Distribution and Habitat Use of Snag-nesting Purple Martins in Western Oregon

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BACKGROUND

The western sub-species of the purple martin is designated as a "critical" sensitive species in the state of Oregon because of concern that the population may decline to the point of qualifying for threatened or endangered status if conservation actions are not taken (ODFW 2017). The purple martin is also a candidate for Threatened status under the B.C. Wildlife Act in British Columbia, and is a Candidate Species for listing in Washington State. For conservation purposes, it is critically important to recognize the distinction between the relatively abundant eastern purple martin subspecies (*Progne subis subis*), with ~10-12 million birds in eastern North America, and the at-risk western purple martin subspecies (*Progne subis arboricola*), with an estimated 3,500 pairs distributed between southwestern BC and southern CA (Western Purple Martin Working Group 2010). The eastern subspecies has become dependent on human-provided habitat, and virtually all individuals nest in artificial housing (Tarof and Brown 2013). In contrast, the western subspecies still nests in natural cavities in the wild (Bettinger 2003, Horvath 1999).

Availability of suitable breeding habitat is a major limiting factor for western purple martin populations. As aerial insectivores, purple martins require open habitat with high insect productivity for foraging. Suitable habitat includes open, post-disturbance forest, such as burns or clear-cuts, where legacy trees and snags provide nesting substrate (Tarof and Brown 2013). Declines in populations have been attributed to the reduction of natural cavities from human activities (e.g., removal of snags during timber harvest). Furthermore, availability of suitable early seral habitat in western Oregon has been reduced as a result of forest management practices that promote early establishment and prolonged dominance of dense conifer forest, and curtailment of timber harvesting under the Northwest Forest Plan (Swanson et al. 2011, Kennedy and Spies 2004). Competition for nest sites from invasive species such as the English sparrow and European starling is also a threat to purple martins nesting near human habitations. This threat is likely reduced for birds that nest in forest lands that are remote from agricultural and urban development (Horvath 1999).

The snag-nesting population of purple martins in western Oregon may represent an opportunity to maintain self-sustaining populations in the Pacific Northwest. However, there is a lack of population survey data to provide a reliable estimate of current population size and distribution of purple martins breeding in natural cavities. Horvath (1999) surveyed purple martins throughout Oregon and concluded that the breeding range had contracted based on absence from previously occupied sites. In that survey, 5% of 784 pairs of martins were found nesting in snags; snags used were typically far from open water, in remote forested uplands that lacked European starlings. Bettinger (2003) surveyed young stands in

western Oregon for snag-nesting purple martins in 2002. Six counties, including Douglas, Coos, and Curry had occupied sites. The majority of clear-cut sites occupied by purple martins were less than 6 years old. The extent of use of natural cavities by purple martins has not been quantified since Bettinger's survey in 2002. The availability of suitable habitat on federal lands has likely decreased in the time since that survey as a result of timber harvest reductions under the Northwest Forest Plan. We conducted an expanded survey of snag-nesting purple martins on BLM and USFS lands similar to surveys conducted in 2002 (Bettinger 2003). Our goal was to provide an assessment of the current status and distribution of the purple martin population in western Oregon. Our specific objectives were to determine the occupancy status of purple martins on BLM and other federal lands at potentially suitable sites in western Oregon, and to develop a model of habitat suitability based on a comparison of habitat attributes at multiple spatial scales measured at used and unused sites. We intend this model to be useful in estimating the amount of suitable habitat available to support purple martin colonies both currently and under future timber harvest regimes.

In conjunction with snag-nesting purple martin surveys, banding at source populations provides the opportunity to track dispersal of individual birds. For example, a purple martin banded as a nestling in 2011 from the large colony at Fern Ridge reservoir (Lane County) was observed nesting at a forest site more than 50 miles away in 2013 (Vesely 2014). Based on this incidental evidence, we hypothesized that birds from established colonies may disperse to colonize upland forest snag habitat. We also wanted to test the hypothesis that birds reared in artificial nesting substrates are capable of nesting in natural cavities (i.e., snags) as adults. Hence, an additional goal was to measure dispersal capabilities of western purple martins and assess the level of connectivity between colonies across the breeding range by banding and re-sighting banded birds.

