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1) **Title:**

The Demography of Northern Spotted Owls (*Strix occidentalis caurina*) on the Willamette National Forest, Oregon.

2) **Principal Investigator and Research Team:**

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3) **Abstract:**

Survey and monitoring results for the 2021 field season are presented here for the central Oregon Cascades northern spotted owl demography study area. Additional survey results for two timber sale planning areas are presented separately in Appendix C. Pair detections (17) were lower than in any previous year. Thirteen pairs nested and fledged a total of 22 young. Incidental detections of barred owls decreased between 2020 and 2021 but the cumulative proportion of sites where barred owls have been detected continued to increase as barred owls were detected for the first time at one additional site. Overall trends were consistent with a declining spotted owl population and an increasing barred owl population.

4) **Introduction:**

Background.

Spotted owl research has been conducted in and around the H. J. Andrews Experimental Forest since the late 1960’s. Graduate research projects that focused on spotted owl natural history, habitat selection, food habits, and home range size (Forsman 1976, 1980; Miller 1989, Swindle 1998) were the earliest studies. Beginning in 1987, researchers started banding spotted owls to provide mark-recapture data to estimate vital rates of the population in the west central Oregon Cascades. Initial banding efforts focused on pairs of spotted owls located in the course of project-related surveys primarily conducted by USDA Forest Service personnel. Locations of nests, daytime roosts, and clusters of nocturnal detections were considered surrogates of spotted owl activity centers (hereafter referred to as “sites”). Each site was represented by a single point and assigned a master site number (MSNO) by the Oregon Department of Fish and Wildlife (Appendix A). By the mid-1990’s more comprehensive surveys across the landscape were conducted and several new sites were discovered. Survey stations in the areas between historic spotted owl sites were grouped by watershed and also treated as sites for use in occupancy analyses.

Potential benefit and utility of the study.

Evaluation of trends in population demography and habitat selection, particularly as barred owls increase in density across the spotted owl's range have increased our understanding of the factors associated with range-wide declines in spotted owl populations (e.g., Dugger *et al*. 2016). Productivity and mark-recapture data for the HJA study area were combined with data from other northern spotted owl demographic studies during weeklong workshops held in January of 1994, 1999, 2004, 2009, 2014 and 2020. During these workshops, the data from HJA were combined with data from other study areas in a meta-analyses of survival, fecundity, annual rate of population change, and recruitment for spotted owl populations across their range (Burnham *et al*. 1996, Franklin *et al*. 1999, Anthony *et al*. 2006, Forsman *et al*. 2011, Dugger *et al.* 2016, Franklin *et al.* 2021). The two most recent meta-analysis workshops included a two-species occupancy analysis to evaluate the effects of barred owls on spotted owl site occupancy (Dugger et al. 2016, Franklin et al. 2021) and the 2020 workshop included a multistate occupancy analysis to more accurately estimate reproductive success by incorporating detection rates, and to assess the effects of several covariates on spotted owl productivity (Rockweit *et al. in review*).

These meta-analyses of northern spotted owl populations across their range have provided important information that supported the validation and monitoring requirements of the NWFP (USDA and USDI 1994), and were an important part of the 2004 species status review (Courtney *et al*. 2004), the development of the Final Recovery Plan (USDI USFWS 2011), the designation of Critical Habitat for the species (USDI USFWS 2012), and the most recent U. S. Fish and Wildlife Service ruling that reported that uplisting northern spotted owls from Threatened to Endangered status was "warranted but precluded" by other listing priorities (USDI USFWS 2020). In addition, data from this study has been used to study occupancy dynamics and to generate annual site occupancy rates (Olson *et al*. 2005) as well as develop predictive models that link demographic rates to vegetative characteristics in owl territories (Olson *et al*. 2004). Our data continue to be used to develop new analytical approaches to understand the effects of habitat (Ackers *et al*. 2015), climate (Glenn 2009, Glenn *et al*. 2010), and barred owl (*Strix varia*) presence (Olson *et al*. 2005, Anthony *et al*. 2006, Forsman *et al*. 2011, Dugger *et al*. 2016) on spotted owl demography, and most recently, this study contributed data to an analysis of the factors influencing breeding dispersal in spotted owls. (Jensen *et al*. 2019, Jensen *et al.*, 2021).

Study objectives.

a. Estimate the proportion of territories where northern spotted owls are detected, determine sex and age composition, and the reproductive success of spotted owls on the Northern Spotted Owl Demography Study Area in the Willamette National Forest, including estimates by land use allocation as designated under the Northwest Forest Plan (NWFP; USDA and USDI 1994; Appendix B).

b. Develop and maintain a capture history matrix of individually marked spotted owls to estimate detection rates, survivorship, recruitment, and the rate of population change using a mark-recapture modeling approach.

c. Create and maintain databases required for analyses of fecundity, survivorship, occupancy, and the annual rate of population change.

d. Collaborate with other researchers examining northern spotted owl ecology throughout the Pacific Northwest.

5) **Study Area**:

The central Cascades northern spotted owl demographic study covers approximately 375,000 ac (151,763 ha) on the western slopes of the Oregon Cascades (Figure 1). The land is administered by the Willamette National Forest and includes the upper McKenzie River watershed, the upper Fall Creek watershed, and a portion of the South Santiam River watershed. The land west of the study area is a mixed ownership of Bureau of Land Management and private forestland. The Three Sisters and Mount Washington wilderness areas form the eastern boundary of the study area. The remainder of the Willamette National Forest lies to the north and south of the study area. Five land use allocations defined by the Northwest Forest Plan are represented (USDA and USDI 1994): matrix lands (26%), adaptive management areas (28%), four late successional reserves (34%), and several congressionally and administratively withdrawn areas (12%). The H. J. Andrews Experimental Forest is located in approximately the center of the study area.

Elevations on the study area range from approximately 1,300 ft. (400 m) to just under 5,300 ft. (1,600 m). The predominant forest type is Douglas Fir (*Pseudotsuga menziesii*) – Western Hemlock (*Tsuga heterophylla*) with stands of Pacific Silver Fir (*Abies amabilis*) and Mountain Hemlock (*Tsuga mertensiana*) at high elevations. Over half of the study area is either non-forest or has been harvested (Miller *et al*. 1996). Of the remaining forested lands, approximately 51% is considered suitable habitat for spotted owls (S. Weber, Willamette National Forest, personal communication). This corresponds closely to the 51.2% of the western Oregon Cascades physiographic province classified as suitable and highly suitable habitat in the 20-year spotted owl habitat monitoring report (Davis *et al*. 2016).

A series of wildfires in August, 2017 resulted in a variable amount of disturbance on approximately 18,000 ha in and around the study area. Most of the fires occurred in wilderness east of the study area, but approximately 30% of the fires burned in and around 33 currently monitored spotted owl sites and 7 site centers not currently monitored. The Terwilliger fire occurred in August, 2018 and encompassed over 4,600 ha and involved 8 additional spotted owl sites. Immediately following the 2020 field season, the Holiday Farm fire started in a largely residential area in the McKenzie River valley. Twelve spotted owl sites were within this fire perimeter by the time it was contained, including 2 sites previously burned in 2018. In 2021, the Gales Creek/Elephant Rock/Ninemile fire included 29 sites in the Fall Creek LSR and the Knoll fire was within 2 sites in the McKenzie River ranger district. Thus, since 2017, at least 82 spotted owl sites have been impacted by wildfire of variable severity.

6) **Methods:**

Survey design and field methods.

We monitored all known northern spotted owl sites within the study area during the spotted owl breeding season (March – August, 2021) and calculated the annual proportion of sites where owls were detected. Sites with a recent history of spotted owl pair detections were visited during the day to identify color-banded spotted owls and determine their nesting and reproductive status according to established protocols (Forsman 1995). If spotted owls were not located at these sites during the initial daytime visits, then nighttime surveys were conducted. We also conducted day visits at several sites that had not been recently occupied to confirm that night surveys were not missing spotted owls in historic activity centers. All other sites were surveyed at night to locate spotted owls before initiating daytime visits. Unbanded, non-juvenile spotted owls located during either day or night visits were captured and fitted with a uniquely numbered USFWS band and a unique color band to facilitate individual identification. Juvenile spotted owls also were captured and banded with a numbered USFWS band and a fledgling color band (red/white stripe).

We determined nesting status for all pairs located by offering them at least four mice on ≥2 visits between 1 April and 31 May. A pair was considered to be "nesting" if any of the four mice were delivered to a nest. If the result of the first visit indicated nesting and was conducted before 15 April, then a second visit was required to confirm nesting status because females may sit on a nest without actually laying eggs early in the spring (Forsman 1995). Nesting also was indicated if a female owl captured for banding had a brood patch, one or more juveniles were observed with one of the adults, or if the remains of nestlings or eggs were located under a known nest tree. Non-nesting was indicated if the adults ate or cached all mice taken on two visits conducted at least 3 weeks apart, provided that at least 4 mice were offered during each visit. If the fate of a mouse was unknown, then that mouse did not count toward the minimum of four mice. Pairs also were classified as non-nesting if a female captured for banding between 15 April and 31 May did not have a brood patch or if the female was observed roosting away from a nest for greater than 60 minutes between 15 April and 15 May. Pairs and single females that met these criteria on or before 31 May provided estimates of the proportion of pairs that nested (*i.e.*, nesting attempts) and the proportion of nesting pairs that hatched ≥1 chick (*i.e.*, nest success rate). After 31 May, it was not possible to distinguish between pairs that nested and failed and pairs that did not attempt to nest (Forsman 1995).

We conducted additional visits to all nest sites to determine the number of young fledged between 1 June and 31 August. A minimum of four mice were offered to each pair on ≥2 occasions to determine if any young were present. Owls previously determined to be non-nesting were considered to have produced no young, although we attempted to confirm this with at least one visit after 31 May. Owls that ate or cached all mice offered on ≥2 visits between 1 June and 31 August also were considered to have not produced young. As with nesting status determinations, if the fate of a mouse was unknown, then that mouse did not count toward the minimum of four mice. For owls that delivered one or more mice to young, the number of young observed out of the nest tree were recorded as the number of young fledged. The highest number of young observed on two visits was the final reproductive status for that pair (Forsman 1995).

Analytical methods.

The numbers of sites where pairs of spotted owls were detected and sites where at least one spotted owl detection occurred were evaluated separately. Single owls that were detected at a particular site ≥3 times over one or two breeding seasons were considered resident, single owls (Forsman 1995). Given that per visit detection probabilities are less than 1.0 (Olson *et al*. 2005), estimates of occupancy rates that do not account for detection rates are negatively biased (MacKenzie *et al*. 2006). Thus, here we summarize the survey data as the proportion of sites where spotted owl detections occurred. See Olson *et al*. (2005), Dugger *et al*. (2016) and Franklin *et al.* (2021) for estimates of spotted owl occupancy rates on this study area.

Spotted owl productivity was summarized as: 1) the proportion of pairs evaluated prior to 31 May that were nesting, 2) the proportion of pairs that fledged at least one young between 1 June and 31 August, 3) the average number of young produced per pair, and 4) the average number of young produced per successful pair. Annual variability in each parameter was examined by comparing the coefficient of variation for each metric.

In 2017, we initiated night surveys at 17 additional historic spotted owl sites in 2 Forest Service planning areas. The Timber Butte planning area was outside of the demography study area to the west of the Fall Cr. LSR and includes 11 sites that were last surveyed by USDA Forest Service (FS) biologists in the mid-1990s. Survey stations were established for these sites in 2017, but surveys were not conducted in 2018 through 2021 pending further Forest Service direction. The Flat Country planning area encompasses the matrix lands within the study area between highway 126 and the Three Sisters Wilderness area. Sixteen sites currently monitored as part of the demography study and six sites not previously monitored are included in the Flat Country planning area. Survey results from the sites not included in the demography study ($n=6$) are presented separately (Appendix C). In 2019, we began consultation with Forest Service biologists regarding the 3-D planning area, a portion of which occurs on the study area. Within the portion of the 3-D planning area that was on the study area there are 18 sites currently monitored by the demography study and one additional site not monitored since 1992. Monitoring of the additional site on the 3-D planning area was reinitiated in 2020 and 2021 survey results for all 19 sites are presented in Appendix C.

We continued to monitor sites where spotted x barred owl hybrids have been located and these results are presented in Appendix D. Unless otherwise indicated, the following summary of survey results excludes hybrids or mixed species pairs and refers only to northern spotted owls.

7) <u>Results</u>:

Proportion of sites where owls were detected

The number of sites we surveyed to protocol in 2021 (158) was lower than the number reported in the past because we could not conduct a third night survey for 14 sites and a 15th site was not surveyed at all (Table 1). Of the 33 sites where we detected spotted owls, approximately half were pairs (52%). Two pairs were found in close proximity (approx. 1 mile apart) in a site polygon previously considered a single historical territory. We established a new site center to account for this additional pair (Augusta Creek West, MSNO 2466). None of the single owls detected met the criteria for resident single status (48%; Table 1). Between 2020 and 2021 the proportion of sites where either a pair or a single owl was detected decreased by 5.1% (Table 1) and the proportion of sites where pairs were detected decreased by 1.3% (Figure 2). The residency status for both the male and the female was determined for all pairs detected.

Sex and age composition

Fifty-two non-juvenile ($\geq$1 year old) and 22 juvenile spotted owls were detected during our surveys in 2021 (Table 2). Forty-three of the non-juvenile owls of known age were at least three years old and one female was identified as a one-year-old. Of the owls that were not identified to age class (8), most were only detected at night and never relocated for identification, which suggested that many of them were transients that did not hold territories. All of the owls that were resighted and identified by unique, non-juvenile color bands (40) were assigned to an age class, as were all of the non-juvenile owls that were captured for initial banding or to replace a juvenile or broken color band (4).

Based on re-observations of known age, non-juvenile owls in 2021, the median age for males on the study area was 10 years ($\bar{x}$ = 11.3, SE = 1.28) and 10.5 years ($\bar{x}$ = 10.5, SE = 2.95) for females. The oldest owl located in 2021 was a 25-year-old female originally banded as an adult in 1999. The oldest male was at least 23 years old and was originally banded as an adult in 2001. Both of these owls may have been older as the exact age of an adult cannot be determined based solely on the coloration of the retrices (Forsman 1981).

The ratio of territorial subadults to adults has decreased since 1987 (R^2 = 0.18 p-value = 0.02, β = -0.002, 95% CI: -0.003 to 0.0004), and only one subadult was detected in 2021. Subadults have been paired much less frequently than adults in every year of the study and the percentage of pairs including at least one subadult has varied widely from a high of 16% in 2016 to no paired subadults in 1995, 2007, 2012, 2013, 2018, 2020. There was no evidence of a time trend in the proportion of territorial pairs that included at least one subadult (R^2 = 0.05, p-value = 0.23, β = -0.10, 95% CI: -0.25 to 0.06).

