouli, S. Emori, L. Erda, K. Hibbard, R. Jones, M. Kainuma, J. Kelleher, J. F. Lamarque, M. Manning, B. Matthews, J. Meehl, L. Meyer, J. Mitchell, N. Nakicenovic, B. O’Neill, R. Pichs, K. Riahi, St. Rose, P. Runci, R. Stouffer, D. van Vuuren, J. Weyant, T. Wilbanks, J. P. van Ypersele, and M. Zurek. 2008. Towards new scenarios for analysis of emissions, climate change, impacts, and response strategies. Geneva: Intergovernmental Panel on Climate Change. Tech Report. p. 132.

- Moulton, C. E., R. S. Brady, and J. R. Belthoff. 2006. Association between wildlife and agriculture: underlying mechanisms and implications in Burrowing Owls. *Journal of Wildlife Management* 70:708–716.
- Murray, M. 2017. Anticoagulant rodenticide exposure and toxicosis in four species of birds of prey in Massachusetts, USA, 2012–2016, in relation to use of rodenticides by pest management professionals. *Ecotoxicology* 26:1041–1050.
- Muscarella, R., P. J. Galante, M. Soley-Guardia, R. A. Boria, J. Kass, M. Uriarte, and R. P. Anderson. 2014. ENMeval: An R package for conducting spatially independent evaluations and estimating optimal model complexity for ecological niche models. Version 0.2.2. *Methods in Ecology and Evolution* 5:1198–1205.
- National Audubon Society. 2012. The Christmas Bird Count historical results. [online] URL: <http://www.christmasbirdcount.org> Accessed: 22 Nov 2015.
- National Audubon Society. 2014. Short-Eared Owl. The Audubon Birds Climate Change Report. [online] URL: <http://climate.audubon.org/birds/sheowl/short-eared-owl> Accessed 17 Jan 2016.
- Newton, I. 2008. The migration ecology of birds. Academic Press, San Diego, CA.
- Nichols, J. D., L. L. Bailey, A. F. O'Connell Jr., N. W. Talancy, E. H. C. Grant, A. T. Gilbert, E. M. Annand, T. P. Husband, and J. E. Hines. 2008. Multi-scale occupancy estimation and modeling using multiple detection methods. *Journal of Applied Ecology* 45:1321–1329.
- Pacific Flyway Council. 2015. Pacific Flyway Council Recommendations and Information Notes, September 2015. Pacific Flyway Council, U.S. Fish and Wildlife Service, Portland, OR.
- Pacific Flyway Council. 2018. Rodenticide Effects on Raptors. Pacific Flyway Council, U.S. Fish and Wildlife Service, Portland, OR.
- Pavlacky Jr., D. C., J. A. Blakesley, G. C. White, D. J. Hanni, and P. M. Lukacs. 2012. Hierarchical multi-scale occupancy estimation for monitoring wildlife populations. *Journal of Wildlife Management* 76:154–162.
- Pawlowsky-Glahn, V., J. J. Egozcue, and R. Tolosana-Delgado. 2011. Lecture notes on Compositional Data Analysis. [online] URL: <http://www.compositionaldata.com/>
- Phillips, S. J., R. P. Anderson, and R. E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190:231–259.
- Phillips, S. J., M. Dudík, and R. E. Schapire. 2017. Maxent software for modeling species niches and distributions (Version 3.4.1). [online] URL: http://biodiversityinformatics.amnh.org/open_source/maxent/. Accessed on 6 September 2019.
- R Core Team. 2019. R: a language and environment for statistical computing. Version 3.6.1. R Foundation for Statistical Computing, Vienna, Austria. [online] URL: <http://www.R-project.org/>
- Ries, L., and K. Oberhauser. 2015. A citizen army for science: quantifying the contributions of citizen scientists to our understanding of monarch butterfly biology. *BioScience* 65:419–430.
- Ridgeway, G. 1999. The state of boosting. *Computing Science and Statistics* 31:172–181.
- Ridgeway, G. 2020. Generalized boosted models: a guide to the gbm package. [online] URL: <https://cran.r-project.org/web/packages/gbm/vignettes/gbm.pdf>
- Sauer, J. R., D. K. Niven, J. E. Hines, D. J. Ziolkowski, Jr, K. L. Pardieck, J. E. Fallon, and W. A. Link. 2017. The North American Breeding Bird Survey, Results and Analysis 1966 - 2015. Version 2.07.2017 USGS Patuxent Wildlife Research Center, Laurel, MD [online] URL: <http://www.mbr-pwrc.usgs.gov/bbs/bbs.html> Accessed 15 September 2017.
- Schlaich, A. E., R. H. G. Klaassen, W. Bouten, C. Both, and B. J. Koks. 2015. Testing a novel agri-environment scheme based on the ecology of the target species, Montagu's Harrier *Circus Pygargus*. *Ibis* 157:713–721.
- Shafizadeh-Moghadam, H., R. Valavi, H. Shahabi, K. Chapi, and A. Shirzadi. 2018. Novel forecasting approaches using combination of machine learning and statistical models for flood susceptibility mapping. *Journal of Environmental Management* 217:1–11.

