CHARACTERISTICS OF SITES OF WESTERN BLUEBIRD NESTS IN MANAGED PONDEROSA PINE FORESTS OF WASHINGTON

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ABSTRACT: I compared characteristics of sites of Western Bluebird (*Sialia mexicana*) nests in natural tree cavities in burned and unburned logged ponderosa pine (*Pinus ponderosa*) forests along the east slope of the Cascade Range of Washington, 2003–2008 and 2010. Tree density and percent debris cover (litter and large woody debris) were greater at nest sites in unburned stands because fire kills live trees and consumes woody debris, and they were the only characteristics in which nest sites in burned and unburned forests differed. In burned stands cavities were oriented primarily east, whereas in unburned stands they were oriented randomly. East-facing cavities may be thermally advantageous early in the day, keeping eggs warmer when the incubating female is away foraging. Most snags containing bluebird nest cavities (73%) were advanced in decay and had broken tops. Of the cavities whose original excavator was known, 27% were excavated by the Hairy Woodpecker (*Picoides villosus*), 12% by the White-headed Woodpecker (*P. albolarvatus*), and 5% by the Northern Flicker (*Colaptes auratus*). Only one nest was located in a non-excavated cavity. Of the 38 second nests, 76% were in the same cavity as the first, even though 38% of these first attempts were unsuccessful, suggesting that suitable cavities are limiting. My results suggest that bluebirds use similar nest sites in burned and unburned ponderosa pine stands and that abandoned woodpecker cavities are critical to the Western Bluebird in these managed forests.

Birds that nest in cavities they do not excavate face unique challenges during the nesting season because they rely on cavities excavated by primary excavators such as woodpeckers or on natural cavities (e.g., hollows from broken branches, rocky cliffs, and holes in exposed banks along streams) (Aitken and Martin 2007). Because of this, the abundance of such secondary cavity-nesters may be constrained by the often limited availability of adequate cavities (Zarnowitz and Manuwal 1985, Holt and Martin 1997). Conservation of secondary cavity-nesters requires an understanding of the characteristics of their nest sites because forest managers can create these habitat features.

The Western Bluebird (*Sialia mexicana*), a secondary cavity-nester, breeds in semi-open forests, forest edges, and burned forests (Guinan et al. 2008). Over much of its range, the Western Bluebird is associated during the breeding season with forests dominated by ponderosa pine (*Pinus ponderosa*) (Germaine and Germaine 2002, Arsenault 2004, Kozma and Kroll 2010). Since European settlement, ponderosa pine forests have changed considerably through decades of fire suppression and logging focused on the selective removal of large-diameter trees (Arno 1996, Hessburg et al. 2005). As a result, today's forests have high densities of small-diameter trees and low densities of large-diameter trees and snags (Keeling et al. 2006, Kozma 2011). To reduce the potential of forest-consuming fires and outbreaks of insect pests, land-management agencies and commercial foresters may thin the trees and burn the understory (Wightman and Germaine 2006) to restore ponderosa pine forests to a condition that is park-like and dominated by large-diameter trees (Converse et al. 2006). It will take many years for these forests to reach this condition, however, and it is unclear the effect these interim forests will have on cavity-nesting birds (Germaine and Germaine 2002). To address this concern, in 2003 I began studying the reproductive ecology of Western Bluebirds using tree cavities in managed ponderosa pine forests of the eastern Cascade Range in Washington (Kozma and Kroll 2010). My objectives were to (1) describe and compare the characteristics of nest trees or snags and other fine-scale habitat features associated with Western Bluebird nest sites in burned and unburned forests and (2) to determine the proportion of excavated and non-excavated cavities in which bluebirds nest.

