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HAIRY WOODPECKER WINTER ROOST CHARACTERISTICS IN BURNED PONDEROSA PINE FOREST

KRISTIN A. COVERT-BRATLAND,[1,3] TAD C. THEIMER,[2] AND WILLIAM M. BLOCK[1]

ABSTRACT.—Winter roosts afford escape from extreme climatic conditions, reduce heat and energy loss, and provide protection from predators for North American woodpeckers. We monitored the use and characteristics of 12 winter roosts used by nine radio-marked Hairy Woodpeckers (*Picoides villosus*) in ponderosa pine (*Pinus ponderosa*) forests of northern Arizona that had experienced wildfire in 1996 and 2000. Roost trees were larger in diameter than 95% of non-roost trees and on average 2.5 times larger within burned areas of similar severity. Roost trees were within patches less dense than 95% of measured patches across study sites, which were on average 1.5 times as dense. Two-thirds of roost trees were created by fire and were smaller than those created by other means. Six birds each used one roost and three males each used two roosts. Two-thirds of the roosts were outside or on the edge of estimated home ranges. Maximum straight-line distances traveled, from roost to farthest point of home range, were >1 km for 8 of 9 birds. Woodpeckers have a significant role in providing cavities for secondary cavity nesters. Thus, understanding habitat requirements for winter roosts could provide managers with essential tools to maintain or enhance populations of this species. *Received 19 October 2005. Accepted 14 July 2006.*

Snags are the principal substrate for both nesting cavities and winter roosts for primary cavity nesters in coniferous forests (Hutto 1995) and snag availability may limit population size (Newton 1994, Schepps et al. 1999). While information has been collected on characteristics of cavities used for nesting (Hutto 1995, Saab et al. 2002), little has been collected on winter roost trees and their use, even though winter is a critical period for resident birds (but see Pileated Woodpecker [*Dryocopus pileatus*], e.g., Bull et al. 1992, Kellam 2003). Low-temperatures, high winds, and precipitation increase metabolic costs (Walsberg 1986, Cooper 1999). Additionally, while shorter days decrease time available for foraging, food resources become limited (Askins 1981). This results in an increased proportion of time birds forage to gain adequate food resources, which leads to increased predation risk (Houston and McNamara 1993). Roost holes alleviate some of these pressures by providing insulation (Askins 1981, 1983), reduced exposure to wind and precipitation, and an increase in nightly energy conservation, thereby reducing time necessary for foraging (Conner 1975, Stauffer and Best 1982, Li and Martin 1991, Cooper and Swanson 1994). Roosts also provide protection from both nocturnal and diurnal predators (Dolby and Grubb 1999).

Fire changes the distribution and abundance of snags available for winter roosts and alters the rate of snag turnover, depending upon the length of inter-fire intervals (Newton 1994). In northern Arizona, ponderosa pine (*Pinus ponderosa*) forests historically experienced low-severity fires every 2–12 years and fires ranged from several hundred to several thousand hectares in size (Covington et al. 1997, Fulé et al. 2003). Within these fires, small patches of snags were generated in high frequency across the landscape (Fulé et al. 2004). As a consequence, this system could have had the potential for relatively rapid snag turnover (Newton 1994). More recently, fire suppression and logging have altered historical fire regimes and have led to dense stands of small-diameter trees that can support large wildfires. Although fire often attracts primary cavity nesters due to an increase in bark- and wood-dwelling insect prey (e.g., Blackford 1955, Koplin 1969, Hutto 1995, Murphy and Lehnhausen 1998), little information exists about where these birds roost relative to burned and unburned areas or the characteristics of trees used as roosts.

[1] U.S. Forest Service, Rocky Mountain Research Station, 2500 S. Pine Knoll Dr., Flagstaff, AZ 86001, USA.

[2] Department of Biology, Northern Arizona University, P. O. Box 5640, Flagstaff, AZ 86011, USA.