The sex ratio among adults ($\geq$ 3-year-olds) identified in 2021 was higher than past estimates (males:females; 1.39:1 in 2021 vs. 1.17:1 averaged over all previous years, n = 35). Among subadults, the sex ratio was more skewed toward males in most years (1.41:1 averaged over all years, n = 27). Small sample sizes in the subadult age class resulted in more annual variation in the sex ratios which ranged from 0:1 in 1994 to 5:1 in 2000. Subadults of only one sex were located in 1995, 1999, 2012, 2013, 2017, 2019 and 2021 making it impossible to estimate a subadult sex ratio in those years. More subadult females than males were detected in 9 of the past 35 years. The average sex ratio among non-juveniles of unknown age was even more variable and heavily skewed toward males (2.60:1 averaged over all years, range: 0.75:1 - 14:1).

Reproductive Success

We were able to survey 10 spotted owl pairs to determine nesting status between 1 April and 31 May 2021 (Forsman 1995; Table 3). Nine of these pairs nested in 2021. The mean percentage of pairs surveyed that nested from 1988 through 2020 was approximately half of the pairs surveyed during that period ($\bar{x}$ = 47%, SE = 5.2, n = 33, Table 3)). However, the long-term mean obscures the striking annual variation in breeding propensity between consecutive years (high vs. low) observed during most of this study (Table 3). Of the pairs that were confirmed to be nesting from 1988 through 2021, most successfully fledged at least one young ($\bar{x}$ = 74%, SE = 3.8, n = 31; Table 3). The percentage of pairs that attempted to nest was more variable (CV = 0.63) than the percentage of nesting attempts that were successful (CV = 0.28). There was no evidence of a relationship between nesting rates and nest success (r = 0.14, 95% CI: -0.22 to 0.47, p-value = 0.45).

Seventeen spotted owl pairs were surveyed for reproductive status by 31 August 2021 (Table 3). This included the 10 pairs that were surveyed for nesting status prior to 1 June 2021, as well as 7 additional pairs that were not located prior to 1 June. The average number of young produced in 2021 was greater than the average across all previous years (2021: $\bar{x}$ = 1.29, 1998 – 2020: $\bar{x}$ = 0.59, SE = 0.07, n = 33; Table 3). With the exception of 1993 and 2018 when no young were fledged, there was little variation in the number of young produced by pairs that successfully nested ($\bar{x}$ = 1.59, SE = 0.04, n = 32, CV = 0.14). There was an association between productivity (fledglings per pair) 2 years previous and increased proportion of pairs with at least one, two-year-old subadult (R^2 = 0.16, p-value = 0.03 β = 4.00, 95% CI: 0.68 to 7.33).

Banding/re-observation

Twenty-four spotted owls were banded in the study area and at the nearby wilderness sites in 2021: one adult male, one adult female and 22 juveniles (Table 4). Since 1987, 684 non-juvenile and 1,123 fledgling spotted owls (1,807 total) have been banded on the study area. In addition, 189 spotted owls have been banded on National Forest, BLM and private lands surrounding the study area. Thirty-six adults previously banded on the study area were resighted. Six non-juvenile spotted owls were recaptured in 2021; two males and two females that had not been located for several years were recaptured to confirm their identity. Additionally, one male and one female were recaptured to replace their fledgling band with a unique color band. The male was originally banded as a fledgling in 2014 and the female was initially banded in 2020. Since 1987, 154 (13%) of the fledglings banded in our study area have been recaptured on the study area. Of the marked fledglings recaptured, most (75%) were recaptured within four years after initial banding. Twenty fledglings (13%) were recaptured as one-year-olds, 36 (23%) as two-year-olds and 98 (64%) as adults. Among those recaptured for the first time as adults, most (75%) were recaptured after 3 or 4 years. The longest period between initial banding and recapture on the study area was 13 years (Figure 3).

Movements

Of the 44 non-juvenile owls identified in 2021, six adult males and two adult females were recaptured or re-sighted at new locations within the study area (1990 – 2020 median number of dispersal events = 10, range: 3 – 21). We observed a positive time trend in the annual proportion of territorial owls dispersing to new locations (R^2 = 0.34, p-value = 0.0004, β = 0.33, 95% CI: 0.17 to 0.49).

Barred owl detections

Incidental barred owl detections have become more common than spotted owl detections in the study area. The percentage of sites where at least one barred owl detection was recorded during the breeding season decreased by 1.6% between 2020 (59.7%) and 2021 (58.1%), but this was still among the highest percentage of sites with $\geq$1 barred owl detection observed since initiation of the study. The cumulative percentage of sites (i.e., sites where barred owls detected $\geq$1 time within a season, on $\geq$1 year of the study) where barred owls have been detected continued to increase in 2021 (Figure 4). There are only 8 sites on the study area where barred owls have not yet been detected. Barred owl fledglings were observed at 25 of the 47 sites where barred owl pairs were detected in 2021.

Problems encountered

Closure of the Deer Creek road (FR 2649) during the Deer Creek Floodplain Enhancement project continued through much of the 2021 field season. This restricted access to the Deer Creek NSO site (MSNO 2449) and greatly increased the time required to access 3 other sites. A large landslide on the Aufderheide Scenic Byway (FR 19) also resulted in the closure of approximately four miles of this main arterial road. An alternate route was established to access the sites south of the landslide, but access was restricted to two sites within the closure area (Rush Creek MSNO 1416 and Boone Creek MSNO 0861).

Four fires on the study resulted in additional road closures that affected site access. The Knoll fire resulted in road closures that affected survey access for four sites although the closure area was reduced after the fire was contained. The Gales Creek, Elephant Rock and Ninemile fires started on 29 July 2021 and eventually merged into one large fire encompassing over 30,000 ac. We could not complete the third night surveys for 11 sites in the Fall Creek LSR as a consequence of the subsequent road closures.

Many other secondary and tertiary roads throughout the study area are no longer maintained and several have been decommissioned. As a consequence, portions of the surveys in these areas were conducted on foot, which considerably increased the time required to complete surveys at these sites.

As in most years, a persistent snowpack delayed our access to high elevation sites. Complete surveys in the matrix sites in the eastern portion of the Flat Country timber sale planning area were not possible until late May. The Horse Creek and South Santiam LSRs include many other high elevation sites where snow typically remains longer into the spring, which also delayed the first surveys until late May. As a result, we were unable to resolve the productivity of more owl pairs on these sites compared to other sites within the study area.

Noise associated with high stream flows and heavy rain in March and April interfered with site visits and nighttime surveys as is typically the case. Several surveys had to be repeated due to the effect of such noise on the detectability of spotted owls (Kissling *et al*. 2010, Lengane and Slater 2002). This forced us to allocate more effort to repeated surveys at some sites which allowed less time to complete the surveys at other sites.

Decreased per-visit detection rates (Olson *et al*. 2005) associated with increased barred owl detections and continued declines of spotted owl populations (Dugger *et al*. 2016) have increased the amount of time and effort required to meet protocol requirements for data collection. Many of the pairs that were previously easy to locate during the day near their historic activity centers now require additional night surveys to relocate them or to confirm they are no longer present. Increased night work has fundamentally changed the survey coverage across the study area from a territory-based, site visit approach to more uniform nighttime survey coverage over large areas. In 2021, we conducted more night surveys using more survey stations than in any previous year (Figure 5). While this improved our coverage of areas near historical activity centers, it has become more difficult to complete all site visits and nighttime surveys required by the effectiveness monitoring protocol (Forsman 1995).

8) <u>Discussion</u>:

Proportion of sites where owls were detected

Throughout the 34 years of the study, survey effort has been frequently adjusted in response to several factors. The apparent increase in the proportion of sites where spotted owls were detected during the first three years of the study was related to increased survey effort by the demographic study combined with surveys conducted for Forest Service timber sales and other projects. From 1990 through 1996, a density study was attempted in the Blue River watershed as well as portions of the Deer Creek and South Santiam watersheds. Outside of these areas, surveys were focused on areas where pairs of spotted owls had been previously located during Forest Service surveys. From 1997 through 1999, we began more complete survey coverage in the four LSRs on the study area. Since 2000, the number of sites surveyed remained relatively constant although survey coverage of the landscape between historical spotted owl sites has increased as more night surveys were conducted to try to relocate spotted owls no longer occupying their previous activity centers.

The proportion of sites surveyed in 2021 where a pair of spotted owls was detected was lower than in any year since the initiation of the study (Table 1). Since 1989, the proportion of sites where pairs were detected has decreased an average of 2.5% per year. Pairs of spotted owls are typically easier to detect due to their fidelity to nest sites and tendency to roost near recently fledged young (Rockweit *et al. in review*). Despite the high frequency of nesting observed on the study area in 2021 we located the fewest number of pairs on record. This is consistent with a declining population of territory-holding individuals. However, sites where we detected unidentified single owls may have actually contained non-nesting pairs that were not responsive during the daytime follow-up visits. To minimize the possibility that pairs go undetected, we routinely conduct multiple follow-up visits and additional surveys when single spotted owls are detected.

The proportion of sites where a spotted owl was detected (either a single or pair) decreased an average of 2.5% per year. Most of this decline occurred in the past 15 – 20 of the past 30 years (Table 1). These estimates included any spotted owl response at a site including auditory detections from unidentified individuals that may have been non-territorial owls.

The proportion of sites where spotted owls were detected and the total number of owls detected each year should not be interpreted as an index of the population size or an estimate of occupancy rate on the study area. This is primarily because this proportion does not account for detection probabilities that are <1.0, and that vary by survey or between years. It is clear that the probability of detecting a spotted owls varies by reproductive status (Mangan et al. 2019, Rockweit *et al. in review*) and is decreased when barred owls are present in the vicinity of a spotted owl territory (Olson *et al.* 2005, Kroll *et al.* 2010, Dugger *et al.* 2011, Dugger *et al.* 2016,). As a result, declines in the proportion of sites where spotted owls were detected underestimates site occupancy rates and the total number of owls detected each year underestimates population size.

Productivity

In contrast to 2020, a relatively high level of productivity was observed in 2021 (Table 3). This is consistent with the autoregressive time trend recently reported across most demographic study areas (Franklin *et al.* 2021). Despite high annual variation in productivity, the continued long-term decline in productivity has resulted in inadequate recruitment to maintain the population of territorial pairs. Only a small proportion of the fledglings we banded have been relocated on a territory in subsequent years and most fledglings recaptured did not appear on a territory until after they were ≥3 years old (Figure 3). Delayed recruitment into the breeding population masked the effects of periodic high productivity on recruitment and extending the time from natal dispersal until an individual colonizes a territory increases exposure of the individual to conditions that may decrease annual survival (Miller 1989, Miller *et al.* 1997).

Environmental conditions can affect spotted owl productivity at several stages, but it was evident that the proportion of pairs that attempted to nest every year was the primary source of variability in productivity of spotted owls. A biannual pattern in nesting attempts was observed from 1988 through 2005 (% pairs nesting; Table 3). This pattern has been broken four times: once during 2000 through 2002, when high rates of nesting were recorded three years in a row, in 2005 and 2006 when low rates of nesting were recorded for two consecutive years, and most recently with two consecutive years of high nesting rates between 2007 and 2008 and between 2014 and 2015. Prior to 2015, higher productivity occurred in even-numbered years but from 2015 through 2021 this pattern shifted to higher productivity in odd-numbered years. A similar pattern of autocorrelation has been observed the other demographic study areas in which years of high productivity alternate with years of low productivity (Franklin *et al*.2021). Climate has been suggested as the underlying factor driving this biannual variation through its effect on prey populations (Franklin *et al*. 2000, Glenn *et al.* 2011), but this has not yet been confirmed with long-term research on prey population dynamics.

Anecdotal observations continue to suggest that pairs of spotted owls in the central western Cascades of Oregon may be more likely to attempt to nest when conditions are warmer and drier than in years when late season storms occur during the early stages of nesting. Episodic storm events before nest initiation may partly explain the variation in reproductive success. Heavy snowfall during February 2018 and 2020 followed by low productivity was consistent with this hypothesis but a more severe late season snowstorm in 2019 did not seem to reduce productivity in the same way. Somewhat milder conditions in February and March 2021 were associated with high productivity. Range-wide estimates of recruitment rates were highest when both total winter precipitation and mean minimum winter temperature were lowest (warm, dry winters), (Dugger *et al*. 2016), but the linkage between climate, the autoregressive effect and spotted owl productivity remains unclear (Glenn *et al*. 2010, Forsman *et al*. 2011).

The total number of young produced has been highly variable among years and was not correlated with the annual number of nesting attempts. Given the strong territorial nature of this species, this is a system where historically (prior to barred owl colonization) we would not predict density dependent effects on fledging success or productivity. Long-term prey cycles affecting the overall condition of breeding birds each year is one possible explanation for patterns in breeding propensity (*i.e.*, proportion of pairs that attempt to breed). A long-term study investigating the demography of small mammal species eaten by spotted owls is currently underway on our study area. We also speculate that storm events during incubation could result in increased nest failures as well as decreased nesting attempts as discussed above.

The number of young fledged per pair also may be affected by stochastic weather events, particularly when the fledglings are young and more vulnerable to chilling and exposure. For example, five of six post-fledging mortalities confirmed in 2008 occurred during a week of cold temperatures and heavy rain in early June shortly after the young left the nest. A similar cluster of fledgling mortalities also was observed in 2004 when a period of unseasonably cold and wet weather occurred during the same period. In most years, weather conditions remained mild throughout June, and few post-fledging mortalities were documented. The weak negative effect of precipitation during the late nesting season (1 May – 30 June) on fecundity evident in past meta-analyses (Glenn *et al*. 2010, Forsman *et al*. 2011) may reflect the periodic loss of young in the nest, if weather is causing mortality of nestlings similarly to effects observed in some years on fledglings. Post-fledging mortalities did not affect our estimates of the number of young fledged or fecundity because juvenile mortalities documented during the post-fledging period are counted as having successfully fledged even if we discover that they did not survive long after fledging.

Predation may affect productivity both before and after fledging. Potential predators sighted on the study area near active territories included great-horned owls (*Bubo virginianus*), northern goshawks (*Accipiter gentilis*), red-tailed hawks (*Buteo jamaicensis*), peregrine falcons (*Falco peregrinus*), and common ravens (*Corvus corax*). Barred owls also may directly impact productivity through predation on spotted owl nestlings or by causing nest abandonment by spotted owls. Direct observations or evidence of predation have been rare (*e.g.,* Leskiw and Gutiérrez 1998) making it difficult to assess the magnitude of this effect. The indirect effect of barred owls on small mammal prey resources important for spotted owls has not yet been investigated, however high densities of barred owls could decrease overall prey resources available for spotted owls.

Northern Spotted owl - Barred Owl relationships

The overall percentage of sites with at least one barred owl detection has increased steadily since 2003. This observation should be interpreted with caution, however. Although detections of barred owls in spotted owl territories have increased in a manner consistent with an expanding barred owl population (Figure 4), data collected incidentally during spotted owl surveys cannot be used to estimate density or population size of barred owls. In addition, detection rates of barred owls at spotted owl sites are likely underestimated because we did not use survey techniques targeted specifically to barred owls (Wiens *et al.* 2011). While barred owl fledglings were detected at 25 spotted owl territories in 2021, these incidental observations cannot be used to estimate barred owl productivity at the population level on our study areas.