METHODS

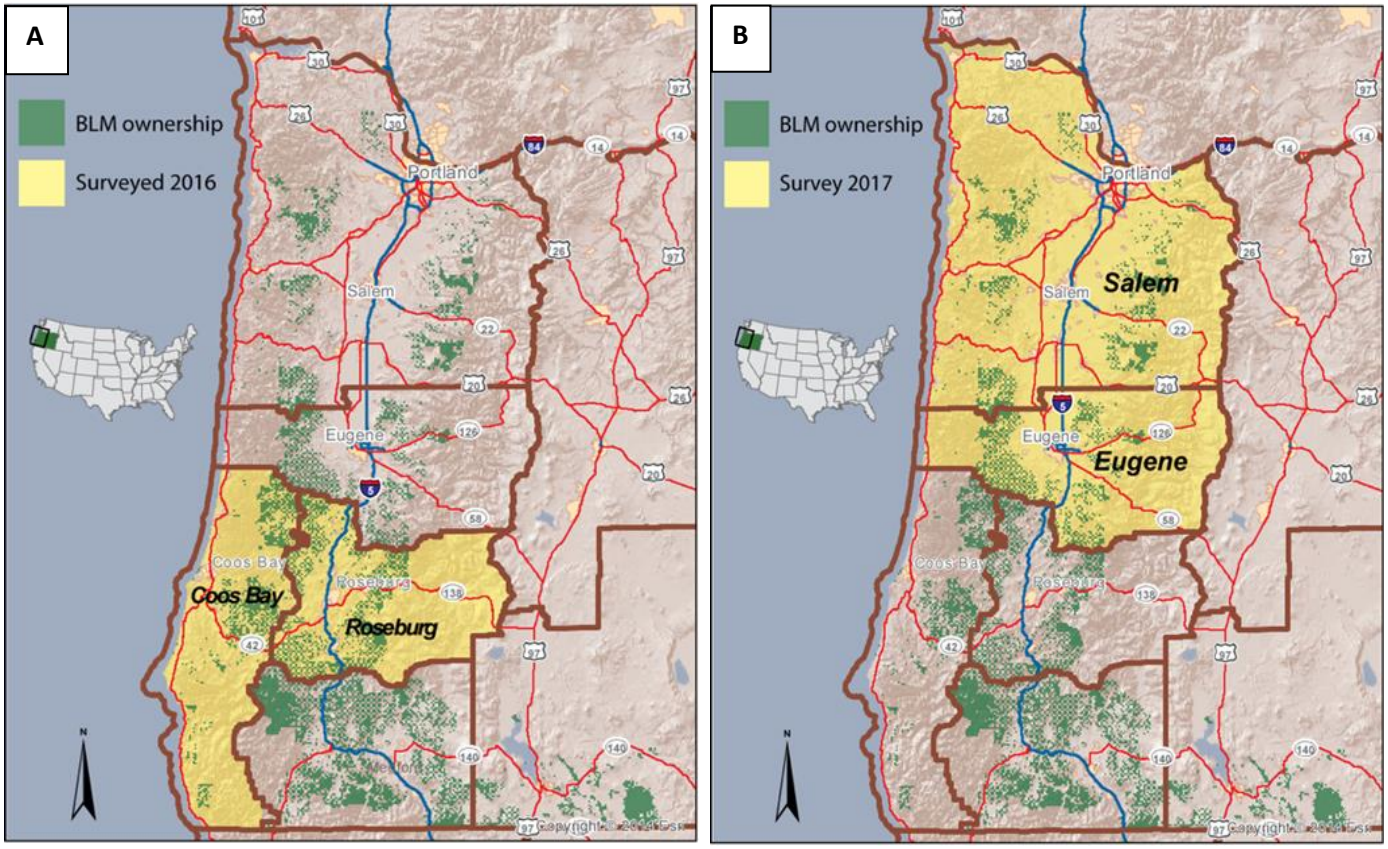
Survey Area

We surveyed southwestern Oregon in 2016 and northwest Oregon in 2017 (Fig. 1). The BLM produced a list of forest stands on public lands in Oregon west of the Cascade Mountains that had been disturbed (e.g. burned or clear-cut) within the last 10 years, had failed to regenerate to expected stocking densities, or had recent incidental detection of purple martins. We surveyed 74 stands randomly selected from this list of potential stands on BLM land in 2016. We also surveyed all stands that had been harvested within the previous 10 years on the Elliot State Forest. We found that many of the identified stands on BLM land in 2016 were no longer in early seral condition, so we narrowed our criteria, resulting in a smaller pool of potential survey stands on public lands in 2017 (Table 1). Stands with no potential nest snags were dropped after the first survey and replaced by stands randomly selected from the list of potential stands. We surveyed a total of 103 unique sites on public land over both years of the study; 8 BLM sites were surveyed in both years (for 111 total surveys on public land sites, Table 1).

While crossing private timberlands to access BLM sites, we encountered numerous sites that met the criteria for stand age and had potentially suitable nest snags. We sought permission to survey private land where these conditions were opportunistically encountered, and where incidental purple martin

sightings were posted to the online database, eBird. Therefore, a large portion of our survey sites in 2017 were not randomly selected, but we feel they are representative of purple martin habitat in western Oregon, given the patchy distribution and special habitat requirements of this species. We surveyed a total of 85 upland forest sites (including gourd racks and nest boxes) under private ownership over both years of the project (Table 1). Four sites on private land were surveyed in both years.

Figure 1. Area covered by surveys for snag-nesting western purple martins during the breeding season in 2016 (A) and 2017 (B).



Occupancy Surveys

Throughout the nest establishment and fledgling production stages, from early May 15 through August 15 of 2016 and 2017, each site was surveyed from one to five times. The first survey was conducted during the nest establishment period between early May and mid-June; we did not make more than one visit to survey sites that did not have any snags. At all sites with at least one snag present the first survey was conducted for at least 20 minutes between 1 hour before and 2 hours after sunrise. Purple martins are territorial and respond vocally to other martins entering their territory, so at sites where no purple martins were detected on the first visit, we played recordings of purple martin dawnsong at subsequent visits to increase detection probability (Grinde et al. 2018). Once an active cavity was confirmed, sites could be surveyed later in the day because high levels of feeding activity were continuous throughout the day. We followed a standardized protocol to determine occupancy status (Cousens and Airola 2006;

Table 2). At active and occupied sites, we tallied birds observed at each visit by age and gender: After Second Year Males (ASYM), Second Year Males (SYM), After Second Year Females (ASYF), Second Year Females (SYF), Hatch Year (HY) or Unknown (UNKN).

Table 1. Number of unique sites in western Oregon surveyed for Purple Martin occupancy status in 2016 and 2017, by ownership. Eight BLM sites and 4 private sites were surveyed in both years; totals in parentheses include re-surveyed sites.

Ownership	2016	2017
Public		
BLM	74	10 (+8)
Elliot State Forest	12	0
USACE	0	6
USFWS	0	1
Total Public	86	17 (25)
Private Industrial		
Campbell-Global	1	2 (+1)
Coquille Tribe	1	0
Hampton	0	2
OSU	0	22
Port Blakely	0	5
Portland Audubon	0	1
Starker	0	9
Weyerhaeuser	5	13 (+2)
Other Private	12	12 (+1)
Total Private	19	66 (70)
Grand Total	105	84

Habitat Descriptions

Snags - The locations of all accessible snags with appropriately sized cavities at survey sites that met forest age criteria (burned or clear-cut within previous 10 years) were marked with GPS and measured, regardless of use by purple martins. Some snags could not be measured because of lack of accessibility due to mature conifer growth, cliffs, yellow jackets nests, impenetrable poison oak, etc. Height, diameter-at-breast-height (DBH), cavity height, decay class, species, cavity origin, and number of cavities were measured and recorded for each snag. We also estimated the distance from each snag to the edge of closed canopy forest using Google Earth, and validated the estimates using Gradient Nearest Neighbor (GNN) tree size classes 5 and 6 to define "mature" forest (Ohmann and Gregory 2002).

Table 2. Criteria for determining occupancy status of potential nesting sites by purple martins.

Colony/Site Status codes
U = *Unoccupied:* No PUMA observed nearby in **20 min** observation period during usual time of peak activity. Monitor <2 hr after sunrise or <2 hr before sunset, esp. prior to nestling feeding activity locally. Monitoring observations should coincide with the nestling feeding period in the area to be conclusive (nesting timing can be highly variable over relatively short distances due to local climate variables).
P = *Present:* Bird(s) observed near or high above potential nest site, feeding, etc., NOT using nesting structures
OC = *Occupied:* Pair(s) of birds perched near or entering cavities or flying about potential nesting structures. Bird(s) seen entering, defending or guarding cavity, or adding nest material.
AC = *Active Cavity Confirmed:* Egg(s) or nestling(s) in nest cavity; evidence includes: young observed at entrance, dead nestlings, nestling begging calls heard from within nest cavity/structure, adults observed delivering food, adults carrying fecal sacks out of cavity.