[3] Corresponding author; e-mail: kbratland@fs.fed.us

Winter roosts are important for over-winter survival, which ultimately affects the number of available breeders entering subsequent nesting periods. Thus, information on roost characteristics used by woodpeckers in burned ponderosa pine forests may help managers make guided decisions to conserve these important primary cavity-nesting species. We present roost characteristics, use, and location relative to home ranges for nine radio-marked Hairy Woodpeckers (*Picoides villosus*) monitored for a study of their winter ecology (Covert-Bratland et al. 2006). We provide baseline data, methods for future investigation, and several hypotheses to direct future research.

METHODS

Study Area.—During winter 2002–2003, we studied Hairy Woodpeckers in monotypic ponderosa pine forests of northern Arizona burned by three different wildfires. In 1996, the Horseshoe and Hochderffer wildfires burned 10,022 ha in the Coconino National Forest 48 km northwest of Flagstaff, Arizona (35° 37′50″ N, 111° 79′62″ W). Because these fires were adjacent to each other, we treated them as one site. The Pumpkin fire burned 5,973 ha in May 2000, in both the Coconino and Kaibab National forests (35° 37′45″ N, 111° 90′79″ W) adjacent to the earlier Horseshoe-Hochderffer fires. Thus, at the time of our study, the sites represented burns that were 7 and 3 years of age, respectively. Fires burned with varying intensity, resulting in a mosaic of high- and moderate-burn severities and unburned areas across the landscape. We sampled in high-severity areas, those where fire reached the forest crown and killed 99% of ponderosa pine, and moderate-severity areas, those where low-intensity surface-fires resulted in <10% tree mortality (adapted from Dwyer and Block 2000).

Other woodpecker species in the study area during winter, in decreasing relative abundance, included Northern Flicker (*Colaptes auratus*), Williamson's Sapsucker (*Sphyrapicus thyroideus*), Three-toed Woodpecker (*Picoides tridactylus*), and Downy Woodpecker (*P. pubescens*) (WMB, unpubl. data). These species were relatively rare, as the relative abundance of each compared to that of the Hairy Woodpecker (with the Hairy Woodpecker as 1) was 0.33, 0.05, 0.03, and 0.01, based on average detections per point-count station. Of these woodpeckers, the Downy Woodpecker is considered a weak excavator (Martin et al. 2004) and the Williamson's Sapsucker roosts in natural or secondary cavities (Dobbs et al. 1997).

Field Methods.—We used radio telemetry to locate and monitor Hairy Woodpecker winter roosts. Between 18 October and 18 December 2002, we searched for Hairy Woodpeckers over 5,000 ha of our study area and mist-netted nine individuals using tape playback calls of Hairy Woodpecker and Northern Pygmy-owl (*Glaucidium gnoma*). Each bird was individually marked with a federal band and two color bands. Additionally, we attached a BD-2, 1.7 g, 18-cm whip-antenna, 14-week-lifespan, transmitter (Holohil Ltd., Carp, Ontario, Canada) to the central two rectrices with epoxy glue and secured with dental floss on the body of the transmitter and at 2 15-cm intervals down the antennae. Transmitter mass was approximately 3% of the bird's body mass.

We located roost cavities of radio-marked birds from 22 October 2002 to 14 March 2003 between 1700 and 2100 hrs MST. Each individual's roost tree was monitored a minimum of four times throughout the season at regular intervals of approximately two weeks. Cavities used were located using radio telemetry, or, if more than one cavity entrance was present in the area of strongest transmission, observers would return the following morning 15 min before sunrise to watch the bird emerge. This process was repeated twice for cavity verification.