Despite the limitations discussed above, a number of associations have emerged between increased barred owl detections and spotted owl detection rate, annual site occupancy, and demographic parameters. Several banded spotted owls have not been relocated following barred owl detections in their historic core areas presumably because they have either died, been excluded from suitable habitat, or were inhibited from responding to our surveys. The presence of barred owls in the Oregon Cascades has been shown to negatively influence the probability of detecting spotted owls as well as affecting the probability that a pair of spotted owls would abandon occupied sites or recolonize an empty site (Olson *et al*. 2005, Dugger *et al*. 2011, Dugger *et al*. 2016, Franklin *et al.* 2021). The principle vital rates (i.e., survival and recruitment) that drive patterns in the rate of population change, also were negatively affected by barred owl presence (Franklin *et al.* 2021). While mortality of displaced non-juvenile spotted owls has not been documented in this study, recent findings indicate that increased abundance of barred owls was associated with decreased apparent survival (Forsman *et al*. 2011, Wiens *et al.* 2014, Dugger *et al.* 2016.), and increased dispersal rates and distances by breeding birds (Jenkins *et al.* 2019, 2021). Finally, barred owls may affect spotted owl productivity either directly (Wiens *et al*. 2014, Mangan *et al*. 2019, Franklin *et al.* 2021) or through their effect on site occupancy by pairs of spotted owls (Olson *et al*. 2005, Dugger *et al.* 2016, Mangan *et al*. 2019). These effects are expected to become more pronounced as barred owl densities increase (Dugger *et al*. 2011, Franklin *et al.* 2021).

Early in the expansion of barred owls into the range of the northern spotted owl, there was concern over the potential for hybridization of barred and spotted owls (Hamer *et al.* 1994). If introgression of barred owl genes into spotted owl populations produces hybrids with greater fitness than spotted owls, hybrids could gradually replace spotted owls if increased barred owl abundance results in increased hybridization (Grant and Grant 1992). Alternatively, if hybridization is the result of scarcity of mates for barred owls and/or if hybrids are less fertile than spotted owls, then the frequency of hybridization may decline as barred owls become more abundant (Hamer *et al*. 1994, Randler 2006).

The first spotted owl x barred owl F1 hybrid was detected on the study area in 1999 (Appendix D). The number of hybrids detected increased through 2004 but has since declined to only 2 or 3 detections per year since 2007. No hybrids were detected in 2020 or 2021. As noted earlier, barred owl abundance has increased to the point that they are detected at most of the spotted owl territories we monitor. These observations are consistent with the hypothesis that behavioral mechanisms usually prevent mating between spotted and barred owls unless potential barred owl mates are scarce (Randler 2006).

For barred owl genes to be introduced into spotted owl populations, backcrossing between F1 hybrids and spotted owls must occur. Most backcrossing that has been reported occurred between F1 hybrids and barred owls; successful backcrossing between F1 hybrids and spotted owls has been rare (Haig *et al*. 2004, Kelly and Forsman 2004, Appendix D). From the information collected to date, it appears that little introgression of barred owl genes into spotted owl populations has occurred on our study area.

Habitat loss

In 2017, we initiated surveys in two timber sale planning areas, one in matrix lands in the eastern portion of the study area (Flat Country) and the other in matrix lands west of the Fall Creek LSR that we have not previous surveyed (Timber Butte, Appendix D). Surveys continued in the Flat County planning area for a fifth year in 2021, but surveys in the Timber Butte planning area have been suspended. In 2019, we reviewed our survey coverage for the 3-D planning area that encompasses most of the northern half of the study area. Surveys for this planning area included several new survey stations at sites currently monitored and the addition of an additional site in an area not surveyed since the early 1980s. Site- and year-specific data will be required to adequately assess the long-term effects of management activities in these planning areas.

Fires occurring on the study area in 2017 were the most extensive since the initiation of the study. Most of the area within 2.4 km of the sites inside the fire perimeters burned at a low intensity. Spotted owl detections in and around the 2017 fires did not reflect a consistent response to the fires. Of the 10 sites in the 2017 fires with a history of pair occupation in the previous five years, only three pairs of spotted owls were subsequently detected.

The Terwilliger fire occurred in August 2018 which included approximately 4,600 ha on both sides of Cougar Reservoir. Seven currently monitored spotted owl sites were potentially affected by the fire and at least four historic core areas are completely within the fire perimeter. One site that had burned in 2017 was burned a second time in 2018. The burned area emergency response (BAER) assessment indicated that approximately 446 ha of suitable spotted owl forest cover were lost and at least three sites are no longer likely to support spotted owls (Doerr 2018).

Immediately following the 2020 field season, the Holiday Farm fire severely impacted much of the residential and privately owned forest lands in the McKenzie Valley. At least 12 currently monitored sites were entirely within the fire perimeter and as many as 29 historic MSNO locations have been impacted including sites not monitored by this study. Most of the currently monitored sites were within side drainages around the periphery of the fire where burn severity was less than in the McKenzie Valley. Rasters provided by the USDA Forest Service Rapid Assessment of Vegetation Condition after Wildfire (RAVG) program indicated that loss of canopy cover ranged from less than 25% to over 75% in the affected sites (Geospatial Technology and Applications Center - https://data.fs.usda.gov/geodata/edw/datasets.php). At 4 spotted owl sites more than 75% of the canopy cover over more than half of the site was lost and these sites are unlikely to support spotted owls in the near future. It is also likely that important north-south dispersal corridors were virtually eliminated by the extreme fire behavior observed in the McKenzie Valley.

The Middle Fork complex of fires started on 29 July 2021 and included the Gales Creek, Elephant Rock and Ninemile fires in the Fall Creek LSR. The Gales Creek fire quickly expanded to encompass the Elephant Rock and Ninemile fires and eventually included 29 sites. The Knoll fire started on 5 August 2021 and included 2 sites. The impact to suitable spotted owl habitat in these areas has not been assessed as burn severity information was not available as of the writing of this report.

Prior to 2017, there had been little habitat loss due to fire on the study area and the response of the spotted owls has difficult to assess because of the low numbers of spotted owls currently in the affected areas. The effects of fire on spotted owls appears complex and related to both the severity and the extent of fire effects on suitable nesting and roosting habitat. . In the mixed conifer forests of the Sierra Nevada, California spotted owls (*Strix occidentalis occidentalis*) used high severity burn areas for foraging and localized high severity fire did not decrease spotted owl site occupancy (Bond et al. 2009, Lee et al. 2012, Lee and Bond 2015). Habitat edges resulting from fire may be one reason for the use of burned areas for foraging by California spotted owls (Eyes *et al.* 2017). More recent fires in California encompassed a larger area and included larger patches of high severity fire and under these conditions, site extinction rate increased and large amounts of habitat were rendered unsuitable for spotted owls (Jones *et al*. 2016). In addition, spotted owls avoided large forest patches impacted by high severity fire (Jones *et al*. 2019).

Northern spotted owls in southwest Oregon used mixed conifer forest stands with burned under-stories or partially removed over-stories, but they tended to avoid areas of complete stand replacement for nesting and roosting (Clark *et al*. 2011, 2013). In northern California, decreased survival and increased recruitment of northern spotted owls was observed in response to wildfire (Rockweit et al. 2017). In addition, habitat suitability in spotted owl nesting/roosting forest cover in mixed conifer forests decreased after high severity fire (Lesmeister *et al*. 2019), but relatively little is known about the effects of wildfire on spotted owl habitat in the moister Douglas fir – western hemlock forests of western Oregon. Historically these forests were characterized by longer fire return intervals and more high severity fire than in the drier mixed conifer forests of California and southwest Oregon (Morrison and Swanson 1990, Cissel et al. 1999). However, old growth conditions that favor spotted owl survival and reproduction have been able to persist under this fire regime by providing a microclimate where high severity fire is less likely (Lesmeister *et al*. 2019). While fire effects are likely to differ in more northern forests, departure from historical fire regimes, with respect to either severity or extent, are likely to be detrimental to spotted owls in the long term (Jones *et al*. 2020).

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11) Publications, Presentations, Data Transfer:

Publications.

Franklin, A. B., K. M. Dugger, D. B. Lesmeister, R. J. Davis, J. D. Wiens, G. C. White, J. D. Nichols, J. E. Hines, C. B. Yackulic, C. J. Schwarz, S. H. Ackers, L. S. Andrews, L. L. Bailey, R. Bown, J. Burgher, K. P. Burnham, P. C. Carlson, T. Chestnut, M. M. Conner, K. E. Dilione, E. D. Forsman, E. M. Glenn, S. A. Gremel, K. A. Hamm, D. A. Herter, J. M. Higley, R. B. Horn, J. M. Jenkins, W. L. Kendall, D. W. Lamphear, C. McCafferty, T. L. McDonald, J. A. Reid, J. T. Rockweit, D. C. Simon, S. G. Sovern, J. K. Swingle, H. Wise. 2021. Range-wide declines of northern spotted owl populations in the Pacific Northwest : A meta-analysis. Biological Conservation, 259. https://doi.org/10.1016/j.biocon.2021.109168

Jenkins, J. M. A., D. B. Lesmeister, E. D. Forsman, K. M. Dugger, S. H. Ackers, L. S. Andrews, S. A. Gremel, B. Hollen, C. E. McCafferty, M. S. Pruett, J. A. Reid, S. G. Sovern, and J. D. Wiens. 2021. Conspecific and congeneric interactions shape increasing rates of breeding dispersal of northern spotted owls. Ecological Applications 0(0), 1–18. https://doi.org/10.1002/eap.2398.

Technology transfer.

a) Project personnel coordinated spotted owl surveys with the district biologists of the Willamette National Forest and continued to provide information on spotted owl locations and demographics for their management needs.

b) S. Ackers provided data on occupancy and productivity of sites within 1.6 km of BLM and private land to the Eugene BLM, Westside Ecological (under contract with the Oregon Department of Forestry) and Weyerhaeuser Inc.

12) **Tables.**

Table 1. Northern spotted owl detections and residency status [a] of northern spotted owl sites (territories) surveyed on the central Cascades study area, Willamette National Forest, Oregon, 1987 – 2021.

Year	Sites surveyed	Sites with pairs detected	Sites with resident single owls	Sites with unknown residency [b]	Sites with ≥1 owl detected (%)	Sites where owls were not detected [c]	Sites not surveyed to protocol [d]
1987	44	20	2	4	26 (59)	-	18
1988	65	51	2	1	54 (83)	-	11
1989	80	73	4	3	80 (100)	-	27
1990	85	76	0	3	79 (93)	6	27
1991	100	79	5	8	92 (92)	8	3
1992	121	96	4	14	114 (94)	7	28
1993	91	46	13	15	81 (89)	10	19
1994	100	69	7	22	98 (98)	2	19
1995	113	73	10	8	91 (80)	22	12
1996	115	73	11	6	90 (78)	25	5
1997	118	73	8	10	91 (77)	27	12
1998	146	90	8	14	112 (77)	34	17
1999	157	95	13	15	123 (78)	34	11
2000	161	93	8	25	126 (78)	36	0
2001	162	93	11	29	133 (82)	29	2
2002	161	87	12	28	127 (79)	34	3
2003	161	96	11	18	125 (78)	36	1
2004	164	95	6	23	124 (76)	40	3
2005	167	93	19	19	131 (78)	36	2
2006	168	83	12	23	118 (70)	50	0
2007	170	82	9	26	117 (69)	53	0
2008	155	73	5	18	96 (62)	59	15
2009	168	68	20	15	103 (61)	65	2
2010	165	70	8	19	97 (59)	68	5
2011	170	52	17	22	90 (53)	79	1
2012	169	53	5	29	87 (51)	82	2
2013	172	50	11	33	94 (55)	77	0
2014	171	51	9	15	75 (44)	96	1
2015	170	45	7	24	76 (45)	96	2
2016	172	31	8	16	55 (32)	116	0

Year	Sites surveyed	Sites with pairs detected	Sites with resident single owls	Sites with unknown residency [b]	Sites with ≥1 owl detected (%)	Sites where owls were not detected [c]	Sites not surveyed to protocol [d]
2017	150	33	1	19	53 (35)	97	22
2018	169	23	8	12	43 (25)	126	3
2019	162	26	3	16	45 (28)	117	7
2020	158	19	2	20	41 (26)	117	11
2021	158	17	0	16	33 (21)	125	14

[a] Residency status was determined by 1995 protocols (Forsman 1995).
[b] Sites where male and/or female owls responded, but criteria for pair or resident single status were not met.
[c] Sites surveyed at least three times at night with no responses or where owls from a neighboring site were detected.
[d] Sites not surveyed or surveyed <3 times at night were not included in the total number of sites surveyed.

Table 2. Sex and age composition of northern spotted owls detected on the Central Cascades Study Area, Willamette National Forest, Oregon, 1987 – 2021.

