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Avian foraging and nesting use of created snags in intensively-managed forests of western Oregon, USA

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ABSTRACT

Snags are critical structural features for managing biological diversity in forests of the Pacific Northwest, USA. However, commercial forests in this region often contain reduced numbers of snags compared to unmanaged forests and managers require effective methods to augment snag numbers in harvest units. Therefore, we created snags by topping live trees with a mechanical harvester and studied foraging and nesting use by cavity-nesting birds of these snags in clearcuts in Douglas-fir (*Pseudotsuga mensezii*) forests along the west slope of the Cascade Mountain Range and east slope of the Coast Range in Oregon, USA. We used a completely randomized design to assign 6 different treatments (single or scattered distribution by 3 different densities) to 31 different harvest units. We created 1111 snags from February 1997 through April 1999 and monitored them from 2–5 years after harvest (1999–2002). Fraction of created snags with nest cavities in harvest units was generally low across all treatments and years of the study, although some individual stands demonstrated increased nesting use with snag age. While the highest fractions of snags with nest cavities were found in units with low density and scattered snags, the mean fraction of snags used for nesting did not differ among treatments. Treatment type, distribution of snags (i.e., scattered or clumped), and associated interactions did not influence fraction of snags used for foraging. However, fraction of created snags used for foraging in all harvest units increased with snag age. Fraction of snags used for foraging was greatest in the low density treatments. While this technique provides managers with a relatively economical option for creating snags, mechanical harvesters cannot be used to create tall, large snags upon which several cavity-dependent species rely and provides only a partial solution to a critical forest management issue.

1. Introduction

Snags are critical components of forest structure, as they support ecological functions relating to energy flow, nutrient recycling, hydrological processes, and wildlife habitat (Harmon et al., 1986). The importance of retaining a range of snag species, sizes, and decay classes has long been recognized, as a substantial number of vertebrate and invertebrates rely on snags to fulfill their life-history requirements (Mannan et al., 1980; Neitro et al., 1985; Bunnell et al., 1999; Hayes, 2003). In the Pacific Northwest more than 100 species of wildlife use snags and at least 53 of these (39 birds and 14 mammals) are dependent on cavities (Thomas, 1979; Neitro et al., 1985; Rose et al., 2001; Bunnell et al., 2002).

The abundance of snags in forests of the Pacific Northwest varies as a result of biological processes and differences in the physical environment that affect community composition, disturbance regimes, and rates of snag recruitment and decomposition (Cline et al., 1980; Spies and Franklin, 1991; Ohmann and Waddell, 2002). Conversion of older forests to intensively managed plantations in the region has altered forest dynamics and processes and influenced dead wood dynamics. Volume of dead wood in managed stands is typically lower than unmanaged stands (Spies et al., 1988; Ohmann et al., 1994; Spies and Franklin, 1991; Ohmann and Waddell, 2002) and this pattern is more pronounced in areas where forest management has been practiced longer (Bunnell et al., 2002). Abundance of dead wood can be reduced by an estimated 90% in Douglas-fir stands that have undergone two rotations of harvest compared to natural old-growth systems (Rose et al., 2001; Arnett, 2007).

Private landowners and nonfederal resource management agencies have undertaken efforts to retain and perpetuate snags in managed forests. However, retaining snags can be costly to private

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forest land owners and, in many instances, may be illegal under laws set forth by the Occupational Safety and Health Administration (Ohmann and Waddell, 2002; Wilhere, 2003). Additionally, retaining snags may conflict with operational efficiency or economic and fire management objectives (Lewis, 1998). Several authors have suggested creating snags to increase abundance and distribution of these structures across the landscape (e.g., Cline et al., 1980; Bull and Partridge, 1986). Numerous methods for creating snags or decay in live trees are available to land managers seeking to achieve management objectives for dead and dying trees (e.g., Bull and Partridge, 1986; Lewis, 1998; Filip et al., 2004). Topping live trees is a popular approach for creating snags and may be the most effective because this creates entry sites to the heartwood for decay fungi (Harris, 1983; Brandeis et al., 2002; Walter and Maguire, 2005).

