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Authors: DANA RIPPER, JAMES C. BEDNARZ, and DANIEL E. VARLAND

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Research Article

Landscape Use by Hairy Woodpeckers in Managed Forests of Northwestern Washington

DANA RIPPER,[1,2] *Department of Biological Sciences, Arkansas State University, P.O. Box 599, Jonesboro, AR 72467, USA*
JAMES C. BEDNARZ, *Department of Biological Sciences, Arkansas State University, P.O. Box 599, Jonesboro, AR 72467, USA*
DANIEL E. VARLAND, *Rayonier Inc., 3033 Ingram Street, Hoquiam, WA 98550, USA*

ABSTRACT The hairy woodpecker (*Picoides villosus*) is a keystone species in forest ecosystems of Washington, USA, providing nesting and roosting cavities for many species of wildlife. Therefore, management practices that promote healthy populations of this bird will help to conserve cavity-nesting communities as a whole. The objective of this study was to determine patterns in forest type and landscape use by hairy woodpeckers, and thus, provide landscape-level recommendations to forest managers. We documented the ranging patterns and habitat use of 23 hairy woodpeckers on the Olympic Peninsula using radiotelemetry and a Geographic Information System analysis. Use patterns of stand age, type, and size, as well as distance-from-edge analyses revealed that the hairy woodpecker is a relative generalist in its use of the managed forest landscape. However, certain features, such as older stands with large trees, were used more heavily by nesting pairs. Hairy woodpeckers used 61–80-year forest stands significantly ($P < 0.05$) more than expected relative to their availability within the birds' home ranges. We also documented significant underuse of 6–10-year and 11–20-year stands, whereas the birds used 41–60-year stands, >80-year stands, and clear-cuts (<5 yr) equivalent to their availability. We suggest that hairy woodpeckers select older stands with larger, dying trees for foraging, but also use clear-cuts proportionally due to the residual snags, decaying trees, and remnant dead wood available. Higher use ($P < 0.001$) by hairy woodpeckers of small forest patches (0–5 ha) and intermediate-sized stands (5–30 ha) than large patches (>30 ha) may be a result of the older, higher-quality habitat available in small stands in the managed forest landscape. We recommend that land managers interested in maintaining healthy managed forest ecosystems with a full complement of cavity-using species in forests of western Washington and northwestern Oregon maintain a landscape mosaic with approximately 45% of the landscape in stands >40 years, and >30% of the landscape in stands >60 years. (JOURNAL OF WILDLIFE MANAGEMENT 71(8):2612–2623; 2007)

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As primary cavity-excavators, woodpeckers (Picidae) act as keystone species in forest ecosystems by providing nesting and roosting habitat for many other wildlife species (Aubry and Raley 2002, Bednarz et al. 2004). The abundance and diversity of cavity-nesting wildlife is often directly related to the amount of woodpecker activity in an area (Martin et al. 2004). Therefore, effective forest management practices should consider the habitat requirements of woodpeckers to maintain key ecological processes that would benefit many wildlife species.

Woodpecker conservation requires knowledge of their overall habitat requirements, including, but not limited to, nesting habitat. Most studies of woodpeckers, and associated conservation practices seeking to promote their habitat use, typically concentrate on nesting habitat requirements, especially by the creation and retention of snags (Bull and Holthausen 1993, Mannan et al. 1996, Brandeis et al. 2002). However, a management emphasis exclusively on nesting substrate does not address the full spectrum of woodpeckers' habitat requirements. Swallow et al. (1986:576) suggested that management practices that focus on characteristics of individual nest trees "obscure the importance of forest characteristics surrounding a potential nesting site." Their research indicated that certain forest characteristics (e.g., snag basal area, tree species diversity) were better predictors of woodpecker use than characteristics of the nest tree (e.g., dbh, ht, amt of bark remaining on tree). Welsh and Capen (1992) determined that suitable woodpecker nesting substrate did not appear to be a factor limiting population density; in fact, woodpecker populations were much lower than predicted based on available nesting habitat. This suggests that factors other than nest-site availability clearly play a role in limiting woodpecker populations.

There are ≥53 cavity-dependent species of birds and mammals that use cavities in forests of western Oregon and Washington, USA (Brown 1985). In the managed forests of the Olympic Peninsula, the hairy woodpecker (*Picoides villosus*) is the most common primary cavity-excavator (Bednarz et al. 2004). Most previous research on hairy woodpeckers in the western United States has focused on the nesting ecology (e.g., Nelson 1988, Schreiber and de Calesta 1992, Ohmann et al. 1994). These studies indicate that hairy woodpeckers require large snags for nesting and tend to be associated with relatively large, unbroken tracts of old-growth forest. However, recent work (D. Juliano and J. Bednarz, Arkansas State University, unpublished data; D. Varland, Rayonier, unpublished data) on the Olympic Peninsula demonstrated that hairy woodpeckers inhabit and may thrive in managed, secondary forests. This research indicated that hairy woodpeckers nested at stand edges between second-growth forest (50–80 yr) and clear-cut areas or young stands. The high nest success ($n = 34$ nests) of 88.2% that Ripper (2002) observed in this population suggested that the reproduction of these

[1] *E-mail: villosus@hotmail.com*
[2] *Current address: Rocky Mountain Bird Observatory, 230 Cherry Street, Fort Collins, CO 80521, USA*

birds was more than adequate for population replacement (e.g., Martin et al. 1996).

Information on foraging habitats of hairy woodpeckers is limited, especially in a managed forest context, and most previous research on this species has focused on microhabitat characteristics (e.g., Morrison and With 1987, Lundquist and Manuwal 1990). Mannan et al. (1980) investigated the use of forest stands in western Oregon, ranging in age from 35 years to >200 years old, by several species of cavity-nesting birds, including hairy woodpeckers. They found that the density and diversity of cavity-nesters was greater in older stands and that signs and observations of foraging birds also increased as a function of stand age. Hairy woodpeckers showed a tendency toward using large snags (>50 cm dbh) for both nesting and foraging (Mannan et al. 1980). Also, Conner (1980) documented the use of habitat in southwestern Virginia at the forest stand level and found that hairy woodpeckers used a variety of stand types, but mostly older timber (70% of observations in >70-yr-old stands).

Lundquist (1988) studied the foraging preferences of hairy woodpeckers in the Douglas fir (*Pseudotsuga menziesii*)–western hemlock (*Tsuga heterophylla*) forests of the southern Washington Cascades. The forest stands investigated by Lundquist were also relatively old (80% of stands were >100 yr) compared to industrial forests. No correlation was found between the abundance of foraging hairy woodpeckers and the age of forest stands, though snags used by foraging woodpeckers were significantly larger than random trees (Lundquist 1988).