Year	Adults (M, F)	Subadults [a] (M, F)	Age unknown (M, F)	Non-juveniles [b] (M, F)	Juveniles [c]
1987	53 (29, 24)	7 (4, 3)	15 (14, 1)	75 (46, 28)	12
1988	98 (49, 49)	18 (11, 7)	9 (4, 5)	125 (64, 61)	40
1989	135 (72, 63)	17 (10, 7)	14 (8, 6)	166 (90, 76)	27
1990	134 (72, 62)	9 (2, 7)	28 (17, 11)	171 (91, 80)	37
1991	152 (82, 70)	14 (8, 6)	44 (25, 19)	210 (115, 95)	30
1992	170 (88, 82)	10 (4, 6)	30 (17, 13)	208 (109, 101)	116
1993	122 (72, 50)	6 (4, 2)	23 (16, 7)	151 (92, 59)	0
1994	144 (77, 67)	8 (1, 7)	14 (8, 6)	166 (86, 80)	28
1995	151 (76, 75)	2 (2, 0)	19 (13, 6)	172 (91, 81)	22
1996	140 (71, 69)	9 (5, 4)	17 (13, 4)	166 (89, 77)	68
1997	139 (71, 68)	9 (5, 4)	21 (9, 12)	169 (85, 84)	24
1998	172 (86, 86)	8 (6, 2)	40 (27, 13)	220 (119, 101)	42
1999	169 (89, 80)	2 (2, 0)	56 (36, 20)	227 (127, 100)	21
2000	169 (85, 84)	6 (5, 1)	53 (36, 17)	228 (126, 102)	60
2001	189 (98, 91)	7 (4, 3)	38 (25, 14)	234 (127, 107)	83
2002	168 (89, 79)	11 (4, 7)	46 (26, 20)	225 (119, 106)	67
2003	172 (93, 79)	17 (7, 10)	40 (21, 19)	229 (121, 108)	25

Year	Adults (M, F)	Subadults [a] (M, F)	Age unknown (M, F)	Non-juveniles [b] (M, F)	Juveniles [c]
2004	187 (99, 88)	15 (7, 8)	29 (19, 10)	231 (125, 106)	105
2005	171 (92, 79)	12 (5, 7)	54 (33, 21)	237 (130, 107)	13
2006	149 (82, 67)	11 (6, 5)	37 (23, 14)	197 (111, 86)	20
2007	178 (90, 88)	2 (1, 1)	30 (24, 6)	210 (115, 95)	48
2008	154 (82, 72)	4 (2, 1, 1 Unk.)	18 (10, 8)	176 (93, 81, 1 Unk.)	31
2009	155 (82, 73)	5 (3, 1, 1 Unk.)	27 (19, 8)	187 (104, 82, 1 Unk.)	28
2010	134 (72, 62)	10 (6, 3, 1 Unk.)	37 (17, 19, 1 Unk.)	181 (95, 84, 2 Unk.)	56
2011	122 (63, 57, 2 Unk.)	4 (2, 2)	20 (15, 5)	146 (80, 64, 2 Unk.)	2
2012	119 (66, 53)	1 (0, 0, 1 Unk.)	22 (16, 6)	142 (82, 59, 1 Unk.)	25
2013	122 (65, 57)	2 (1, 0, 1 Unk.)	34 (23, 11)	158 (89, 68, 1 Unk.)	7
2014	113 (60, 53)	2 (1, 1, 0)	18 (14, 4)	133 (75, 58)	59
2015	95 (53, 42)	4 (1, 3)	23 (21, 2)	122 (75, 47)	45
2016	71 (40, 31)	11 (7, 4)	9 (7, 2)	91 (54, 37)	1
2017	77 (42, 35)	1 (0, 1)	15 (6, 4, 5 Unk.)	93 (48, 40, 5 Unk.)	38
2018	54 (31, 23)	0 (0, 0)	18 (11, 5, 2 Unk.)	82 (42, 28, 2 Unk.)	0
2019	62 (35, 27)	1 (0, 1)	16 (5, 3, 8 Unk.)	79 (40, 31, 8 Unk.)	24
2020	49 (31, 18)	0 (0, 0)	12 (4, 3, 5 Unk.)	61 (35, 21, 5 Unk.)	4
2021	43 (25, 18)	1 (0, 1)	8 (4, 1, 3 Unk.)	52 (29, 20, 3 Unk.)	22

[a] One- and two-year-old age classes combined.
[b] Adults and subadults combined.
[c] Includes the total number of young located from 15 May to 31 August, including pre- and post-fledging mortalities.

Table 3. Breeding propensity and productivity for northern spotted owls in the Central Cascades Study Area, Willamette National Forest, Oregon from 1988 – 2021.

	Nest status surveys (1 April – 31 May)			Reproductive status surveys (1 April – 31 August)			
Year	Pairs checked for nesting status [a]	Pairs nesting (%)	Successful nests (%)	Pairs checked for reproductive status [b]	Pairs fledging young (%)	Number of young fledged	Mean number of young per pair
1988	35	25 (71)	15 (60)	39	20 (51)	35	0.90
1989	40	9 (23)	6 (67)	49	10 (20)	17	0.35
1990	49	39 (80)	19 (49)	63	29 (46)	36	0.57
1991	45	13 (29)	10 (77)	58	16 (28)	30	0.52
1992	62	46 (74)	40 (87)	61	47 (77)	86	1.41
1993	29	2 (7)	0 (0)	50	0 (0)	0	0.0
1994	56	26 (46)	16 (62)	63	21 (33)	28	0.44
1995	54	13 (24)	12 (92)	73	13 (18)	22	0.30
1996	52	46 (88)	32 (70)	66	42 (64)	68	1.03
1997	58	20 (34)	14 (70)	63	15 (24)	24	0.38
1998	64	44 (69)	23 (52)	81	28 (35)	41	0.51
1999	41	10 (24)	7 (70)	76	11 (14)	21	0.28
2000	56	34 (61)	25 (74)	76	37 (49)	60	0.79
2001	60	31 (52)	25 (81)	86	48 (56)	81	0.94
2002	58	37 (64)	32 (86)	76	42 (55)	62	0.82

	Nest status surveys (1 April – 31 May)			Reproductive status surveys (1 April – 31 August)			
Year	Pairs checked for nesting status [a]	Pairs nesting (%)	Successful nests (%)	Pairs checked for reproductive status [b]	Pairs fledging young (%)	Number of young fledged	Mean number of young per pair
2003	58	13 (22)	7 (54)	76	14 (18)	25	0.33
2004	66	55 (83)	46 (84)	92	62 (67)	100	1.09
2005	53	16 (30)	7 (44)	67	12 (18)	13	0.19
2006	52	11 (21)	10 (91)	66	13 (20)	20	0.30
2007	57	33 (58)	26 (79)	70	31 (44)	48	0.69
2008	37	21 (57)	14 (67)	62	22 (35)	31	0.50
2009	34	11 (32)	10 (91)	63	16 (25)	28	0.44
2010	42	38 (90)	27 (71)	47	30 (64)	47	1.00
2011	16	0 (0)	--	43	1 (2)	2	0.04
2012	30	22 (73)	11 (50)	38	17 (45)	25	0.66
2013	31	3 (10)	3 (100)	48	4 (8)	7	0.15
2014	33	28 (85)	27 (96)	46	34 (74)	56	1.22
2015	32	23 (72)	21 (91)	39	26 (67)	44	1.13
2016	15	1 (7)	1 (100)	30	1 (3)	1	0.03
2017	17	15 (88)	13 (87)	29	23 (79)	36	1.24
2018	11	0 (0)	--	20	0	0	0
2019	12	9 (75)	8 (89)	24	16 (67)	24	1.00

	Nest status surveys (1 April – 31 May)			Reproductive status surveys (1 April – 31 August)			
Year	Pairs checked for nesting status [a]	Pairs nesting (%)	Successful nests (%)	Pairs checked for reproductive status [b]	Pairs fledging young (%)	Number of young fledged	Mean number of young per pair
2020	5	0 (0)	--	14	3 (21)	4	0.29
2021	10	9 (90)	8 (89)	17	13 (77)	22	1.29
Average	40	21 (48)	15 (74)	55	21 (38)	34	0.61

[a] Includes pairs that were given at least four mice on two or more occasions before 31 May.
[b] Includes pairs that were given at least four mice on two or more occasions from 1 June to 31 August in addition to the pairs that were evaluated prior to 31 May.

Table 4. Number of new spotted owls banded, re-sighted, and recaptured by sex and age in the central Cascades study area and in nearby wilderness sites in the Willamette National Forest, Oregon during 2021.

	New owls banded			Owls re-sighted			Owls recaptured [a]		
Age Class	Males	Females	Unk.	Males	Females	Unk.	Males	Females	Unk.
Adult	1	1	0	21	15	0	3	2	0
Subadult	0	0	0	0	0	0	0	1	0
Juvenile	-	-	22	-	-	-	-	-	-

[a] Any owl previously fitted with a USFWS band that was recaptured either to replace a fledgling color band or to replace a damaged or missing adult color band.

13) Figures.

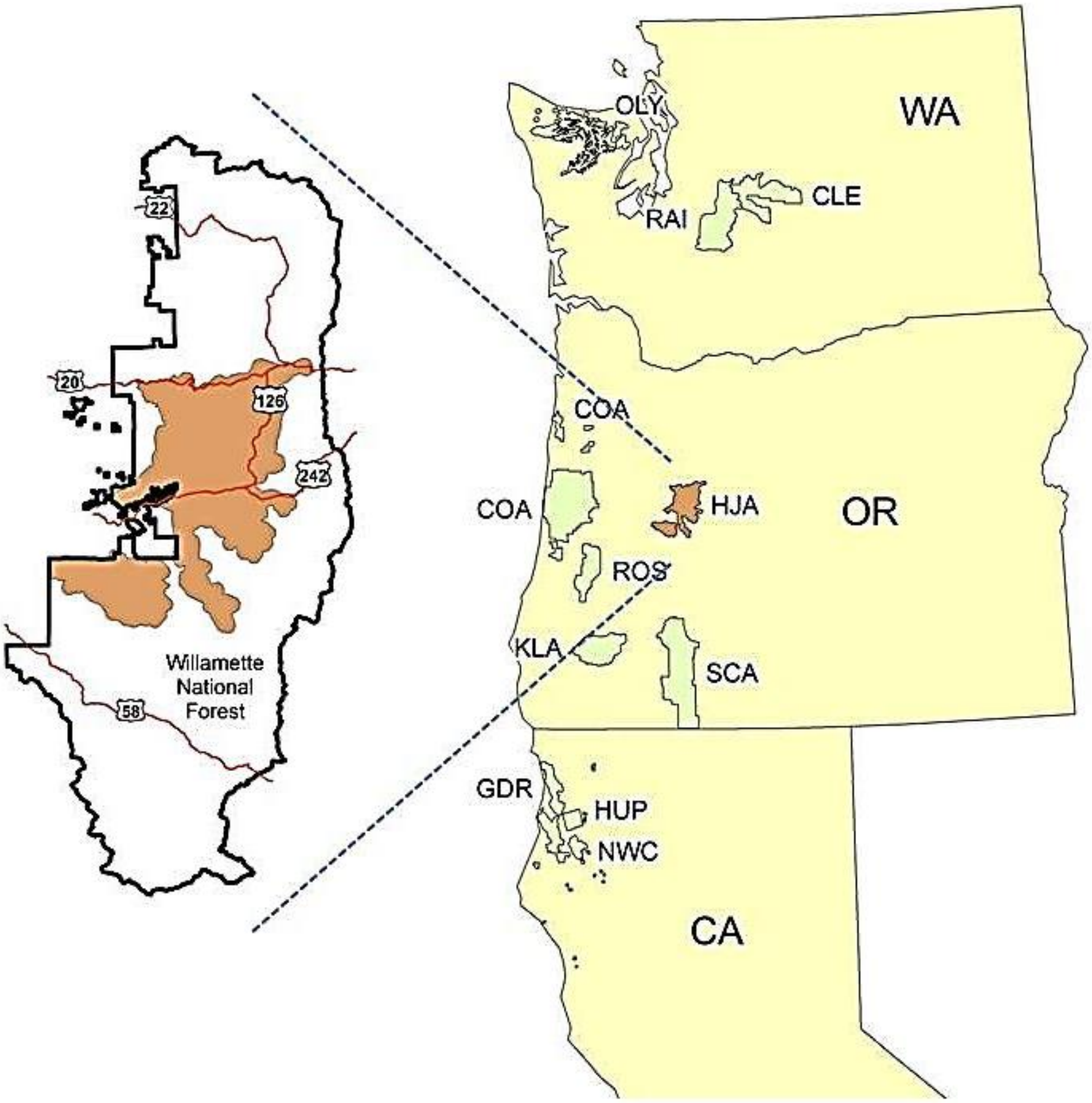

Figure 1. Location of the H.J. Andrews northern spotted owl demography study area as included in the 2020 meta-analysis (Franklin *et al*. 2021). The boundary of the study area was delineated by buffering all spotted owl site centers by 1.6 km to approximate the area covered by surveys.

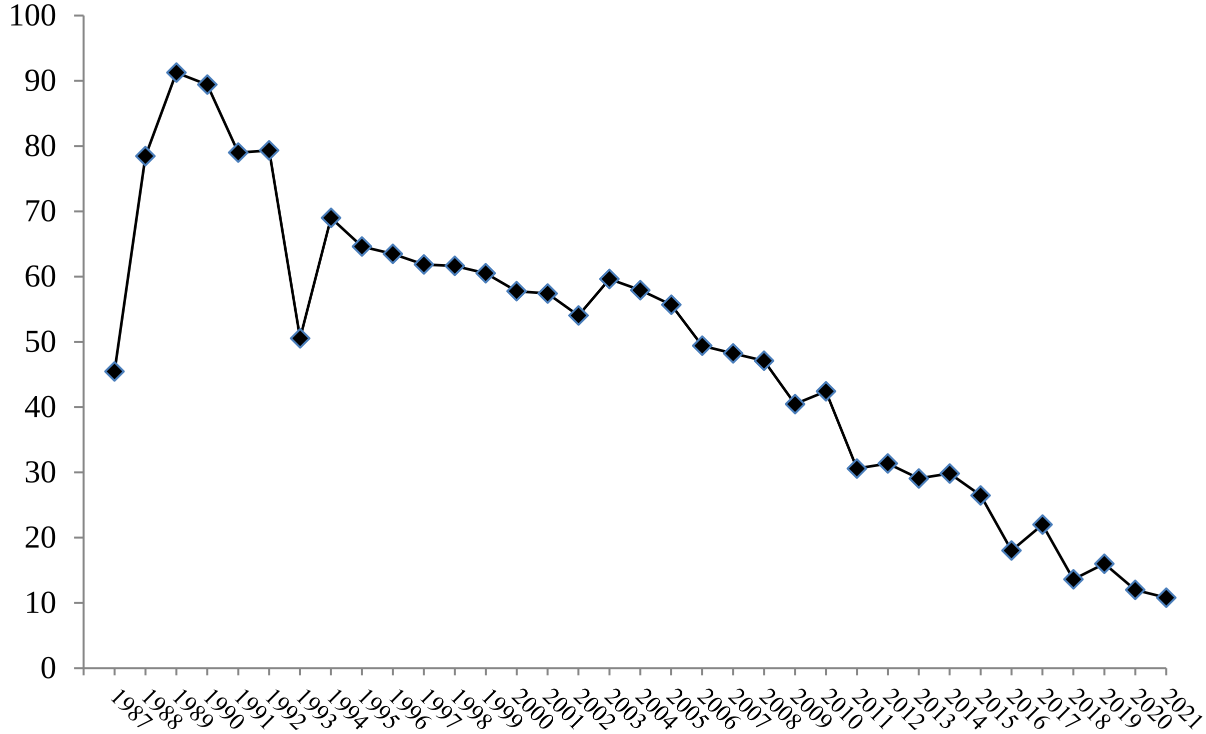

Figure 2. Percentage of sites surveyed for northern spotted owls where pairs of spotted owls were detected in the central Cascades study area, Willamette National Forest, Oregon from 1987 – 2021.