Early seral condition - We quantified area of early seral forest at two spatial scales using the Gradient Nearest Neighbor Model Data from 2016 (GNN; Ohmann and Gregory 2002). For the purposes of this study, early seral forest was defined as forest having an average quadratic mean diameter (QMD) of <10cm (Betts et al. 2010). We classified pasture and other non-forest vegetation types separately from early seral. We used a 120 acre (95 ha) circular plot around each snag to represent stand-level characteristics, based on the maximum allowable clearcut size under the Oregon Forest Practices Act. We used a 1-km radius circular plot (314 ha (776 acre)) to represent landscape level characteristics within foraging range for adult purple martins. We based this plot size on conversations with Dr. Jason Fischer, Conservation Program Manager for Disney's Animals, Science and Environment, who has observed that the majority (>95%) of feeding flights of eastern purple martins were less than 1 km. For each site, we averaged the early seral area for all overlapping plots. The GNN model predicts forest structural characteristics at a 30-meter pixel resolution by utilizing Forest Inventory Analysis (FIA) plots, mapped environmental data, and Landsat Thematic Mapper Imagery (Betts et al. 2010). At larger spatial scales, GNN predictions more closely match observed values for vegetation characteristics, including QMD (Ohmann and Gregory 2002). The GNN data from 2016 is the most recent, contiguous data available for all of western Oregon.

In total, we measured habitat characteristics at 201 snags. However, because we were unable to measure some variables for 41 snags, we had a total of 160 snags available to develop the habitat model (see below). Of these, 36 snags were on public lands and 124 snags were on privately owned timberland.

Data Analysis

We developed a set of candidate models to characterize purple martin habitat at multiple spatial scales based on a comparison of seven variables at used and unused nest sites: snag level (DBH, cavity height,

decay class), stand level (area of early seral within 95 ha, distance to closed-canopy forest, elevation), and landscape level (area of early seral within 314 ha plot centered on snags). We standardized all explanatory variables to account for their different scales of measurement. To maximize model parsimony, we checked the usefulness of all predictor variables by conducting univariate tests to compare the medians of variables between used and unused groups. We used a two-sided Mann-Whitney Test for these comparisons because variables did not meet assumptions of normal distribution. All variables except snag DBH showed significant differences between used and unused groups, so we excluded the DBH variable from the set of candidate models. We used smoothed histograms (Peck and Devore 2011) to provide a more complete visualization of the differences between groups than could be provided by a single measure of central tendency, such as the mean or median. Smoothed histograms, or probability density functions, more accurately reflect distribution of the underlying variable because they reduce distortion from randomness that can be accentuated in box histograms, especially with small data sets. We also conducted a post-hoc comparison of the same variables between public and private survey sites using two-sided Mann-Whitney Tests.

We used a generalized linear mixed effects model using a binomial distribution and a logit link to quantify the relationship between area of early seral habitat and snag characteristics and probability of use of a snag for nesting by purple martins. We used a base model that tested the explanatory power of area of early seral habitat at two spatial scales, and created nested candidate models by adding variables starting from the snag-level and working up to the landscape-level spatial scale (Table 3). Every candidate model contained a random effect representing variation among stands and a random effect representing variation among landscapes. We used the ANOVA function in RStudio (version 1.1.383) to calculate AIC and BIC values and chose the best candidate model based on the lowest AIC and BIC values (Table 3). All analyses were done with RStudio version 1.1.383 (2006-2017).

Table 3. Candidate models with BIC and AIC values for characterizing purple martin nesting habitat in upland forest sites in western Oregon.

Model ID	Model Description	BIC	AIC
Model 1	Linear mixed effects with area of early seral within 95 ha and 314 ha plots	173.49	158.27
Model 2	Model 1 + Cavity Height	176.03	159.11
Model 3	Model 1 + Cavity Height, Decay Class	178.43	158.72
Model 4	Model 1 + Cavity Height, Decay Class, Distance to Mature Forest Edge	183.33	160.60
Model 5	Model 1 + Cavity Height, Decay Class, Distance to Mature Forest Edge, Elevation	186.66	161.21

Banding and Band Re-sighting

We continued an ongoing nestling banding program that the USGS and the U.S. Army Corps of Engineers (USACE) began in 2011. We expanded the banding effort from Fern Ridge Reservoir and Cottage Grove Lake to multiple sites in the Coos Bay area where colonies are maintained in artificial housing on estuaries, and to upland forest sites in Benton County. We banded 283 purple martins in

2016 and 383 in 2017 (Table 4), bringing the total of birds banded since 2011 to 1,087. All birds were banded with a coded, color leg-band to make them individually identifiable.

Table 4. Number of purple martins banded in 2016 and 2017.

Location	Habitat Type	2016	2017	Total
Coos Bay	Low elevation wetland	92	100	192
USACE	Low elevation wetland	146	228	374
Stayton	Upland forest nest boxes	.	6	6
Dunn	Upland forest – gourds and snags	45	49	94
Total		283	383	666

A critical component of the banding program is to conduct re-sighting surveys for marked birds to obtain information on demographics and dispersal that can only be obtained from recaptures or re-sightings of identifiable individuals. Therefore, we conducted a band re-sighting effort to track dispersal of banded birds, complementing on-going efforts by USACE, USGS, Oregon Wildlife Institute, and Columbia River Gorge National Scenic Area to color-band nestling purple martins at established breeding colonies. We searched for banded birds at low elevation wetland sites primarily by boat, and on foot at all occupied sites discovered during occupancy surveys. We spent approximately 60 person hours in 2016 and approximately 220 hours in 2017 on band-resighting effort.