- Shirk, J. L., H. L. Ballard, C. C. Wilderman, T. Phillips, A. Wiggins, R. Jordan, E. McCallie, M. Minarchek, B. V. Lewenstein, M. E. Krasny, and R. Bonney 2012. Public participation in scientific research: a framework for deliberate design. *Ecology and Society* 17:207–227.
- Shcheglovitova, M., and R. P. Anderson. 2013. Estimating optimal complexity for ecological niche models: A jackknife approach for species with small sample sizes. *Ecological Modelling* 269:9–17.
- Stevens Jr., D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* 99:262–278.
- Swengel, S. R., and A. B. Swengel. 2014. Short-eared Owl abundance and conservation recommendations in relation to site and vegetative characteristics, with notes on Northern Harriers. *Passenger Pigeon* 76:51–68.
- U.S. Geological Survey. 2012. LANDFIRE: LANDFIRE Existing Vegetation Type layer. [Online]. <http://www.landfire.gov/viewer/>
- Village, A. 1987. Numbers, territory-size and turnover of Short-Eared Owls *Asio flammeus* in relation to vole abundance. *Ornis Scandinavica* 18:198–204.
- Ware, H. E., C. J. W. McClure, J. D. Carlisle, and J. R. Barber. 2015. A phantom road experiment reveals traffic noise is an invisible source of habitat degradation. *Proceedings of the National Academy of Sciences* 112:12105–12109.
- West, N. E. 2000. Synecology and disturbance regimes of sagebrush steppe ecosystems. Pages 15–26 in Entwistle, P. G., A. M. DeBolt, J. H. Kaltenecker, and K. Steenhof (Editors.). Proceedings: sagebrush steppe ecosystems symposium June 21-23, 1999 Boise, Idaho USA. U. S. Bureau of Land Management publication no. BLM/ID/PT-001001+1150, Boise, Idaho, USA.
- White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. *Bird Study* 46 Supplement:120–138.
- Wiggins, D. A., D. W. Holt, and S. M. Leasure. 2006. Short-eared Owl (*Asio flammeus*), The Birds of North America Online, Poole, A. (Editor). Ithaca: Cornell Lab of Ornithology;
- Zuur, A. F., E. N. Ieno, and C. S. Elphick. 2010. A protocol for data exploration to avoid common statistical problems. *Methods in Ecology and Evolution* 1:3–14.
- Zuur, A. F., E. N. Ieno, N. J. Walker, A. A. Saveliev, and G. M. Smith. 2009. Mixed Effects Models and Extensions in Ecology with R. Springer, New York, NY.

7 APPENDIX I: EBIRD DATA COMPARISON

While not an official part of our program objectives, we decided to evaluate eBird data as a possible less expensive alternative to implementing the full Project WAfLS surveys. The eBird dataset represents worldwide reports of bird species observed, contributed by community-scientists into a central repository (eBird Basic Dataset 2020). The eBird system includes a complex set of checks and balances to try to maintain data quality and the data is freely available to researchers.

We chose to compare and report effort-adjusted eBird observations of Short-eared Owls against our model-developed occupancy rates. We first downloaded the entire United States observation database. We filtered this database down to our years of interest (2015 – 2020), our months of interest (March – June), and our States of interest. We normalized the Short-eared Owl observations by total eBird effort by dividing the number of Short-eared Owl observations in a given year and State by the total number of eBird checklists for that year and State that fall within the survey stratum for Project WAfLS. We reported this rate as the number of Short-eared Owl checklists per 100 total checklists. We reported and plotted the Pearson’s correlation by State.

The number of eBird checklists submitted within our survey stratum and survey window has grown steadily over the past six years in nearly all of our States (Table 11).

