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Effects of Experimental Removal of Barred Owls on Population Demography of Northern Spotted Owls in Washington and Oregon—2015 Progress Report

Open-File Report 2016–1041

U.S. Department of the Interior
U.S. Geological Survey

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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
inch (in)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
	Volume	
acre-foot	1,233.48	cubic meter

International System of Units to Inch/Pound

Multiply	By	To obtain
	Volume	
liter (L)	0.2641	gallon (gal)

Effects of Experimental Removal of Barred Owls on Population Demography of Northern Spotted Owls in Washington and Oregon—2015 Progress Report

By J. David Wiens[1], Katie M. Dugger[2], Krista E. Lewicki[1], and David C. Simon[1]

Abstract

Evidence indicates that competition with newly established barred owls (*Strix varia*) is causing rapid declines in populations of northern spotted owls (*Strix occidentalis caurina*), and that the long-term persistence of spotted owls may be in question without additional management intervention. A pilot study in California showed that lethal removal of barred owls in combination with habitat conservation may be able to slow or even reverse population declines of spotted owls at local scales, but it remains unknown whether similar results can be obtained in larger areas with different forest conditions and where barred owls are more abundant. In 2015, we implemented a before-after-control-impact (BACI) experimental design on two study areas in Oregon and Washington with at least 20 years of pre-treatment demographic data on spotted owls to determine if removal of barred owls can improve population trends of spatially associated spotted owls. Here we provide an overview of our research accomplishments and preliminary results in Oregon and Washington in 2015.

Background and Study Objectives

Barred owls (*Strix varia*) have expanded their geographic range from eastern to western North America, and their newly expanded range now completely overlaps that of the federally threatened northern spotted owl (*S. occidentalis caurina*). Evidence indicates that competition with invading barred owls is causing rapid declines in populations of spotted owls, and that the long-term persistence of spotted owls may be in question without additional management intervention (Wiens and others, 2014; Dugger and others, 2016). A pilot study in coastal California indicated that lethal removal of barred owls in combination with habitat conservation may be able to slow or even reverse population declines of spotted owls at local scales (Diller and others, 2016), but it remains unknown whether similar results can be obtained in larger areas with different forest conditions and where barred owls are more abundant.

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[1]U.S. Geological Survey.
[2]Oregon Cooperative Fish and Wildlife Research Unit.

In 2013, the U.S. Fish and Wildlife Service released a Final Environmental Impact Statement and Record of Decision for the experimental removal of barred owls to benefit northern spotted owls (U.S. Fish and Wildlife Service, 2013). Four study areas were identified with at least 20 years of pre-treatment demographic data on spotted owls to test whether competitive interactions with barred owls cause population declines of spotted owls, and if so, whether active management of barred owls can improve population trends of spotted owls. Experimental removals were initiated in Hoopa/Willow Creek in northern California in 2013. Preliminary results from that portion of the study are summarized by Higley (2014, Barred owl experimental removal: Hoopa study area end of season report) and Franklin and others (2015).

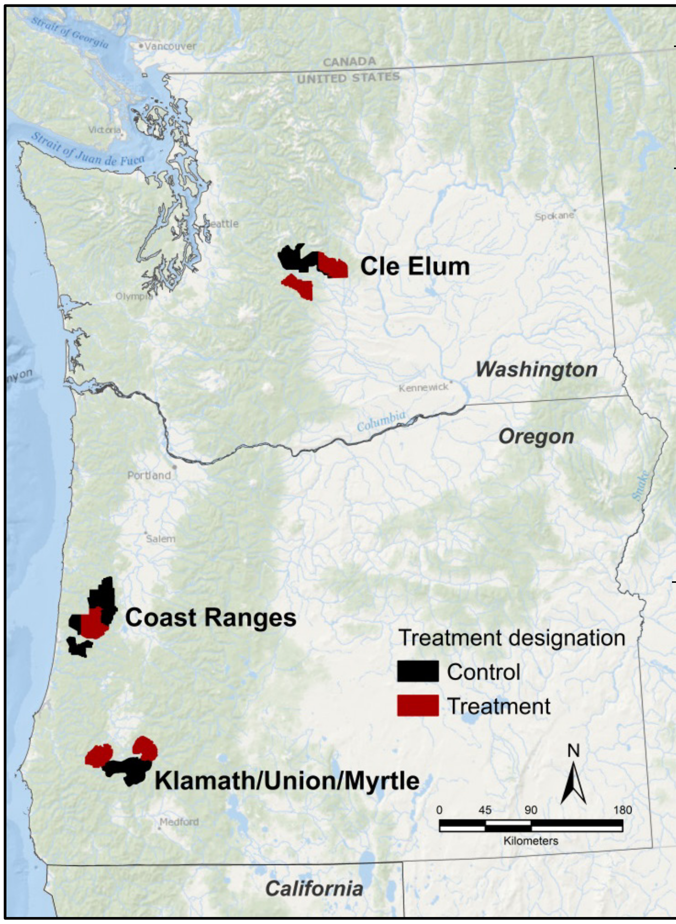
In 2015, we initiated surveys and experimental removal of barred owls in three study areas in Washington and Oregon. The overarching goal of the study is to test the research hypothesis that the presence of barred owls causes declines in the population rate of change of spotted owls (λ), or one of the demographic components driving declines in populations (survival, reproduction, recruitment, site occupancy dynamics; Johnson and others, 2008). Specific objectives are to:

1. Determine the effect of experimental removal of barred owls on population dynamics of spotted owls with respect to site-occupancy dynamics, reproductive output, survival, recruitment, and annual rate of population change (λ_t).
2. Estimate pre- and post-removal differences in the proportion of area used and intensity of use by barred owls in control and treatment portions of each study area.
3. Estimate the amount of effort and cost required to maintain low numbers of barred owls and achieve positive effects on vital rates of territorial spotted owls

Herein we provide an overview of our research accomplishments in Oregon and Washington in 2015.

Experimental Study Areas

In 2015, we initiated the study in three study areas in Washington and Oregon (fig. 1). The study areas vary in climate, vegetation composition, and topography, but all are dominated by conifer or mixed conifer-hardwood forests (Dugger and others, 2016). These areas were selected based on many considerations, including availability of pre-treatment demographic data on spotted owls, land ownership, and the need to identify the effect of barred owls on spotted owls across the broad range of forest conditions (U.S. Fish and Wildlife Service, 2013). The study areas are comprised of mostly federal lands, but fieldwork also occurred on adjacent State and private lands with the written permission of the landowner. A mixture of ownerships was included so that results and inferences from the study would not be limited to certain ownerships and forest conditions in the spotted owl's geographic range.



Study area and treatment level	Area (km²)	Number of historical spotted owl territories	Number of barred owl survey hexagons[1]
Cle Elum			
Treatment	775	45	113
Control	670	32	111
Coast Ranges			
Treatment	607	46	106
Control	1,085	58	176
Klamath/Union/Myrtle[2]			
Treatment	765	83	146
Control	755	86	136

[1]Barred owl survey hexagons are 500-ha each in size.

[2]Fieldwork on this study area was not completed in 2015 because of insufficient land access to conduct pre-treatment surveys of barred owls.

Figure 1. Control (no barred owls removed) and treatment (barred owls removed) portions of three study areas in Washington and Oregon used to examine the effects of experimental removal of barred owls on population demography of northern spotted owls.

Methods

Owl Surveys and Demographic Monitoring

This study uses species-specific surveys of spotted owls and barred owls to track annual changes in populations of both species on control and treatment portions of each study area. Surveys of spotted owls were conducted by biologists and agencies already responsible for the long-term demographic monitoring of northern spotted owls under the Northwest Forest Plan (Lint and others, 1999, Dugger and other, 2016). Under this monitoring program, spotted owls are surveyed each year to document site occupancy, locate owls, confirm bands of previously color-marked owls, band previously unmarked owls, and determine the number of young produced by territorial pairs. Demographic monitoring of spotted owls will continue in all study areas over the duration of the experiment to document post-treatment population trends.

We used a survey protocol specifically developed for barred owls (U.S. Fish and Wildlife Service, 2015) in combination with the general occupancy survey design developed by Wiens and others (2011) to track annual changes in occurrence and intensity of use of barred owls on control and treatment portions of each study area. Our sampling scheme for barred owls used a standard occupancy design (MacKenzie and others, 2002, 2006) in which a grid of 500-ha hexagons (Wiens and others, 2011) were overlaid on each study area and surveyed repeatedly over three sampling periods: March 1–May 8 (Period 1); May 9–July 17 (Period 2); and July 18–September 30 (Period 3). Sampling periods were established to approximate mean transition dates between incubation, nestling, and fledgling-dependency breeding stages of barred owls (Wiens and others, 2011, 2014). During each survey occasion, observers used an amplified megaphone (Wildlife Technologies, Manchester, N.H.) to broadcast digitally recorded barred owl calls at established call points distributed to provide complete coverage of each survey hexagon. A hexagon was considered to be used by a territorial pair of barred owls if: (1) both sexes were observed within 400 m of each other on ≥1 visits; (2) both sexes were observed perched together at the same time; or (3) at least one adult was observed with young (Wiens and others, 2011). Additional details on the survey design and field protocols we used to survey barred owls are provided in Wiens and others (2011) and U.S. Fish and Wildlife Service (2015).