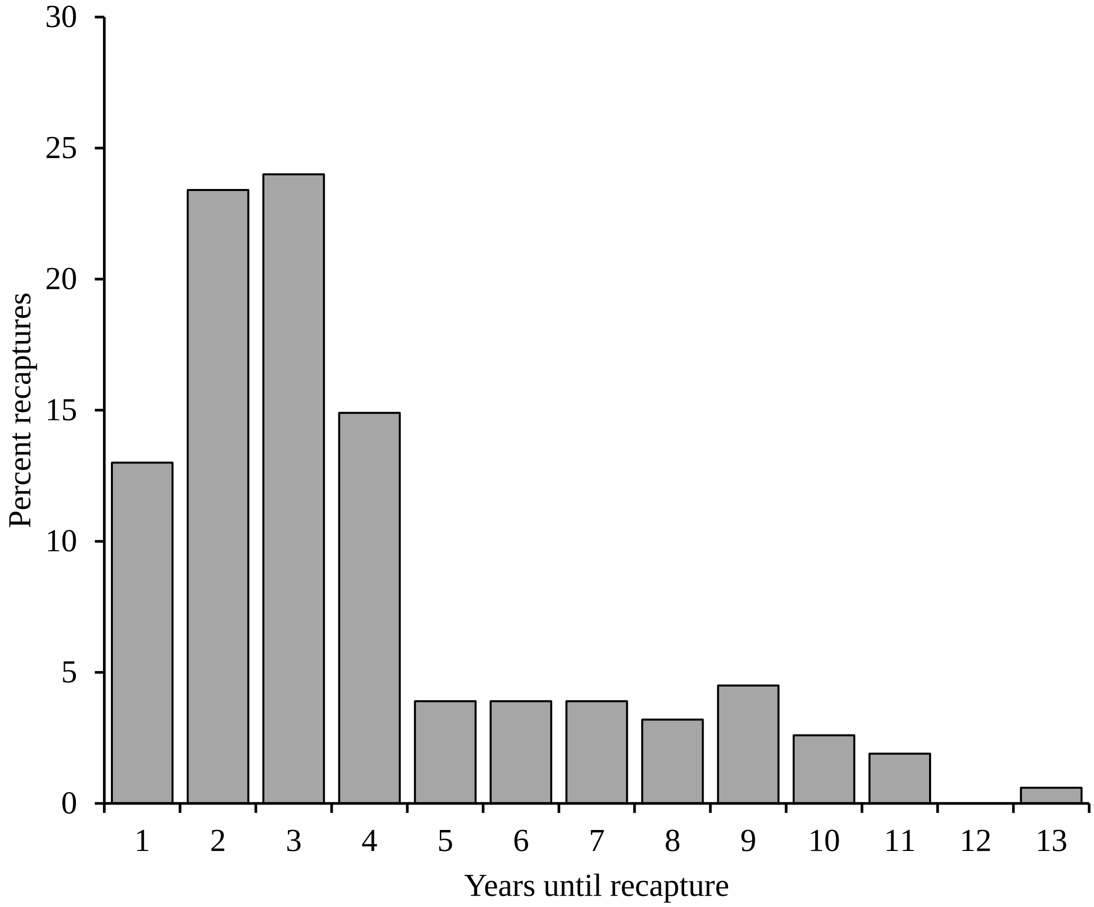

Figure 3. Years until the first recapture of 150 northern spotted owls banded as fledglings in the central Cascades study area, Willamette National Forest, Oregon from 1987 – 2021.

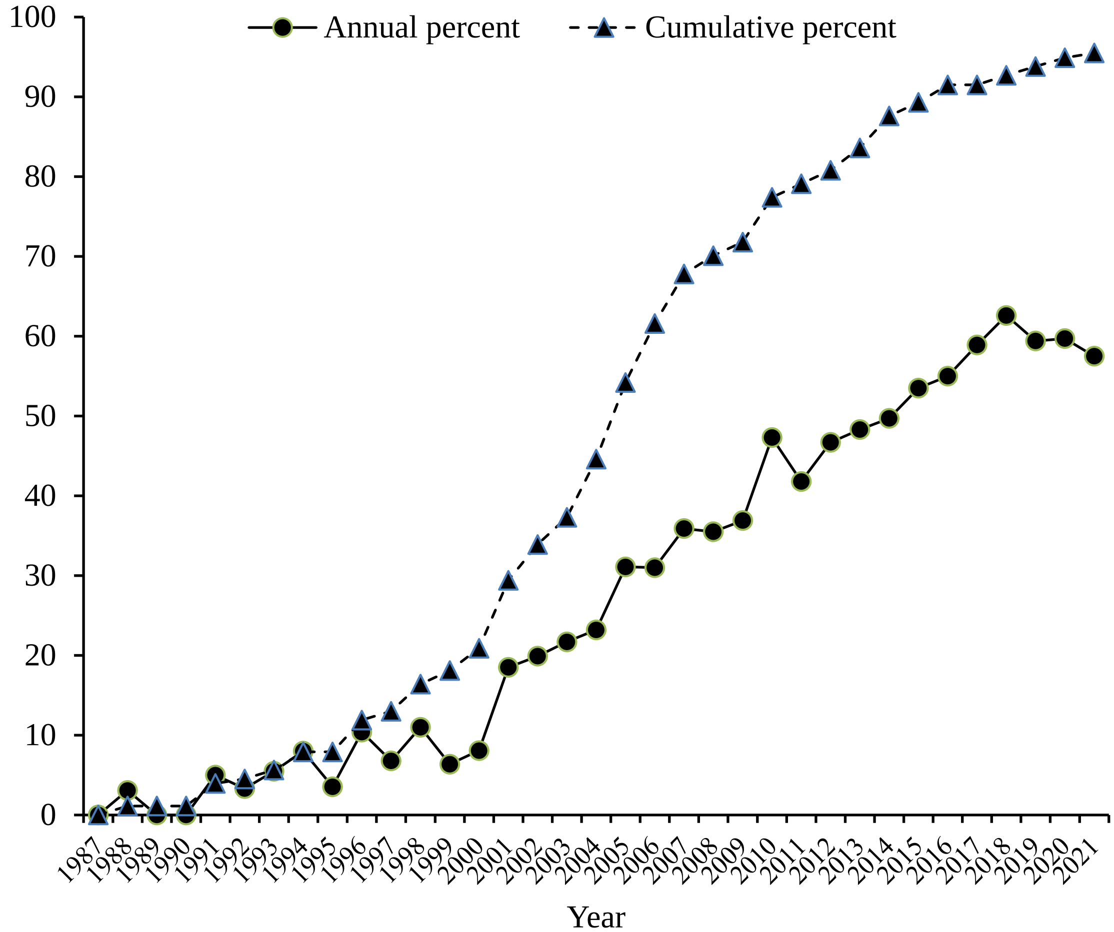

Figure 4. Annual and cumulative percentage of sites where incidental detections of barred owls (*Strix varia*) have occurred while surveying for northern spotted owls in the central Cascades study area, Willamette National Forest, Oregon from 1988 – 2021.

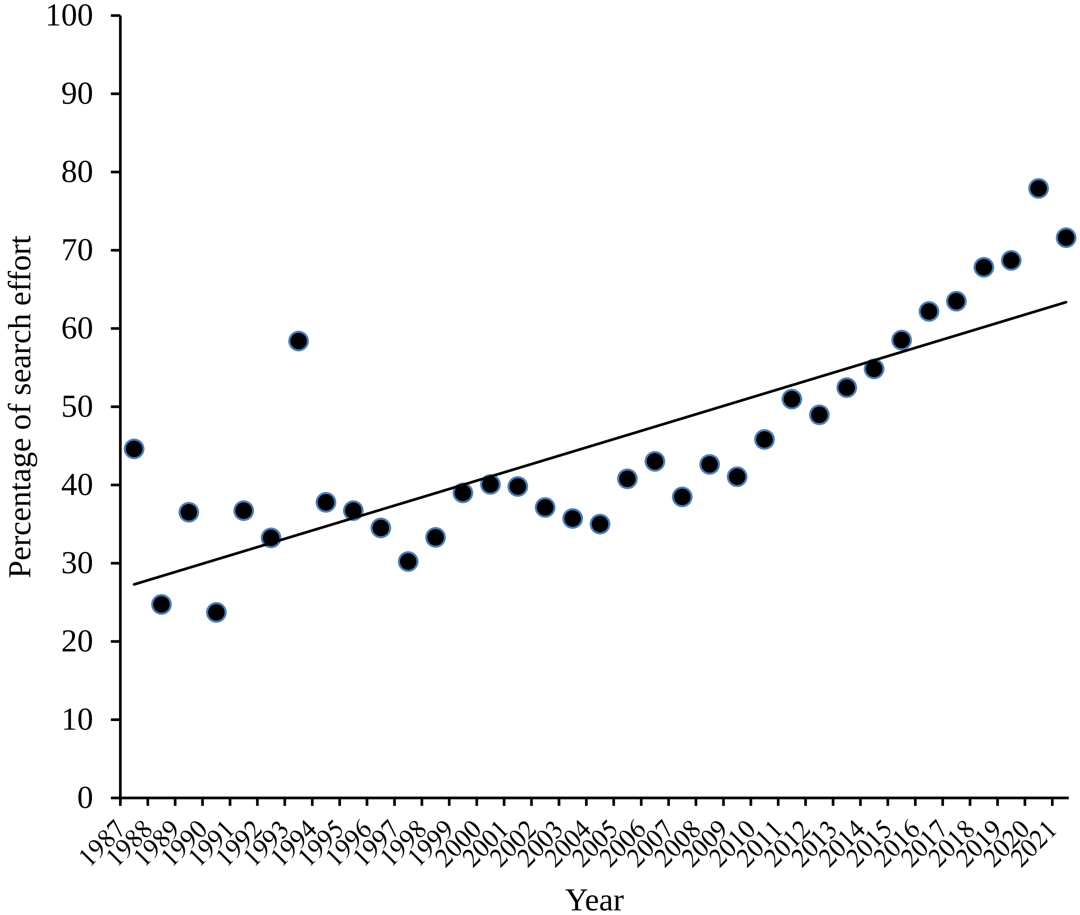

Figure 5. Percentage of search effort conducted as night surveys annually in the central Cascades study area, Willamette National Forest from 1987 through 2021.

14) **Appendices**.

Appendix A. Master site number revisions.

In February 2009, the master site numbering system (MSNO) and the associated locations for the site centers maintained by the Oregon Department of Fish and Wildlife (ODFW) were reviewed and compared to the site center database maintained by the Willamette National Forest (WNF). The name and master site number of 44 sites in our database were revised to match the earliest site centers in the ODFW database (Table A1). In most cases, this required only a change in the name or MSNO of the sites that we monitored. In five instances, this required re-assignment of survey results to better reflect the survey effort at particular ODFW site centers.

Table A1. Master site number (MSNO) and site name revisions as of 26 October 2009.

District	ODFW MSNO	ODFW Site Name	Previous MSNO	Previous Site Name
McKenzie River	0032	Upper McRae Creek	0033	Middle McRae Creek
	0033	Lower McRae Creek	3025	
	0085	Lamb Butte		Lowder Mountain
	0111	NF Quartz Creek		N Fk Quartz Creek
	0113	East Fork McKenzie	5043	E Fk McKenzie River
	0119	Middle Horse Creek	0982	
	0750	Pasture Creek	0850	
	0818	Horsepasture Mount		Horsepasture Mtn
	0821	Great Spring		Great Spg-Clear Lake
	0836	Lost Creek	2442	White Branch Creek
	0850	Upper Horse Creek	2824	
	0851	Lower Roney Creek	2835	
	0857	Lowder Mountain		Upper East Fork
	0869	EF Augusta Creek		E Fk Augusta Creek
	0871	Wolf Rock	2844	Mann Creek
	2465	Hagan Block	5071	
	2477	Gate Creek	5070	
	2826	Indian Fork	1414	Indian Creek
	2827	Lost Branch	0836	Lost Creek
	2831	Castle Creek	1737	
	4085	Upper Cook Creek	3962	
Middle Fork	1015	Slick Creek	4549	West Slick Creek

District	ODFW MSNO	ODFW Site Name	Previous MSNO	Previous Site Name
Middle Fork	1017	Tiller Ninemile		Tiller-Ninemile Cr
	1020	West Delp Creek	4421	Upper Delp
	1028	Logan Creek	2858	Logan Creek
	1031	Briem Creek	4476	
	1032	Upper Pernot Creek	2888	
	1063	Delp Creek Tributary	1020	West Delp Creek
	2899	Upper Marine Creek	1028	Lower Logan Creek
	2463	Saturn Creek	1031	Saturn-Briem Creek
	2861	Little Fall Creek 2		Little Fall Creek Trib
	2867	South Puma Creek	4082	Pumarine
	4549	West Slick Creek	1015	Slick Creek
Sweet Home	0007	Burnside Creek	2956	Indian Tombstone
	0012	Indian Creek	4093	Indian Creek (Sweet)
	0013	Echo Creek		Echo Creek-Lost Prairie
	0064	Boulder Cr (Sweet)	0641	
	0668	Parks Creek	0664	
	0689	Upper Two Girls	5052	
	0694	Squaw Mountain	4098	
	1156	Gordon Meadows	0646	
	1322	Gordon Meadows West	5058	
	2964	East Wildcat Mount		East Wildcat Mountain
	4405	Squaw Headwaters		Squaw Creek Headwaters

Appendix B. Survey and monitoring results by land use allocation.

The first formal spotted owl reserve design estimated that 15 – 20 pairs of spotted owls would be necessary to support a stable population in a habitat reserve (Thomas *et al*. 1990). The Final 2008 Northern Spotted Owl Recovery Plan also recommended that category 1 managed owl conservation areas (MOCAs) be capable of supporting at least 20 pairs, and category 2 MOCAs should be capable of supporting 1 – 19 pairs while also providing connectivity between category 1 areas (U.S. Fish and Wildlife Service 2008). The Final Revised Recovery Plan released in 2011 (U.S. Fish and Wildlife Service 2011) has withdrawn the MOCA network and recommended that managers continue to consider the LSR land use allocation under the NWFP as the current reserve network. Here, we summarized the survey and monitoring results separately for the three primary land use allocations on the central Oregon Cascades northern spotted owl demography study area: late-successional reserves (LSR), adaptive management areas (AMA), and matrix habitats as defined in the Northwest Forest Plan (USDA and USDI 1994). We were particularly interested in the productivity (number of fledglings produced per pair) and detections of northern spotted owls in the four LSRs on the study area as this land use allocation was intended to provide the habitat base for recovery of the subspecies.

Detections compared among land use allocations.

In 2021, the highest proportion of sites where a territorial spotted owl was detected (either a single or pair) was in the AMA land allocation (24%), which was decrease of 7% from 2020 (Table B1). The proportion of sites where spotted owls were detected decreased by 2% in the matrix allocation and 5% in the LSR allocation between 2020 and 2021 (Table B1).

The proportion of territories where a pair was detected decreased in the AMA allocation by 4% between 2020 and 2021. Pair detections increased by 7% in the matrix and decreased by 4% in the LSR allocation (Figure B1). Only one pair was detected in the Fall Creek and South Santiam LSRs in 2021 and two pairs were detected in the Horse Creek LSR (Table B2). The Hagan LSR continued to lack pair detections (Table B2). Overall, a lower percentage of pair detections occurred on LSR sites (5%) relative to matrix (20%) and AMA sites (7%), and the trend since 1997 has been a decrease in pairs detected in all three allocations (Figure B1).