To evaluate the habitat requirements of hairy woodpeckers in western Washington, where >75% of the forests have been subject to intensive forest management, we investigated their ranging patterns, forest stand use, and landscape use in the lowlands on the northwestern Olympic Peninsula during the late nesting and postfledging periods. Our primary objectives were 1) to determine how hairy woodpeckers used the managed-forest landscape in terms of stand age, size, and basal area composition and 2) to provide conservation recommendations to landowners and land managers interested in conserving this keystone species. We addressed the following research questions and associated hypotheses:

1. What stages of forest growth and associated vegetative structure are used by foraging hairy woodpeckers?

Hypothesis: Hairy woodpeckers use relatively mature (>60 yr) forest stands as indicated by their reported foraging on large-diameter, decaying trees (Nelson 1988, Mannan et al. 1996). Following this, we predicted that foraging hairy woodpeckers would tend to use older forest stands with a large mean diameter at breast height and a relatively low tree density (Kricher 1993).

2. Do foraging hairy woodpeckers select habitat patches of particular sizes?

Hypothesis: Historically, forests in western Washington consisted of large tracts of old-growth forest with small, natural breaks in an otherwise homogenous mature habitat (Franklin and Dyrness 1988, Ohmann et al. 1994). Based on this assumed association between hairy woodpeckers and old-growth forest (Mannan et al. 1980), we predicted that this species would show disproportionate usage of large tracts relative to small stands of the same forest type.

3. What is the effect of forest edge on the foraging habitat selection of hairy woodpeckers?

Hypothesis: Several researchers have implied that hairy woodpeckers require large, contiguous tracts of old growth or mature forest for its nesting and foraging habitat (Mannan et al. 1980, Nelson 1988, Ohmann et al. 1994). Based on this research, we predicted that hairy woodpeckers in managed forest landscapes will forage in stand interiors more frequently than near edges within their home ranges.

STUDY AREA

Over the past 100 years, much of the forestland in the Pacific Northwest has been transformed, mostly by logging, into a mosaic of relatively young seral stands (Franklin and Dyrness 1988, Scott 1999). In western Washington and northwestern Oregon, these forestlands were characterized by Sitka spruce (*Picea sitchensis*) and western hemlock zones (Franklin and Dyrness 1988) or as westside lowlands conifer–hardwood forest (Chappell et al. 2001). On the Olympic Peninsula, logging was and continues to be most active in the forested lowlands that surround the Peninsula's central core of rugged mountains and high-elevation forests. Lowland forests were mostly privately and state owned, with 347,000 ha in private ownership and 164,000 ha managed by the Washington Department of Natural Resources (DNR; Holthausen et al. 1995). Olympic National Forest (365,000 ha) and the Olympic National Park (254,000 ha) lands occurred mostly at higher elevations on the Olympic Peninsula; Olympic National Forest lands were managed for multiple uses under the Northwest Forest Plan (U.S. Department of Agriculture and U.S. Department of the Interior Bureau of Land Management 1994) and Olympic National Park lands were not managed for commercial timber harvest.

We conducted this study on lands used primarily for timber production within a 30-km radius of Forks, Clallam County, Washington. The 2 primary landowners were Rayonier and the state of Washington (DNR-managed lands); forestlands were a heterogeneous matrix of recent clear-cuts, young stands, intermediate growth (>60 yr), and a small proportion of older stands (>100 yr) in riparian areas and in small, isolated patches. Forest stands were dominated by western hemlock, with the secondary tree species being Douglas fir, Sitka spruce, western red cedar (*Thuja plicata*), and red alder (*Alnus rubra*). The majority of forest stands in this area ranged from 1 ha to 50 ha in size (S. Katzer, Rayonier Geographic Information System [GIS] forest stand information, unpublished data).

METHODS

Nest Finding

We located hairy woodpecker nests by searching forest and forest edges for suitable snags and fresh cavities (Ripper

2002). We also used adult and nestling vocalizations to aid in the location of nest sites. Adults often vocalized as they foraged nearby nests, and when they returned to a nest to feed their young. Nestlings >10 days old could be heard vocalizing during and between feedings. Finally, if we saw foraging woodpeckers in an area, we observed these birds and attempted to follow them until we found the nest cavity.

Capturing and Radiotagging Woodpeckers

We trapped woodpeckers at their nest cavities using either a hoop net on a pole (Bull and Holthausen 1993), a goal-post style net (Jacobs and Proudfoot 2002), or a canopy net (Munn 1994). We fabricated a hoop net using a 60 × 90 cm black fish net frame, fitted with mist net mesh (36-mm mesh size) and attached to a telescopic fiberglass pole that could be extended up to 10 m. Our goal-post net consisted of a customized 36-mm mesh mist net attached to a 1.5 × 1.5-m, goal-post configured metal frame. We hoisted the goal-post frame in front of a cavity using aluminum telescopic poles and secured the frame with 2 guy-lines on each side. We trapped at higher cavities with a 3 × 6-m canopy net raised to the cavity height by a pulley system (Munn 1994). We used this net set up to heights of 25 m.

We outfitted captured birds with 1.4-g transmitters (Holohil Systems, Inc., Carp, ON, Canada) using a modified figure-eight harness (Rappole and Tipton 1991). We used an elastic thread secured with super glue in the anterior tube of the transmitter, and fitted it to the bird so that 2 loops were positioned around the base of the birds' legs snugly. The body of the transmitter rested on the bird's synsacrum. We then placed the thread through the posterior tube of the transmitter, knotted, and secured it with super glue. We measured the size of the elastic loops with calipers. We custom-fitted all birds captured in 2000 with transmitters in the field. In 2001, we used loop-size measurements from 2000 birds and the first 2 birds captured in 2001 to construct transmitter harnesses prior to trapping. We measured transmitter harness loops with a calipers; loops of 21-mm or 22-mm fit on hairy woodpeckers.

Radiotracking

Radiotracking of hairy woodpeckers occurred from May to July 2000 and from April to June 2001. We obtained point locations using triangulation on each radiotagged bird during its daily foraging activities. We recorded the azimuth (declination corrected) to the strongest transmitter signal detected at 3 established receiver sites. A successful triangulation consisted of 3 azimuths taken to a stationary woodpecker within a 5-minute period. If it was apparent to us that the woodpecker being tracked moved during the 5-minute triangulation period, we discarded the triangulation attempt. We also discarded triangulations in which we recorded bearings at only 2 receiver sites. We conducted triangulation attempts every 10 minutes. We established receiver sites prior to the tracking sessions and these remained fixed throughout the season. We obtained Global Positioning System (GPS) coordinates for each receiver site using a Trimble GeoExplorer GPS receiver. We differentially corrected all GPS coordinates to maximize accuracy.