Table 11. Number of eBird checklists with Short-eared Owls and total checklist, within our survey stratum and survey window (March-June), by year, and by State.

	2015		2016		2017		2018		2019		2020	
	Owl Checklists	Total Checklists										
CA	42	8,833	72	9,665	100	11,654	250	13,873	113	16,063	51	17,500
ID	168	4,394	131	4,244	132	5,877	254	7,445	96	8,437	151	11,569
MT	236	6,516	139	8,570	475	10,630	227	11,118	452	10,653	168	11,320
NV	3	589	25	601	16	678	7	924	3	956	10	722
OR	229	9,232	151	10,462	73	12,048	159	13,261	212	16,474	167	15,688
UT	130	2,492	167	2,656	137	3,251	195	3,734	28	4,243	164	4,027
WA	88	5,606	48	6,374	175	8,355	149	11,125	65	11,294	132	11,596
WY	50	2,279	49	2,723	11	4,336	35	5,883	18	6,456	76	7,924
Total	946	39,941	782	45,295	1,119	56,829	1,276	67,363	987	74,576	919	80,346

The correlation of eBird reports of Short-eared Owls and our calculated occupancy rates, ranged widely between states, from -0.98 in Oregon to 0.99 in Montana (Figure 11). The relative magnitude among states for eBird also largely aligned with the magnitude of our occupancy rates, except for Utah, where the eBird magnitude was relatively higher (Figure 11).