Overall spotted owl productivity was higher than long-term averages in 2021 (matrix 2021: 1.3 young/pair, $\bar{x}$ = 0.6 young/pair, SE = 0.09, n = 25; AMA 2021: 1.7 young/pair, $\bar{x}$ = 0.6 young/pair, SE = 0.09, n = 25; LSR 2021: 1.0 young/pair, $\bar{x}$ = 0.6 young/pair, SE = 0.09 n = 25; Table B3). Two young were produced by one pair in the Fall Creek LSR which usually has the highest productivity of the 4 LSRs on the study area (Fall Creek 2021: 2.0 young/pair, $\bar{x}$ = 0.7 young/pair, SE = 0.12, n = 24). Two young were produced in Horse Creek LSR and one was produced in the South Santiam LSR. No young were produced in the Hagan LSR (Table B3).

Wilderness Area surveys.

Six sites located in the Three Sisters and Mount Washington Wilderness Areas within 2 km of the wilderness area boundary were surveyed on an irregular basis from 1989 through 1996. Since 1997, these sites have been surveyed annually. The data summarized here does not include a site in the Three Sisters Wilderness Area as this pair crossed the wilderness area boundary and nested in the Horse Creek LSR. The distance between the wilderness and LSR locations was >1 mile so it was not considered a dispersal event. That site is accounted for in the LSR totals. The proportion of these sites where pairs were detected was initially high in the wilderness area sites (>80%) but has generally declined since 2000 (<60%; with the exception of 2005). No pairs were detected in these sites in 2020 (Table B4).

Thirty-five sites located in the Three Sisters and Mount Washington Wilderness Areas were surveyed irregularly from 1987 through 1999. Twenty-five spotted owls have been banded at these sites, although only one adult female was resighted on the Warm Springs study area. One male and one female owl banded on the study area were re-sighted in the wilderness. Survey effort at these sites was never adequate to estimate dispersal across the wilderness boundary.

Discussion.

Variation in pair detections in the LSR allocation is particularly pertinent to the effectiveness of the Northwest Forest Plan, as these areas constitute the reserve network for the recovery of the northern spotted owl. Our monitoring results suggest that not all LSRs were equally capable of supporting breeding pairs of spotted owls. The Fall Creek LSR lost 24 pairs from 2000 to 2021 and currently supports only 1 pair of spotted owls, rendering this LSR virtually ineffective as a reserve. The South Santiam, Horse Creek, and Hagan LSRs were never likely to support more than 20 pairs of spotted owls but may still provide connectivity within the reserve network. These LSRs are relatively small and contain a large proportion of mature forest (vs. old-growth) more suitable for foraging and dispersal than for roosting or nesting.

It is important to note that the LSR design was intended to preserve late-successional forest ecosystems rather than to directly benefit any one species (USDA and USDI 1994). Not all late-successional forests can be classified as old growth or as high-quality spotted owl habitat, but they may still be important in preserving ecosystem functions at the landscape level

From 2000 – 2004, and in 2007 and 2017, the largest numbers of young were produced in the LSR allocation (Table B3). In 2005, 2006, 2008 through 2015, and 2018 through 2021, productivity in the LSRs was lower than in the matrix and AMA allocations. With the exception of 2016 when the only young produced was in the South Santiam LSR, most of the young produced in the LSR allocation have been from the Fall Creek LSR (Table B5). Very few young have been produced in the Horse Creek and South Santiam LSRs, and young were rarely produced at all in the Hagan LSR (Table B5). The wide fluctuations in productivity in the Fall Creek LSR and the relatively low numbers of young produced since 2005 suggest that this area may no longer be a reliable source of recruits.

One possible reason for the decline in productivity in the Fall Creek LSR has been the high numbers of barred owls in the watershed. Since 2000, an average of 40% of all barred owl detections each year has been in the Fall Creek LSR (range: 27% – 65%). In most years, there have been nearly as many barred owls in the Fall Creek LSR as have been detected in the matrix and AMA allocations combined. This may have been due to a greater abundance of low elevation, low slope, riparian habitats as well as the high amounts of late seral forest in the Fall

Creek LSR relative to the rest of the study area which seems to be habitat most readily used by barred owls (reviewed in Livezey 2007, Singleton *et al*. 2010, Singleton 2015, Wiens *et al*. 2014). In addition to a direct negative effect of barred owls on spotted owl fecundity (Wiens *et al*. 2014), declining survival and recruitment in response to increasing barred owl populations also would impact overall population productivity through the direct loss of breeding spotted owls (Forsman *et al*. 2011, Dugger *et al.* 2016, Mangan *et al*. 2019, Franklin *et al.* 2021).

Although the matrix and AMA allocations are subject to timber harvest, they previously contained many productive spotted owl pairs that have made substantial contributions to population recovery. The 2012 critical habitat designation (U.S. Fish and Wildlife Service 2012, 2020) identified approximately 100,000 ha (69%) of forested lands within the study area as critical spotted owl habitat. This includes all four of the LSRs and over 50,000 ha of additional habitat, primarily in matrix and AMA allocations. Given that timber harvest may still occur in the matrix and AMA allocations (http://www.fs.usda.gov/resources/willamette/landmanagement/resourcemanagement), it will be critical to continue keeping management agencies informed of the most recent locations of these productive pairs as well as individuals newly recruited into the breeding population.

Table B1. Northern spotted owl detections and residency status at northern spotted owl sites by Northwest Forest Plan land-use allocation (USDA and USDI 1994) on the central Cascades study area, Willamette National Forest, Oregon, 1997 – 2021.

Land use allocation [a]	Year	Sites surveyed	Sites with pairs detected	Sites with resident single owls	Sites with unknown residency	Sites with ≥ 1 owl detected (%)	Sites where owls were not detected	Sites not surveyed to protocol
Matrix	1997	40	29	2	0	31 (78)	9	2
	1998	41	26	3	2	31 (76)	10	3
	1999	42	26	3	1	30 (71)	12	2
	2000	39	24	2	5	31 (79)	8	0
	2001	38	26	3	6	35 (92)	3	1
	2002	38	22	2	7	31 (82)	7	0
	2003	37	26	1	3	30 (81)	7	1
	2004	38	25	1	5	31 (82)	7	0
	2005	39	25	2	4	31 (79)	8	0
	2006	39	22	1	4	27 (69)	12	0
	2007	39	23	1	1	25 (64)	14	0
	2008	37	23	0	2	25 (68)	12	2
	2009	39	20	4	1	25 (64)	14	0
	2010	38	21	0	0	21 (55)	17	0
	2011	39	18	3	1	22 (56)	17	0
	2012	39	17	1	3	21 (54)	18	0
	2013	39	14	2	3	19 (49)	20	0
	2014	38	16	1	1	18 (47)	20	1
	2015	39	12	2	4	18 (46)	21	0
	2016	39	9	3	4	16 (41)	23	0
	2017	36	10	0	3	13 (36)	23	3
	2018	38	7	4	2	13 (34)	25	1

Land use allocation [a]	Year	Sites surveyed	Sites with pairs detected	Sites with resident single owls	Sites with unknown residency	Sites with ≥ 1 owl detected (%)	Sites where owls were not detected	Sites not surveyed to protocol
Matrix	2019	38	6	3	2	11 (29)	27	1
	2020	37	5	2	2	9 (24)	28	2
	2021	40	8	0	1	9 (23)	31	0
AMA	1997	45	31	4	1	36 (80)	9	3
	1998	44	33	1	4	38 (86)	6	1
	1999	43	30	2	4	36 (84)	7	1
	2000	43	30	2	1	33 (77)	10	0
	2001	44	27	4	5	36 (82)	8	0
	2002	42	27	4	5	36 (86)	6	2
	2003	43	30	2	4	36 (84)	7	0
	2004	45	26	2	4	32 (71)	13	0
	2005	45	26	9	5	40 (89)	5	0
	2006	45	24	4	7	35 (78)	10	0
	2007	47	22	4	11	37 (79)	10	0
	2008	44	21	1	4	26 (59)	18	3
	2009	44	19	5	5	29 (66)	15	1
	2010	48	22	3	6	31 (65)	17	0
	2011	48	16	4	3	23 (48)	25	0
	2012	48	12	2	10	24 (50)	24	0
	2013	48	14	4	12	30 (63)	18	0
	2014	48	16	2	3	21 (44)	27	0
	2015	48	17	1	6	24 (50)	24	0
	2016	48	11	2	2	15 (31)	33	0
	2017	48	9	0	7	16 (33)	32	0

Land use allocation [a]	Year	Sites surveyed	Sites with pairs detected	Sites with resident single owls	Sites with unknown residency	Sites with ≥ 1 owl detected (%)	Sites where owls were not detected	Sites not surveyed to protocol
AMA	2018	48	8	2	3	13 (27)	35	0
	2019	48	10	0	6	16 (33)	32	0
	2020	45	5	0	9	14 (31)	31	3
	2021	45	3	0	8	11 (24)	34	3
LSR	1997	27	8	2	9	19 (70)	8	7
	1998	55	27	3	8	38 (69)	17	13
	1999	66	35	7	10	52 (79)	14	8
	2000	73	35	2	18	55 (75)	18	0
	2001	74	35	4	18	57 (77)	17	1
	2002	75	34	6	14	54 (72)	21	0
	2003	75	36	8	11	55 (73)	20	0
	2004	75	41	2 [b]	13	56 (75)	19	2
	2005	77	40	8	7	55 (71)	22	0
	2006	78	34	7 [b]	10	51 (65)	27	0
	2007	77	35	4 [b]	12	51 (66)	26	0
	2008	68	27	4 [b]	11	42 (62)	26	9
	2009	77	27	9 [b]	8	44 (57)	33	1
	2010	73	25	3 [b]	13	41 (56)	31	4
	2011	78	15	9 [b]	17	41 (53)	36	1
	2012	78	21	2 [b]	17	40 (51)	36	2
	2013	78	20	5 [b]	16	41 (53)	37	0
	2014	78	18	5 [b]	10	33 (42)	45	0
	2015	78	14	2 [b]	13	29 (37)	46	2
	2016	78	9	4 [b]	10	23 (30)	55	0

Land use allocation [a]	Year	Sites surveyed	Sites with pairs detected	Sites with resident single owls	Sites with unknown residency	Sites with ≥ 1 owl detected (%)	Sites where owls were not detected	Sites not surveyed to protocol
LSR	2017	60	12	1 [b]	8	21 (35)	39	18
	2018	76	6	1 [b]	7	14 (18)	61	2
	2019	68	7	0	8	15 (22)	53	6
	2020	69	6	0	8	14 (20)	55	6
	2021	66	4	0	7	10 (15)	56	11

[a] Sites with LUA designation of “Other”, “Private”, and “Wilderness” are not included here.
[b] This total includes one resident male spotted owl that has been paired with a spotted x barred hybrid female owl.

Table B2. Summary of survey effort and spotted owl detections in the four late-successional reserves (LSR) in the Central Cascades Study Area, Willamette National Forest, Oregon from 1997 – 2021.

LSR	Year	Sites surveyed	Sites with ≥1 owl detected (%)	Sites with pairs detected (%)
Fall Creek (LSR-219)	1997	0	-	-
	1998	23	17 (74)	13 (57)
	1999	36	30 (83)	23 (64)
	2000	40	33 (83)	25 (63)
	2001	40	34 (85)	24 (60)
	2002	41	36 (88)	25 (61)
	2003	41	35 (85)	21 (51)
	2004	40	31 (78)	24 (60)
	2005	42	30 (71)	24 (57)
	2006	42	30 (71)	20 (48)
	2007	42	30 (71)	20 (48)
	2008	36	25 (69)	16 (44)
	2009	41	23 (56)	14 (34)
	2010	38	23 (61)	15 (39)
	2011	43	25 (58)	9 (21)
	2012	42	24 (57)	15 (36)
	2013	43	28 (65)	13 (30)
	2014	43	19 (44)	11 (26)
	2015	43	17 (40)	6 (14)
	2016	43	11 (26)	5 (12)
	2017	34	12 (35)	7 (21)
	2018	41	7 (17)	4 (10)
	2019	37	7 (19)	3 (8)
	2020	39	6 (15)	3 (8)

LSR	Year	Sites surveyed	Sites with ≥1 owl detected (%)	Sites with pairs detected (%)
	2021	33	6 (18)	1 (3)
Hagan (LSR-215)	1997	3	2 (67)	1 (33)
	1998	4	3 (75)	2 (50)
	1999	5	3 (60)	0
	2000	5	3 (60)	1 (20)
	2001	5	5 (100)	2 (40)
	2002	5	2 (40)	1 (20)
	2003	5	3 (60)	2 (40)
	2004	5	3 (60)	2 (40)
	2005	5	4 (80)	1 (20)
	2006	5	3 (60)	3 (60)
	2007	5	3 (60)	1 (20)
	2008	4	1 (25)	1 (25)
	2009	5	2 (40)	2 (40)
	2010	5	1 (20)	0
	2011	5	2 (40)	0
	2012	5	3 (60)	0
	2013	5	0	0
	2014	5	0	0
	2015	5	1 (20)	0
	2016	5	0	0
	2017	5	0	0
	2018	5	0	0
	2019	5	0	0
	2020	5	0	0
	2021	5	0	0

LSR	Year	Sites surveyed	Sites with ≥1 owl detected (%)	Sites with pairs detected (%)
Horse Creek (LSR-218)	1997	12	8 (67)	3 (25)
	1998	14	9 (64)	7 (50)
	1999	13	9 (69)	7 (54)
	2000	13	8 (62)	7 (54)
	2001	13	9 (69)	4 (31)
	2002	14	8 (57)	3 (21)
	2003	14	10 (71)	7 (50)
	2004	14	11 (79)	8 (57)
	2005	14	10 (71)	4 (29)
	2006	14	8 (57)	5 (36)
	2007	14	9 (64)	6 (43)
	2008	13	8 (62)	6 (46)
	2009	14	11 (79)	6 (43)
	2010	14	8 (57)	5 (36)
	2011	14	8 (57)	3 (21)
	2012	14	7 (50)	4 (29)
	2013	14	7 (50)	3 (21)
	2014	14	8 (57)	4 (29)
	2015	14	7 (50)	5 (36)
	2016	14	8 (57)	1 (7)
	2017	8	2 (25)	2 (25)
	2018	14	4 (29)	0
	2019	14	3 (21)	2 (14)
	2020	13	2 (15)	1 (8)
	2021	15	2 (13)	2 (13)
S. Santiam (LSR-217)	1997	12	9 (75)	4 (33)
	1998	14	9 (64)	5 (36)

LSR	Year	Sites surveyed	Sites with ≥1 owl detected (%)	Sites with pairs detected (%)
S. Santiam (LSR-217)	1999	12	10 (83)	5 (42)
	2000	15	11 (73)	2 (13)
	2001	15	8 (53)	4 (27)
	2002	15	8 (53)	5 (33)
	2003	15	8 (53)	6 (40)
	2004	15	10 (67)	6 (40)
	2005	16	11 (69)	11 (69)
	2006	16	9 (56)	5 (31)
	2007	16	9 (56)	8 (50)
	2008	15	8 (53)	4 (27)
	2009	16	8 (50)	5 (31)
	2010	15	9 (60)	7 (47)
	2011	16	6 (38)	3 (19)
	2012	16	6 (38)	2 (13)
	2013	16	7 (44)	4 (25)
	2014	16	5 (31)	3 (19)
	2015	16	5 (31)	3 (19)
	2016	16	4 (25)	3 (19)
	2017	13	7 (54)	3 (23)
	2018	16	4 (25)	2 (23)
	2019	12	5 (42)	2 (17)
	2020	12	6 (50)	2 (17)
	2021	14	3 (21)	1 (7)

Table B3. Summary of reproductive success of northern spotted owls stratified by land use allocation on the Central Cascades Study Area, Willamette National Forest, Oregon from 1997 – 2021.