Few studies have evaluated avian use of created snags and all have centered on inoculation of trees with decay fungi (e.g., Brandeis et al., 2002), girdling the trunk, usually near ground level (e.g., Hallett et al., 2001; Brandeis et al., 2002), or trees that were blasted or topped with a chainsaw at mid-crown or higher (e.g., Chambers et al., 1997; Hallett et al., 2001; Boleyn et al., 2002; Brandeis et al., 2002; Walter and Maguire, 2005). Mechanical timber harvesting equipment used for ground-based operations (e.g., feller-buncher—a motorized vehicle with a saw attachment that can rapidly cut and gather one or several trees) can be used to top live trees below the canopy height. Operators can efficiently create several of these "short" snags during either commercial thinning or clearcutting operations and the tops of these trees can be used for commercial products. However, to our knowledge, an evaluation of avian use of snags created by mechanical harvesters has not been conducted. Therefore, we evaluated avian use of snags created by topping live trees with mechanical harvesters in commercially managed forests in the western Oregon Cascade Range, USA. Our objectives were to quantify characteristics of created snags and quantify avian foraging and nesting use of created snags. Based on results from previous studies (e.g., Chambers et al., 1997; Hallett et al., 2001; Brandeis et al., 2002; Walter and Maguire, 2005), we predicted that: (1) use of created snags for nesting would be low during the first several years of creation, due to slow decay processes of freshly topped, healthy trees; (2) use of created snags for foraging would be immediate and increase over time; and (3) on average, single snags would not be used more frequently than snags that were created in clumps (i.e., grouped with other snags).

2. Methods

2.1. Study area

We conducted our study on Weyerhaeuser Company's Calapooya Tree Farm, located in Lane and Douglas Counties along the west slope of the Cascade Mountain Range near Cottage Grove, Oregon, USA (Fig. 1). The study area occurred in the Western Cascades Physiographic Province and was characterized by a maritime climate with wet, mild winters and cool, dry summers (Franklin and Dyrness, 1988). Elevations ranged from 180 m to 1375 m.

The study area was dominated by natural and planted stands of Douglas-fir but other conifers included western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*). Red alder (*Alnus rubra*) was abundant in riparian areas and disturbed sites. Bigleaf maple (*Acer macrophyllum*) was also common throughout the study area in upland and riparian areas. Understory vegetation was typically dominated by salmonberry (*Rubus spectabilis*), thimbleberry (*R. parviflorus*), salal (*Gaultheria shallon*), huckleberry (*Vaccinium spp.*), red elderberry (*Sambucus racemosa*), vine maple (*Acer circinatum*), and swordfern (*Polystichum munitum*). Common primary cavity-nesters in this area include the hairy woodpecker (*Picoides villosus*), northern flicker (*Colaptes auratus*), pileated woodpecker (*Dryocopus pileatus*), red-breasted sapsucker (*Sphyrapicus ruber*), and downy woodpecker (*Picoides pubescens*) (Mannan et al., 1980; Walter and Maguire, 2005). Secondary cavity-nesters include chestnut-backed chickadee (*Poecile rufescens*) and house wren (*Troglodytes aedon*).

Since the mid 1960s, these forests have been managed primarily for wood production using intensive high-yield timber management, usually including planting nursery-grown seedlings, fertilization, control of competing deciduous vegetation, precommercial and commercial thinning, and clearcutting on 45–60 year rotations. At the landscape level, conifer forests were interspersed with riparian reserves and other inoperable areas, recent clearcuts, and small gaps associated with streams, topography, and roads. Our experimental units were selected randomly and are representative of forest stands in a western Oregon landscape dominated by industrial management. Natural snag densities, especially large snags >50 cm dbh, are low in industrial forests (Ohmann et al., 1994; Bunnell et al., 2002). Arnett (2007) reported an average density of 0.82 snags/ha (SE = 0.27) for all snags > 25.4 cm in diameter in 21–40 year-old-forest stands similar to those in our study, nearly 2.7 times fewer snags/ha compared to similar aged stands on federal lands. Snag retention in surrounding harvest units followed Oregon Forest Practice regulations that stipulate retaining 5 green trees (i.e., live, merchantable trees) or snags > 10 m in height and 27 cm in diameter per hectare (Oregon Department of Forestry, 2007). However, our experience suggests that green trees, rather than snags, were usually retained to meet these requirements, thus providing few if any snags immediately following harvest.