We considered that most triangulation points were likely associated with foraging activities and were thus used to address the question of landscape use by foraging hairy woodpeckers. We based this assumption on 2 facts: 1) we conducted this study during the brood-rearing and post-fledging periods of nesting season, at which time adult birds are almost constantly engaged in procuring food for young, and 2) a companion study (Ripper 2002), not presented here, involved homing to and direct observation of the same radiotagged woodpeckers on 52 occasions ($n = 26$ woodpeckers), and in almost all cases birds were recorded to be actively probing and collecting insects, or flying between foraging sites.

Landscape-Use Analysis

We entered triangulation bearing sets into the Orchard Training Area Triangulation Program (B. A. Hoover, National Biological Services, United States Geological Survey, unpublished data), which provided a location estimate in X,Y coordinates based on the convergence of azimuths from receiver sites. This program also calculated error ellipses around each point location estimate using the Maximum Likelihood Estimate technique (White and Garrott 1990), providing an error ellipse that theoretically has a 99% probability of including the point location. To eliminate poor triangulations or low-accuracy locations, we accepted only those points for analysis that had a 99% error ellipse smaller than 0.5 ha. If 2 triangulations that we collected within 30 minutes of each other both had error ellipses <0.5 ha, we accepted only the first triangulation to maintain independence of point locations (Hansteen et al. 1997). Thus, we collected all locations included in the analysis ≥30 minutes apart.

We entered all accepted point locations into the ArcView GIS database to estimate the home ranges of radiotagged birds using the minimum convex polygon (MCP; including 100% of points) and fixed kernel utilization distribution (based on a 95% use contour) techniques (Worton 1987, White and Garrott 1990).

To determine whether the number of point locations obtained on a woodpecker directly affected the estimated home range size, we plotted the home range size against number of point locations for each bird and examined these data using a linear regression analysis. Based on this analysis, we determined that home range size estimates were not significantly affected by the number of point locations if we used ≥25 locations in either the MCP ($r^2 = 0.0279$, $P = 0.481$) or kernel technique ($r^2 = 0.0313$, $P = 0.447$). We therefore included all birds with ≥25 point locations in the landscape-use analyses (Pasinelli et al. 2001) and the number of locations used in the analysis per bird varied from 25 to 82 ($\bar{x} = 48$). We averaged data from mated pairs ($n = 3$ pairs) or parent–fledgling groups ($n = 1$ group with ad M and 2 fledglings) for landscape analyses, resulting in only one set of data (data from one woodpecker or an averaged data set) used for each occupied home range.

We overlaid home ranges and forest stand information in GIS to determine the forest types available to each woodpecker. We classified forest stand types by age, dominant tree species, and structural categories based on forest-inventory data available in GIS coverage from Rayonier and DNR:

1. We classified stand age as <5 years, 6–10 years, 11–20 years, 21–40 years, 41–60 years, 61–80 years, or >80 years. We also lumped a variety of rare nonforest types into one nonforest habitat class (e.g., marsh, road, human structures).
2. We calculated mean diameter at breast height, which is an estimate of the mean tree diameter within a stand, using the stand's overall basal area and density of tree stems (U.S. Forest Service 1984). We classified stands as 0–9 cm, 10–20 cm, 21–30 cm, 31–40 cm, 41–50 cm, 51–60 cm, or >60 cm mean diameter at breast height.
3. We classified dominant tree species, defined as the tree species comprising ≥50% of the basal area of a stand and classified as western hemlock, Sitka spruce, Douglas fir, red alder, western hemlock–Douglas fir mix (50% each species planted), western hemlock–Sitka spruce mix, western hemlock–red alder mix, or western hemlock–western red cedar mix.
4. We determined tree density in stems per hectare classified as 0–49 stems/ha, 50–149 stems/ha, 150–247 stems/ha, 248–494 stems/ha, 495–740 stems/ha, and >740 stems/ha.

During the course of a preliminary GIS analysis, we found that there were several gaps in the database coverage provided by Rayonier and DNR. These gaps represented land held by small property owners that did not have GIS coverage. To characterize habitat within coverage gaps, during the 2001 field season we ground-truthed each forest stand for which information was not available. Ground-truthing consisted of

1. surveying the stand for a representative site,
2. establishing a variable-radius plot using a 20-factor basal-area factor prism to determine the trees that were to be included in the plot,
3. measuring the diameter at breast height of all trees within the variable-radius plot,
4. classifying the stand into one of the aforementioned dominant tree species classes and stand-age classes based on comparison with known-aged stands.

We used the number of trees within the plot and the mean tree diameter at breast height to calculate the basal area and stems per hectare for each stand (U.S. Forest Service 1984). The information obtained via ground-truthing allowed us to fill in stand information polygons not included in the available GIS coverage.

Habitat Use Within Home Ranges

To determine whether radiotagged birds were using forest stand types in proportion with their availability, we used Bailey's confidence intervals around the proportion of point locations within each habitat class (Bailey 1980, Cherry 1996). We then compared the confidence interval with the available proportion of that habitat type within the bird's home range. In this way, we tested whether habitats were used by forgaging birds in proportion to their availability. Bailey's confidence intervals are conservative estimates of use designed to protect against type I errors (Cherry 1996). We completed these analyses based both on the availability of habitat classes within the 95% fixed kernel and 100% MCP estimated home ranges. These results were very similar; thus, we primarily presented the analysis based on the fixed kernel approach, because recent work suggests this technique may provide a more accurate representation of a bird's home range or use area (Barg et al. 2005). However, we also reported the resource use patterns that were identified with the MCP approach, because this technique may be an alternative representation of the habitat types within the spatial-use range of a foraging animal, and hence potentially available even though these habitat patches are not being actively exploited.

Habitat Use Within Core Areas

We experimented with various probability contours using the fixed kernel utilization distribution to determine the percentage of the kernel home range that could best represent a woodpecker core-use area. We chose the 60% probability contour as the basis for further core-use analyses. Fifty percent probability contours generally resulted in 2 or more isolated use areas; many woodpeckers appeared to have 2 areas of concentrated point locations. Larger contours (65%, 70%, and 75%) encompassed relatively large areas in which we did not record any point locations. The 60% probability contour provided a contiguous area of probable use around the most concentrated point location clusters. This was consistent with the definition of core area proposed by some other researchers (e.g., Springer 1982, Don and Rennolls 1983) who generated core-use areas by including the most clustered 60–80% of point locations.

We measured the composition of home range and core-use areas in terms of the proportions of forest stand types present. We compared these data with the proportions of stand types available in 100% MCP and 95% fixed kernel home ranges using 2-proportion tests to determine if the composition of core-use areas differed from that of home ranges. We also assessed whether hairy woodpeckers used particular habitats disproportionately within core areas using Bailey's method (Cherry 1996) as described above.