Land use allocation	Year	Number of pairs [a]	Number (%) of pairs fledging young	Number of young fledged	Average number of young per successful pair	Average number of young per pair (all pairs)
Matrix	1997	25	6 (24)	10	1.67	0.40
	1998	24	12 (50)	17	1.42	0.71
	1999	23	1 (4)	2	2.00	0.09
	2000	23	10 (43)	17	1.70	0.74
	2001	26	10 (38)	17	1.70	0.65
	2002	19	11 (58)	16	1.45	0.84
	2003	22	2 (9)	3	1.50	0.14
	2004	25	19 (76)	30	1.58	1.20
	2005	21	3 (14)	3	1.00	0.14
	2006	20	6 (30)	10	1.67	0.50
	2007	20	10 (48)	15	1.50	0.75
	2008	20	6 (30)	9	1.50	0.45
	2009	20	9 (43)	17	1.89	0.85
	2010	17	12 (71)	17	1.42	1.00
	2011	16	0 (0)	0	0	0
	2012	16	9 (56)	13	1.44	0.81
	2013	14	1 (7)	2	2.00	0.14
	2014	17	14 (82)	23	1.64	1.35
	2015	12	8 (67)	13	1.63	1.08
	2016	7	0 (0)	0	0	0
	2017	10	9 (90)	13	1.40	1.30

Land use allocation	Year	Number of pairs [a]	Number (%) of pairs fledging young	Number of young fledged	Average number of young per successful pair	Average number of young per pair (all pairs)
Matrix (cont.)	2018	6	0	0	0	0
	2019	7	5 (71)	9	1.80	1.30
	2020	4	0	0	0	0
	2021	8	6 (75)	10	1.67	1.30
	Ave.	16.9	6.8 (39.7)	10.6	1.60	0.63
AMA	1997	28	8 (29)	13	1.63	0.46
	1998	32	7 (22)	9	1.29	0.28
	1999	29	5 (17)	9	1.80	0.31
	2000	25	12 (48)	20	1.67	0.80
	2001	24	14 (54)	24	1.71	1.00
	2002	25	10 (40)	13	1.30	0.52
	2003	23	4 (17)	8	2.00	0.35
	2004	26	19 (73)	32	1.68	1.23
	2005	19	7 (33)	8	1.14	0.42
	2006	20	5 (25)	8	1.60	0.40
	2007	16	4 (25)	6	1.50	0.38
	2008	17	10 (59)	15	1.50	0.88
	2009	17	3 (18)	5	1.67	0.29
	2010	14	11 (79)	15	1.36	1.07
	2011	14	1 (7)	2	2.00	0.14
	2012	8	3 (38)	5	1.67	0.63
	2013	13	0 (0)	0	0	0
	2014	15	9 (60)	16	1.78	1.07

Land use allocation	Year	Number of pairs [a]	Number (%) of pairs fledging young	Number of young fledged	Average number of young per successful pair	Average number of young per pair (all pairs)
AMA (cont.)	2015	14	10 (71)	17	1.70	1.21
	2016	11	0 (0)	0	0	0
	2017	7	5 (71)	8	1.60	1.10
	2018	8	0	0	0	0
	2019	8	6 (75)	8	1.33	1.00
	2020	3	0	0	0	0
	2021	3	3 (100)	5	1.67	1.70
	Ave.	16.8	6.5 (38.8)	9.8	1.60	0.61
LSR [b]	1997	5	0 (0)	0	0.00	0.00
	1998	21	7 (32)	12	1.71	0.57
	1999	20	5 (25)	10	2.00	0.50
	2000	24	14 (68)	22	1.57	0.92
	2001	32	22 (69)	37	1.68	1.16
	2002	28	19 (66)	31	1.63	1.11
	2003	27	5 (17)	9	1.80	0.33
	2004	38	22 (56)	34	1.55	0.89
	2005	26	2 (7)	2	1.00	0.08
	2006	24	2 (8)	2	1.00	0.08
	2007	32	15 (47)	23	1.53	0.72
	2008	23	6 (25)	7	1.17	0.30
	2009	24	4 (17)	6	1.50	0.25
	2010	16	7 (44)	15	2.14	0.94
	2011	13	0 (0)	0	0	0

Land use allocation	Year	Number of pairs [a]	Number (%) of pairs fledging young	Number of young fledged	Average number of young per successful pair	Average number of young per pair (all pairs)
LSR (cont.)	2012	14	4 (29)	6	1.50	0.43
	2013	20	3 (15)	5	1.67	0.25
	2014	14	10 (71)	15	1.50	1.07
	2015	12	8 (67)	14	1.75	1.17
	2016	10	1 (10)	1	1.00	0.10
	2017	10	8 (80)	14	1.80	1.40
	2018	4	0	0	0	0
	2019	5	2 (40)	3	1.50	0.6
	2020	4	2 (50)	2	1.00	0.5
	2021	5	3 (60)	5	1.70	1.00
	Ave.	18.5	7.1 (37.5)	11.5	1.53	0.60

[a] Includes only pairs that were given at least 4 mice on two or more occasions prior to 31 August.
[b] The LSR estimates were computed for 1998 - 2021 because the Fall Creek LSR was not completely surveyed in 1997.

Table B4. Wilderness boundary sites surveyed concurrently with the demographic study in the central Cascades study area, Willamette National Forest, Oregon from 1997 – 2021.

Year	Sites surveyed [a]	Sites with pairs	Number of pairs producing young	Number of young fledged
1997	5	4	1	2
1998	5	5	1	1
1999	5	5	0	0
2000	5	3	0	0
2001	5	4	0	0
2002	5	2	0	0
2003	6[b]	3	0	0
2004	6	2	0	0
2005	6	5	0	0
2006	6	3	1	2
2007	6	3	3	4
2008	5	2	0	0
2009	6	3	0	0
2010	7[c]	3	0	0
2011	7[c]	1	0	0
2012	7[c]	2	0	0
2013	6	2	0	0
2014	6	2	2	3
2015	6	1	1	1
2016	6	1	0	0
2017	4	1	0	0
2018	6	2	0	0
2019	5	2	2	2
2020	5	1	0	0
2021	5	0	0	0

[a] Includes only sites that were surveyed at least 3 times at night.
[b] One site previously within an LSR has been re-assigned to the wilderness based on the 3 most recent owl locations.
[c] A second pair was located from an LSR site over 1 mile into the wilderness

Table B5. Summary reproductive statistics in the four late-successional reserves (LSR) in the Central Cascades Study Area, Willamette National Forest, Oregon from 1997 – 2021.

LSR	Year	Nesting surveys [a]	Pairs nesting	Reproductive surveys [b]	Pairs fledging young (%)	Young fledged	Young per successful pair	Young per all pairs
Fall Creek (LSR-219)	1997	Fall Creek not surveyed by OCFWRU staff in 1997.						
	1998	9	7	10	4 (40)	8	2.00	0.80
	1999	8	2	12	4 (33)	8	2.00	0.67
	2000	11	9	19	12 (67)	20	1.67	1.05
	2001	13	6	23	15 (65)	24	1.60	1.04
	2002	17	14	22	15 (71)	27	1.80	1.23
	2003	14	2	18	2 (11)	4	2.00	0.22
	2004	19	12	23	13 (59)	22	1.69	0.96
	2005	14	6	17	0	0	0	0
	2006	15	0	16	0	0	0	0
	2007	14	9	20	11 (58)	16	1.45	0.80
	2008	8	4	18	5 (29)	6	1.20	0.33
	2009	8	2	13	5 (38)	4	1.33	0.31
	2010	9	8	9	4 (44)	9	2.25	1.00
	2011	3	0	9	0	0	0	0
	2012	10	7	9	3 (33)	5	1.67	0.55
	2013	7	0	14	1 (7)	2	2.00	0.14
	2014	5	5	8	7 (88)	10	1.43	1.25
	2015	5	3	6	3 (50)	6	2.00	1.00
	2016	2	0	4	0 (0)	0	0	0
	2017	3	3	5	4 (80)	8	2.00	1.60
	2018	2	0	3	0	0	0	0
	2019	1	1	2	1 (50)	2	2.00	1.00
	2020	1	0	1	0	0	0	0
	2021	0	-	1	1 (100)	2	2.00	2.00
Hagan (LSR-215)	1997	1	1	0	0	0	0	0
	1998	1	1	1	0	0	0	0
	1999	0	-	0	-	-	-	-

LSR	Year	Nesting surveys [a]	Pairs nesting	Reproductive surveys [b]	Pairs fledging young (%)	Young fledged	Young per successful pair	Young per all pairs
Hagan	2000	0	-	0	-	-	-	-
(LSR-215)	2001	1	1	2	2 (100)	3	1.50	1.50
	2002	1	0	1	0	0	0	0
	2003	1	1	1	0	0	0	0
	2004	2	1	2	0	0	0	0
	2005	0	-	0	-	-	-	-
	2006	1	0	1	0	0	0	0
	2007	1	0	1	0	0	0	0
	2008	1	0	1	0	0	0	0
	2009	1	1	2	0	0	0	0
	2010	0	-	0	-	-	-	-
	2011	0	-	0	-	-	-	-
	2012	0	-	0	-	-	-	-
	2013	0	-	0	-	-	-	-
	2014	0	-	0	-	-	-	-
	2015	0	-	0	-	-	-	-
	2016	0	-	0	-	-	-	-
	2017	0	-	0	-	-	-	-
	2018	0	-	0	-	-	-	-
	2019	0	-	0	-	-	-	-
	2020	0	-	0	-	-	-	-
	2021	0	-	0	-	-	-	-
Horse Cr.	1997	2	0	3	0	0	0	0
(LSR-218)	1998	2	0	6	2 (40)	2	1.00	0.33
	1999	4	2	4	1 (20)	2	2.00	0.50
	2000	3	2	3	1 (33)	1	1.00	0.33
	2001	2	1	4	3 (60)	6	2.00	1.50
	2002	2	1	3	1 (33)	1	1.00	0.33
	2003	3	1	5	2 (50)	3	1.50	0.60
	2004	2	2	8	5 (63)	7	1.40	0.88

LSR	Year	Nesting surveys [a]	Pairs nesting	Reproductive surveys [b]	Pairs fledging young (%)	Young fledged	Young per successful pair	Young per all pairs
Horse Cr. (LSR-218)	2005	3	0	4	1 (25)	1	1.00	0.25
	2006	2	1	2	1 (50)	1	1.00	0.50
	2007	3	1	6	2 (40)	4	2.00	0.67
	2008	1	0	2	0	0	0	0
	2009	1	1	5	1 (20)	2	2.00	0.40
	2010	3	3	3	2 (67)	5	2.50	1.67
	2011	1	0	5	0	0	0	0
	2012	1	0	3	0	0	0	0
	2013	1	1	3	1 (33)	1	1.00	0.33
	2014	1	0	3	1 (33)	1	1.00	0.33
	2015	2	2	3	3 (100)	4	1.33	1.33
	2016	0	-	2	0 (0)	0	0	0
	2017	1	1	2	2 (100)	2	1.00	1.00
	2018	0	-	0	-	-	-	-
	2019	1	1	2	1 (50)	1	1.00	0.50
	2020	0	-	1	1 (100)	1	1.00	1.00
	2021	2	1	2	1 (50)	2	2.00	1.00
S. Santiam (LSR-217)	1997	4	2	5	0	0	0.00	0.00
	1998	4	2	5	1 (25)	2	2.00	0.40
	1999	1	0	4	0	0	0.00	0.00
	2000	1	1	2	1 (50)	1	1.00	0.50
	2001	2	2	3	2 (67)	4	2.00	1.33
	2002	2	2	3	3 (100)	3	1.00	1.00
	2003	3	1	6	1 (17)	2	2.00	0.33
	2004	4	4	6	4 (67)	5	1.25	0.83
	2005	4	1	7	1 (14)	1	1.00	0.14
	2006	4	1	5	1 (20)	1	1.00	0.20
	2007	3	1	7	2 (29)	3	1.50	0.43
	2008	4	2	4	1 (25)	1	1.00	0.25
	2009	2	0	5	0	0	0	0

LSR	Year	Nesting surveys [a]	Pairs nesting	Reproductive surveys [b]	Pairs fledging young (%)	Young fledged	Young per successful pair	Young per all pairs
S. Santiam (LSR-217)	2010	1	1	6	1 (17)	1	1.00	0.17
	2011	0	-	3	0	0	0	0
	2012	0	-	2	1 (50)	1	1.00	0.5
	2013	4	1	5	1 (20)	2	2.00	0.4
	2014	2	2	3	2 (67)	4	2.00	1.33
	2015	2	1	3	2 (67)	4	2.00	1.33
	2016	2	1	3	1 (33)	1	1.00	0.33
	2017	1	0	3	2 (67)	4	2.00	1.33
	2018	1	0	1	0	0	-	0
	2019	1	0	1	0	0	-	0
	2020	0	-	2	1 (50)	1	1.00	0.5
	2021	0	-	2	1 (50)	1	1.00	0.5

[a] Includes pairs and females given at least four mice on at least two occasions by 31 May and all females examined for a brood patch while in hand by 30 June.
[b] Includes all pairs and females given at least four mice on at least two occasions by 31 August.