2.2. Experimental design and treatments

We used a completely randomized design with repeated measures (Milliken and Johnson, 1992) with each harvest unit (clearcut) as the experimental unit. The age of the snags was a repeated factor, because snags were evaluated for nesting and foraging activity at ages 1–5. All scheduled 1997–1999 clearcut harvest units >20 ha and with >50% of the unit available for harvesting with ground-based equipment were considered available for sampling. Treatments were defined by snag density [expressed as trees per ha (TPH)] and distribution pattern (single-scattered versus clumped). We subjectively defined three different density levels (low, 0.08 TPH; medium, 0.2 TPH; and high, 0.4 TPH) based on coordination with operations foresters and compromises based on logistical, safety, and financial considerations. These densities were multiplied by number of ha in each unit to derive a target number of trees for topping. Clumps constituted 5–7 trees/clump with trees no greater than 10 m apart from one another. For example, a 100 ha unit assigned the high density/single-scattered treatment would have 40 individual trees scattered across the unit; the high density/clumped treatment would have ~8 clumps created in the unit. We randomly assigned the 6 treatment combinations to harvest units and we attempted to replicate each treatment 5 times (3 × 2 factorial treatment structure × 5 replications, $n = 30$ units).

We consulted with harvest managers and equipment operators regarding specific treatment prescriptions and size and distribution of created snags desired for each experimental unit, and operators had flexibility to choose trees to top based on value and location relative to safety and logistical constraints. Operators used a feller-buncher to create snags by raising the saw and topping a tree as high as the machine could safely extend (generally 5–10 m high). We instructed operators to target trees with minimum dimensions of >30.5 cm diameter at the top of the tree and >6 m high. Operators created 1111 snags on 31 experimental harvest settings in the study area from February 1997 to April 1999 (Table 1). Of the