Structural and burn characteristics of the roost tree, patch, and surrounding forest were measured. For each roost tree, we recorded: (1) roost tree location (UTM using Garmin 12 Global Positioning System [GPS] units); (2) roost tree species, its likely cause of death, and the tree's burn severity (unburned, moderate, or high), diameter at breast height (dbh), percent retained bark, and whether it was topped (upper portion of the trunk broken off); (3) number of cavities in the roost tree and which were occupied by the Hairy Woodpecker; and (4) height and orientation of each cavity. We also recorded data for the patch around the roost tree: (1) burn severity within

a 25-m radius; (2) distance to nearest patch of alternate severity (e.g., if a roost was in an unburned patch where was the nearest patch of moderate- and high-severity burn) using the roost tree as the point from which measurements were taken; (3) tree density; and (4) mean patch dbh. We calculated patch tree density using the point-center quarter method by averaging distances from the roost tree to the four nearest trees (≥2 m in height) in each cardinal quadrant (Cottam and Curtis 1956). Similarly, we calculated the mean patch dbh by averaging the dbh measurements of the same four trees. We then compared that mean to the dbh of the roost tree.

We compared roost tree and patch measurements to the mean of each variable measured within the surrounding ponderosa pine system studied by placing randomly oriented vegetation grids (100 × 100 m grid cells) over study sites in ArcView 3.2a (Environmental Systems Research Institute 2004). Thus, we could find the exact location of each grid-intersection in the field using GPS. At each intersection (n = 338), we selected the nearest tree to serve as the random center-tree and within each cardinal quadrant selected the tree closest to the center tree to measure tree density and mean patch dbh. We recorded the center tree's species, burn severity, dbh, percent-retained bark, and whether it was topped. We measured the distance to all trees in each cardinal quadrant and their respective dbh. We used Wilcoxon signed ranks test to compare roost tree dbh, density, and patch dbh to the mean of each variable in the surrounding forest of the same age and burn severity. We used Mann-Whitney tests to compare the dbh and number of cavities in fire-killed snags versus snags created by other means. Mean orientation and significance of cavity orientation for all cavities were calculated using Rayleigh's test (Zar 1999:616). All tests were performed using SPSS (SPSS, Inc. 2002). Statistical significance was set at $\alpha = 0.05$ and means are presented ± SE.

The youngest post-burn age of a high-severity roost tree in which Hairy Woodpeckers would create a cavity was based on observations of cavity excavation in the younger Pumpkin fire. We were able to monitor cavity creation one year prior to collecting roost data, which was taken only during the second year of the overall study (Covert-Bratland et al. 2006). During foraging observations, which were conducted by systematically searching 300-m belt-transects 2–5 times during winter 2001–2002 and 2002–2003, any observation of a Hairy Woodpecker excavating a cavity was noted. The total number of excavations for two seasons is presented for fires representing 2 and 3 years post-wildfire.

Location of Roosts Relative to Diurnal Home Range.—We calculated the distance from the roost to several points within each individual's diurnal home range (Covert-Bratland et al. 2006). We defined diurnal home range as the area used for daily foraging and other activities between 0800 and 1600 hrs excluding travel to and from roost sites. We used both the 85% fixed-kernel (pre-hoc smoothing factor) and minimum convex polygon (MCP) methods calculated with ''Animal Movement'' extension (Hooge and Eichenlaub 1997) in ArcView 3.2a (Environmental Systems Research Institute 2004) to estimate home ranges. We classified the location of each roost relative to the diurnal home range (Covert-Bratland et al. 2006) as either inside (within the diurnal home range but not within 50 m of the edge), on the edge (within ± 50 m of the 85% contour), or outside the home range (>50 m from the 85% contour edge, in which case the distance was calculated as below).

We found no information on distances traveled by Hairy Woodpeckers in the literature to compare to distances traveled in this study. We established baseline movement distances for future research by calculating the distance from each bird's roost tree to (1) the closest point on the 85% contour interval, (2) the arithmetic mean of the diurnal home range estimated by the fixed-kernel method, and (3) the farthest known diurnal foraging location. We used the ''Animal Movement'', ''X-tools'' (Environmental Systems Research Institute 2004), and ''Weighted Mean'' extensions (Jenness 2004) in ArcView 3.2a to calculate these distances.