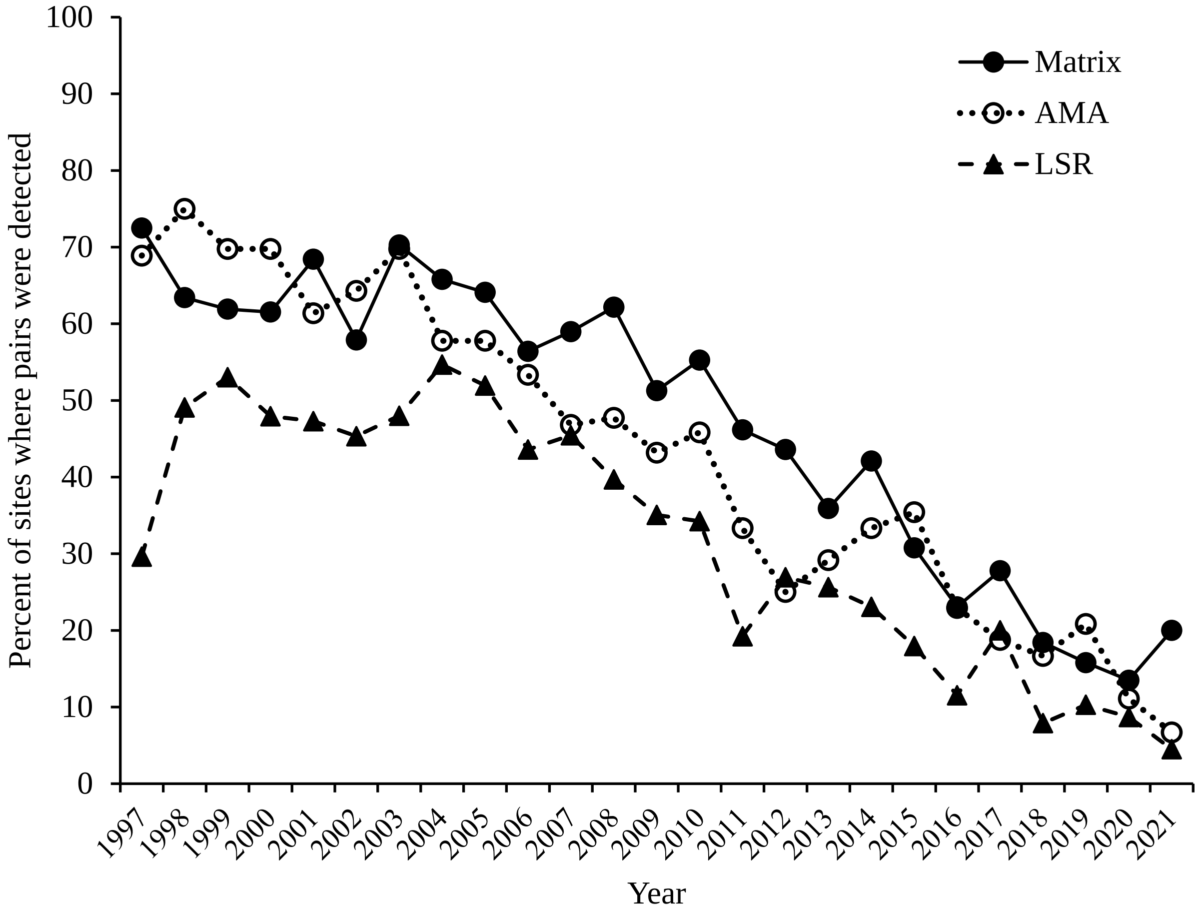

Figure B1. Percentage of sites where pairs of northern spotted owls were detected compared among land use allocations in the central Cascades study area, Willamette National Forest, Oregon from 1997 – 2021.

Appendix C. Timber sale surveys.

We initiated surveys at 17 additional historic NSO sites in two Forest Service planning areas in 2017. Six of these sites were in the Flat Country planning area located in the matrix lands west of the wilderness boundary. In 2020, an additional site was added to account for the modification of the location of two proposed harvest units. The Flat Country area also included 10 sites already monitored as part of the demography study (Table C1). Several of the sites in this timber sale include survey stations inside as well as outside of the planning area boundary. The other 11 new sites were in the Timber Butte planning area in the matrix land southwest of the Fall Creek LSR.

Surveys in the Flat Country planning area continued through 2021. A minimum of 3 complete night surveys were conducted from 157 survey stations in this area (15 sites). Stations were located with respect to the distribution of suitable spotted owl habitat, locations of the proposed harvest units, and historic pair and nest locations. Additional daytime walk-in surveys to historical activity centers also were conducted at 6 of these sites. Late winter snowfall on the forest roads in the eastern portion of the planning area delayed complete surveys for most of these sites until May. We were able to conduct several partial surveys at the affected sites to augment the survey coverage early in the season so that many of the survey stations in the lower western half of the planning area were surveyed 4 or more times. One pair nested and fledged 2 young at a site partially within the planning area, but the nest site was approximately 0.25 mile south of the boundary. Numerous barred owl detections occurred, including 6 barred owl pairs, 4 of which produced young (Table C1). Plans for 2022 are to continue surveys of the sites included in the demography data within the Flat Country planning area but the sites added in 2017 and 2020 will not be surveyed.

In 2019, we began consulting with Forest Service biologists regarding the 3-D timber sale planning area. The demography study area included a portion of this planning area with 18 sites currently monitored as part of the demography study, with one additional site not monitored since 1992. Surveys in 2021 in this area revealed 2 nesting spotted owl pairs which produced 3 young, 3 non-nesting pairs and 2 single spotted owls. Surveys at one site were discontinued after one night survey to avoid disturbing a pair at a neighboring site. Additional daytime walk-in surveys were conducted at 8 historical activity centers to supplement the night surveys.

Table C1. Summary of 2021 Forest Service planning area surveys in the central Cascades study area, Willamette National Forest. Sites not previously included in the demography study are in *italics*.

Planning area	Sites (MSNO)	Survey stations	2021 Summary
Flat Country EIS	Anderson Creek (2408)	14	1 day visit, 4 night surveys, no STOC detections, 2 STVA detections
	Anderson Headwaters (0831)	7	3 night surveys, no STOC detections, 2 STVA detections
	Belknap Springs (2829)	8	4 night surveys, no STOC detections, nesting STVA pair
	Boulder Creek (2409)	13	1 day visit, 3 night surveys, no STOC detections, nesting STVA pair
	East Beaver Marsh (2415)	4	1 day visit, 3 night surveys, no STOC detections, 2 STVA detections
	East Boulder Creek (1738)	12	1 day visit, 3 night surveys, no STOC detections, 3 STVA detections
	Fingerboard Prairie (0983)	13	3 night surveys, no STOC detections, 2 STVA detections
	Frissell Creek (0823)	7	3 night surveys, no STOC detections, no STVA detections
	Irish Camp Lake (2834)	8	3 night surveys, no STOC detections, 5 STVA detections
	Kuitan Lake (2419)	10	3 night surveys, no STOC detections, 4 STVA detections
	Lost Branch Creek (2827)	11	3 night surveys, no STOC detections, 2 nesting STVA pairs
	NF Boulder Creek (0833)	13	3 night surveys, no STOC detections, 1 STVA detection
	Norwegian Creek (0829)	13	1 day visit, 3 night surveys, no STOC detections, nesting STVA pair
	Scott Creek (0817)	16	3 night surveys, no STOC detections, 1 STVA detection
	Sweetwater Creek (2838)	10	3 night surveys, no STOC detections, no STVA detections
	Upper Kink Creek (0826)	11	3 night surveys, no STOC detections, nesting STVA pair

Planning area	Sites (MSNO)	Survey stations	2021 Summary
	West Scott Mountain (2456)	3	3 night surveys, no STOC detections, no STVA detections
	White Branch Creek (2442)	6	7 day visits, 4 night surveys, nesting STOC pair fledged 2 young, no STVA detections
3-D EA	Bunchgrass Creek (2411)	7	2 day visits, 3 night surveys, no STOC detections, no STVA detections
	Burnside Creek (0007)	8	5 daytime visits, 2 night surveys, single STOC female identified, STVA pair detected
	Carmen Reservoir (0825)	6	1 day visit, 3 night surveys, no STOC detections, no STVA detections
	East Beaver Marsh (2415)	4	1 day visit, 3 night surveys, no STOC detections, 2 STVA detections
	East Wildcat Mount (2964)	4	9 day visits, 2 night surveys, non-nesting STOC pair and additional STOC adult, no STVA detections
	Echo Creek (0013)	5	5 day visits, nesting STOC pair fledged 2 young, no STVA detections
	Fish Lake (0123)	7	3 night surveys, no STOC detections, no STVA detections
	Great Spring (0821)	7	3 night surveys, no STOC detections, no STVA detections
	Indian Creek (0012)	6	4 daytime visits, nesting STOC pair fledged 1 young, no STVA detections
	Lava Lake (2445) / Crescent Maude (0670)	6	3 night surveys, no STOC detections, 3 STVA detections
	Lost Lake (0815)	3	3 night surveys, no STOC detections, no STVA detections
	Lower Browder Creek (2424)	9	1 day visit, 3 night surveys, , no STOC detections, STVA pair detected
	McKenzie Gulch (2451)	12	1 day visit, 3 night surveys, no STOC detections, no STVA detections
	Nash Crater (0816)	4	3 night surveys, no STOC detections, no STVA detections

Planning area	Sites (MSNO)	Survey stations	2021 Summary
	North Browder Creek (2972)	4	1 night survey, further surveys discontinued to avoid disturbance to the STOC pair at East Wildcat Mount
	Norwegian Creek (0829)	10	1 day visit, 3 night surveys, no STOC detections, nesting STVA pair
	Potato Hill (0820) / Santiam Pass (2432)	8	3 night surveys, no STOC detections, no STVA detections
	Smith Reservoir (0822)	10	3 night surveys, no STOC detections, no STVA detections
	Smith Ridge (0824)	7	1 day visit, 3 night surveys, no STOC detections, 3 STVA detections
	Smith River (0673) / Smith River South (0671)	8	3 night surveys, no STOC detections, 1 STVA detection
	Tamolitch Falls (2447)	7	3 night surveys, no STOC detections, 1 STVA detection
	Tombstone Summit (0011)	8	3 night surveys, no STOC detections, 2 STVA detections
	Upper Gate Creek (0672)	3	3 night surveys, no STOC detections, no STVA detections
	Upper Smith River (2027) / Dane Prairie (0704)	3	2 day visits, 3 partial night surveys (4 stations inaccessible), no STOC detections, 1 STVA detection
	Wildcat RNA (0827)	7	3 night surveys, no STOC detections, no STVA detections

Appendix D. Hybridization between spotted and barred owls.

Since 1999, we have located 12 non-juvenile spotted-barred owl F1 hybrids at 17 different sites (Table D1). We observed eight cases involving a spotted owl paired with a hybrid or barred owl and five cases involving hybrid males paired with barred owl females. In addition, a male spotted owl was observed paired with a female barred owl (1 case) and with a female F1 hybrid owl (2 cases). A single case of a barred owl male paired with a female F1 hybrid also has been observed, although this pair did not attempt to nest. In 2019 we located one banded hybrid female and recorded two unidentified hybrid females on the study area. The banded female hybrid was last observed paired with a male barred owl in 2014; pair status for this female was not determined in 2019, although she was detected on the same occasion as spotted owl and barred owl males. No hybrids were detected in 2020 or 2021.

Table D1. Summary of spotted x barred hybrid owl activity in the Central Cascades Study Area, Willamette National Forest, Oregon from 1999 – 2021.

Year	MSNO	Male species [a]	Female species	Number of young fledged	Additional STOC observations
1999	4549	STXX	STVA	1	Pair, reproduction unknown
2000	4549	STXX	STVA	Unknown	None
2001	1015	STOC	STVA	2	None
	4549	STXX	--	--	Female, 1 auditory detection
2002	2446	STVA	STXX	Unknown	Male, 1 auditory detection
	4549	STXX [b]	STVA	2	None
2003	1013	--	STXX [c]	Unknown	Resident male
	1031	STXX	--	--	Male, 1 auditory detection
	4549	STXX	--	--	None
2004	1015	STXX	--	--	None
	1031	STXX [d]	STVA	2 [e]	None
	2444	STOC	STXX [c]	Non-nesting	None
	2447	--	STXX	Unknown	Pair, 1 auditory detection
	2861	STXX	STVA	Unknown	Male, visual identification
	2897	--	STXX [f]	Unknown	Male, 1 auditory detection
	4392	STXX [g]	STVA	Unknown	Pair, 1 auditory detection
	4549	STXX	STVA	Unknown	Male, 1 auditory detection
2005	1031	STXX [d, h]	STVA	1 [i]	None
	2861	STXX	--	Unknown	Unk. sex, 1 auditory detection
	4392	STXX	--	Unknown	Pair, failed nesting attempt
	4549	STXX	STVA	Unknown	Unk. sex, 1 auditory detection
2006	1012	STXX [g]	--	Unknown	Male, visual, not identified
	4549	STXX	STVA	Unknown	Female, 2 auditory detections
	1016	STXX	--	Unknown	Male, visual identification
	1031	STXX [d]	STVA	2 [e]	None
	2410	--	STXX	Unknown	Pair, no young produced

Year	MSNO	Male species [a]	Female species	Number of young fledged	Additional STOC observations
	2444	STOC	STXX [c]	Non-nesting	None
2007	1013	STOC	STXX [c]	0	None
	2413	--	STXX	Unknown	Pair, non-nesting
	4392	STXX [g]	--	Unknown	None
2008	1013	STOC	STXX [c]	0	Male, 1 auditory detection
	4392	STXX [g]	--	Unknown	Male, 3 auditory detections
2009	1013	STOC	STXX [c]	0	Male, 2 auditory detections
	4196	STXX	--	Unknown	None
2010	1013	STOC	STXX [c]	0	None
	4196	STXX	--	Unknown	None
2011	1013	STOC	STXX [c]	0	None
	2427	STVA	STXX [f]	Unknown	Pair, no young produced
2012	1013	STOC	STXX [c]	0	None
2013	1013	STOC	STXX [c]	0	None
	4196	STXX	STVA	Unknown	None
2014	1013	STOC	STXX [c]	Unknown	None
	2427	STVA	STXX [f]	Unknown	Pair, 2 young fledged
2015	0007	STXX	--	Unknown	None
	1013	STOC	STXX [c]	Unknown	None
2016	1013	STOC	STXX [c]	Unknown	None
2017	1013	STOC	STXX [c]	Unknown	None
2018	1013	STOC	STXX [c]	Unknown	None
2019	2410	STOC	STXX	Unknown	None
	2413	--	STXX [f]	Unknown	Pair, 1 young fledged
	2423	STOC	STXX	Unknown	None

[a] STOC = northern spotted owl, STVA = barred owl, STXX = spotted x barred owl hybrid.
[b] Banded as an adult on 9 June 2002; orange/yellow tab, left leg.
[c] Banded 141 km SSW of the study area as a fledgling on 21 June 2001, color band replaced 30 April 2003: pink/white dots/orange tab, left leg. This owl was also re-sighted at site 1032 on 13

August 2003.

[d] Banded as an adult on 17 May 2004; green/white triangles, right leg.

[e] One backcross fledgling banded on 21 June 2004; white/red triangles, left leg.

[f] Banded as an adult on 26 May 2004; black/white dots/white tab, left leg. Color band lost and replaced with orange/black dots/white tab, left leg in 2011.

[g] Banded 103 km SW of the study area as a 2-year-old on 11 March 2003, re-sighted on the study area on 19 May 2004; green/white diagonals/orange tab, left leg.

[h] Lost original color band. New band attached on 20 June 2005; pink/white dots/black tab, right leg.

[i] Single backcross fledgling banded on 20 June 2005; red/white stripe, left leg.