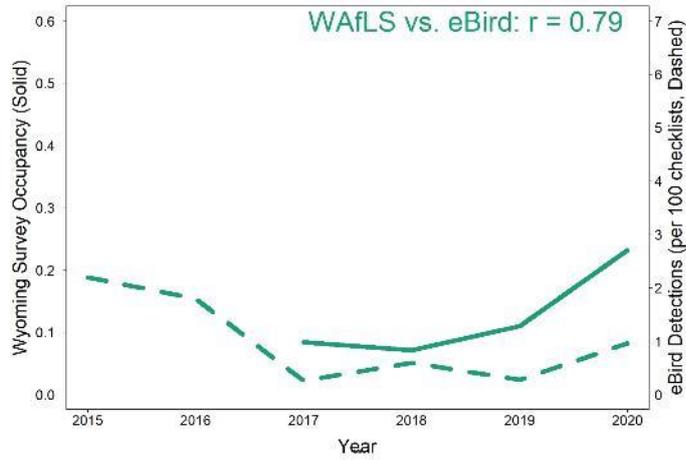
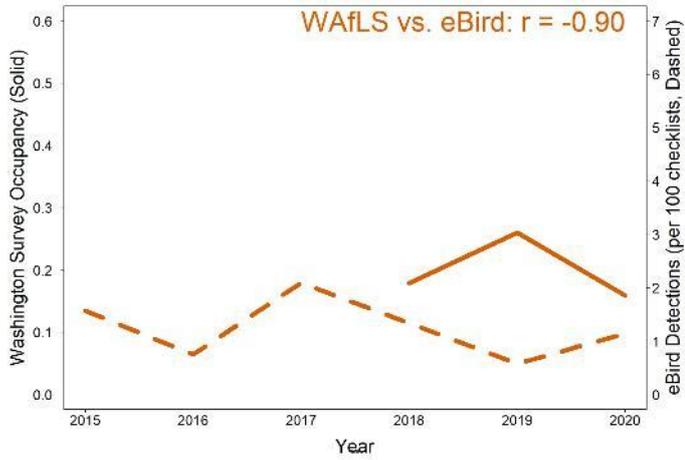
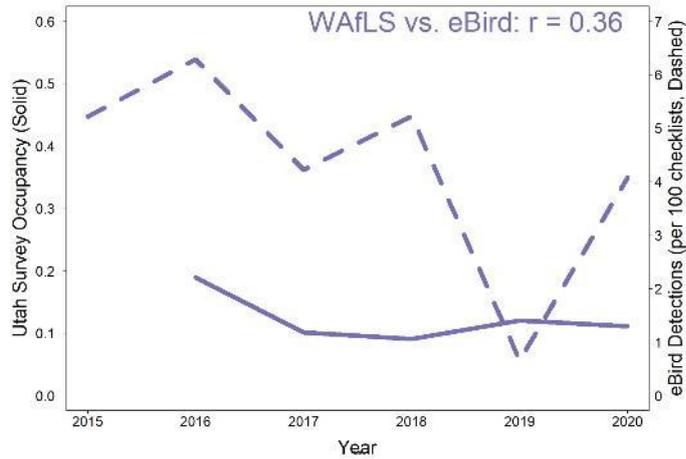
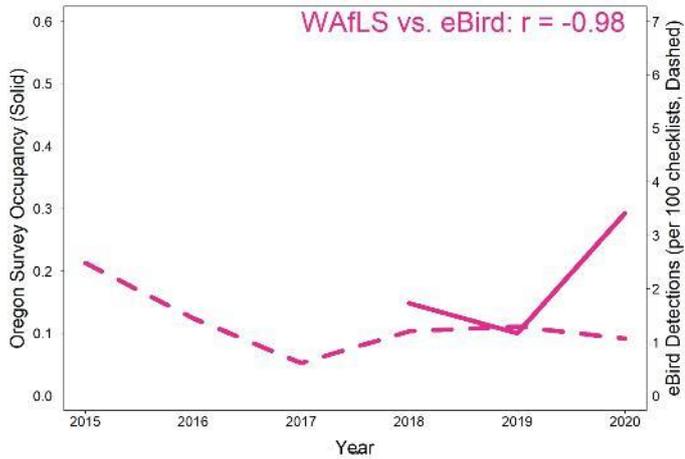
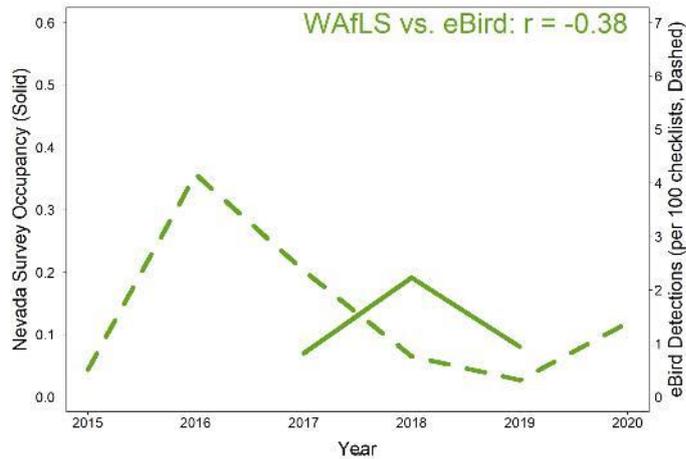
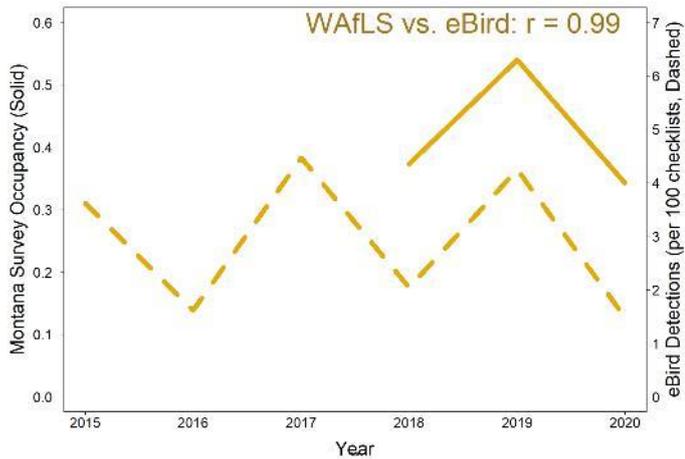
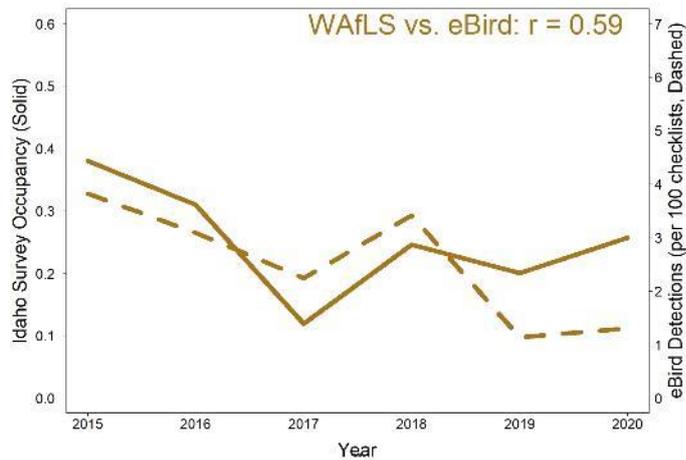
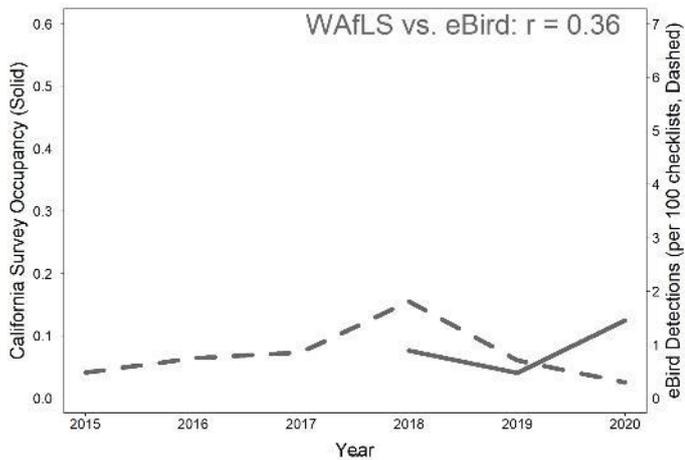