STUDY AREA AND METHODS

My study took place along the eastern slope of the Cascade Range in southern Kittitas, Yakima, and Klickitat counties, Washington, from 2003 to 2008 and in 2010 (for a map of the study area, see Figure 1 in Kozma and Kroll 2010). The eastern Cascades have a complex topography (Everett et al. 2000) and hot, dry summers; >80% of the annual precipitation falls during winter (Wright and Agee 2004). The study area ranges in elevation from 560 to 1180 m, encompassing parts of the Okanogan-Wenatchee National Forest and lands owned by the Washington Department of Natural Resources, Western Pacific Timber Company, and one private landowner. This study was part of a larger one investigating the reproductive ecology of primary cavity-nesters (Kozma and Kroll 2012), in which each forest stand contained a breeding pair of White-headed Woodpeckers (*Picoides albolarvatus*). I selected these stands opportunistically on the basis of reviews of areas proposed for logging where I encountered White-headed Woodpeckers and by reviewing a database of historical sightings maintained by the Washington Department of Fish and Wildlife (Buchanan et al. 2003). Stands comprised ~660 ha of ponderosa pine or mixed-conifer forests, and no part of the study area was harvested, burned or salvage-logged during the study.

The overstory of the study area contained a mix of tree species dominated by ponderosa pine (percentage of ponderosa pine ranged from 33 to 100% and was >75% in most stands; Kozma 2011). Douglas-fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), and grand fir (*Abies grandis*) occurred in smaller numbers, depending upon the site's history, elevation, and aspect. The understory was dominated by antelope bitterbrush (*Purshia tridentata*), wax currant (*Ribes cereum*), snowbrush ceanothus (*Ceanothus velutinus*), snowberry (*Symphoricarpos albus*), and shinyleaf spirea (*Spiraea betulifolia* var. *lucida*). The study area contained 18 forest stands where timber had been harvested within the past 25 years. Nine of these stands burned 1–9 years before my study and had some degree of salvage logging ranging from occasional removal of dead trees for firewood to commercial harvest with mechanized equipment. The remaining nine stands were unburned and were managed for trees of uneven ages by thinning or shelterwood harvest.

I searched for Western Bluebird nests from mid-April to mid-June, 2003 to 2008. In 2010, I recorded Western Bluebird nests found incidentally while

I was monitoring woodpecker nests. Because of time constraints, I searched a subset of the 18 stands in each year, and stands that I monitored within a given year I searched at least once every 7–10 days. I located nests by checking cavities in which I knew bluebirds to have nested in previous years and by following adults carrying nesting material or food to new or previously unknown cavities. To confirm that a cavity contained an active nest (i.e., at least one egg was laid), I inspected cavities with a Tree Top Peeper IV, a portable telescoping probe and video camera (Kozma and Kroll 2010). If cavities were higher than 11 m, I confirmed nesting by behaviors such as the female entering for an extended period and adults carrying food to the cavity or removing fecal material. If I observed an active bluebird nest in the same cavity after the initial attempt ended, I assumed that cavity was being reused by the same pair of bluebirds (Stanback and Rockwell 2003).

I sampled the vegetation around each nest cavity after the bluebirds were no longer using it. At each nest tree or snag (“nest substrate”), I recorded the following variables: species of the substrate, degree of decay (scale 1–4; Table 1), height (m), diameter at breast height (dbh; cm), cavity height (m), slope (%), canopy cover (%), shrub height (m), and the original excavator of the cavity, if known. I measured shrub, cavity, and nest-substrate height with the telescoping nest-inspection pole (graded in m and cm) or with a clinometer for cavities and nest substrates higher than 11 m (Kozma 2012). I calculated a cavity’s relative height by dividing the cavity’s height by the nest substrate’s height (Siegfried et al. 2010). I used a spherical crown densiometer at the base of the nest substrate to estimate canopy cover in the four cardinal directions, then averaged the four estimates (Farnsworth and Simons 1999). I was able to determine the original excavator of 57 cavities because I also monitored nests of primary excavators in the same study area and I marked all nest substrates with a numbered aluminum tag (Kozma 2012).