Barred Owl Removals

We used well-established field protocols for experimental removal and scientific collection of barred owls (U.S. Fish and Wildlife Service, 2013; Diller and others, 2014, 2016). We primarily used lethal removal methods for barred owls. Barred owls detected in treatment areas during surveys were lethally removed using 12-gauge shotguns with non-toxic bird shot. Our protocol for removals prohibits collection of nesting barred owls with dependent young (U.S. Fish and Wildlife Service, 2013). As a consequence, removals occurred during the nonbreeding season (September–March). We anticipated frequent colonization of barred owls into areas where barred owls have been removed (Yackulic and others, 2014; Diller and others, 2014, 2016), so we conducted regular follow-up visits to determine occupancy at these sites and conduct additional removals of barred owls as needed. These efforts will ultimately permit us to estimate re-colonization rates of experimental treatment areas by barred owls following removals.

Lethal and non-lethal removal of barred owls was authorized under Federal Fish and Wildlife Permit No. M1B14305B-4, Oregon Department of Fish and Wildlife Scientific Taking Permit No. 111-15, and Washington State Scientific Collection Permit No. HENSON 15-290. All survey and removal methods, and field personnel engaged in these activities, were approved by the Institutional Animal Care and Use Committee (IACUC) at Oregon State University prior to initiating fieldwork.

Data Summary and Analysis

We used survey data on spotted owls to summarize pre-treatment occupancy and reproductive status of spotted owls on control versus treatment portions of the Cle Elum and Coast Ranges study areas. We followed Lint and others (1999) in determining site occupancy, pair status, and reproduction of spotted owls. We used Theissen polygons (Dugger and others, 2016) to delineate historical territories used by spotted owls in each study area. For barred owls, we summarized survey detections of territorial pairs obtained during the breeding season using: (1) the mean center of repeated survey detections of a territorial pair; or (2) the location of fledged young (Wiens and others, 2011). We used this method to characterize general numbers and distribution of territorial pairs of barred owls detected in control versus treatment portions of each study area, but relied on estimation methods described below to more accurately quantify and track the occurrence of barred owls in these landscapes.

Estimation of Proportion of Area Used and Intensity of Use by Barred Owls

We used single-season occupancy models (MacKenzie and others, 2002, 2006) in program MARK (White and Burnham, 1999) to estimate the probability of detecting ≥1 barred owl at sampling unit *i* during survey occasion *t*, given presence (*p*), and the proportion of sampled area used by barred owls (ψ). This method uses the spatial pattern of detections and non-detections over repeated visits to sample sites to estimate occurrence of a species while accounting for imperfect detection during surveys. A sample site in our study was a 500-ha hexagon used to survey barred owls. Territory boundaries of individual barred owls may overlap >1 survey hexagon, so we interpreted the occupancy parameter (ψ) as the probability of ≥1 barred owl using a hexagon during the breeding season (MacKenzie and others, 2006). For each study area, we considered models where detection probabilities (*p*) were held constant, varied with survey occasion (t), or increased/decreased from survey Period 1 to Period 3 (T). We assessed evidence for a pre-treatment difference in ψ and *p* between control and treatment sites by comparing support for models with and without treatment area effects. In total, we ranked eight candidate models using information-theoretic methods (Burnham and Anderson, 2002). We assessed fit of single-season occupancy models to our data using a bootstrap estimate of the Pearson's chi-square statistic (MacKenzie and Bailey, 2004).

As an alternative measure of barred owl occurrence, we explored the use of the Royle/Nichols occupancy-abundance model (Royle and Nichols, 2003) to estimate intensity of use of sample sites by barred owls. This model estimates density (λ, the average number of individuals per sample site), and assumes that detection histories among sample sites are independent. Our survey protocols minimized the likelihood of detecting the same individuals in adjacent sampling units, but we could not rule out this possibility entirely because sample plots were not centered on actual territories and barred owls were not individually marked. As a consequence, estimates of λ are likely to overestimate actual density of barred owls, so we interpreted estimates of λ as the average number of individuals using a sample unit, and r_i as the unconditional probability of detecting ≥1 barred owl at sampling unit *i* during the breeding season (Royle and Nichols, 2003). The model assumes that use intensity across sites follows a Poisson distribution (with mean=λ), so we also considered an alternative model with a negative-binomial distribution to test the validity of this assumption. We assessed evidence for pre-treatment differences between control and treatment areas in λ and r by comparing models with and without treatment area effects. We did not consider time-dependency in r because the model assumes constant detection probability within a season (Royle and Nichols, 2003). All sample sites in our analysis were of equal size (500 ha), which permitted us to estimate intensity of use for an entire study area as: $\widehat{N} = \hat{\lambda} \times n_s$, and SE($\widehat{N}$) = SE($\hat{\lambda}$) × n_s (where $\hat{\lambda}$ is the estimated mean intensity of use per sample plot, and n_s is the number of sample sites surveyed (Royle, 2004).