Figure 11. Project WAfLS survey occupancy rates (left axis, solid line) as compared to eBird reports of Short-eared Owls, per 100 checklists between March and June of each year, within our defined survey stratum (right axis, dashed line).

8 APPENDIX II: 2020 SURVEY PROTOCOL

Western Asio flammeus Landscape Survey (WAfLS) Protocol

Protocol Version: 2020a

Equipment Needed:

1) GPS unit or Smartphone. We will use “decimal degrees” for all coordinates (e.g., IBO Offices are located at 43.605187°, -116.211022°). There are many free smartphone apps to provide you with GPS coordinates. Here are some suggestions:

Android: Try “Polaris GPS Navigation: Hiking, Marine, Offroad” by DS Software. Open app and tap the center star for coordinates. Select the coordinate type in the upper right “...” and choose “Degrees”.

iPhone: Try “Current Altitude Free” from Hearn Apps, LLC.
or: “Easy GPS” from 2kit consulting
or: “Free GPS” from CodeBurners

- 2) datasheet and map
- 3) civil twilight times for your grid (Please download from program website for official times)
- 4) clipboard (or hard surface to write on) and writing utensil (pen preferred)
- 5) binoculars
- 6) stopwatch or clock to keep track of minute-by-minute intervals of the survey.
- 7) survey partner (optional... but it’s easier and more fun with two people; record # of observers)
- 8) this survey protocol (for reference)
- 9) flashlight for reading datasheet at last point

Dates of Surveys:

Surveys should be conducted during the period of short-eared owl (SEOW) pair formation. These dates vary by state and by elevation so check the information for the grid you signed up for (also in Table 1). Surveys must be done between these dates. Each survey route assigned to you should be surveyed twice during this period – once during the first 3-week visit window, and once during the second 3-week visit window. We prefer to have at least one week between the two visits, but this is not required.



Table 1. Suggested survey timing for each of the two visits derived from mean elevation of the survey grid cell and expected courtship period of Short-eared Owls within each participating state.

CA, ID, OR, WA	Elevation below 4000ft.	Elevation 4000 - 6000ft.	Elevation above 6000ft.	
Visit 1	March 1 - March 21st	March 16 - April 7th	April 1st - April 21st	
Visit 2	March 22nd - April 15th	April 8th - April 30th	April 22nd - May 15th	
MT	Elevation below 4000ft.	Elevation 4000 - 6000ft.	Elevation above 6000ft.	
Visit 1	March 16 - April 7th	April 1st - April 21st	April 15th - May 6th	
Visit 2	April 8th - April 30th	April 22nd - May 15th	May 7th - May 28th	
NV, UT	Elevation below 5000ft.	Elevation 5000 - 6000ft.	Elevation above 6000ft.	
Visit 1	March 1 - March 21st	March 16 - April 7th	April 1st - April 21st	
Visit 2	March 22nd - April 15th	April 8th - April 30th	April 22nd - May 15th	
WY	Elevation below 5000ft.	Elevation 5000 - 6000ft.	Elevation 6000 - 7000ft.	Elevation above 7000ft.
Visit 1	March 10 - March 31st	March 24 - April 14th	April 7th - April 28th	April 14th - May 5th
Visit 2	April 1st - April 22nd	April 15th - May 6th	April 29th - May 20th	May 6th - May 27th

Timing of Surveys:

Surveys should be conducted during the time of day when Short-eared Owl courtship is occurring and can be seen by a human observer. Therefore, surveys **must** be performed over 90 total minutes, between 100 minutes and 10 minutes before the end of civil twilight (later than sunset, defined to be when the sun is 6 degrees below the horizon) for the township you are in. We have created an online table for each survey route and date. Please look up survey start time and end time prior to leaving for your survey. These times are specific for your route and for your day of survey. Do NOT start early. If you survey outside of these times, we cannot use your data.