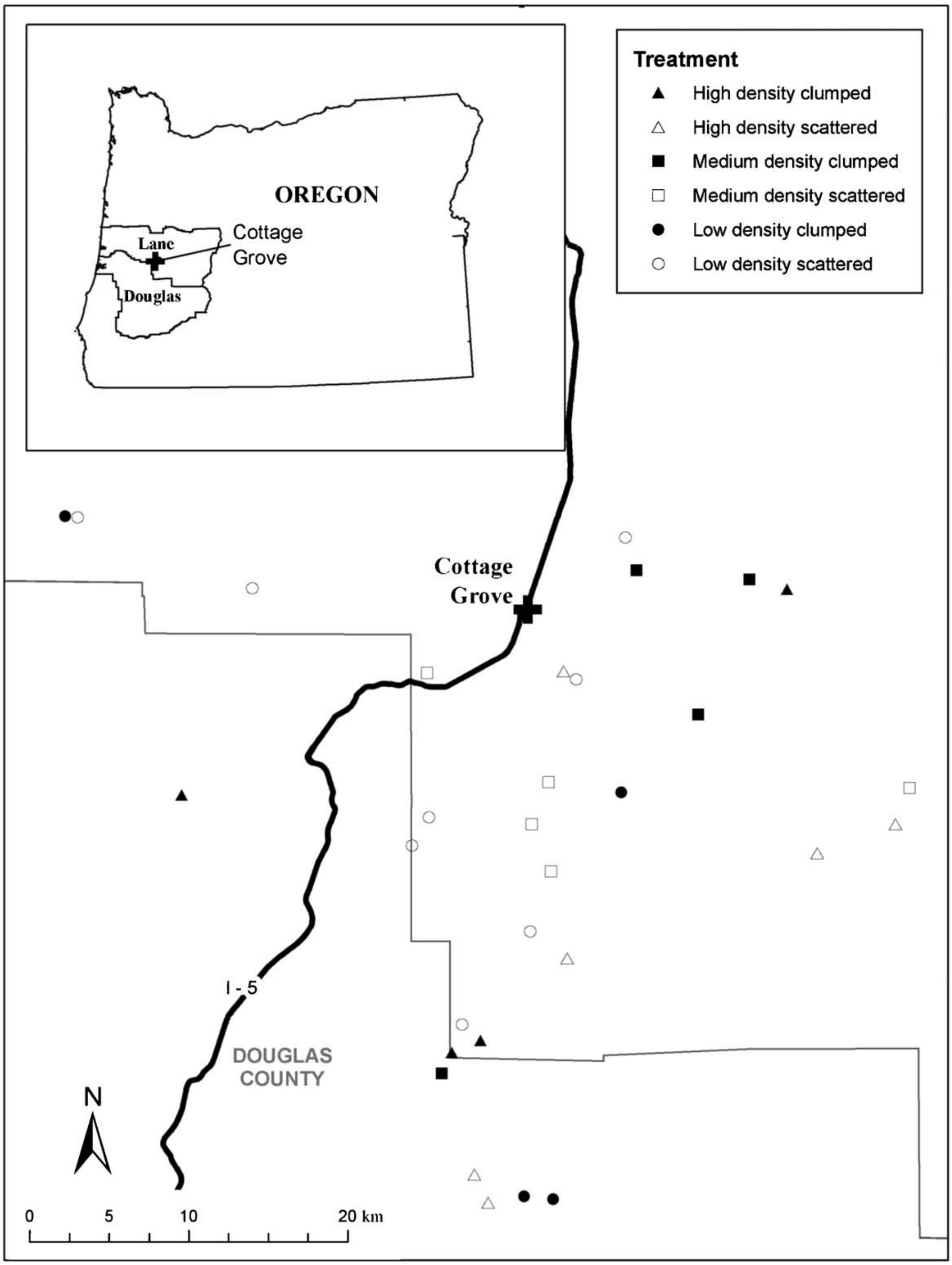

Fig. 1. Location of the study area and harvest units (n = 31) by treatment type in Lane and Douglas Counties, Oregon, USA, 1998–2002.

1111 snags, 828 were Douglas-fir (76%); 164 were western hemlock (15%); 65 were western red cedar (6%); 22 were bigleaf maple (2%); 11 were other hardwoods (1%). However, our desired replication of all treatment combinations was not achieved as a result of logistical and safety issues and miscommunication. The final number of replicate harvest units in each treatment, based on our criteria, was 4 low clumped (LC), 7 low single (LS), 4 medium clumped (MC), 6 medium single (MS), 4 high clumped (HC), and 6 high single (HS) (Table 2). Harvest units ranged from 20.2 to 47.3 ha in size (Table 1). The average nearest neighbor distance between treatments was 3.3 km (95% CL: 2.1, 4.4; range 0.8–13.8 km). By 2001, 21 trees were missing and assumed to have been removed by firewood cutters. Thus, we monitored 1090 created snags for wildlife use and included these in our final analysis.

Table 1
Summary data for 31 harvest units and snags created by topping with mechanical harvesters near Cottage Grove, Oregon, USA, 1997–1999.

Stand	HA	Treatment	Number of trees (clumps)	DBH (cm)			Height (m)		
				Mean	SE	Range	Mean	SE	Range
1	25.5	Low single	13	52.7	2.3	42.7–67.1	7.1	0.2	6.1–9.2
2	35.6	Low single	12	73.9	2.4	63.5–92.5	6.2	0.1	5.5–7.0
3	42.5	Low single	18	43.6	3.2	25.4–75.7	6.1	0.1	5.5–6.7
4	27.1	Low single	7	46.9	2.3	34.3–52.3	7.1	0.3	6.1–7.9
5	29.1	Low single	9	55.8	4.7	29.2–72.4	6.3	0.3	4.3–7.0
6	20.2	Low single	11	44.1	2.0	37.3–60.7	6.0	0.2	5.2–7.3
7	22.3	Low single	9	70.0	1.7	58.4–76.2	7.1	0.3	6.1–8.5
9	23.5	Low clump	5 (1)	42.4	3.5	34.5–53.1	6.0	0.3	4.9–6.7
10	28.3	Low clump	15 (3)	41.9	2.7	24.6–57.9	7.3	0.1	6.1–7.9
11	22.3	Low clump	10 (2)	47.4	2.4	35.6–60.5	6.1	0.1	5.5–6.7
12	41.2	Low clump	17 (4)	53.2	3.7	37.3–101.1	6.3	0.1	5.5–7.0
8	44.9	Medium single	38	50.0	2.2	35.6–88.9	6.3	0.1	5.5–7.0
13	27.1	Medium single	34	58.4	1.5	40.4–71.9	6.6	0.1	5.5–7.9
14	27.5	Medium single	23	48.4	2.6	30.2–75.7	5.9	0.1	4.6–7.0
15	20.2	Medium single	33	39.9	1.7	26.2–69.3	5.4	0.1	4.3–7.0
16	37.2	Medium single	35	46.7	2.2	20.8–89.7	6.7	0.1	5.2–7.9
17	30.0	Medium single	39	43.9	1.9	16.5–90.2	6.7	0.2	4.3–8.2
18	45.7	Medium clump	35 (8)	52.4	1.3	33.5–68.8	6.9	0.1	4.6–7.9
19	38.9	Medium clump	51 (10)	38.3	1.1	20.1–56.9	7.2	0.1	5.2–8.8
20	42.5	Medium clump	37 (7)	44.0	1.7	22.1–66.3	6.6	0.1	4.9–10.1
21	40.5	Medium clump	45 (9)	46.4	1.5	32.0–71.9	7.5	0.1	5.8–9.2
22	25.5	High single	37	47.1	1.8	17.8–80.8	5.9	0.1	4.0–7.6
23	40.9	High single	42	56.4	1.3	32.3–67.6	6.4	0.1	3.7–7.6
24	36.4	High single	55	44.2	1.2	31.0–69.3	6.9	0.1	4.6–9.2
25	21.5	High single	30	75.5	2.1	47.0–99.1	6.3	0.1	5.5–7.3
26	38.9	High single	48	46.9	1.2	31.8–66.3	5.7	0.1	4.6–6.7
27	32.0	High single	76	42.6	1.0	29.2–67.6	6.3	0.1	5.2–7.3
28	45.7	High clump	54 (13)	35.1	1.0	20.3–51.6	7.9	0.1	6.1–10.1
29	44.5	High clump	55 (11)	56.0	1.3	34.5–82.6	6.9	0.1	5.5–7.9
30	47.3	High clump	112 (22)	47.2	1.0	23.1–71.6	6.3	0.1	4.9–7.6
31	38.9	High clump	106 (21)	50.1	1.2	28.5–82.0	5.2	0.1	4.3–7.3
All snags			1111	49.7	1.7	17.8–101.1	6.5	0.1	3.7–10.1