RESULTS

We located and measured 12 Hairy Woodpecker roost trees during winter 2002–2003 (Tables 1, 2). Three females and three males each used one roost tree during the period

TABLE 1. Characteristics of winter roost trees and roost-tree patches (as defined by point-center quarter) used by Hairy Woodpeckers in ponderosa pine forest burned in the Pumpkin (3 years post-wildfire) and Horseshoe/Hochderffer (7 years post-wildfire) wildfires, Coconino National Forest, Arizona, during winter 2002–2003. Characteristics of roost trees and patches are given first, followed by the mean ± SE of trees and patches present in the surrounding forests within the corresponding burn age and burn severity.

Burn age	Gender	Bird	Roost tree species[a]	Snag type[b]	Roost tree burn severity[c]	Patch burn severity	DBH (cm)	Surrounding DBH (cm)	Tree density	Surrounding tree density	Patch DBH (cm)	Surrounding patch DBH (cm)
3	F	894	PIPO	S	UNB	UNB	88.0	22.5 ± 1.8	0.23	0.44 ± 0.06	19.6	21.1 ± 1.5
	M	100	PIPO	FK	HIGH	MOD	72.2	17.4 ± 1.3	0.14	0.28 ± 0.03	32.1	29.1 ± 1.1
		951a	PSME	FK	HIGH	HIGH	60.8	17.4 ± 1.3	0.27	0.44 ± 0.03	34.1	19.9 ± 0.1
		951b	POTR	FK	HIGH	HIGH	24.6	17.4 ± 1.3	0.44	0.44 ± 0.03	9.5	19.9 ± 0.1
7	F	182	PIPO	FK	HIGH	MOD	27.9	24.5 ± 1.0	0.15	0.21 ± 0.01	38.3	28.7 ± 0.6
		990	PIPO	FK	HIGH	HIGH	45.1	24.5 ± 1.0	0.14	0.19 ± 0.01	29.6	24.6 ± 0.6
	M	209a	PIPO	S	MOD	MOD	66.9	30.5 ± 1.2	0.11	0.21 ± 0.01	21.1	28.7 ± 0.6
		209b	PIPO	BBK	MOD	MOD	89.0	30.5 ± 1.2	0.21	0.21 ± 0.01	27.6	28.7 ± 0.6
		293	PIPO	CF	MOD	MOD	45.5	30.5 ± 1.2	0.18	0.21 ± 0.01	34.6	28.7 ± 0.6
		835	PIPO	FK	HIGH	HIGH	55.0	24.5 ± 1.0	0.11	0.19 ± 0.01	32.5	24.6 ± 0.6
		910a	PIPO	FK	HIGH	HIGH	50.3	24.5 ± 1.0	0.13	0.19 ± 0.01	17.3	24.6 ± 0.6
		910b	PIPO	FK	HIGH	HIGH	41.0	24.5 ± 1.0	0.18	0.19 ± 0.01	30.3	24.6 ± 0.6

[a] PIPO = *Pinus ponderosa*, ponderosa pine.
PSME = *Pseudotsuga menziesii*, Douglas-fir.
POTR = *Populus tremuloides*, quaking aspen.
[b] S = Snag, pre-fire.
FK = Fire killed ponderosa pine.
BBK = Bark beetle killed tree.
CF = Cat face, dead portion in live PIPO tree, likely caused by lightning.
[c] UNB = unburned.
MOD = moderate.
HIGH = high.

TABLE 2. Winter roost tree use and location relative to diurnal home range attributes (fixed kernel estimate) of Hairy Woodpeckers in the Pumpkin (3 years post-wildfire) and Horseshoe/Hochderffer (7 years post-wildfire) wildfires, Coconino National Forest, Arizona, winter 2002–2003. Distances are from the roost tree to (1) the nearest point along the edge of the 85% kernel contour (negative values indicate roost trees inside the home range), (2) the center of the home range calculated using arithmetic mean, and (3) the farthest known foraging location of a bird within its diurnal home range.