Forest Patch Size

To determine whether foraging hairy woodpeckers select forest stands on the basis of patch size, we first determined the birds' use of particular habitat types in order to standardize the forest patches that we chose for the size analysis. Based on observed forest-use patterns, we included only stands >40 years in the forest patch-size analysis. Within the home ranges of individual birds, congruent forest stands of >40 years that were separate polygons in

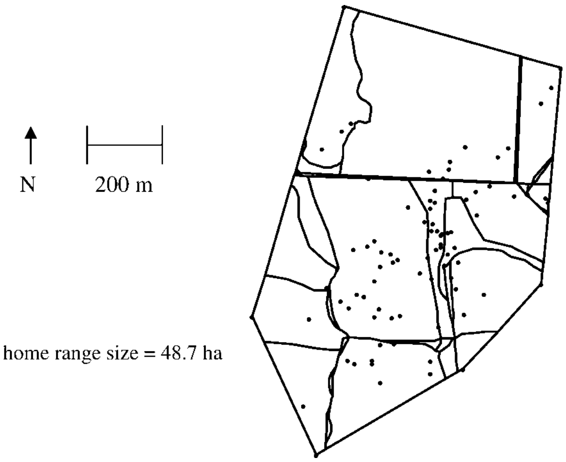


Figure 1. Example home range estimated with the 100% minimum convex polygon technique and point locations (n = 82) of radiotagged hairy woodpecker 01–05M in managed forest habitat on the northwestern Olympic Peninsula, Washington, USA, 2001. Lines within home range represent forest stand boundaries.

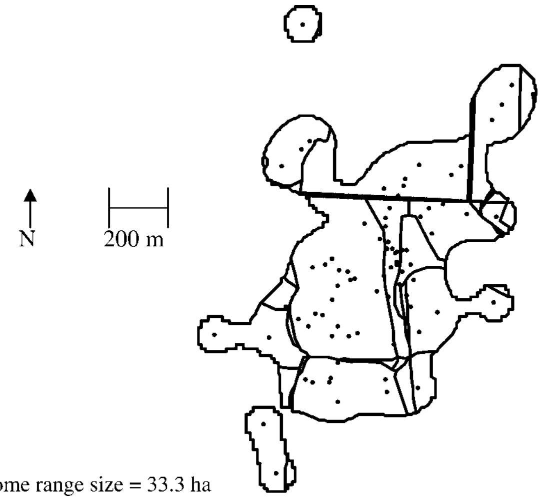


Figure 2. Example home range estimated with the 95% fixed kernel technique and point locations (n = 82) of radiotagged hairy woodpecker 01–05M in managed forest habitat on the northwestern Olympic Peninsula, Washington, USA, 2001. Lines within home range represent forest stand boundaries.

GIS stand coverage were considered one contiguous stand suitable for woodpecker foraging. We used MCP home ranges to determine the extent of forest stands available to each woodpecker. We chose the MCP home range estimator because this method may be more accurate than fixed kernel when the sample size of point locations is small (<30 points/bird; Seaman et al. 1999, Vonhof et al. 2004, but see Barg et al. 2005).

We classified forest patches into 3 categories: small (0–5 ha), intermediate (5.1–30 ha), and large (>30 ha). We performed a chi-square Test of Association on pooled data from all birds to determine whether the number of point locations within each size category was consistent with the number of point locations expected based on the total land area within each patch-size category.

Use of Interior Versus Edge Habitat

Using ArcView, we generated random points within each of the forest stands >40 years old in each hairy woodpecker MCP home range. The number of random points generated was equal to the number of woodpecker point locations recorded within the stands ($n = 406$). We then measured the distance of each random and used point location to the edge of the nearest stand <10 years old. We compared distances from random points to edges with distances of woodpecker point locations to edges using 2 sample t-tests.

RESULTS

We trapped 8 hairy woodpeckers from 4 different nests in 2000 and 17 woodpeckers from 16 nests in 2001. Of the 25 hairy woodpeckers radiotagged in 2000 and 2001, 23 provided us with sufficient data (≥25 locations) for further analyses ($n = 21$ ad birds, 2 fledglings). Tracking duration of individual birds ranged from 8 days to 61 days, with a mean duration of 45 days. We attempted a mean of 88 triangulations per bird (range = 15–139 attempts). The number of triangulations completed was slightly fewer, averaging 80 per bird (range = 9–130). Using the criterion of error ellipses <0.5 ha for inclusion in further analyses, we accepted a mean of 48 locations per bird (range = 3–82). The variation in the number of triangulations used in the analysis was due to the differences in the topography within birds' home ranges; with some sites relatively level and logistically easier to collect data and some sites more difficult to obtain acceptable accuracy for triangulations. Although we tried to sample all individuals evenly, we completed our analysis post fieldwork, resulting in some variation in the number of suitable locations among individual radiotagged birds.

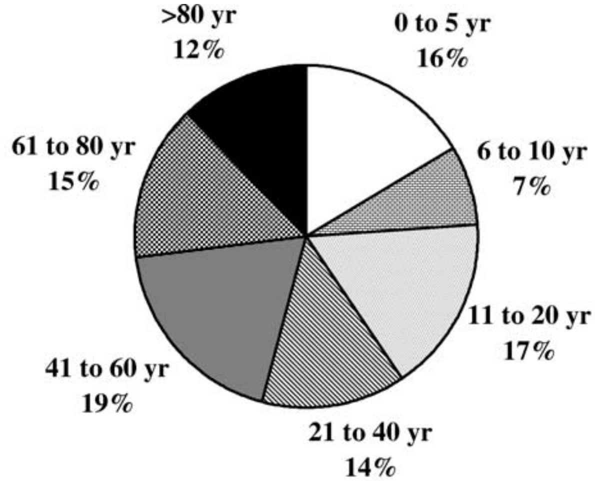
Home Range and Landscape Use

We calculated MCP and fixed kernel home range estimates for 23 woodpeckers. Overall MCP home range size varied from 16.3 ha to 177.2 ha ($\bar{x} = 58.0$ ha; Fig. 1). Fixed kernel home range size ranged from 24.0 to 127.6 ha ($\bar{x} = 64.4$ ha; Fig. 2). We excluded one bird from further landscape analyses because its kernel home range boundaries extended past the area of available GIS coverage. Overall, MCP and kernel home ranges encompassed similar landscape configurations (Fig. 3). Male hairy woodpeckers maintained home ranges (MCP $\bar{x} = 43.8$ ha, kernel $\bar{x} = 89.0$ ha, $n = 15$) similar in size to the home ranges of females (MCP $\bar{x} = 68.2$, kernel $\bar{x} = 83.8$, $n = 6$, t-test: $P > 0.10$).