Research Accomplishments and Preliminary Results

We completed surveys of barred owls on the treatment and control portions of the Cle Elum and Coast Ranges study areas during March–September, and initiated removals of barred owls on treatment portions of these study areas in September. Surveys of barred owls were initiated on the Klamath/Union/Myrtle study area but were incomplete because of delays in securing land access and research agreements with private landowners. As a consequence, experimental removal was not initiated in this study area, and we focus on preliminary results from research activities completed in Cle Elum and Coast Ranges study areas only. Land access agreements are being secured to initiate surveys and experimental removal of barred owls on the Klamath/Union/Myrtle study area in March 2016.

Owl Surveys and Demographic Monitoring

Spotted Owls

Surveys of spotted owls were completed at a total of 181 territories historically used by spotted owls on the experimental portions of the Cle Elum and Coast Ranges study areas (table 1). At least one spotted owl was detected at 36 (20%) of 181 territories, whereas territorial pairs of spotted owls were detected at a total of 21 (12%) territories. Pre-treatment, naïve (i.e., uncorrected for imperfect detection) estimates of the proportion of historical territories used by spotted owls tended to be greater in control versus treatment portions of both study areas, but sample sizes were very small. Note that estimates of occupancy and reproduction of spotted owls we report here are specific to the experimental (control/treatment) portion of each long-term demographic study area, so estimates may vary from those reported for all portions of these study areas being monitored under the Northern Spotted Owl Northwest Forest Plan Monitoring Program (for additional details, see: http://www.reo.gov/monitoring/reports/northen-spotted-owl-reports-publications.shtml).

Table 1. Northern spotted owl survey effort, detections at historical territories, and reproduction on control and treatment portions of the Cle Elum and Coast Ranges experimental study areas, Washington and Oregon, 2015.

Experimental study area	Historical spotted owl territories surveyed	Territories used by ≥1 spotted owl (% of sites surveyed)	Territories used by spotted owl pair (% of sites surveyed)	Territories with ≥1 young fledged (% of sites with pairs)
Cle Elum, Washington	77	11 (14%)	7 (9%)	3 (43%)
Treatment	45	4 (9%)	2 (4%)	1 (50%)
Control	32	7 (22%)	5 (16%)	2 (40%)
Coast Ranges, Oregon	104	28 (27%)	14 (13%)	3 (21%)
Treatment	46	10 (22%)	3 (7%)	0
Control	58	18 (31%)	11 (19%)	3 (27%)

Barred Owls

We attempted to survey each barred owl sample site on three occasions, but logistical difficulties with initial access resulted in fewer than three surveys of several sites (table 2). Future surveys will be more efficient because survey routes have been established, permission to conduct surveys on all ownerships has been secured, and the number of surveyors for each study area has been increased. We surveyed barred owls at least once at 223 and 277 sample sites over three sampling periods and recorded a total of 582 and 1,222 detections of non-juvenile barred owls in the Cle Elum and Coast Ranges study areas, respectively. On average, we observed more detections of individual barred owls per 500-ha sample sites in Coast Ranges (mean=2.91 ± 1.98 [SD]) than in Cle Elum (mean=1.93 ± 1.57 [SD] barred owls detected per site; fig. 2). In many cases, we were able to detect >1 territorial pair of barred owls simultaneously from the same call-point, which permitted us to differentiate among pairs at these sites. One sample hexagon in the Oregon Coast Ranges, for example, had 10 detections of individual barred owls during a single survey occasion, which included three territorial pairs and one additional male that was apparently single.

Based on the criteria we used to summarize survey observations of territorial pairs of barred owls, we detected a total of 141 territorial pairs in Cle Elum (77 in treatment areas, 64 in control area), and 277 territorial pairs in Coast Ranges (113 in treatment area, 164 in control area; appendix A). The mean number of pairs of barred owls detected within historical territories of spotted owls (i.e., Thiessen polygons) was 1.27 ± 1.02 (SD) in Cle Elum (range = 0–4), and 1.89 ± 1.12 (SD) in the Oregon Coast Ranges (range = 0–4), with negligible pre-treatment differences between treatment and control areas.

Table 2. Barred owl survey effort and detections obtained over three survey periods in the Cle Elum and Coast Ranges experimental study areas, Washington and Oregon, 2015.

Study area	Survey period	Survey dates	Sites surveyed	Sites with ≥1 barred owl detected (% of sites surveyed)
Cle Elum, Washington	1	March 1–May 8	90	61 (68%)
	2	May 9–July 17	120	79 (66%)
	3	July 18–September 30	143	116 (81%)
	All occasions	March 1–September 30	223	173 (78%)
Coast Ranges, Oregon	1	March 1–May 8	92	80 (87%)
	2	May 9–July 17	201	154 (77%)
	3	July 18–September 30	221	191 (86%)
	All occasions	March 1–September 30	277	245 (88%)