Burn age	Gender	Bird	Nights used of total observed	Distance to nearest high-severity patch (m)	Distance to nearest moderate-severity patch (m)	Distance to HR[a] edge (m)	Distance to HR center (m)	Distance to farthest location in HR (m)
3	F	894	6/6	200	20	1,019.5	1,346.3	1,618.0
	M	100	5/5	250	—	205.8	374.9	565.3
		951a	1/5	—[b]	90	0.0	498.2	1,524.2
		951b	4/5	—	175	0.0	298.0	1,006.0
7	F	182	4/4	1,207	—	−373.3	500.5	2,045.0
		990	5/5	—	15	−379.5	1,007.0	2,306.3
	M	209a	4/5	25	—	5.7	159.9	1,446.8
		209b	1/5	450	—	140.1	561.8	1,427.9
		293	5/5	200	—	161.1	376.9	1,375.6
		835	6/6	—	25	40.2	377.8	1,302.6
		910a	4/5	—	15	−338.3	689.4	2,075.2
		910b	1/5	—	18	−217.3	594.0	1,936.3

[a] HR = home range.
[b] Indicates roost tree is within column severity.

monitored, and three additional males used two different roosts (Table 2). Eight roost trees were killed by fire, 3 in the 3-year-old burn and 5 in the 7-year-old burn. These 8 roost trees were categorized as high-severity and the majority (6 of 8) was within high-severity burned areas. Of those in high-severity areas, 4 of 6 were within 25 m of the edge of a moderate-severity patch. Roost trees killed by other means were in unburned areas that had not experienced fire since the roost was created, were within moderate-severity areas, and/or were killed by a secondary mortality agent after fire injury. Most trees retained the majority (mean = 82 ± 6.8%, range = 31–100%) of their bark. All trees leaned less than 5% from vertical and all but three trees were topped. Those not topped were either still alive or recently killed, precluding the decay process that would lead to topping.

Roost trees ranged in size from 24.6 to 89 cm dbh (mean = 55.5 ± 6.0 cm), and 9.5–31 m in height (mean = 18.9 ± 2.7 m). Roost trees used by Hairy Woodpeckers were on average 2.5 times larger in dbh than those in the surrounding forest within the same burn and age class ($Z = -3.1$, $P = 0.001$). Fire-killed trees were substantially smaller in dbh (mean = 47.1 ± 5.7 cm) than roost trees created by other means (mean = 72.3 ± 10.3 cm, $Z = -1.9$, $P = 0.03$). Regardless of burn age or severity, the mean density of trees surrounding the roost tree was substantially less than of trees in the surrounding forest ($Z = -3.1$, $P = 0.001$). The mean patch dbh of the trees closest to the roost tree was variable and did not differ from that of trees closest to a random tree in the surrounding forest ($Z = -0.8$, $P = 0.43$). Roost tree dbh was larger (6–69%) than the patch mean for all but one roost tree.

All roost trees had multiple cavities (range = 2–10, mean = 4.8 ± 0.8), however, each bird used only one cavity repeatedly and most appeared to be newly created that winter ($n = 11$). Fire-killed roost trees tended to have fewer cavities on average (mean = 3.9 ± 0.79) than snags created by other mortality factors (mean = 6.7 ± 1.44, $Z = 1.63$, $P = 0.051$). Cavity entrances ranged from 1.8 to 18.4 m (mean = 8.0 ± 1.2 m) above the ground corresponding to 9–85% of the total tree height. Five cavity entrances were under branches. The majority of roost hole entrances ($n = 9$, Fig. 1) faced north-northeast (mean angle = 21.27, angular dispersion 56.1°, $Z = 2.68$, $P = 0.006$) whereas those that faced south or west were on northeast slopes or in roost trees surrounded by dense unburned forest. Hairy Woodpeckers were observed excavating cavities 5 times in burned areas 2 years post-wild-