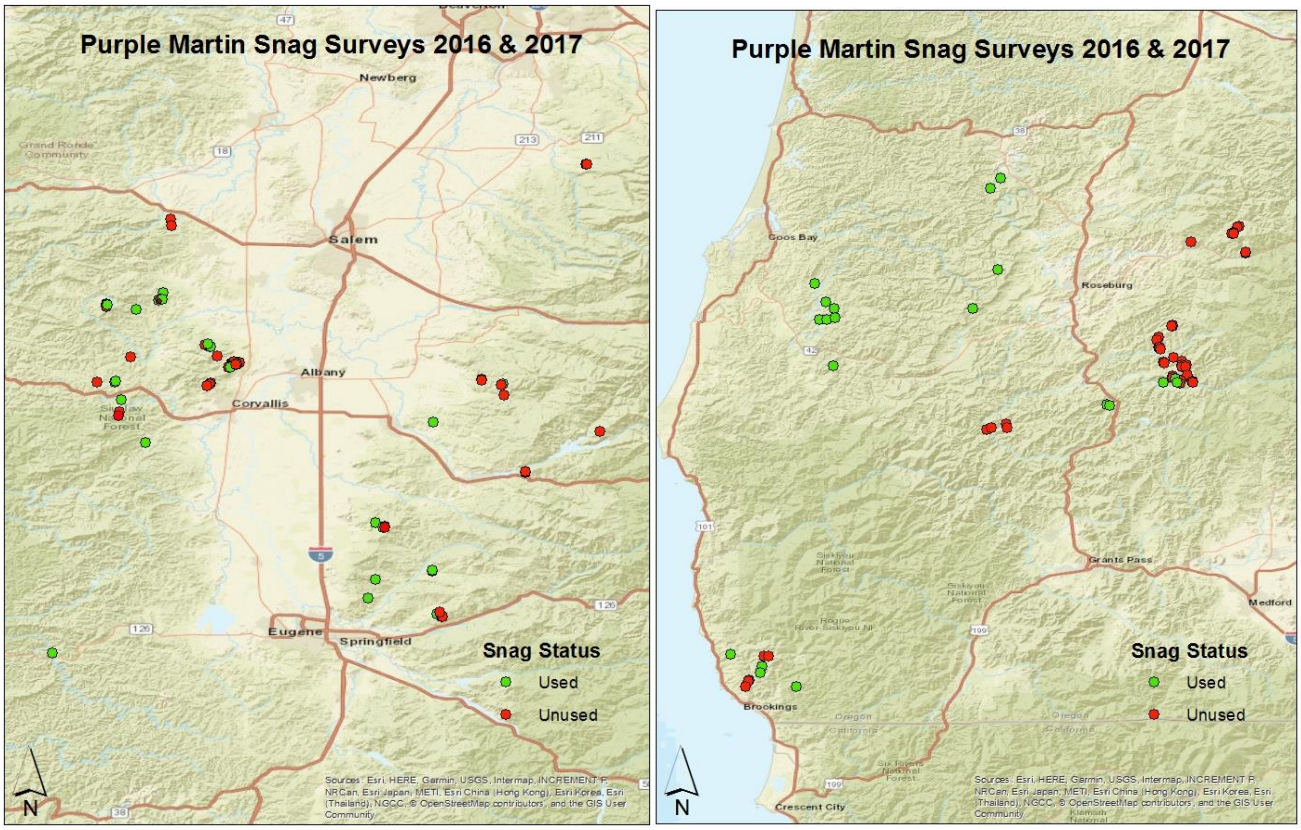
RESULTS

Summary of Survey Results

We found snag-nesting purple martins widely distributed throughout the study area in western Oregon (Fig. 2; Appendix A). Out of a total of 111 sites surveyed on public lands in both years (103 unique sites plus 8 BLM site surveyed both years), we found 17 nests at 16 occupied sites (occupancy rate = 15%). We found no evidence of use by purple martins on the Elliot State Forest. The occupancy rate on BLM land alone was 18% (15 sites used for nesting out of 84 sites surveyed). We found 56% of the sites we surveyed on private lands to have at least one pair of nesting martins (68 nests during 48 site surveys), but this is not a reliable estimate of occupancy rates on private lands across western Oregon because survey sites were not randomly selected.

Of 62 snags with active cavities, 53 were conifers and primarily Douglas fir (*Psuedotsuga menziesii*). Nine nests were in hardwood snags: 5 in big-leaf maple (*Acer macrophyllum*), one each in alder (*Alnus rubra*), madrone (*Arbutus menziesii*), cottonwood (*Populus tremuloides*), and an unidentified hardwood species. Most cavities (50) originated from woodpeckers, primarily Northern flicker (*Colaptes auratus*). Nest cavities in 9 snags originated from decay or branch breakage and three cavities had unknown origins. Sixteen occupied snags were purposefully created during logging operations.

Figure 2. Status of snag-nesting western purple martin colonies at sites surveyed in northwestern (A) and southwestern (B) Oregon, 2016-2017. Sites classified as “Used” had strong evidence of nesting or confirmed reproduction.