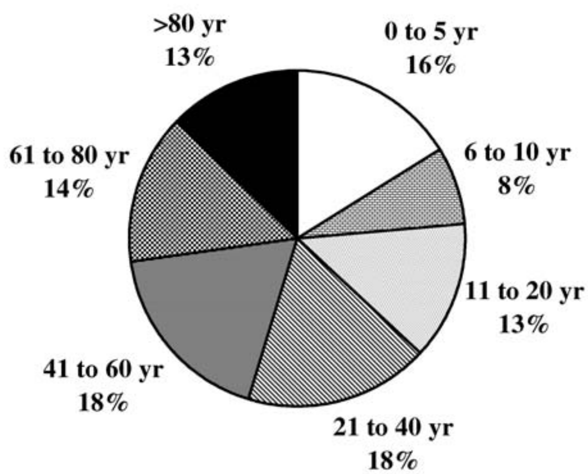
Stand Age Class

The age composition of forest stands within hairy woodpecker home ranges was similar in MCP and fixed kernel home ranges (Fig. 3). Older stands (>40 yr) comprised 46% of MCP home ranges and 45% of kernel areas (Fig. 3). There was no significant difference in the amount of each stand type in MCP home ranges versus kernel home ranges (2-proportion tests: $P > 0.05$ for all comparisons).

Woodpecker use within forest patches varied considerably by stand age. Hairy woodpeckers used clear-cuts (<5 yr) in



Composition of Minimum Convex Polygon home ranges



Composition of fixed kernel home ranges

Figure 3. Forest composition as classified by stand age within minimum convex polygon and fixed kernel home ranges of hairy woodpeckers ($n = 23$) on the northwestern Olympic Peninsula, Washington, USA, 2000–2001.

proportion with their availability in both MCP and fixed kernel home ranges (Table 1). Analysis of data from fixed kernel home ranges indicate that the birds on average used (95% CI = 0.158–0.241) the 21-year to 40-year stand type significantly less than it was available (0.256; Table 1). Conversely, hairy woodpeckers displayed a significant greater use (95% CI = 0.215–0.306 in MCP, 0.235–0.331 in kernel) of the intermediate-age forest habitat (61–80 yr) in comparison to the availability in both MCP (0.180) and fixed kernel (0.200) home ranges (Table 1). Hairy woodpeckers used old forest (>80 yr) in proportion to its availability (Table 1). Finally, there was significant selection against non-forest habitat such as urban areas and roads; although these types of habitats were located within the home ranges of some birds, we did not record any points in nonforest habitat (Table 1).

Diameter at Breast Height Class

The mean diameter at breast height composition of home ranges was also similar between MCP and kernel home ranges. The majority of stands within MCP home ranges (62%) and kernel areas (65%) had a mean diameter at breast height of <40 cm. We found no differences in the proportion of stand types within MCP home ranges versus kernel home ranges (2-proportion test: $P > 0.05$).

Hairy woodpeckers used stands in the diameter at breast height size classes 0–9 cm, 10–20 cm, and 21–30 cm in proportion to their availability based on both the MCP or kernel home range analysis approaches (Table 2). Woodpeckers used the 31–40 cm diameter at breast height category significantly less than expected relative to its availability (Table 2). Woodpeckers used the 41–50-cm diameter at breast height stand type significantly more than expected, and used stands in the 51–60-cm and >60 cm diameter at breast height categories in proportion to their availability when analyzed by either home range estimator (Table 2).

Dominant Tree Species

Stands dominated by western hemlock were most common across the landscape in our study area; these made up 27% of stands in both MCP and kernel home ranges. The remaining stand types were also similar between the 2 home range estimators. Western hemlock–Sitka spruce and western hemlock–red alder each made up 15% of MCP home ranges, whereas western hemlock–red alder mixed stands were 17% of fixed kernel areas. Other stand types were present in proportions ranging from 6% to 12%.

Hairy woodpeckers used western hemlock–dominated stands in proportion to their availability within both MCP and kernel home ranges and selected against Sitka spruce–dominated stands (Table 3). However, the woodpeckers used mixed western hemlock–red alder stands more than expected (Table 3).

Tree Density

Few stands within hairy woodpecker home ranges had stem densities of 0–49 stems/ha (3% of MCP, 2% of kernel home ranges). Stands with 50–149 stems/ha, 250–494 stems/ha, and 248–494 stems/ha comprised similar proportions of both MCP (8%, 21%, and 27%, respectively) and fixed kernel home ranges (8%, 22%, and 28%, respectively). The proportion of stands with 494–740 stems/ha differed slightly between home range types (30% of MCP, 26% of kernel), as did the proportion of stands with >740 stems/ha (11% of MCP, 14% of kernel). Overall, hairy woodpeckers used forest stands in proportion to their

Table 1. Hairy woodpecker use of forest stands of various age classes within minimum convex polygon (MCP) and 95% fixed kernel home ranges on the northwestern Olympic Peninsula, Washington, USA, 2000–2001.

Age class (yr)	MCP available	MCP 95% CI of obs use[a]	Kernel available	Kernel 95% CI of obs use[a]	n[b]
0–5	0.177	0.138–0.214	0.160	0.130–0.206	17
6–10	0.175	0.028–0.109*	0.073	0.035–0.120	8
11–20	0.240	0.129–0.208*	0.205	0.155–0.248	18
21–40	0.212	0.206–0.304	0.256	0.158–0.241*	17
41–60	0.317	0.264–0.352	0.347	0.264–0.354	19
61–80	0.180	0.215–0.306*	0.200	0.235–0.331*	15
>80	0.116	0.072–0.142	0.121	0.076–0.153	15
Nonforest	0.024	0.000–0.016*	0.028	0.00–0.023*	7

[a] 95% CI calculated around proportions of each habitat used by woodpeckers based on Bailey's intervals (Cherry 1996).
[b] Calculations for CI and proportion available for each forest stand type are based on the no. of woodpeckers that had each stand type within their home ranges.
* Indicates significance at the $P < 0.05$ level.

availability with regard to stem density within both MCP and fixed-kernel home ranges.

Woodpecker Core-Use Areas

We generated 60% fixed kernel probability contours for all 23 hairy woodpeckers for which we had ≥25 point locations. The mean number of point locations included in the core area was 30 (range = 10–47), 57% of all point locations. The mean core area size was 12.7 ha (range = 2.4–29.9). A linear regression indicated that the size of the woodpeckers' core-use areas was influenced by the number of point locations included in the 60% probability contour ($r^2 = 0.223$, $P = 0.048$).

Habitat Composition of Core-Use Areas

In general, hairy woodpecker core-use areas did not differ significantly in forest stand age when compared to either MCP or fixed kernel home ranges (Figs. 3 and 4). The one exception to this overall similarity was that MCP home ranges had a significantly greater proportion (0.10) of area in >60 cm diameter at breast height stands than did the core-use areas (0.03, $P = 0.043$).

Forest stands within the woodpeckers' core-use areas were fairly evenly distributed by age. Clear-cuts and young (<21 yr) stands made up 45% of core-areas. Woodpecker home ranges were further comprised of 21–40-year stands (16%), 41–60-year stands (17%), and 61–80-year stands (13%; Fig. 4). Only 9% of core-use areas were contained in >80-year forests (Fig. 4). Overall, hairy woodpeckers used 61–80-year stands significantly more than they were available within core-use areas (use = 0.326–0.472, available = 0.292; Table 4). No other stand ages were used out of proportion with their availability within core areas (Table 4).