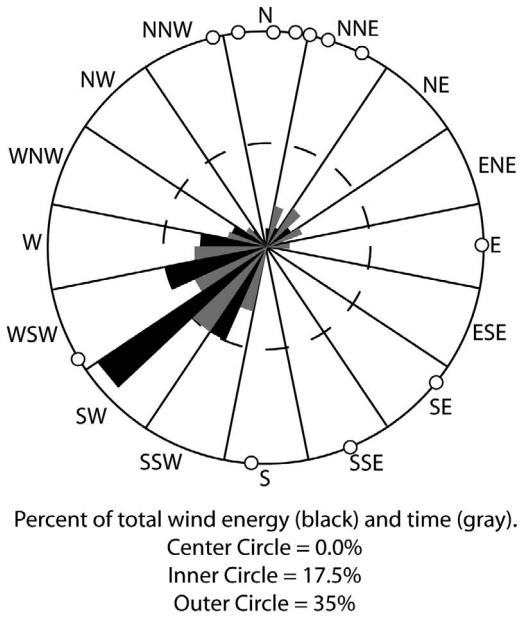

FIG. 1. Orientation of roost entrance holes (open circles) relative to southwest prevailing winds (Acker 2003) used by Hairy Woodpeckers within the Horseshoe/Hochderffer and Pumpkin burns, Coconino National Forest in northern Arizona during winter 2002–2003.

fire and 21 times in burned areas 3 years post-wildfire.

Only males changed roost trees during the study (Table 2). One male moved to a secondary roost within two weeks prior to the first week of December, whereas the other two males switched during the last week of February, only several weeks prior to nesting initiation. Two males moved to secondary roosts that were 100–200 m closer to their home range centers, whereas one moved to a location 400 m away. All three secondary roosts were closer (mean = 225.3 m) to the farthest foraging locations for those individuals, or the farthest extent of their home range.

Four roosts were outside of the calculated home range (fixed kernel method), four were within 50 m of the edge, and four were inside the home range (Table 2). The mean distance to home range boundaries for roost trees outside the home range, was 381.6 ± 213.1 m (range = 140.1–1,019.5 m). Three roosts were outside of the diurnal home range (MCP method), three were on the edge, and six were inside (Fig. 2). Distances from the roost tree to the center of the kernel home range averaged 565.4 ± 94.3 m (range = 159.9–1,346.3 m). The mean distance from roosts to the home range center for birds occupying 3-year-old burned areas was 629.4 ± 242.5 m versus 533.4 ± 88.9 m for birds occupying older burns, even though home range sizes for birds in older burns were larger.

DISCUSSION

All roost cavities were either in dead trees (snags) or within dead tissue in live trees, suggesting that Hairy Woodpeckers limited cavity excavation to dead tissue. Ponderosa pine has high volumes of sapwood relative to rot-resistant heartwood (Lowell and Cahill 1996). This ratio facilitates decay in portions of the tree of greatest volume, where cavities can then be excavated (Bull et al. 1997). Sapwood without rot is relatively hard and resists excavation (George and Zack 2001), making tree decay prior to excavation critical. Woodpeckers spend considerable energy excavating cavities and factors that decrease wood hardness and density would decrease energy expenditure needed to make cavities (Conner et al. 1976, Schepps et al. 1999). This would be especially beneficial during winter when energy requirements for survival are elevated (Walsberg 1986).

Most winter roosts were in fire-killed trees, in areas that had experienced high-severity wildfire, and in 3- and 7-year-old burned areas. Hairy Woodpeckers also used snags present before fire, indicating that roosts may be used after a fire if the roost tree and cavity are not too damaged. Historically, fire was the primary disturbance agent within northern Arizona's ponderosa pine forests (Covington et al. 1997), and could have generated small patches of snags in high frequency across the landscape (Fulé et al. 2004). Fire generates snags both directly by killing trees, and indirectly by increasing the susceptibility of surviving trees to secondary mortality agents that exploit the initial fire-caused injury (Salaman 1934, Flanagan 1996, McHugh and Kolb 2003).