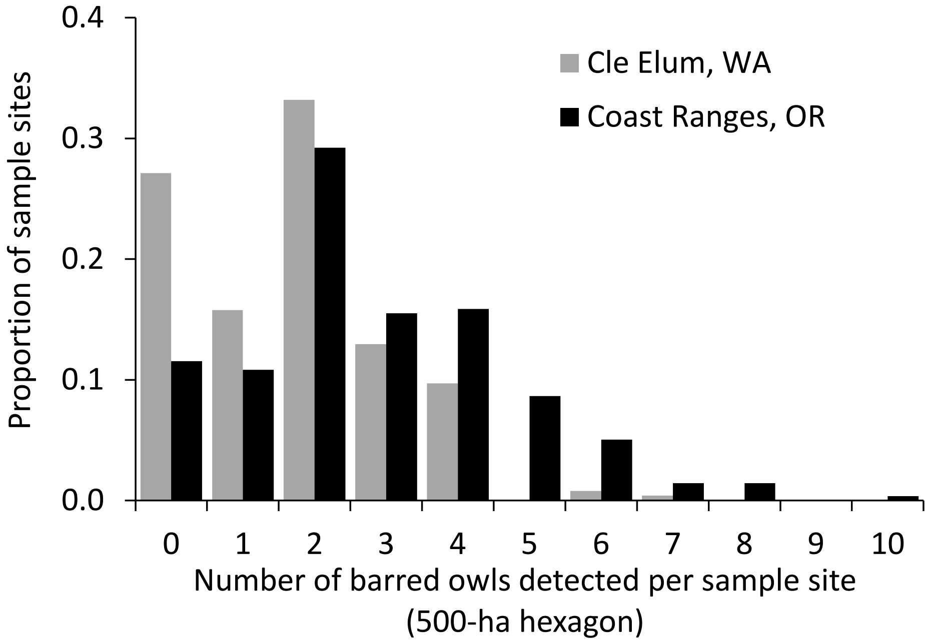


Figure 2. Proportion of sample sites (500-ha survey hexagons) with up to 10 individual barred owls detected during nighttime surveys of barred owls completed in Washington and Oregon, 2015.

Proportion of Area Used and Intensity of Use by Barred Owls

We found no evidence of lack of model fit for the Cle Elum (χ^2= 1059.0, P = 0.310, $\hat{c}$ = 1.03) or Oregon Coast Ranges (χ^2= 1411.2, P = 0.840, $\hat{c}$ = 1.02) study areas, indicating adequate fit of single-season occupancy models to survey data for barred owls. The estimated conditional probability of detecting ≥1 barred owl during a single survey occasion (p) ranged from 0.81 in Coast Ranges to 0.94 in Cle Elum (table 3). Single-season occupancy models that accounted for time-dependency among survey occasions in detection rates received greater support than models that did not (appendixes B and C). Model-averaged, pre-treatment estimates of proportion of area used (ψ) and intensity of use (λ) by barred owls varied little between treatment and control portions of each study area (table 2), and models that included an effect of treatment area on these parameters were not strongly supported by the data (appendixes B and C).

Estimates of intensity of use of control and treatment areas by barred owls (*N*) also were similar in each study area, although we observed wide confidence intervals around estimates in the Coast Ranges (table 3). Estimates of intensity of use from the Royle/Nichols model (λ, *N*) do not represent actual numbers of barred owls because individuals could have been detected in >1 sample site, which could lead to positive bias in terms of inferring density. Nonetheless, the model does permit a means to estimate use of landscapes by barred owls while accounting for large differences in the numbers of barred owls detected among sample sites (e.g., fig. 2). Future analyses will incorporate spatial data (e.g., distribution of old forest within sample plots) to account for potential sources of spatial heterogeneity in estimates of use and use intensity by barred owls. We also note that our estimates of unconditional detection (r) from the Royle/Nichols model assumed constant detection rates during the breeding season—an assumption that was probably violated given the level of within-season variation we found in the conditional probability of detection (p). We were uncertain how within-season variation in detection rates might have influenced estimates of intensity of use, but per-visit detection rates were consistently high (>80%), so bias of parameter estimates should be minimal.

Table 3. Model averaged estimates, with standard errors (SE) and lower (LCI) and upper (UCI) 95%-confidence intervals, of the proportion of area used (ψ), intensity of use of 500-ha sample sites (λ), and conditional (p) and unconditional (r) probabilities of detection for barred owls in two study areas in Washington and Oregon, 2015.