Hairy woodpecker core-use areas also showed a relatively even distribution of forest stand use classified by diameter at breast height. These use areas were comprised of 20% stands with diameter at breast height of 0–9 cm, 18% of 10–20-cm diameter at breast height stands, 16% each of 21–30-cm and 31–40-cm diameter at breast height stands, and 18% of 41–50-cm diameter at breast height stands. Stands with a mean diameter at breast height of 51–60 cm and >60-cm stands were minimally represented, as 9% and 3% of core-use areas, respectively. We found only one significant difference in use of stands classified by mean diameter at breast height; hairy woodpeckers used stands in the 41–50-cm class significantly more than expected (Table 5).

Similar to availability analyses based on home ranges, western hemlock dominated most stands (32%) within hairy woodpecker core-use areas. Western hemlock–red alder dominated 17% of stands, followed by Douglas fir (9%), western hemlock–Douglas fir mixed stands (7%), Sitka spruce (8%), western hemlock–Sitka spruce mix (9%), and western hemlock–western red cedar mixed stands (8%). There were no significant differences between woodpecker use and availability for any of these stand types in core-use areas.

Table 2. Hairy woodpecker use of forest stands of various diameter at breast height classes within minimum convex polygon (MCP) and 95% fixed kernel home ranges on the northwestern Olympic Peninsula, Washington, USA, 2000–2001.

Dbh class (cm)	MCP available	MCP 95% CI of obs use[a]	Kernel available	Kernel 95% CI of obs use[a]	n[b]
0–9	0.191	0.148–0.221	0.171	0.138–0.212	18
10–20	0.041	0.006–0.156	0.170	0.118–0.187	18
21–30	0.256	0.226–0.330	0.224	0.186–0.279	16
31–40	0.230	0150–0.225*	0.251	0.162–0.241*	19
41–50	0.216	0.255–0.341*	0.211	0.243–0.330*	20
51–60	0.184	0.155–0.248	0.200	0.191–0.306	12
>60	0.027	0.019–0.074	0.036	0.012–0.062	11

[a] 95% CI calculated around proportions of each diam size class used by woodpeckers based on Bailey's intervals (Cherry 1996).
[b] Calculations for CI and proportion available for each forest stand type are based on the no. of woodpeckers that had each stand type within their home ranges.
* Indicates significance at the $P < 0.05$ level.

Table 3. Hairy woodpecker use of forest stands with various dominant tree species within minimum convex polygon (MCP) and 95% fixed kernel home ranges on the northwestern Olympic Peninsula, Washington, 2000–2001.

Dominant species	MCP available	MCP 95% CI of obs use[a]	Kernel available	Kernel 95% CI of obs use[a]	n[b]
Western hemlock	0.556	0.516–0.605	0.598	0.535–0.626	23
Sitka spruce	0.145	0.051–0.140*	0.133	0.040–0.118*	9
Douglas fir	0.164	0.080–0.177	0.128	0.074–0.169	7
Red alder	0.120	0.093–0.217	0.127	0.085–0.198	6
Western hemlock–Douglas fir	0.249	0.202–0.329	0.238	0.153–0.281	6
Western hemlock–sitka spruce	0.133	0.104–0.187	0.164	0.129–0.233	13
Western hemlock–red alder	0.154	0.155–0.251*	0.138	0.141–0.232*	11
Western hemlock–western red cedar	0.052	0.042–0.144	0.077	0.042–0.144	6

[a] 95% CI calculated around proportions of each dominant tree species class used by woodpeckers based on Bailey's intervals (Cherry 1996).
[b] Calculations for CI and proportion available for each forest stand type are based on the no. of woodpeckers that had each stand type within their home ranges.
* Indicates significance at the $P < 0.05$ level.

No hairy woodpecker core-use area contained stands in the 0–49 stems/ha category. The majority of stands (64%) within the woodpeckers' core-use areas had 248–740 tree stems/ha. The remaining stands had 50–149 stems/ha (3%), 150–247 stems/ha (19%), or >740 stems/ha (14%). Hairy woodpeckers used all stands classified by tree density in proportion with their availability in core areas.

Forest Patch Size

Based on our findings that hairy woodpeckers display significantly higher use of 61-year to 80-year forest stands, use 41-year to 60-year stands relative to their availability, and select younger stands less often, we used only stands >40 yr in forest patch-size analyses. We based this analysis on data from 22 birds; we excluded one woodpecker from this analysis because it had no stands >40 years within its home range. A frequency distribution of forest patch sizes showed that the patches were clumped in 3 groups: 0–5 ha (small), 5.1– 30 ha (intermediate), and >30 ha (large).

Woodpeckers showed a significant ($P < 0.001$, $n = 713$ points) difference between the observed and expected number of point locations when we compared the 3 patch size categories. The chi-square results also revealed that in all 3 categories, there were differences between the number of point locations observed as compared to what we expected. Hairy woodpeckers had more point locations than expected in small patches and intermediate-sized stands. We recorded far fewer point locations in large stands than expected (Table 6).

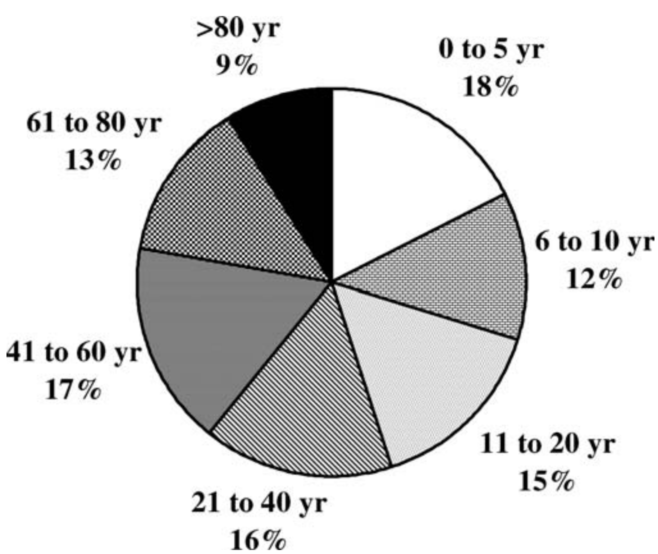


Figure 4. Forest stand composition classified by age within hairy woodpecker core-use areas determined using 60% fixed kernel probability contour ($n = 23$) on the northwestern Olympic Peninsula, Washington, USA, 2000–2001.

Use of Interior Versus Edge Habitat

Using hairy woodpecker point locations within forest stands >40 years, we calculated the distance of each location to the nearest edge of a <10-year stand for 15 birds and compared these to distances from random points. Point locations of hairy woodpeckers were the same mean distance ($\bar{x} = 175.6$ m, $n = 406$) to forest stand edges as random locations ($\bar{x} = 172.0$, $n = 406$, $P = 0.849$).