Weather:

Your survey should be completed during periods of good or fair weather. Clouds are fine, but you should avoid any steady rain or snow. Breezy conditions are also ok, but strong winds should be avoided. Previous survey results have found that detection rates of Short-eared Owls decrease with higher winds, probably due to observer effects and that wind may discourage owls from performing courtship flights.

Choosing Route:

If you are choosing your own route within a grid, please remember that you will need a five mile stretch of road, with as few turns as possible. The grids are 6.2 miles square, so your survey will need to span most of the grid. Choose a road with little traffic, where you can safely pull off of the road to survey. Choose a road with as much diversity as you can find (e.g., combinations of shrubland, grassland, and agriculture; the free Google Earth software is very useful for this). Zoomed in single grid maps are available on the portal. If uncomfortable with laying out the points, just ask your state volunteer coordinator for help. If your route includes a sharp turn, you will have to travel $\frac{3}{4}$ of a mile to the next point to ensure that the points are at least $\frac{1}{2}$ mile apart. If you find that your route is inaccessible due to private land access, muddy roads, or other issues, just notify us. We expect to have a few failed routes. Unfortunately, we are not able to preview all routes across all states. Note: you will survey the **same points** on each of your two visits (but these need not be the same points as used in previous years). Please consider surveying routes in the opposite order on the second visit (not required; points 1 – 11 on visit 1, and points 11 – 1 on visit 2). If you reverse the route, please remember that the point numbers must be associated with a single location – point #1 is a physical location whether you survey it first or last.

Mileage, Hours, and Affiliation:

The datasheet asks for your total round trip mileage to complete the survey (estimates are fine). These are vehicle miles and are not duplicated per person. There are three fields, one for volunteers, one for miles being paid by a non-federal agency, and the last for miles paid for by a federal agency. State and federal



employees may still be volunteers if they are on their own time and in a personal vehicle. State and NGO employees should be considered federal if their involvement is paid for with federal funds. We also want to know your total time investment (please include initial sign-up, studying, and preparation in your first visit, surveying, and data entry). Please add this up for all people participating (e.g., 2 people for 4 hours = 8 hours total). Hours are also split by whether the hours are volunteer hours or being paid by an agency (non-federal and federal). This will be used to report on the overall volunteer contribution. Affiliation refers to which birding, volunteer, or professional group(s) you heard about this opportunity through or participate in. This may include online groups. We want to recognize those organizations as well (e.g., Golden Eagle Audubon, Southwestern Idaho Birders, McCall Master Naturalists, Professional (BLM), Professional (IDFG), Idaho Birding, IBLE, ...).

Survey Procedure:

Each survey consists of *at least* 8 observation points, spaced 800 meters (0.5 miles) apart, but may extend up to 11 survey points. Active surveying is performed at each point for 5 minutes. *Arrive at the first point at least 5 minutes in advance of the beginning of the survey to organize data sheets, record weather conditions, etc.* We also suggest visiting the points and collecting habitat data prior to the survey so as to maximize the available time during the survey window.

1) Locate a start point of the survey (surveys can begin at either end of the established route) using a GPS unit or smartphone. There are many free smartphone applications that will provide you with coordinates. We will use “**decimal degrees**” for all coordinates (e.g., IBO Offices are located at 43.605187°, -116.211022°). Please record at least 5 digits to the right of the decimal point. This may require a settings change on your GPS or Smart Phone. Some units may report the longitude as 116.211022 **W** instead of -116.211022. That is fine, we will drop the “W” and add the “-“ later.

2) Identify the best vantage point within approximately 50 meters of the survey point. This vantage point may be a slight mound off the roadway, or it may be the bed of your truck, or if terrain is relatively flat, it may be the roadway in front of or behind your vehicle. Wherever you end up, make sure you have a good view of the surrounding landscape. **Please do not survey from within your car and do not trespass on private land to gain an optimal vantage point unless you have explicit permission from that landowner!**

3) At the beginning of each 5 minute survey period, begin scanning the surrounding area, including ground and sky, for any SEOW presence. Surveys should be done using a combination of scanning with binoculars and scanning with the naked eye (and, of course, listening). All SEOW observations should be recorded on the data sheet. Best efforts should be made to avoid double-counting SEOWs within each 5-minute survey, however, please note any observations at the next point if the bird is still visible.