2.3. Field data collection

During our initial visit, usually within 3–6 months of creation, we recorded location of each snag with a Global Positioning System (GPS) and we recorded species of each snag and measured diameter at breast height (cm), diameter at the top of the snag (cm), and height (m). We visually estimated percentage of bark remaining on each snag and assigned the snag to one of 6 decay classes based on Brown (1985). We revisited each created snag annually to determine use by cavity-nesting birds. During subsequent annual visits for each snag we recorded number of nest cavities and cavity starts, number of foraging cavities, and presence (yes/no) of woodpecker foraging/flaking activity. Measurements of use were taken from 1999 to 2002, so the effect of snag age on foraging and nesting use was estimated for snag ages 2–5.

2.4. Data analysis

The treatment structure was a full factorial arrangement of 3 densities and 2 distributions. Harvest units were the experimental units, and individual snags were subsamples. The binary responses assessed over time were individual instances of nesting and foraging activity. We used generalized estimating equations (GEE) to model treatment, snag age, and treatment × age effects for cavity nester responses using the GENMOD procedure in SAS (SAS Institute Inc., 2004). The GEE method is an extension of generalized linear models that provides for correlated discrete data (Stokes et al., 2000; Fieberg et al., 2009), and is commonly used for repeated measures or longitudinal data (Diggle et al., 2002). The method requires specifying a working correlation structure, but the resulting standard errors are consistent even if the assumed structure is not correct (Stokes et al., 2000; Meyers et al., 2002). Our generalized linear model used a logit link and binomial errors with an autoregressive order one (AR1) correlation structure. AR1 implies that the correlation between measurements depends on time between measurements and decreases as time between measurements increases, which seems to be reasonable based on the biology of our study system. We verified this to be a reasonable working correlation structure by comparing the model-based standard error estimates with the final robust estimates (Meyers et al., 2002).

Table 2
Numbers of harvest units by treatment and age of snags created by mechanical harvesters, Cottage Grove, Oregon, USA, 1999–2002.