DISCUSSION

This research focused primarily on documenting the forest stand attributes that are selected by hairy woodpeckers at the landscape level. We predicted that this species would use >60-year-old forest stands with large-diameter trees for foraging. This hypothesis was supported by our findings in that hairy woodpeckers used 61-year to 80-year and 41-cm to 50-cm diameter at breast height forest stands significantly more than expected in both complete home ranges and 60% core-use areas (Tables 1, 2, 4, and 5). The hypothesis was neither supported nor refuted by our finding that hairy woodpeckers used >80-year-old stands in proportion with their availability. Secondarily, we addressed hypotheses regarding selection of forest stands based on their size, and whether or not the hairy woodpecker selected forest edge or interior for foraging. The hypothesis that hairy woodpeckers use large forest patches disproportionately was not supported by our data (Table 6). Our data also did not support the prediction that hairy woodpeckers preferred forest interior; radiotagged birds did not forage farther from the edges than would be expected relative to random locations.

Hairy woodpecker ranging patterns determined using radiotelemetry differed from what was previously reported from some observational studies. We estimated that the

Table 4. Hairy woodpecker use of forest stands of various age classes within core-use areas identified using 60% probability fixed kernel contour on the northwestern Olympic Peninsula, Washington, USA, 2000–2001.

Age class (yr)	Proportion available	95% CI of obs use[a]	n[b]
0–5	0.169	0.116–0.215	15
6–10	0.027	0.019–0.133	8
11–20	0.224	0.144–0.268	12
21–40	0.338	0.229–0.376	15
41–60	0.394	0.329–0.469	16
61–80	0.292	0.326–0.472*	12
>80	0.189	0.100–0.260	8
Nonforest	0.048	0–0.062	3

[a] 95% CI calculated around proportions of each habitat used by woodpeckers based on Bailey's intervals (Cherry 1996).
[b] Calculations for CI and proportion available for each forest stand type are based on the no. of woodpeckers that had each stand type within their home ranges.
* Indicates significance at the $P < 0.05$ level.

mean hairy woodpecker 95% fixed kernel home range was 64.4 ha. Males ($n = 15$) also maintained home ranges of a similar mean size to females ($n = 6$). However, a larger sample size, especially of female hairy woodpeckers, would help clarify any possible differences in ranging patterns between the sexes. Observations by Lawrence (1967) suggested that hairy woodpecker feeding ranges in the eastern United States were 2–3 ha, whereas Kilham (1983) stated that these birds used areas of approximately 25 ha. Kilham (1983) also proposed that males ranged further from the nest and maintained larger feeding territories than females. Both of these studies were conducted in deciduous forest habitat in the eastern United States. Based on our review of Jackson et al. (2002), hairy woodpecker habitat and ranging patterns are highly variable across its range; we suggest our home range findings may not be comparable to earlier studies of this species in dissimilar habitats. Furthermore, to compare home range sizes effectively, habitat quality must be held relatively constant, because woodpeckers using fragmented habitat may require larger home ranges to meet their foraging requirements (Pasinelli et al. 2001).

Table 5. Hairy woodpecker use of forest stands of various size classes within core-use areas identified using 60% probability fixed kernel contours on the northwestern Olympic Peninsula, Washington, USA, 2000–2001.

$\bar{x}$ dbh (cm)	Proportion available	95% CI of obs use[a]	n[b]
0–9	0.155	0.114–0.205	16
10–20	0.188	0.146–0.260	16
21–30	0.248	0.241–0.393	14
31–40	0.288	0.191–0.327	14
41–50	0.294	0.297–0.426*	18
51–60	0.363	0.290–0.473	9
>60	0.044	0.006–0.161	4

[a] 95% CI calculated around proportions of each habitat used by woodpeckers based on Bailey's intervals (Cherry 1996).
[b] Calculations for CI and proportion available for each forest stand type are based on the no. of woodpeckers that had each stand type within their home ranges.
* Indicates significance at the $P < 0.05$ level.

Table 6. Chi-square Test of Association Comparison of number of point locations ($n = 713$; overall $P < 0.001$) observed and expected in >40-year forest stands classified by size within minimum convex polygon home ranges of hairy woodpeckers on the northwestern Olympic Peninsula, Washington, USA, 2000–2001.

Patch size class	Total area in class (ha)	Obs no. of point locations	Exp no. of point locations
Small (0–5 ha)	32	52[a]	43
Intermediate (5.1–30 ha)	314	479[a]	401
Large (>30 ha)	350	182[a]	269

[a] Obs point locations significantly different from expected.

Differential use of forest stand types within hairy woodpecker home ranges has not been previously documented using radiotelemetry. Our landscape-level composition analyses of hairy woodpecker home ranges indicated that this bird is somewhat of a habitat generalist, with some apparent selection for stands on the higher end of the available age and tree-diameter size spectrum. We found significant selection of 61–80-year forest stands using both MCP and fixed kernel estimates of habitat available within home ranges (Table 1). This was coupled with significantly lower use of sapling (6–10 yr) and pole timber (11–20 yr) stands within MCP home ranges, as well as a lower use of young forest (21–40 yr) within kernel home ranges. Clear-cuts, 41–60-year stands, and >80-year stands were used in proportion with their availability.

These use patterns may be a result of preference in hairy woodpeckers for foraging on decaying wood (Ripper 2002). Relatively young forest stands (11–20 yr) mostly contain small trees (2.5–25 cm dbh) with little decay, resulting in little recruitment of new dead or dying wood (Ohmann and Waddell 2002). In older stands (e.g., trees >25 cm dbh, Ohmann and Waddell 2002; stand age 61–80 yr, this study), more dead wood becomes available to woodpeckers via fungal rot and wood-boring insects. In western Washington, clear-cuts and some early-successional stands still have residual dead wood present in the form of slash, downed logs, and retained snags (Ohmann and Waddell 2002). We often observed hairy woodpeckers foraging for wood-boring insects on dead wood in clear-cuts, an observation that is supported by Conner and Crawford (1974). These researchers documented hairy woodpecker use of clear-cuts in Virginia, where they spent 75% of time feeding on downed logs and slash piles and the remainder on standing snags.

Over time, retained snags and other dead wood in clear-cuts and young stands are lost to blowdown and decay processes. Bull and Holthausen (1983) found that ponderosa pine (*Pinus ponderosa*) snags remained standing on the landscape for a mean duration of 5 years, with larger snags (>50 cm dbh) surviving longer than small snags (<50 cm dbh). Furthermore, Bull and Holthausen (1983) and Hughes (2000) found that hairy woodpeckers use snags in relatively early stages of decay. These findings support our suggestion that hairy woodpeckers may continue to use harvested areas during the first several years after clear-cutting because of the residual standing snags and other available decaying wood.