For each Short-eared Owl detected, note how the bird was initially detected (sight or sound), which of the five minutes within the survey it was detected (indicate all minutes observed; e.g., a bird may be observed in the second, fourth and fifth minutes, but not in first or third – three checks), the general direction of the bird from your location (to nearest N, NE, E, SE, S, SW, W, NW), the estimated distance to nearest 200m (roadside power pole are roughly 100m apart), the behaviors observed, the sounds heard, and the type of habitat over which the bird was located. Only mark birds that are *positively* identified. If you are unsure, there is a separate area on the datasheet top record that.

Start Time (24h, e.g., 1843): _____ (entered in "Points Surveyed" section of portal, not "Observations" section)

Short-eared Owl Observations:

How SEOW detected (seen/heard)	Initial Distance <input checked="" type="checkbox"/>				Initial Direction (N, NE, E, ...)	Habitat where obs. (shrub, grass, ag, marsh, other)	Minutes Observed (Check all <input checked="" type="checkbox"/>)					Vocalizations/Sounds (list all - hoots, barks, screams, wing clip, bill snap)	Behavior (list all - perched, foraging, direct flight, agonistic, courtship)
	< 200m	200-400m	400-600m	> 600m			1	2	3	4	5		

Number of unconfirmed Short-eared Owl Observations: _____ (enter in "Points Surveyed" Section of data portal)

Other Focal Species Observations: Must fill in all categories (0 = none observed)

# Long-eared Owls	# Northern Harriers	# Ferruginous Hawks	# Burrowing Owls	# Long-billed Curlews	Swainson's Hawk

4) When 5 minutes of survey at a point are complete, quickly finish recording SEOW observations, recalling and recording any other positive raptor identifications you made, record the habitat (if not done prior, spend no more than 1 minute), and travel to your next survey point – 800 meters (0.5 miles) down the survey route. If you must turn a sharp corner, then travel 0.75 miles to the next point. These points should be determined by simply driving 0.5 miles in your car (or 0.75 miles if you turned a corner), stopping, and determining the best vantage point within 50 meters of your vehicle. At least 8 survey points should be completed within the 90 minute period allotted, but complete as many as you can up to 11.

Note: To complete at least 8 survey points in 90 minutes, you will have approximately 7 minutes between survey points. This is a suggestion but not necessarily a requirement. It does not matter if you only take 6 minutes between one, and then take 8 minutes between another set of points, as long as at least 8 points are completed in the 90 minute window. If road conditions do not permit the completion of all 8 points in the 90 minutes allotted, just complete as many as you can.

5) The survey is complete after 90 minutes have elapsed since the first survey began. Again, if for some reason you were unable to complete 8 points in 90 minutes, please make a note of this in the datasheet. The provided online time schedules indicate start time and the latest time to begin a point for each survey grid. After surveys are complete, **review the datasheet for completeness.**



Datasheet and Variables:

The provided datasheet has blanks for all the required survey information. Below are guidelines for each variable.

Air Temperature – measured in degrees Fahrenheit (F), to nearest 5 degrees is fine.

Wind Classification – measured using the Beaufort Wind Scale at the start point only. If wind conditions change dramatically during the survey, please make a note of this. See scale below:

- 0 = Calm: smoke rises vertically
- 1 = Light Air: Smoke drift indicates wind direction, still wind vanes
- 2 = Light Breeze: Wind felt on face, leaves rustle, vanes begin to move
- 3 = Gentle Breeze: Leaves and small twigs constantly moving, light flags extended
- 4 = Moderate Breeze: Dust, leaves, and loose paper lifted, small tree branches move
- 5 = Fresh Breeze: Small trees in leaf begin to sway
- 6 = Strong Breeze: Larger tree branches moving, whistling in wires (not recommended to survey)
- 7 = Near Gale: Whole trees moving, resistance felt walking against wind (not recommended to survey)
- 8-12 = Gale – Hurricane (DO NOT conduct survey in these conditions): Twigs breaking off trees, generally impedes progress.