Cavities were associated with snags >4 years old in studies of non-fire-killed roost trees. Scott (1978) found that most non-fire killed snags used by cavity nesters were at least 6 years old in northeastern Arizona and

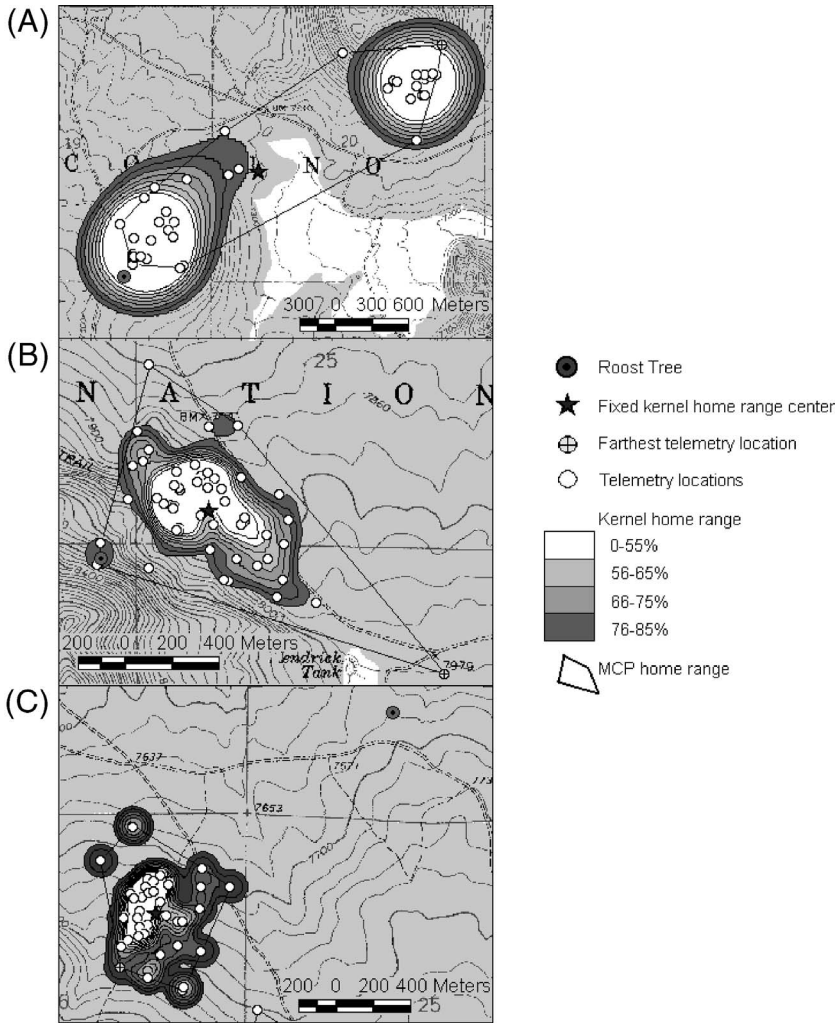

FIG. 2. Three Hairy Woodpecker winter roosts and home ranges as estimated by the 85% fixed kernel and minimum convex polygon (MCP) methods. Home range centers were estimated by the arithmetic mean and the farthest known diurnal location was measured by radio telemetry. Roosts shown are: (A) inside home range (bird ID 990), (B) on the edge of the home range (bird ID 951a), and (C) outside the home range (bird ID 894). All roosts were within the Coconino National Forest in northern Arizona during winter 2002–2003.

Bull et al. (1997) reported excavation in ponderosa pine 4–8 years following tree death. We observed Hairy Woodpeckers excavating cavities in snags created by high-severity fire at 2 and 3 years post-wildfire, indicating that high-severity burned ponderosa pine is available for excavation sooner than those created by other means. This is likely because ponderosa pine trees consist of 50–75% sapwood, which typically rots within 2 and appreciably deteriorates by 3 years following wildfire (Kinney 1955, Lowell and Cahill 1996, Bull et al. 1997). Thus, roost trees created by fire are more abundant because patches or swaths of trees die (Schubert 1974) and become available for excavation sooner than unburned snags. While literature exists on the decay process in burned trees (Kinney 1955, Morrison and Raphael 1993, Lowell and Cahill 1996, McHugh and Kolb 2003), little exists for trees succumbing to other mortality agents and how this affects cavity excavation by primary cavity nesters (Jackson and Jackson 2004).