I sampled habitat in circles of radii of 2, 5, and 11.3 m centered on each nest substrate (modified from James and Shugart 1970 and Martin et al. 1997). Within the 2-m circle, I estimated the percent cover of herbaceous plants (forbs and grasses) and debris (large woody debris and litter). In the

Table 1 Stage of Decay of Trees and Snags in Which Western Bluebirds Nested in Managed Ponderosa Pine Forests, Eastern Cascade Range, Washington, 2003–2008 and 2010

	Proportion[a]				
	Type 1	Type 2	Type 3	Type 4	Total
Ponderosa pine	0.04	0.08	0.21	0.49	0.82
Douglas-fir	0.00	0.02	0.03	0.06	0.11
Western larch	0.01	0.00	0.02	0.02	0.04
Grand fir	0.00	0.00	0.00	0.02	0.02
Willow (*Salix sp.*)	0.00	0.00	0.00	0.01	0.01
Total	0.05	0.10	0.26	0.59	1.00

[a]Type 1, live tree with a dead top or other defect; type 2, recently dead tree with brown foliage; type 3, snag with moderate decay, foliage and small branches missing, top intact; type 4, snag in advanced decay with broken top and most branches gone (Kozma 2009).

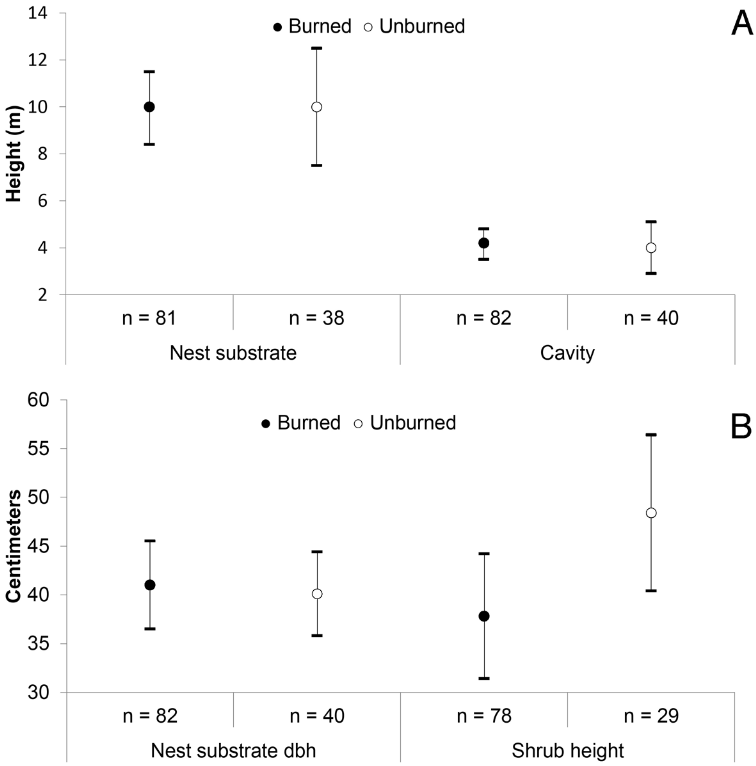
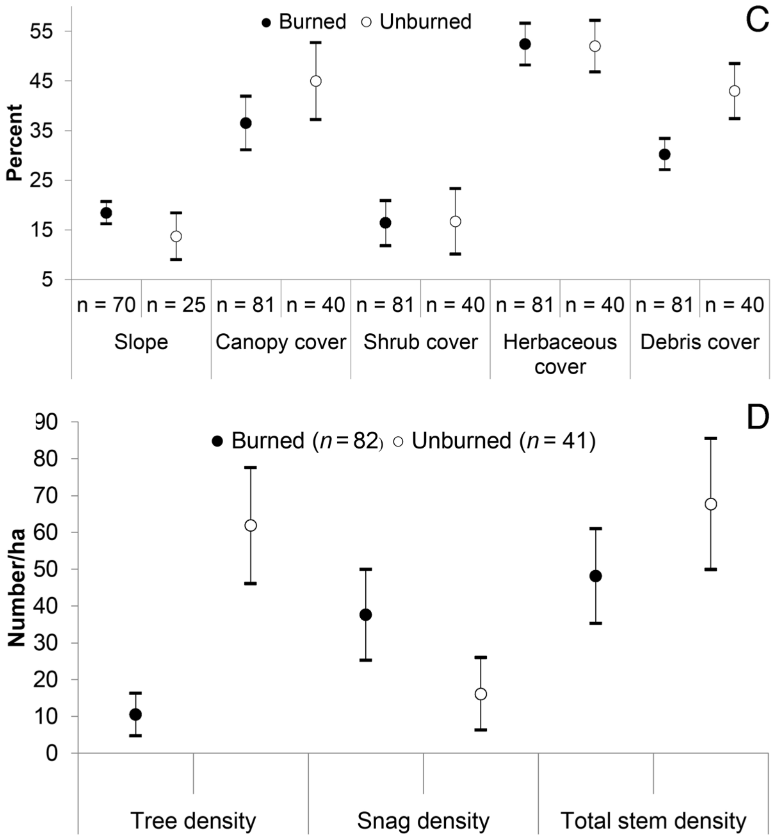