Cloud Cover Classification – measured at start point only. Classified as **cloudy** (100% cloud cover), **mostly cloudy** (50-99% cloud cover), **partly cloudy** (1-49% cloud cover), and **clear** (0% cloud cover).

Owl Behavior Classification – recorded at initial detection of each individual owl (i.e. if same individual owl is re-sighted, do not change the behavioral classification) classified as **perched, foraging, direct flight, agonistic, or courtship** (Holt and Leasure 1993).

Owl Vocalizations/Sounds – any sound produced by a Short-eared Owl should be classified as **hoots, barks, screams, wing clapping, bill clapping** (Holt and Leasure 1993).

Initial Direction – Record the general direction (e.g., N, NE, E, ...) of where the bird was *first* detected.

Initial Distance – estimated distance to where the bird was first detected. This is rounded to nearest 200 meters. Roadside power poles are typically 100 meters apart. The categories are roughly less than 2 power poles, 2 – 4 power poles, 4 – 6 power poles, or greater than 6 power poles away. This is an estimate, so do your best but don't worry if it is not accurate. You can practice your distance estimation prior to the survey in case your route does not have power poles.

Habitat where owl observed – The general classification of habitat where the owl was initially observed. For example, the point habitat might be 90% shrubland and 10% riparian, but the owl was observed in the riparian vegetation. If the bird is flying, what habitat was it flying over when initially observed.

Vegetation Cover Classification – measured at each survey point. This should be recorded for each survey visit. For most points the values may not change, but agriculture could change from stubble to dirt if the field has been tilled since the last visit. This is a quick assessment. Do not spend more than about 1 minute determining habitat. If you prefer to be less rushed, you may travel the route prior to your survey to establish points and record vegetation (recommended!).

Record values to the nearest **10%**. Recorded as percentage of various land types within approximately 400 meters/yards (1/4 mile) of each survey point (half distance between points). **Values should total to 100%**. Please double check this. **Shrubland** may include grass, but is determined by at least a regular distribution of shrubs. Shrubland is split into two categories – **low** = knee height or shorter, and **high** = greater than knee

height. **Grassland** may include a few shrubs, but there should not be many and should not be regular on the landscape. Grassland has two possible categories – **cheatgrass monoculture** (dominated by short cheatgrass), and **complex grassland** (taller grasses, bunch grasses, diverse species [may also include cheatgrass]) **Agriculture** is broken down into four classes including **fallow** (land has not been used for at least a few years and is overrun by grass, weeds, and shrubs), **dirt** (ground has been tilled to bare dirt or very short stubble, not high enough to provide shelter for mice or voles), **stubble** (last year’s growth is still present and is at least a few inches tall – enough to provide some shelter and refuge for mice and voles), and **green** (new growth for this year). Pasture is considered agriculture and should be put into nearest agriculture category. **Marsh/riparian** indicates the presence of water, riparian vegetation, reeds, or cattails.

Examples:



Tall Shrub (Photo: Jimmie Yorgensen)



Low Shrub (Photo: Von Welch)



Cheatgrass Monoculture

(Photo: nature80020, Creative Commons License)



Complex Grassland (Photo: BLM)



Agriculture – Green (foreground, Photo: Elizabeth Burtner)



Agriculture – Dirt (Photo: Elizabeth Burtner)



Agriculture – Fallow (Photo: Rob Miller)



Agriculture – Stubble (Photo: Rob Miller)



Marshland (Photo: Don and Sheri Weber)

Grazing and livestock – Does the habitat around the point look grazed (very short grass, trimmed shrubs, cow-pies etc.) and how much of the landscape appears grazed? If you are unsure, put zero. If animals are present, how much of the landscape do they have access to? Also, count the number of livestock within ¼ mile (it is ok to estimate if there are large numbers).

Other Observations – At the conclusion of each 5-minute point count, record the number of Long-eared Owls, Northern Harriers, Ferruginous Hawks, Burrowing Owls, Swainson’s Hawks, or Long-billed Curlews seen or heard during the 5-minute point count. Please record the number observed, or zero if none were observed. Only these species should be entered into the data entry portal. If you wish to report other species, you are free to enter them into eBird.

Data Submission:

We ask that you submit all data into the online data portal. This can be done after each visit of the survey (preferred) or after you complete both visits (two data submissions). Also, please let your state coordinator know when you have completed a survey and when you have entered data.

Please submit your data via the online project portal no later than **May 31st**.

THANK YOU, THANK YOU, THANK YOU for contributing to this project!