[An index of total numbers of barred owls using treatment versus control portions of each study area (N) is also included]

Parameter	Cle Elum, Washington				Coast Ranges, Oregon			
	Estimate	SE	LCI	UCI	Estimate	SE	LCI	UCI
$\psi_{treatment}$	0.835	0.038	0.747	0.896	0.969	0.020	0.891	0.992
$\psi_{control}$	0.814	0.039	0.725	0.879	0.967	0.019	0.902	0.990
$p_{period\ 1}$	0.816	0.052	0.692	0.897	0.883	0.035	0.794	0.937
$p_{period\ 2}$	0.838	0.048	0.721	0.912	0.806	0.042	0.710	0.876
$p_{period\ 3}$	0.938	0.026	0.827	0.979	0.885	0.026	0.823	0.928
$\lambda_{treatment}$	1.918	0.270	1.388	2.447	4.755	1.645	1.531	7.978
$\lambda_{control}$	1.869	0.262	1.355	2.382	4.476	1.393	1.747	7.206
r_{season}	0.679	0.070	0.529	0.799	0.378	0.109	0.197	0.601
$N_{treatment}$	427.6	60.2	309.6	545.7	1317.1	455.6	424.2	2210.0
$N_{control}$	416.7	58.4	302.2	531.2	1240.0	385.8	483.8	1996.2

Barred Owl Removals

Experimental removal of barred owls was initiated in late September in treatment portions of the Cle Elum and Coast Ranges experimental study areas, and will continue through March 2016. As a consequence, we report preliminary results through December 31, 2015 only. From September 19 to December 31, we removed a total of 254 individual barred owls in Washington and Oregon (116 females, 128 males, and 10 barred owls of undetermined sex; table 4). This represented approximately 46 and 44% of the total number of individual barred owls detected during surveys of treatment areas in Cle Elum and Coast Ranges, respectively. We anticipate the number of barred owls removed to increase as we continue to expand removal activities during January–March 2016. The preliminary sample included a minimum of 71 territorial pairs of barred owls (i.e., cases where a male and female were both collected within 150-m apart on the same removal occasion). With one exception, we used lethal removal methods for all barred owls collected. The exception was a single adult male barred owl that was captured in the Coast Ranges treatment area and transported to a permanent holding facility at the High Desert Museum in Bend, Oregon, for educational purposes.

Table 4. Total number of individual barred owls removed from treatment portions of the Cle Elum and Oregon Coast Ranges study areas, Washington and Oregon, September–December 2015.

Month, 2015	Cle Elum, Washington	Coast Ranges, Oregon
September	27	15
October	74	83
November	5	44
December	1	5
Total	107 (50 female, 54 male, 3 undetermined sex)	147 (66 female, 74 male, 7 undetermined sex)

We fired 258 shots from 12-gauge shotguns to lethally remove 253 barred owls from experimental treatment areas. We had three cases where the first shot was not lethal so a second shot was immediately taken, and two cases where a shot was taken that apparently missed the bird. Both missed shots were taken from close range (<15 yards), and in both cases the targeted owl was observed flying away into the forest canopy, apparently unharmed. Nineteen (7.5%) of 253 barred owls required euthanasia to ensure rapid death following a single, apparently non-lethal shot. Euthanasia was administered immediately following a non-lethal shot using a Ballista penetrating bolt device (Bunny Rancher, Frankfort ME) approved for use on barred owls by the IACUC. We successfully recovered 252 carcasses of barred owls following lethal removal; we were unable to recover the carcass of one female barred owl in Cle Elum that got stuck in a tree that was unsafe to climb.

Schedule to Completion

Year	Tasks
Year 1 (2015)	• Survey both species on control and treatment areas (March–August) • Initiate removals of barred owls on designated treatment areas in Coast Ranges (COA) and Cle Elum (CLE; September–December) • **Year 1 progress report** summarizing surveys and removals (February 2016)
Year 2 (2016)	• Continue removal of barred owls on COA and CLE treatment areas during the non-breeding season (January–March) • Survey both species on control and treatment areas (March–August); initiate pre-treatment surveys on Klamath (KLA) • Conduct removals of barred owls on designated treatment areas in COA and CLE; initiate removals on KLA (September–December) • **Year 2 progress report** including a preliminary analysis of first-year treatment effects on barred owls in COA and CLE (January 2017)
Year 3 (2017)	• Conduct opportunistic removal of barred owls in all treatments (January–March) • Survey both species on control and treatment areas (March–August) • Conduct removals of barred owls on designated treatment areas (September–December) • **Year 3 progress report** (January 2018)
Year 4 (2018)	• Conduct opportunistic removal of barred owls (January–March) • Survey both species on control and treatment areas (March–August) • Conduct removals of barred owls on designated treatment areas (September–December) • **Year 4 progress report** including an assessment of treatment effect on occupancy, survival, and λ_t of spotted owls; determine study area-specific need to continue experiment for additional year(s) in COA and CLE
Year 5 (2019)	• If needed and decided upon by all study participants based on results of study in Year 4, conduct additional removals of barred owls on designated treatment areas (January–March) • Conduct opportunistic removals of barred owls on KLA (September–December) • Survey both species on control and treatment areas (March–August) • **Year 5 progress report** including an assessment of treatment effect on occupancy, survival, and λ_t of spotted owls; determine need to continue experiment for additional year(s) (January 2019)