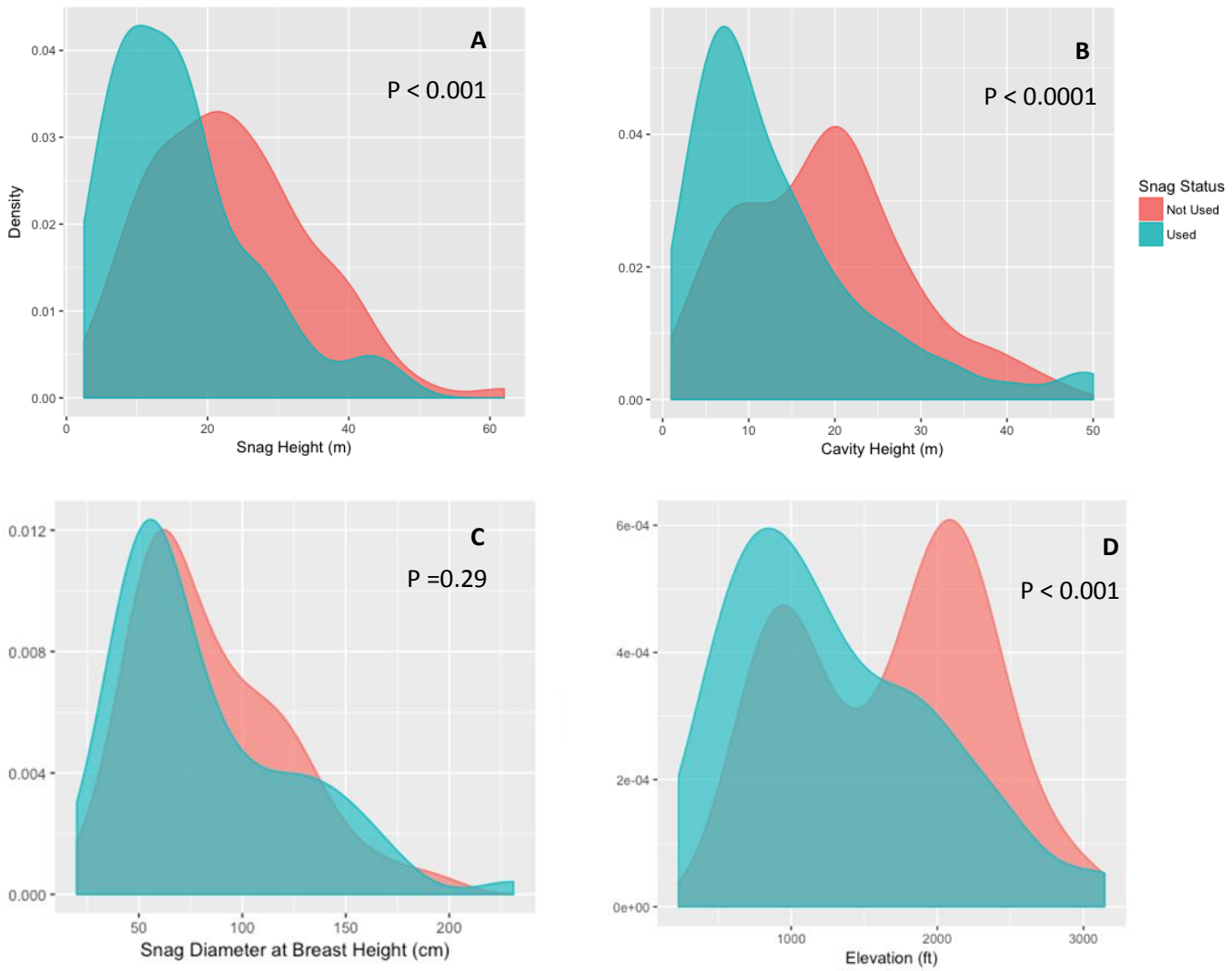


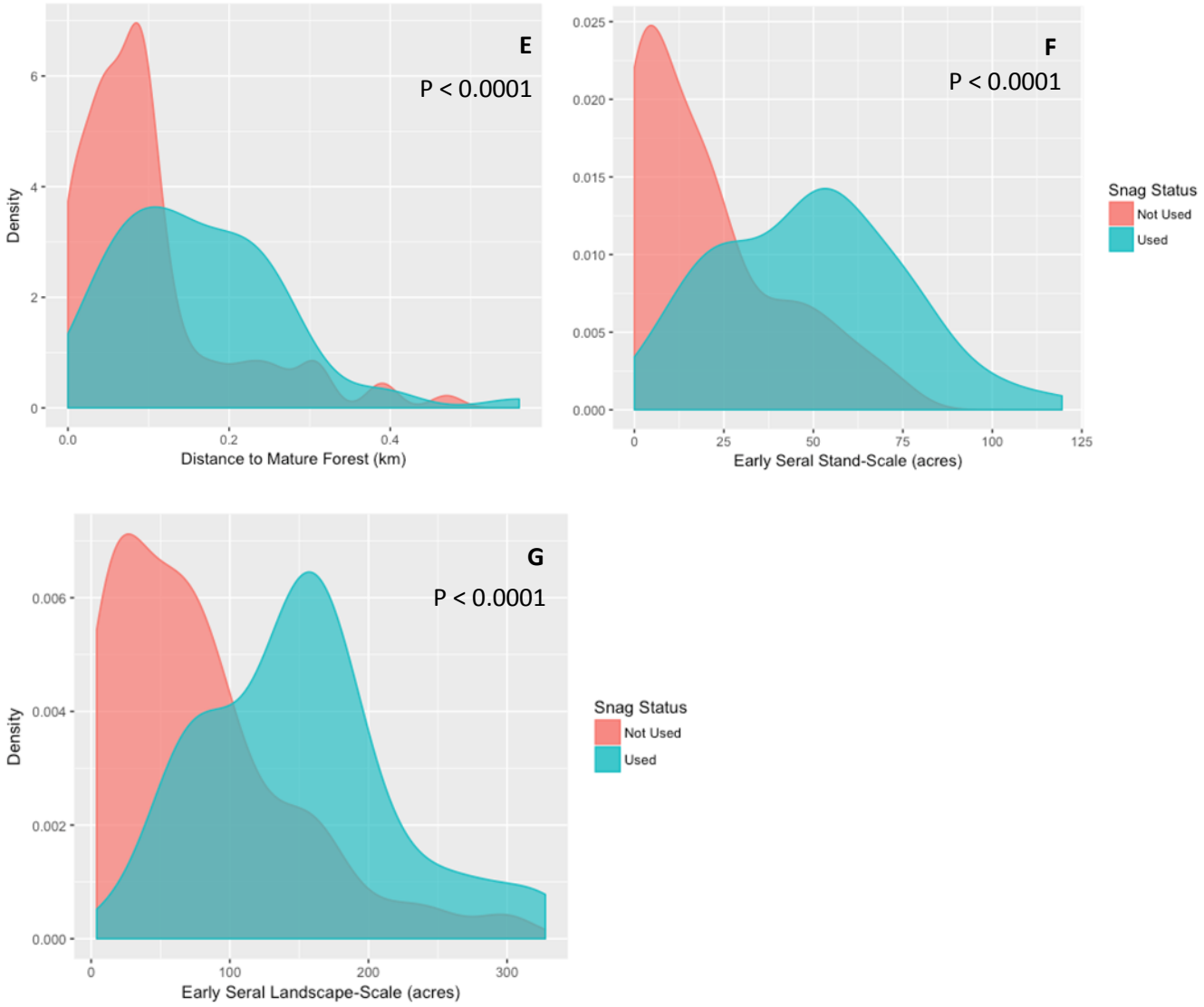
Habitat Model

Each of the seven variables that we used to characterize purple martin habitat were significantly different between used and unused nest sites except for snag DBH (Fig. 3). The median cavity height was shorter than for unused snags, and the median height of snags used for nesting also was lower for nest cavities (Figs. 3A and 3B). The median elevation at used snags was lower than at unused snags (Fig. 3D). Median distance to closed canopy forest, and median area of early seral at the stand (95 ha) and landscape (314 ha) spatial scales were all greater at used than unused nest sites (Figs. 3E-G).

We found strong statistical evidence that the odds of purple martins occupying a snag are affected by the area of early seral habitat within a stand ($F_{1,70} = 25.29$, $p = <0.0001$). The odds of a purple martin occupying a snag increases multiplicatively by 1.05-fold (95% CI 1.02 to 1.08-fold) for every 1 acre increase in early seral forest habitat in a stand (Fig. 4).

Figure 3. Smoothed histograms comparing habitat variables at upland forest sites used for nesting by western purple martins with unused sites in western Oregon, 2016-2017. The vertical axis is frequency density—the number of cases per unit of the variable on the horizontal axis. The P-value is the probability associated with the null hypothesis of no difference between used and unused groups.




E
P < 0.0001
Density
Distance to Mature Forest (km)
F
P < 0.0001
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Density
Early Seral Landscape-Scale (acres)
Snag Status
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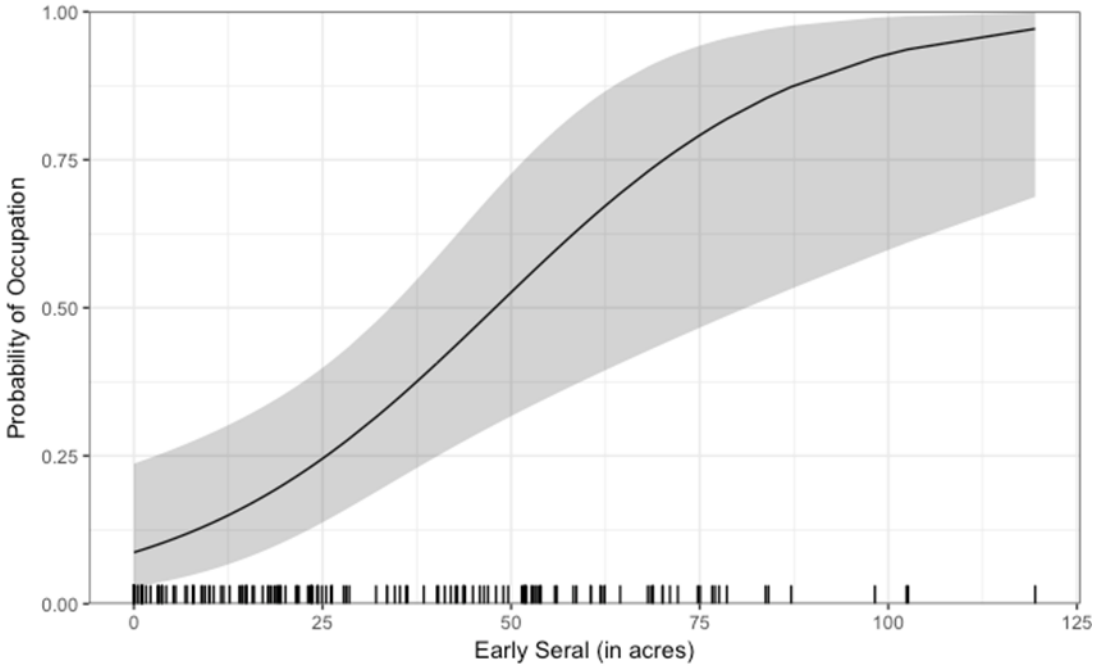
Used