Figure 1. Mean (95% confidence interval with sample sizes) characteristics of sites of Western Bluebirds nests in burned and unburned managed ponderosa pine forests of the eastern Cascade Range, Washington, 2003–2008, and 2010. (A) nest-substrate height and cavity height; (B) nest-substrate dbh and shrub height; (C) percent slope, canopy cover, shrub cover, herbaceous cover, and debris cover; (D) tree density, snag density, and total stem density.

5-m circle I visually estimated the percent cover of each shrub species. In the 11.3-m circle (0.04 ha) I counted trees and snags in three categories of dbh (25.4–50.8 cm, 50.8–76.2 cm, and ≥76.2 cm).

Because in some years samples were small, for analyses I pooled all years' nests. If bluebirds reused a cavity in a subsequent year, I randomly chose one attempt and used the sampling of vegetation during that attempt in the analyses. I categorized dbh as all trees ≥25.4 cm, all snags ≥25.4 cm, and all trees and snags combined (Kozma and Kroll 2010). I used a chi-squared test for goodness of fit to determine if the category of decay of nest substrate differed from that expected by chance. In my comparisons of vegetation variables in burned and unburned stands, no overlap of 95% confidence intervals suggested a statistically significant difference (Kozma



2012). I used Rayleigh's test to determine if the orientation of cavities in burned and unburned stands clustered around a mean (Zar 1974). For all statistical tests I set $\alpha = 0.05$.

RESULTS

I monitored 182 nest attempts, of which I am presenting the results of vegetation sampled at 123 nest sites (83 in burned and 40 in unburned stands) because of multiple attempts in the same cavity. Ponderosa pine contained 82% of cavities used by bluebirds, followed by Douglas-fir (11%; Table 1). The degree of decay of nest substrates was distributed nonrandomly ($\chi^2 = 89.5$, df = 3, $P < 0.01$), with the greatest proportion of bluebird cavities located in snags in the most advanced stage of decay (Table 1). Of the 57 cavities whose original excavator I knew, 33 were excavated by Hairy Woodpeckers (*Picoides villosus*), 15 by White-headed Woodpeckers, 6 by

Northern Flickers (*Colaptes auratus*), 2 by Black-backed Woodpeckers (*P. arcticus*), and 1 by a Williamson's Sapsucker (*Sphyrapicus thyroideus*). An additional 53 cavities had entrances of a diameter nearly identical to that of a cavity excavated by *Picoides* and smaller than that of one excavated by a flicker, but I did not identify the species. Only one nest was located in a natural, unexcavated cavity. Of the 38 second nests attempted by the same pair of bluebirds, 29 (76%) were in the same cavity as the first attempt even though 11 (38%) of these first attempts were unsuccessful.

Debris cover and tree density were greater at bluebird nests in unburned than in burned stands (Figure 1), but no other vegetation variables I measured differed (Figure 1). Likewise, the mean relative cavity height in burned stands (0.54; 95% CI: 0.47, 0.60) was similar to that in unburned stands (0.55, 95% CI: 0.45, 0.65). In burned stands the mean orientation of cavities was 121°, and values were significantly clumped around the mean ($n = 83$, $r = 0.195$, $z = 3.167$, $0.05 > P > 0.02$). In unburned stands, the mean orientation was 247°, but the distribution did not differ from random ($n = 39$, $r = 0.206$, $z = 1.651$, $0.20 > P > 0.10$).