We also found that hairy woodpeckers selected stands in the 41–50-cm diameter category (Tables 2 and 5). This was coupled with selection against 31–40-cm diameter at breast height stands. These findings were consistent with the trends we observed in hairy woodpecker selection of older forest stands, as well as an analysis of the selection of individual foraging trees, wherein hairy woodpeckers primarily used larger diameter trees (Ripper 2002). Woodpeckers used trees in the 2 largest diameter at breast height categories, 51–60 and >60 cm, in proportion with their availability. These findings also seem to be consistent with information from east Texas, USA (Shackelford and Conner 1997), where hairy woodpeckers used mature, disturbed pine–hardwood stands where dead wood was abundant, but where younger pines were present.

Additionally, we observed some trends in hairy woodpecker selection of forest stands based on dominant tree species (Table 3). In both MCP and kernel home ranges, hairy woodpeckers used Sitka spruce–dominated stands less than expected relative to their availability. Upon reviewing our GIS forest-stand information, we found that although Sitka spruce stands were not consistently younger, they were typically of a smaller mean diameter at breast height than some other stands available within the birds' home ranges. Many (67%) Sitka spruce stands within the woodpeckers' home ranges fell into the 31–40-cm diameter at breast height category, a class that was used significantly less than expected (Table 2). Based on these results, we propose that tree size was a more important factor than the specific tree species in the hairy woodpecker's selection of foraging sites.

We also found that hairy woodpeckers used western hemlock–red alder codominant stands significantly more than expected based on their availability in both home range types (Table 3). Importantly, our GIS stand information showed that nearly all of the western hemlock–red alder stands within hairy woodpecker home ranges were >40 years, a finding that is consistent with the birds' observed preference for older stands with large trees.

We detected no significant trends in hairy woodpecker use of forest stands based on tree density. This is somewhat surprising because the older stands that tend to be selected by hairy woodpeckers are usually associated with a lower tree density (e.g., 61–80-yr stands on the northwest Olympic Peninsula average approx. 600 stems/ha, whereas 6–10-yr stands average approx. 1,600 stems/ha; L. Raynes, Rayonier, personal communication). However, we found no statistical correlation in our stand data between tree density and age. Thus, hairy woodpecker selection of forest stands in our study area is driven by the age and size of the trees, but not the density of trees.

The forest-stand age of woodpecker core areas (as defined by a 60% fixed kernel probability contour) did not differ significantly from that in either MCP or fixed kernel home ranges. Core areas may be important when determining conservation plans for a species, because the core is thought to contain resources that are essential for individuals' survival (Samuel et al. 1985). However, Bingham and Noon (1997) emphasized that although core areas are assumed to provide critical habitat, this assumption has not been tested adequately. We demonstrated that hairy woodpeckers on the Olympic Peninsula used core areas similar in age to their overall home ranges. Thus, we suggest that conservation planning based solely on core-area estimates could lead to the maintenance of an area too small to support viable nesting pairs (Pasinelli et al. 2001). Our habitat-use analyses of core areas supported findings from MCP and kernel home ranges, suggesting that using home range to examine the use and availability of stand types may be the best assessment of habitat selection for this species.

We did not detect a disproportionate use of large forest patches within our study area. Conversely, we found that there were significantly more points in small (0–5 ha) and intermediate (5.1–30 ha) stands than expected and fewer point locations in large stands (>30 ha). These results were somewhat surprising, as several researchers have implied that hairy woodpeckers prefer large, contiguous forest stands (Mannan et. al 1980, Ohmann et al. 1994). We note that older forest stands in our study area tend to be the smaller patches (e.g., remnant patches of uncut forest). We propose that the woodpeckers may frequent smaller stands due to the higher quality of habitat; again, the age and size of trees within stands seems to be more important than forest patch size in the selection of stands by foraging hairy woodpeckers. Thus, we suggest that our findings do not indicate a preference for small forest patches per se.

Finally, our data showed that hairy woodpeckers do not forage farther from stand edges than would be expected at random. We note that edge and interior are relative terms that have been described differently by many researchers (e.g., Burke and Nol 1998). For example, a designation of interior as 200 m from the edge would render some stands interior-free in the managed forest landscape of Washington. The GIS stand information for our study area shows that 22% of >40-year forest patches do not have interior area >200 m from an edge. Moreover, our data revealed that hairy woodpeckers had no real bias in their use of forest edge or interior in the context of the managed forests of the Olympic Peninsula. These findings are consistent with those of Shackelford and Conner (1997) in east Texas and Campbell et al. (1990) in British Columbia, Canada, both of which indicated that hairy woodpeckers tend to use mature forests close to edges caused by disturbance.

Some caution must be taken related to any assessment of habitat use based on radiotelemetry data. For example, Aebischer et al. (1993) identify 4 common problems involved in the interpretation of radiotelemetry data. We attempted to minimize these potential pitfalls in several ways: 1) by utilizing only triangulated points collected for individuals 30 minutes apart; 2) using each bird's home range as the unit by which we defined available habitat, as opposed to using arbitrarily selected study-site boundaries,

3) comparing woodpecker locations to random points generated within home ranges for forest patch size and edge vs. interior analyses, and 4) utilizing each bird, or family, as independent units for landscape-use analyses. Still, we caution that the hairy woodpeckers in our study area may have shown selection for certain stand types (e.g., 61–80-yr stands) as an artifact of avoidance of other stand types (11–20-yr stands), an effect that Aebischer et al. (1993:1321) term "non-independence of proportions." We argue that whether actual habitat use was a result of selection or avoidance, these data are useful in determining landscape configurations best suited to support hairy woodpecker populations in northwestern Washington. We also emphasize that the nesting success of 88% for hairy woodpecker nests ($n = 34$ nests; Ripper 2002) documented during this study, including the radiotagged birds, indicates that the landscape configurations within hairy woodpeckers' home ranges were adequate to support successful reproduction.

MANAGEMENT IMPLICATIONS

As the hairy woodpecker is the most common primary cavity-excavator in many western coniferous forests (e.g., Saab et al. 2004), habitat enhancement that benefits this woodpecker will conserve many other associated species of wildlife. Forest management producing a mosaic of stands of different ages and types would be adequate to support this species, as well as be reasonable in the context of timber production. Based on our results, we recommend a heterogeneous landscape matrix with approximately 45% of the landscape in stands >40 years, and 30% of all stands >60 years, interspersed with harvested areas and younger stands. Snag creation and retention management is in widespread use to provide nesting substrate for cavity-nesters (e.g., Farris et al. 2002; Huss et al. 2002). We suggest that to maximize effectiveness of snag and wildlife tree retention and creation, these practices be implemented in stands >60 years and within stands bearing trees with a mean diameter at breast height >40 cm, as these stand types were disproportionately selected by hairy woodpeckers.

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