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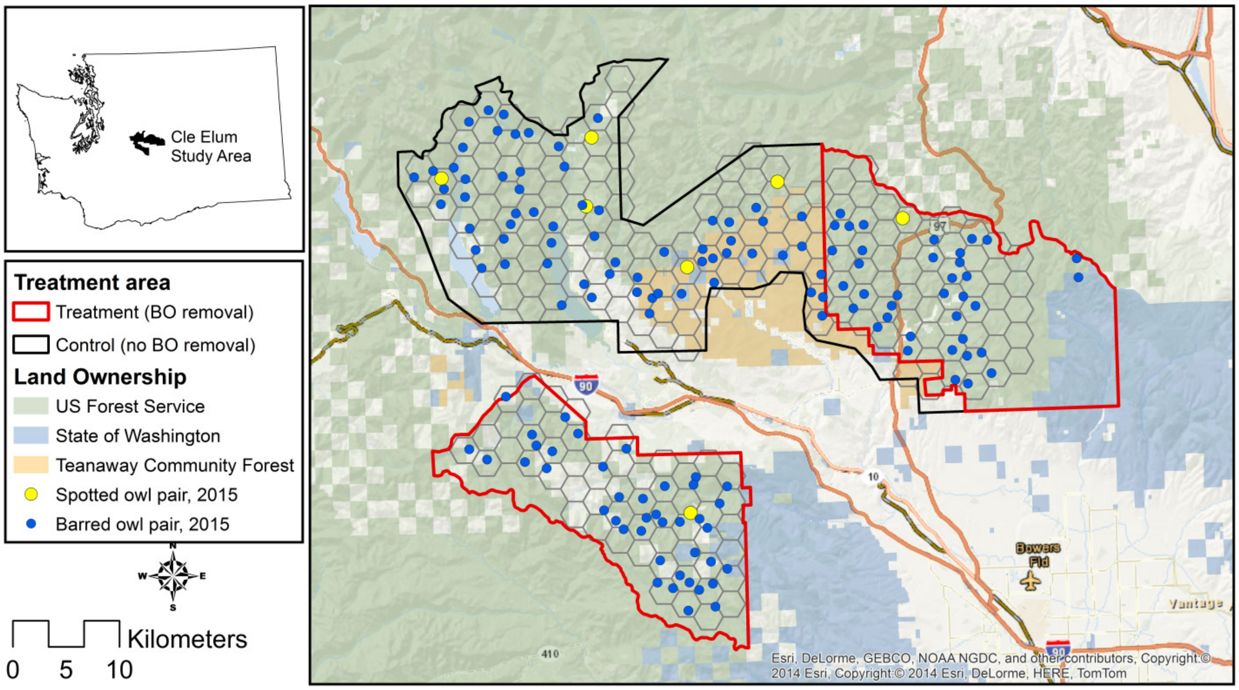
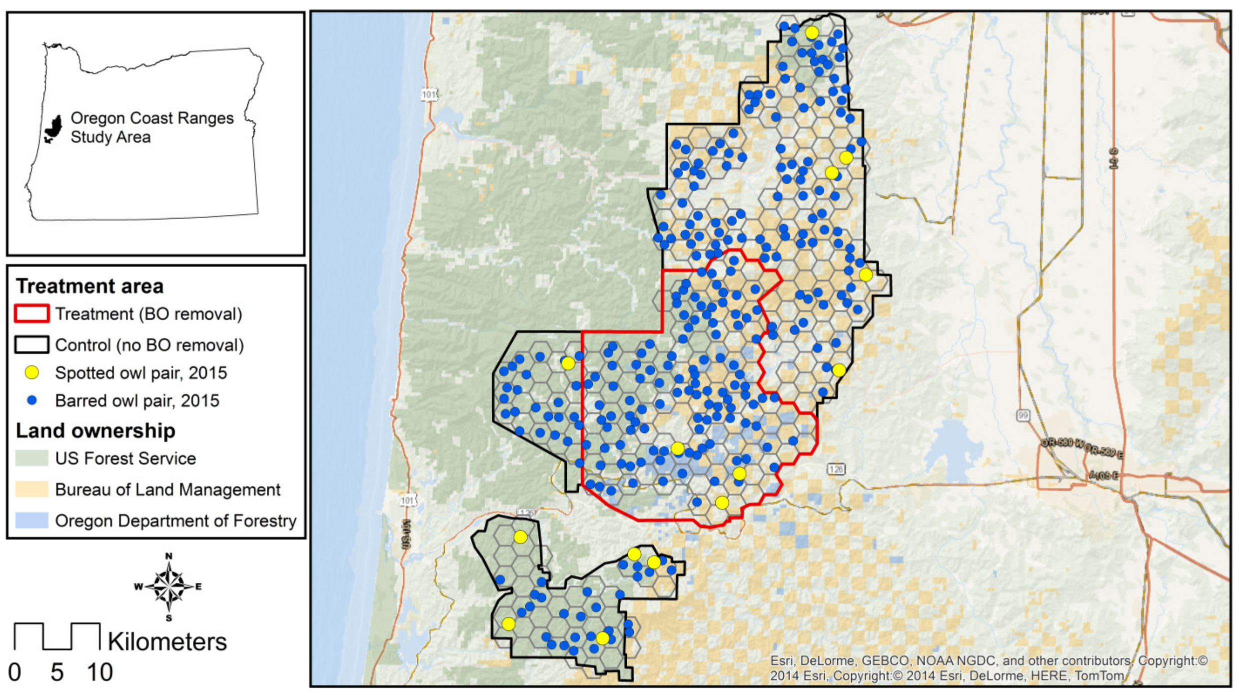
Appendix A. Pre-Treatment Distribution of Territorial Pairs of Northern Spotted Owls and Barred Owls in Two Experimental Study Areas in Washington and Oregon, 2015