DISCUSSION

The majority of Western Bluebird nests were in ponderosa pine snags, which is not surprising given that ponderosa pine was the dominant tree in the study area (Kozma 2011). Bluebirds nested almost exclusively in cavities excavated by woodpeckers. The availability of non-excavated, natural cavities may be limited in my study area by the lack of old-growth deciduous trees of large diameter (dbh >50 cm; Kozma 2011), which are more likely to have natural cavities, although I did not sample the availability of excavated to unexcavated cavities. Studies finding a greater proportion of use of non-excavated cavities have generally been done in more mature forests (Bai et al. 2003, Wesołowski 2007); older trees are more likely than younger trees to contain non-excavated cavities in the form of broken or hollow branches and crevices behind loose bark.

Bluebirds most frequently used cavities in snags far along in decay. This likely reflects the selection of such snags by the Hairy and White-headed woodpeckers, whose cavities bluebirds used most often, because these two woodpeckers excavate most of their cavities in snags with advanced decay (Kozma 2012). Even though Northern Flicker cavities are abundant in my study area (114 flicker nests monitored from 2003 to 2010; Kozma 2012), bluebirds rarely nested in them. This was unexpected because other species nest in flicker cavities extensively (Martin and Eadie 1999, Gentry and Vierling 2008). Cavities with smaller entrances (e.g., those excavated by *Picoides* woodpeckers) may be more attractive to bluebirds because they are more easily defended, may reduce the number of potential predators able to enter the cavity, and are better at maintaining the cavity's internal temperature (Rhodes et al. 2009). Indeed, Arsenault (2004) and Saab et al. (2009) found that Western Bluebirds nest most frequently in cavities smaller than those excavated by flickers. Furthermore, Arsenault (2004) concluded that cavity size was the most important characteristic distinguishing nest sites of four different cavity-nesters.

For second nests, Western Bluebirds frequently reused cavities, even if the first nest was unsuccessful. This was also unexpected because the Eastern Bluebird (*Sialia sialis*) is more likely to change sites if the previous attempt failed (Gowaty and Plissner 1997). Bluebirds that reuse a cavity within the same season risk exposing their second brood to an increase in ectoparasites (Stanback and Rockwell 2003). In addition, an increase of predation on these second nests can be expected, especially if the first nest was preyed upon (Sonerud 1985). Although I did not measure the availability of cavities, in my study area, which is composed primarily of managed forests, bluebirds may be faced with a scarcity of suitable cavities (Aitken et al. 2002). As a result, alternate cavities may be occupied, suboptimal, outside of the territory, or of unknown quality (Harvey et al. 1979, Stanback and Rockwell 2003). If bluebirds are unable to find suitable alternate cavities, they may be forced to reuse cavities (Stanback and Dervan 2001).

In only two vegetation variables, debris cover and tree density, did bluebird nest sites in burned and unburned forest differ. Both of these variables were lower in burned areas because fire kills live trees and removes downed logs and other debris from the ground and because during salvage logging some live trees whose crown is scorched and so not expected to live are removed. In burned forest, bluebirds preferred cavities facing east. In burned stands, which are more open than unburned stands, east-facing cavities may have a thermal advantage because they can be warmer than cavities oriented in other directions (Hooge et al. 1999). East-facing cavities may warm up faster in the morning, allowing the eggs to stay warmer when the incubating female leaves the nest to forage (males do not incubate). Arsenault (2004) also found that Western Bluebirds used east-facing cavities more and north-facing cavities less than expected from the orientation of unused cavities. Other secondary cavity-users such as the American Kestrel (*Falco sparverius*) and Tree Swallow (*Tachycineta bicolor*) also prefer natural cavities or nest boxes oriented east (Raphael 1985, Ardia et al. 2006). Primary excavators often selectively excavate cavities facing east as well, although it is unclear if they are selecting this orientation because of its thermal advantages or are taking advantage of the occurrence of heartrot (Saab et al. 2004). In my study area, Hairy and White-headed woodpecker cavities in burned areas had a mean orientation of 154° and were not randomly distributed ($n = 79$, $r = 0.253$, $Z = 5.06$, $0.01 > P > 0.005$), while the orientation of cavities excavated by these two woodpeckers in unburned areas was randomly distributed ($n = 87$, $r = 0.126$, $Z = 1.38$, $0.50 > P > 0.20$). Therefore, bluebirds nesting in burned areas may also be selecting cavities with an east aspect because they are the most readily available.

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