Figure 4. The estimated relationship between the probability that a snag will be used for nesting by purple martins and the area of early seral habitat. The gray ribbon is the 95% confidence interval and the solid line indicates the estimated values. The tick marks represent observations at sites surveyed in western Oregon during the breeding season (May – July) in 2016 and 2017.



Band Re-sighting

We fully read (documented complete code string) a total of 21 unique bands in 2016 and 68 bands in 2017. Most banded birds that we re-sighted were in their second year, but at least four individuals were originally banded in the first year of the banding program, 2011. Many band reads at Fern Ridge Reservoir were first time reads, but a number of band reads repeatedly seen in both survey years at the same nesting location suggest site fidelity in some birds. No nestlings had been banded at USACE-operated Dorena Lake before this summer, but we observed birds originally banded at Cottage Grove Lake occupying nest boxes there, suggesting movement between the Cottage Grove Lake and Dorena Lake colonies, which are 10 miles apart.

Our band re-sighting effort led to the first confirmation of the use of natural snag cavities by birds hatched from artificial housing units in Oregon. Two birds banded in artificial gourds in upland forest habitat in different years were found nesting in snag cavities 9 and 13 miles from their banding locations. These two birds were a second-year female using a nest cavity in a natural Douglas-fir snag and an adult male nesting in a natural snag cavity in a dying big-leaf maple.

At the beginning of fall migration in late August, we observed many banded martins of all ages and from all over the region at Fern Ridge Reservoir (west of Eugene). Among the banded birds re-sighted at

Fern Ridge Reservoir during post-breeding dispersal and pre-migration staging was a second-year female, originally banded as a nestling at Steigerwald National Wildlife Refuge in the Columbia River Valley of Washington State. At 114 miles, this was the greatest distance between banding location and re-sighting location that we recorded.

DISCUSSION

We found that breeding purple martins were widely distributed throughout western Oregon, but our results confirm that their distribution in upland forest is restricted to areas of early seral habitat. This strong positive association of purple martin occupancy with recently disturbed forests likely explains why purple martins were relatively rare on public forest lands managed under the Northwest Forest Plan. Reductions in timber harvest over the last two decades have decreased the availability of early post-disturbance forest on public lands (Kennedy and Spies 2004, Swanson et al. 2011). We observed that forest regrowth at many sites on BLM land that had been previously clearcut apparently rendered the sites no longer suitable for nesting, even when regeneration was poor, and in spite of the presence of large snags. Instead, purple martins were more common on private lands where continuous cycles of regeneration harvesting maintain sufficiently large areas of early seral habitat.

The significantly larger distance to closed canopy forest for nest snags compared to unused snags, combined with the positive relationship to area of early seral condition, highlights the importance of snags in the open as nesting substrates for this species. For example, we found no evidence of purple martins using the Elliott State Forest, managed by the Oregon Department of Forestry, in spite of the availability of many acres of early seral condition created by recent harvest activity and intentionally created snags. We believe that the created snags in the Elliott were not colonized by purple martins because they were primarily located close to the edges of the units. We did note use of these snags by other cavity-nesting species (e.g., Northern Flicker), indicating that they were sufficiently decayed to provide nest cavities. As the largest swallow in North America, purple martins are morphologically and behaviorally suited to flight in open spaces (Brown and Tarof 2013). They may also prefer to nest away from forest edges to decrease risk of predation from forest-dwelling predators, such as squirrels and owls. The small size of snag-nesting colonies, often only one or two pairs, may put them at greater risk of predation than larger colonies because the effectiveness of mobbing to deter predators likely increases with colony size (Arroyo et al. 2001). Higher risk of predation may increase the importance of selecting nest sites away from forest edges. Our data suggest that snags < 100 m from closed-canopy forest were infrequently used for nesting (Fig. 3D).

Snags used for nesting differed from unused snags in other characteristics, in addition to their average distance from forest edge. The lower heights of snags used for nesting compared to those of unused snags (Fig. 3B) may reflect the use of snags and portions of snags with more advanced decay, as is expected for secondary cavity users. However, the lower height of used compared to unused cavities (Fig. 3A) was not expected because lower cavities are likely to be more vulnerable to predation. Comparison of snag characteristics between used and unused groups may have been confounded by differences between public and private ownerships. A post-hoc comparison of snag characteristics between ownership groups (used and unused snags combined) indicated that differences between public

and private followed the same pattern as differences between used and unused nest sites. Mean snag height and cavity height were both less on private than on public land (Table 5). In addition, we found no evidence that purple martins were selecting nest sites on the basis of snag diameter (Fig. 3C), but neither did snag DBH differ between public and private lands (Table 5). Altogether, this suggests that purple martins may not be very selective of nest snags, but instead may use snags in proportion to availability. Indeed, at numerous sites we found pairs nesting in the only snag available in a unit, even when that snag was little more than a high stump (Fig. 5). On the other hand, tall, large-diameter snags, were sometimes used by more than one pair of martins, while supporting other cavity-nesting species at the same time (Fig. 6). An evaluation of nesting success relative to snag size, condition, and location would be required for a more accurate assessment of the relationship between snag characteristics and population dynamics. Because the purpose of our survey was to assess the distribution of snag-nesting martins in western Oregon, we were not able to track nest success.

As previously mentioned, snag-nesting colonies were generally small, typically consisting of one or two pairs, and rarely as many as 6 pairs. We believe that colony size is limited by the number of available cavities. Evidence to support this hypothesis includes observations of rapid colonization of artificial housing erected in clearcuts in the Oregon State University Research Forest, where snags of appropriate condition were not immediately available (Fig. 7). We also observed expansion of colonies that began in artificial housing into created snags (approximately 50-cm DBH) 4 years after trees were topped to create snags.