Appendix B. Model Selection Results for Single-Season Analysis of Proportion of Area Used (ψ) and Detection Probability (*p*) of Barred Owls in Two Experimental Study Areas in Washington and Oregon, 2015

Model parameters defined as: **ψ** = the probability of ≥1 barred owl using a sampling unit (500-ha hexagon) during the survey season (March–September); ***p*** = the probability of detecting ≥1 barred owl at sampling unit *i* during survey occasion *t*, given presence. Models with area effects allow parameter estimates to vary between treatment and control areas. Time effects modeled as constant (.), varying with survey occasion (t), or increasing from the survey Period 1 to Period 3 (T).

Study Area	Model	AIC*c*	Delta AIC*c*	AIC*c* Weights	Num. Par	Deviance
Cle Elum, Washington	{ψ(.) *p*(t)}	380.068	0.000	0.378	4	-682.838
	{ψ(area) *p*(t)}	381.026	0.958	0.234	5	-683.973
	{ψ(.) *p*(T)}	381.224	1.156	0.212	3	-679.608
	{ψ(area) *p*(T)}	382.608	2.540	0.106	4	-680.298
	{ψ(.) *p*(.)}	384.765	4.696	0.036	2	-674.012
	{ψ(area) *p*(.)}	386.520	6.451	0.015	3	-674.313
	{ψ(.) *p*(g)}	386.801	6.733	0.013	3	-674.031
	{ψ(area) *p*(area)}	388.589	8.520	0.005	4	-674.317
Coast Ranges, Oregon	{ψ(.) *p*(t)}	466.206	0.000	0.582	4	-801.462
	{ψ(area) *p*(t)}	468.226	2.020	0.212	5	-801.516
	{ψ(.) *p*(.)}	470.773	4.566	0.059	2	-792.792
	{ψ(.) *p*(g)}	470.799	4.593	0.059	3	-794.810
	{ψ(.) *p*(T)}	472.184	5.978	0.029	3	-793.425
	{ψ(area) *p*(.)}	472.479	6.273	0.025	3	-793.130
	{ψ(area) *p*(area)}	472.857	6.651	0.021	4	-794.811
	{ψ(area) *p*(T)}	474.007	7.801	0.012	4	-793.661

Appendix C. Model Selection Results for an Analysis of Intensity of Use of Sample Plots (λ) and Unconditional Detection Probability (*r*) of Barred Owls in Two Experimental Study Areas in Washington and Oregon, 2015

Model parameters defined as: **λ** = average number of individual barred owls using a sample unit (500-ha hexagon) during the survey season (March–September); ***r*** = the unconditional probability of detecting ≥1 barred owl at sampling unit *i* during the survey season; varadd = additional variance added to **λ** to invoke the Royle/Nichols negative binomial model (all other models assume a Poisson distribution with a mean of **λ**; Royle and Nichols, 2003). Models with group effects (g) allow parameter estimates to vary between treatment and control sites within study areas. Time effects modeled as constant (.), varying with survey occasion (t), or increasing from survey Period 1 to Period 3 (T).

Study Area	Model	AIC*c*	Delta AIC*c*	AIC*c* Weights	Num. Par	Deviance
Cle Elum, Washington	{λ(.) *r*(.)}	384.69	0.00	0.508	2	-674.09
	{λ(g) *r*(.)}	386.52	1.82	0.204	3	-674.32
	{λ(.) *r*(g)}	386.70	2.01	0.186	3	-674.13
	{λ(g) *r*(g)}	388.51	3.82	0.075	4	-674.40
	{λ(g) *r*(g), varadd(.)}	390.48	5.80	0.028	5	-674.52
Coast Ranges, Oregon	{λ(.) *r*(.)}	469.24	0.00	0.32	2	-794.32
	{λ(g) *r*(.)}	469.54	0.29	0.28	3	-796.07
	{λ(.) *r*(g)}	469.56	0.32	0.27	3	-796.05
	{λ(g) *r*(g)}	471.59	2.35	0.10	4	-796.08
	{λ(g) *r*(g), varadd(.)}	473.66	4.42	0.04	5	-796.08

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