Treatment	Total harvest units	Harvest units evaluated at each snag age			
		Age 2	Age 3	Age 4	Age 5
Low clumped (LC)	4	4	4	4	2
Low single (LS)	7	7	7	5	4
Medium clumped (MC)	4	4	4	4	2
Medium single (MS)	6	6	6	5	2
High clumped (HC)	4	4	4	3	1
High single (HS)	6	6	6	4	3
Total	31	31	31	25	14

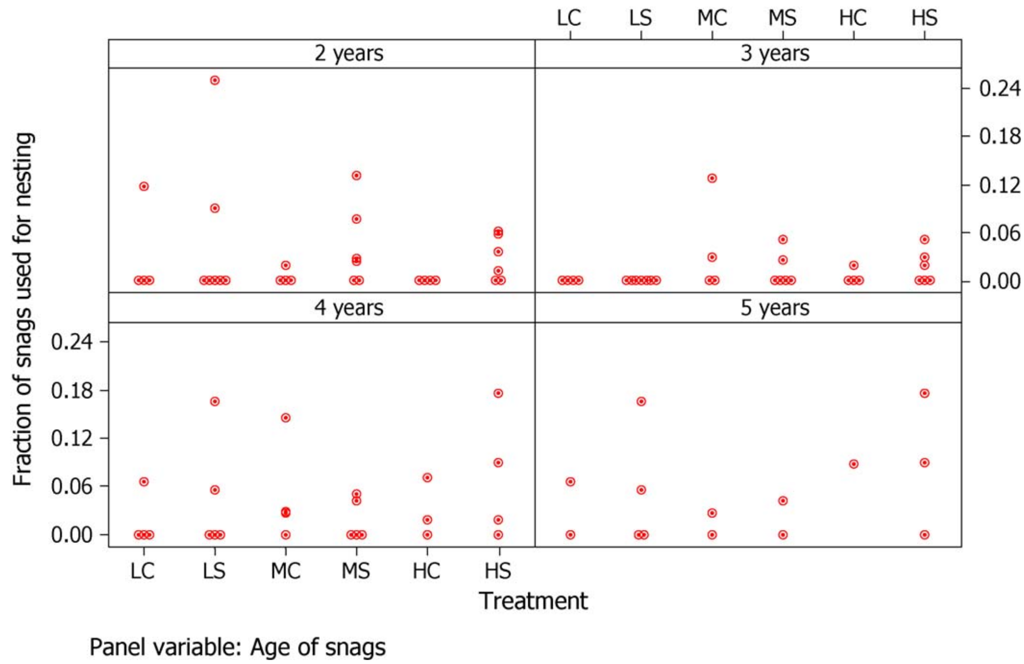

Fig. 2. Fraction of created snags used for nesting in individual harvest units by each treatment and snag age, Cottage Grove, Oregon, USA, 1998–2002. Low, medium, and high refer to snag densities (trees per hectare) and treatments are low clumped (LC), low single (LS), medium clumped (MC), medium single (MS), high clumped (HC), high single (HS). Symbols represent individual stands in each treatment.

Table 3
Type III tests for (1) treatment component effects (distribution, density, and the interaction between distribution and density) and (2) age component effects (linear and lack-of-fit) on fraction of created snags used for foraging, Cottage Grove, Oregon, USA, 1999–2002.

Contrast	Degrees of freedom	χ^2	Pr > χ^2
Distribution	1	0.04	0.843
Density	2	5.34	0.069
Distribution × density	2	0.54	0.764
Age: linear	1	5.09	0.024
Age: lack-of-fit	2	3.53	0.171

We examined Type III Chi-square tests to determine the significance of treatment, snag age, and treatment × age effects. In addition, we used orthogonal contrasts to further divide the treatment effect into its components of density, distribution, and the interaction between density and distribution. Similarly, we divided the snag age effect into a linear component, which tests for a linear trend, and a lack-of-fit component, which tests for other unspecified trends in total (Steel and Torrie, 1980). We used least-squares means (SAS Institute Inc., 2004) to estimate means, standard errors, and 95% confidence intervals for the treatment and age effects. We calculated means on the logit scale and back-transformed these to the percent scale. Finally, we used the GLM procedure in SAS (SAS Institute Inc., 2004) to determine if significant differences existed in mean diameter at breast height and mean height of created snags by treatment. All tests were judged to be significant at an alpha level of 0.05.

3. Results

Mean diameter at breast height of all 1111 created snags was 49.7 cm (SE = 1.7, range = 17.8–101.1) and mean height was 6.5 m (SE = 0.1, range = 3.7–10.1; Table 1). Diameter at breast height ($n = 31$, $F_{5,25} = 0.88$, $P = 0.51$) and height ($n = 31$, $F_{5,25} = 1.04$, $P = 0.42$) of snags did not differ among treatments. We did not find evidence of a strong correlation between dbh and height (Pearson's correlation coefficient = 0.21; 95% CL: 0.15, 0.26).