Table 5. Comparison, using Mann-Whitney Test, of mean values with standard deviations (Std) for variables quantified to assess habitat for purple martins between snags on public (n= 95 snags) and private (n=57 snags) forest lands in western Oregon.

	Private		Public		
Variable	Mean	Std	Mean	Std	P-value
DBH (cm)	88.5	49.2	80.5	31.3	0.767
Snag Height (m)	17.3	12.0	22.6	10.6	<0.001
Cavity Height (m)	13.7	10.3	18.7	10.5	0.002
Elevation (m)	1384	763	1624	647	0.008
Dist. To Closed-canopy Forest (km)	0.165	0.111	0.099	0.092	<0.0001
Early seral – 0.5 km radius (acres)	53.7	20.3	16.9	18.8	<0.0001
Early seral – 1 km radius (acres)	163.0	68.7	68.2	54.8	<0.0001

Given the difficulty of obtaining accurate estimates of snag occurrence, density, and condition (Bull et al. 1990, Bate et al. 1999), not to mention estimating the number of snags with suitable nest cavities and the number of cavities per snag, an estimate of the population size of snag-nesting purple martins remains elusive. We found too few sites on public lands that provided the requisite combination of snags in early post-disturbance stands of sufficient size to estimate a reliable occupancy rate to use as a basis for a population estimate. The occupancy rate of 53% that we observed on non-randomly selected sites on private lands may be a more realistic, if not statistically robust, estimate for the region as a whole because we selected those sites on the basis of having experienced a recent stand-replacing disturbance and the presence of at least one snag, not on the basis of observed purple martin activity. Similar to our

survey, Bettinger's 2002 survey for snag-nesting purple martins covered clear-cuts that were 10 years old or younger, but she reported a much higher occupancy rate of 74% (53 sites occupied out of 72 sites surveyed). Her survey focused on the same BLM Districts we covered, and included some sites on National Forest, State land, and private land in western and southwestern Oregon as well. The difference in occupancy rates between her survey and ours suggests that the population of snag-nesting purple martins in western Oregon may have declined over the last 15 years. However, we suggest that a map of potentially suitable habitat throughout western Oregon developed from our habitat model would provide a tool for more accurate estimates of occupancy rates based on a random sample of sites identified as potentially suitable (e.g., occupancy probability > 50%) across all ownerships. LiDAR may provide a means of obtaining estimates of snag densities and heights in harvest units and recent burns (Vogeler et al. 2015, Casas et al. 2016) that would be extremely useful in assessments of purple martin nesting habitat.

CONCLUSIONS

The combination of early seral forest with snags standing in the open that defines suitable nesting habitat for purple martins in upland forests of western Oregon is relatively rare. While we found that public forest lands managed under the Northwest Forest Plan for several decades commonly supported snags, recent post-disturbance openings of sufficient size for purple martins were scarce. Conversely, early post-disturbance conditions were abundant across private, commercial timberlands, but snags were typically scarce within harvest units. Furthermore, although we found many clearcuts on private lands that still supported one or two snags as of our survey dates, snags are likely to become increasingly rare on private industrial lands. First, some of the small snags in which we found nesting martins were the only snags available in a harvest unit, and these snags are unlikely to remain standing for long (Fig. 5). Secondly, the prevalent management focus on fiber production under short harvest rotation intervals on private industrial lands will preclude development of large snags to replace legacy snags that are currently standing from previous rotations as they are lost to attrition.

Intentional creation of snags from live trees retained at harvest is one way to provide the essential combination of nesting substrate in early seral habitat for purple martins. However, modification of existing practices for snag creation may be necessary to provide suitable nest sites. Although practice of retaining intentionally created snags at the edges of clear-cut harvest units minimizes safety hazards and is more convenient for harvesters, our research indicates that purple martins are unlikely to use snags close to the edge of closed-canopy forest. Additionally, snags that are created at the time of harvest are not immediately available for nesting because it takes several years for cavities to form through the process of decay and woodpecker activity (Chambers et al. 1997). Therefore, the usefulness of created snags as a nesting substrate may be limited temporally, especially under management for rapid reestablishment of conifers. By the time snags have sufficient decay to provide nest cavities, the development of the next stand has narrowed the window of suitable early seral condition for purple martins. Where a management goal is to provide nesting habitat for purple martins and other cavity-nesters that use snags in open environments, we suggest that retention of existing snags during harvest

operations could increase the length of functional early seral nesting habitat. Alternatively, intentionally creating snags several years in advance of harvest may increase the likelihood that nest cavities would already be available by the time the forest canopy is removed.

The use of artificial housing is another potential strategy for mitigating snag scarcity and for bridging gaps in nest site availability between creation of new snags and the formation of cavities. The use of artificial housing as a temporary solution for providing nesting habitat is supported by the propensity for purple martins to readily inhabit artificial housing, and by our finding that martins fledged from artificial housing can readily transfer to natural cavities in snags as nesting adults. We suggest, however, that natural cavities offer at least two significant advantages for the long-term maintenance of wild purple martin populations in the Pacific Northwest: 1) snags provide nesting, roosting, and foraging habitat for other native cavity-users in addition to purple martins, and 2) natural cavities don't require human maintenance. Ensuring the presence of snags in early seral forest may be the best strategy for maintaining self-sustaining populations of wild purple martins.

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Figure 5. Examples of small snags used for nesting by purple martins in clear cut harvest units where no other snags were available for nesting. A. Burned alder (*Alnus rubra*) snag 3.5 meters high, with 2 cavities at 2.5 meters above the ground, and one pair of nesting purple martins. B) Nesting behavior by three purple martins (a pair of adults and a second-year female) was observed at this fir snag with a northern flicker (*Colaptes auratus*) cavity at 2.5 m above ground in July 2016. Photos by Joe Metzler.

Figure 6. Examples of “apartment” snags, used for nesting by multiple pairs of purple martins and other cavity-nesting species. Note female purple martin emerging from cavity (yellow arrow) below adult male purple martin and violet-green swallow (*Tachycineta thalassina*) in photo B. Photos by Lorelle Sherman.