Hairy Woodpeckers used roost trees with on average two times the bark coverage than found for cavity nesters in northeastern Arizona (>40%, Scott 1978). Retention of charred bark likely provides thermoregulatory benefits because temperatures under fire-blackened bark are higher than under non-charred bark (Kinney 1955). This difference could reduce winter energy expenditures of individuals within roosts until retained heat dissipated. Considering that our roost trees were smaller in size than those in other studies (Raphael and White 1984, Horton and Mannan 1988, Saab et al. 2002), intact burned bark on small trees might provide similar insolative values as larger trees with less bark. Alternatively, use of small roost trees with more bark could reflect the abundant availability of small snags created by wildfire and the rarity of large snags (Ganey 1999) in this system.

Hairy Woodpeckers oriented their roosts away from southwest winds that predominate in northern Arizona nightly (Staudenmaier et al. 2002, Acker 2003). Roost cavities were oriented on average 108.4° from southwest, while those that were not were sheltered from winds due to their placement on a northerly slope or within thick unburned vegetation. Non-random orientation of cavity entrances away from prevailing winds was also established for woodpeckers as a group (Conner 1975, 1977; Stauffer and Best 1982) and Downy Woodpeckers using artificial snags (Peterson and Grubb 1983, Petit et al. 1985). Petit et al. (1985) also found cavity entrances oriented more towards prevailing winds were in canyons or on protective slopes. Roost switches may also be a mechanism that decreases roost ventilation and heat loss caused by prevailing winds. We observed three males that changed roosts. The first male in relatively open terrain, maintained a northerly direction after moving, the second changed from a southerly to a northerly direction, and the third moved to a roost tree significantly lower on a north facing slope.

One-quarter to one-third of the roosts we documented were outside the boundaries of the bird's diurnal home range. Thus, diurnal estimates of movement patterns may underestimate the distance birds move in a day as well as home range size based on diurnal home ranges that do not include roosting habitat. Managers concerned with providing habitat requirements for this U.S. Forest Service Management Indicator Species (Ganey 1999) should consider whether diurnal area requirements include or exclude roosts and choose an appropriate home range estimator based on the biology of the birds within their area of charge.

Fire creates snags that could be used as roosts by woodpeckers by either immediately killing the tree, or by damaging it sufficiently that it succumbs to other mortality agents over time. High-severity fire creates high densities of snags quickly, which may become available sooner to woodpeckers, and include a greater range of tree sizes available for use by woodpeckers as roosts. However, these snags have reduced longevity compared with non-fire snags (Raphael et al. 1987, Morrison and Raphael 1993, Hejl 1994). Moderate-severity fire creates snags over a longer time period through secondary mortality agents such as insect attack or drought (Salaman 1934, Flanagan 1996, Santoro et al. 2001, McHugh and Kolb 2003), but susceptibility depends on canopy scorch (McHugh and Kolb 2003). These snags may have greater longevity but are rarer across the landscape (Ganey 1999). Thus, if fire is the predominant mortality agent, or leads to the greatest indirect mortality via secondary mortality agents, suppression inherently decreases snags across the landscape. Reducing all fires to low-severity could remove both sources of snags, as low-intensity ground fires produce little scorch, injury, and resultant mortality and susceptibility to secondary mortality agents (Furniss 1965, Ryan and Reinhardt 1988, Flanagan 1996, Santoro et al. 2001, McHugh and Kolb 2003). It is believed that snags are in low densities (Ganey and Vojta 2004), but it is unknown if northern Arizona forests contain densities of snags that limit roost tree availability. Further study of roost tree availability at the home range and landscape scale, and how natural and prescribed fire affects availability, warrants future examination.

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