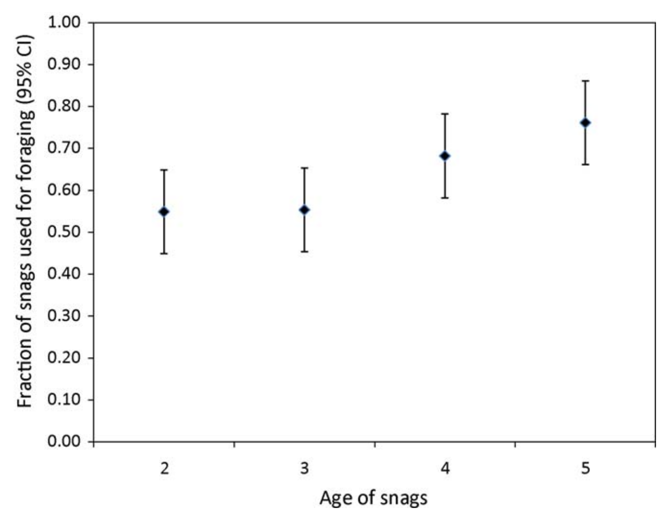

Fig. 3. Least-square mean estimates and 95% confidence intervals for percentage of created snags used for foraging by age for all treatments combined, Cottage Grove, Oregon, USA, 1999–2002.

The fraction of created snags with nest cavities in harvest units was generally low across all treatments and years of the study, although some individual stands demonstrated increased nesting use over time (Fig. 2). The median fraction of snags with nest cavities for all years combined was 0.02 for all treatments and did not differ among treatments ($\chi^2 = 0.54$, $P = 0.76$).

We did not find significant effects for the interaction of treatment type and age ($\chi^2 = 15.3$, $P = 0.43$) or treatment type ($\chi^2 = 5.54$, $P = 0.35$) on foraging use. Snag age, however, was nearly significant ($\chi^2 = 6.78$, $P = 0.079$), and its linear component was significant ($\chi^2 = 5.09$, $P = 0.024$; Table 3). Created-snag foraging use increased by ~20% from snag age 2 to snag age 5 (Fig. 3).

Using the contrasts for treatment type (Table 3), we did not find significant effects for the interaction of distribution and density of snags ($\chi^2 = 02.86$, $P = 0.24$), the distribution of snags ($\chi^2 = 1.6$,

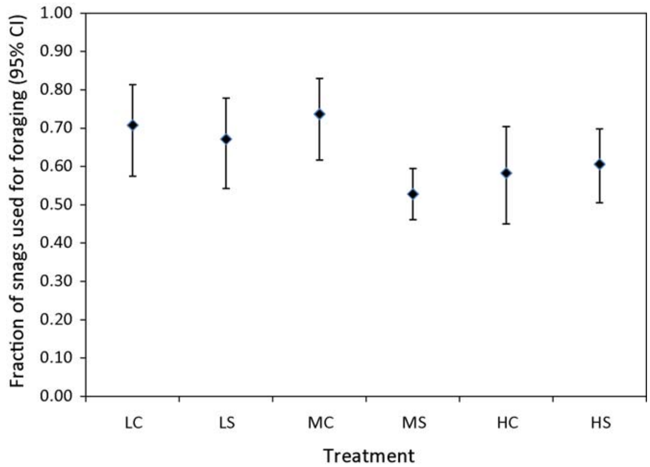

Fig. 4. Least-square mean estimates and 95% confidence intervals for fraction of created snags used for foraging by treatment, Cottage Grove, Oregon, 1999–2002. Treatments are low clumped (LC), low single (LS), medium clumped (MC), medium single (MS), high clumped (HC), high single (HS).

$P = 0.21$), or the density of snags ($\chi^2 = 1.46$, $P = 0.48$) on foraging use. The greatest fraction of snag use occurred in the MC treatment (Fig. 4) in which ~75% of the snags were used across the 4 years of monitoring. The lowest fraction of use occurred in the MS treatment, in which 55% of the snags were used for foraging across the 4 years of the study (Fig. 4).