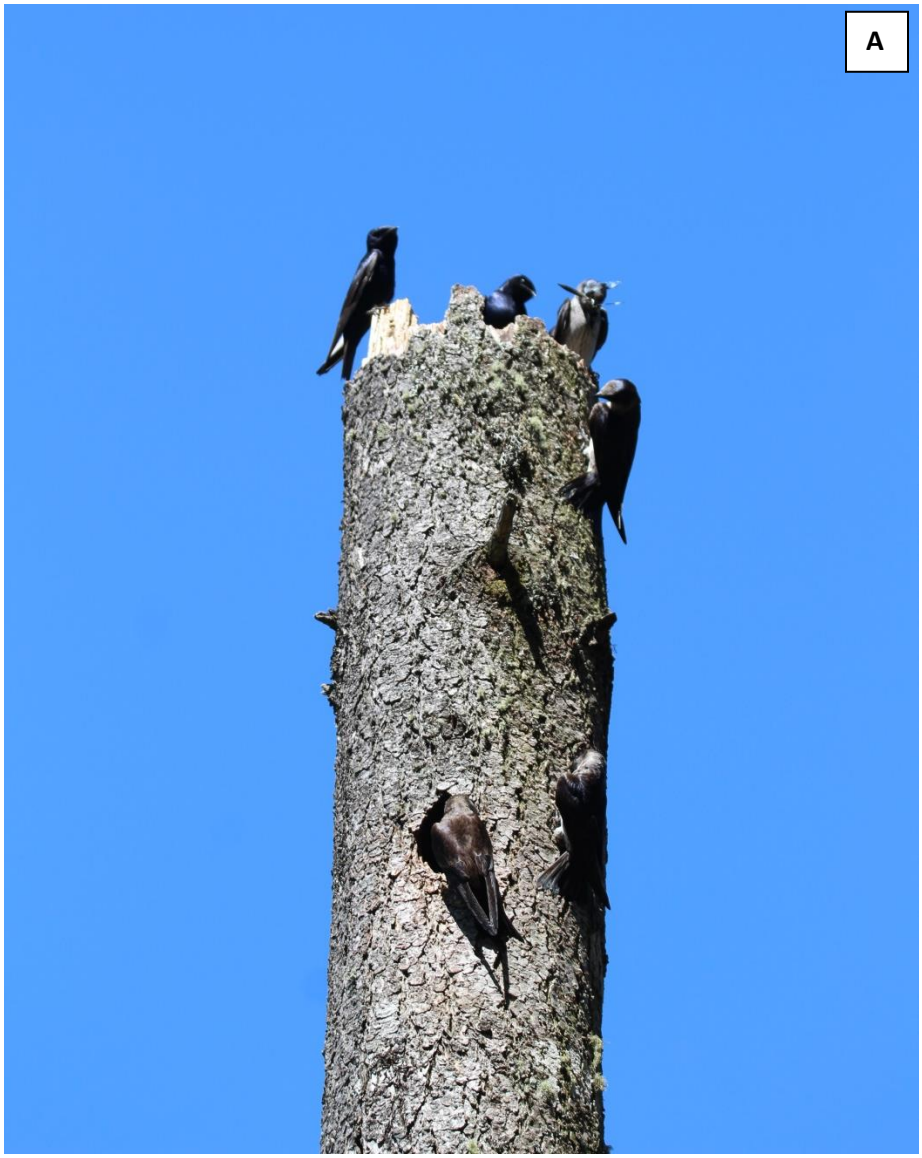

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Figure 7. Artificial housing erected in 2014 in clearcuts in the Oregon State University Research Forest, Benton County Oregon, were rapidly colonized by purple martins. Note the newly created snags in background that were not available as a nesting substrate until cavities formed through decay and woodpecker excavation 4 years later. (As of July 2, 2018, two of the created snags in this unit were being used by 3 pairs of nesting purple martins and a pair of European starlings (*Sturnus vulgaris*) were nesting in a cavity in a third created snag).

LITERATURE CITED

Arroyo, B., F. Mougeot, V. Bretagnolle. 2001. Colonial breeding and nest defence in Montagu's harrier (Circus pygargus). Behavioral Ecology and Sociobiology 50(2): 109-115.

Bate, Lisa J.; Garton, Edward O.; Wisdom, Michael J. 1999. Estimating snag and large tree densities and distributions on a landscape for wildlife management. Gen. Tech. Rep. PNW-GTR-425. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 76 p.

Bettinger, K. 2003. 2002 Western Oregon snag-nesting purple martin surveys with notes from 1999-2000 pilot effort. Northwest Habitat Institute, Corvallis, OR.

Betts, M. G., Hagar, J. C., Rivers, J. W., Alexander, J. D., McGarigal, K. and McComb, B. C. (2010), Thresholds in forest bird occurrence as a function of the amount of early-seral broadleaf forest at landscape scales. Ecological Applications, 20: 2116–2130. doi:10.1890/09-1305.1

Bull, E.L., Holthausen, R.S., Marx, D.B., 1990. How to determine snag density. W. J. Appl. For. 5 (2), 56–58.

Casas, Á., M. García, R.B. Siegel, A. Koltunov, C. Ramírez, and S. Ustin. 2016. Burned forest characterization at single-tree level with airborne laser scanning for assessing wildlife habitat. Remote Sensing of Environment 175: 231-241.

Chambers, C.L., Carrigan, T., Sabin, T.E., Tappeiner, J., McComb, M.C., 1997. Use of artificially created Douglas-fir snags by cavity nesting birds. Western Journal of Applied Forestry 12, 93–97.

Horvath, E. 1999. Distribution, abundance, and nest-site characteristics of purple martins in Oregon. Oreg. Dept. Fish and Wildl. Wildl. Diversity Prog. Tech. Rept. 99-1-01.

Kennedy, R. S. H. and T. A. Spies (2004). "Forest cover changes in the Oregon Coast Range from 1939 to 1993." Forest Ecology and Management 200: 129-147.

ODFW (Oregon Department of Fish & Wildlife) 2017. ODFW Sensitive Species List 2016. http://www.dfw.state.or.us/wildlife/diversity/species/sensitive_species.asp

Ohmann, J. L. and M. J. Gregory . 2002. Predictive mapping of forest composition and structure with direct gradient analysis and nearest-neighbor imputation in coastal Oregon, USA. Canadian Journal of Forest Research 32: 725–741.

Peck, R., and J.L. Devore. Statistics: The exploration & analysis of data. Cengage Learning, 2011.

Swanson, M. E., J. F. Franklin, R.L. Beschta, C.M. Crisafulli, D.A. DellaSala, R.L. Hutto, D.B. Lindenmayer, F.J. Swanson. 2011. The forgotten stage of forest succession: early-successional ecosystems on forest sites. Frontiers in Ecology and the Environment 9(2): 117-125.

Tarof, S. and C.R. Brown. 2013. Purple Martin (*Progne subis*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu/bna/species/287

Vesely, D. 2014. Conserving Purple Martins on McDonald-Dunn Forest, Benton County, Oregon. Oregon Wildlife Institute. 1-10.

Vogeler, J. C., Z. Yang, W.B. Cohen. 2015. Mapping post-fire habitat characteristics through the fusion of remote sensing tools. Remote Sensing of Environment 173:294-303.

Western Purple Martin Working Group. 2010. Interim population objective for the Pacific population of the Western Purple Martin (*Progne subis arboricola*). Available from: Stan Kostka at lynnandstan@earthlink.net).