4. Discussion

In general, our predictions and findings are consistent with those from studies on avian use of snags created by other methods. We predicted and found that use of mechanically topped trees for nesting was low during the first 5 years post-creation, likely because heartwood in these created snags was still relatively sound. Heartwood must be sufficiently decayed before birds begin to construct cavities (Bull et al., 1997), and so the most important determinant of snag suitability is length of time that a tree has been dead (Brandeis et al., 2002). In northeastern Washington, USA, nest cavities were first observed in topped trees after 3 years and percent of these trees with cavities increased from 1.4% of topped trees in decay class 2 to 34.8% of topped trees in decay class 4 (Hallett et al., 2001). In western Oregon, Chambers et al. (1997) found few cavities in newly created snags, but reported a significant increase in cavities in trees topped above mid-canopy after 5 years in all treatments they studied. A follow-up to the Chambers et al. (1997) study found that 88% of these snags had cavities in the first decade after creation (Walter and Maguire, 2005). Additionally, Walter and Maguire (2005) found that topped conifers that remained alive were rarely used for foraging or nesting. While it is possible that the size of snags we created is not suitable for certain cavity-nesting birds, particularly larger species like pileated woodpeckers, we think the fraction of created snags that are used for nesting by some species of cavity-nesting birds that utilize young managed forests will increase in future years as decay rates increase.

Neither Chambers et al. (1997) nor Walter and Maguire (2005) found a relationship between nesting levels and distribution (i.e., clumped versus scattered) of created snags. Our findings corroborate this conclusion, but our sample size of nests was very small and future analysis of snags on our study area may demonstrate an effect of distribution of created snags on level of nesting. Territoriality exhibited by cavity-nesting species undoubtedly influences snag use, although no study has shown that cavity-nesting birds competitively exclude one another. However in situations where cavities are limited or clustered, negative interactions are more evident (Bull et al., 1997; Walter and Maguire, 2005). Assuming snag distribution pattern is not a critical determinant of use by cavity-nesters, clumping snags may be more pragmatic when one considers operational factors such as efficiency of creation, equipment operation, and logistics of monitoring (Chambers et al., 1997).

We did not find a strong relationship between snag density and foraging use. Again, if territoriality is a factor, one would expect foraging use to reach a threshold level in relation to snag density as individual territories would contain sufficient numbers of snags. However, we note that we did not make species-specific observations of nesting and foraging use. Additionally, the distribution of snag sizes in our study was different than other studies in that we created shorter snags from trees that occurred in a managed forest with fewer large diameter trees. As a result, a threshold relationship between snag use and snag density may only be valid for those cavity-nesting birds that used treatment units regularly, primarily smaller species. That is, the density of snags that we examined may have been sufficient for these species to fulfill their life-history requirements. Larger species utilizing bigger territories and require larger snags (e.g., pileated woodpecker) may have only incidentally used the snags we created or included our treatment units as part of individual territories. In these cases, a threshold relationship is unlikely to be supported.

We predicted that foraging use of created snags in our study would be immediate and increase with snag age. Our findings provided some support for this prediction (we documented a small increase with snag age) and corroborate other studies. Bull and Partridge (1986) found that created snags were used for foraging within 2–4 years of creation and most had foraging use after 5 years. Hallett et al. (2001) found little foraging use of snags during their first year of creation, but reported a significant increase in foraging use as decay class increased for all methods of snag creation. Brandeis et al. (2002) reported that woodpeckers foraged most actively on Douglas-fir snags in western Oregon 3 years after creation regardless of time after inoculation. The temporal increase in foraging use of created snags appears to occur regardless of creation method, spatial aggregation, or harvest treatment, and we suggest that monitoring programs allow at least 3 years to pass post-creation before beginning monitoring activities.

5. Management implications

In intensively-managed forests where dead wood recruitment processes have been altered, creating snags may be necessary to compliment green-tree retention practices. Our results indicate that creating snags with a feller-buncher is a viable option for managers interested in increasing the number of snags in young harvest units similar to those we studied. These created snags provide almost immediate foraging habitat that may be critically important to avian communities in landscapes with low snag densities similar to our study. We only evaluated avian responses and stress that other species may have different requirements and responses to snags created with feller-bunchers. In addition, we did not monitor species-specific responses and our findings should be viewed in that context. Previous research indicates that certain bird species require taller and larger snags than those we created in our study. Shorter snags created by this method may also have a shorter temporal suitability than taller, larger snags as the relatively fast growing canopy of managed stands canopy encroaches these snags. While our technique can be used broadly across managed forest landscapes to increase snag numbers generally, managers should address the short-fall of large snags through the retention of either large snags in harvest units or large, old trees that can become large snags.

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