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Authors: Dykstra, Cheryl R., Simon, Melinda M., Daniel, F. Bernard, and Hays, Jeffrey L.

Source: Journal of Raptor Research, 46(2) : 190-200

Published By: Raptor Research Foundation

URL: https://doi.org/10.3356/JRR-11-05.1

J. Raptor Res. 46(2):190–200

HABITATS OF SUBURBAN BARRED OWLS (*STRIX VARIA*) AND RED-SHOULDERED HAWKS (*BUTEO LINEATUS*) IN SOUTHWESTERN OHIO[1]

CHERYL R. DYKSTRA[2]
Raptor Environmental, 7280 Susan Springs Drive, West Chester, OH 45069 U.S.A.

MELINDA M. SIMON
9016 Winthrop Drive, Cincinnati, OH 45249 U.S.A.

F. BERNARD DANIEL
U.S. Environmental Protection Agency, National Exposure Research Laboratory, Cincinnati, OH 45268 U.S.A.

JEFFREY L. HAYS
RAPTOR Inc., 1419 Holmanview Drive, Wyoming, OH 45215 U.S.A.

ABSTRACT.—Little is known about the habitat and ecology of suburban Barred Owls (*Strix varia*), a species sometimes considered the nocturnal equivalent of Red-shouldered Hawks (*Buteo lineatus*). We compared nesting habitat of Barred Owls to that of Red-shouldered Hawks nesting in suburban and urban areas, in and near the city of Cincinnati, Ohio, to determine whether any features distinguished owl nest sites from hawk nest sites. We characterized habitat and land-cover metrics in circular plots of 100 ha and 15 ha, centered on the owl and hawk nests, using ATtiILa software operating within a GIS environment. For the 100-ha plots, the primary cover type in the plots surrounding nests of both species was forest, 41.4 ± 3.4% for Barred Owl plots and 45.9 ± 3.4% for Red-shouldered Hawk plots, followed by low-density residential land: 29.8 ± 4.8% of the Barred Owl plots and 29.3 ± 3.7% of the Red-shouldered Hawk plots. Pasture composed <15% of the plot area for both species and the remainder of the cover types contributed even less. Values of land-cover percentages and metrics did not differ between the species ($P > 0.05$), for either the large plots or the small (15-ha) plots. Using stepwise binary logit regression analysis, we found that no variables discriminated owl plots from hawk plots. We concluded, based on our methodology, that habitat of suburban Barred Owls differed little from habitat of suburban Red-shouldered Hawks in southwestern Ohio.

KEY WORDS: *Barred Owl*; Strix varia; *Red-shouldered Hawk*; Buteo lineatus; *habitat*; *nesting*; *nest sites*; *suburban*; *urban*.

HÁBITATS DE INDIVIDUOS SUBURBANOS DE *STRIX VARIA* Y *BUTEO LINEATUS* EN EL SUDOESTE DE OHIO

RESUMEN.—Poco se sabe acerca del hábitat y la ecología de individuos suburbanos de *Strix varia*, una especie a menudo considerada como el equivalente nocturno de *Buteo lineatus*. Comparamos el hábitat de anidamiento de individuos de *S. varia* con el de individuos de *B. lineatus* que anidan en áreas urbanas y suburbanas, dentro y cerca de la ciudad de Cincinnati, Ohio, para determinar si alguna característica distingue a los sitios de nidada de las lechuzas de los sitios de nidada de los halcones. Caracterizamos el hábitat y la cobertura del suelo en parcelas circulares de 100 ha y 15 ha, centradas en los nidos de las lechuzas y los halcones, usando el software ATtiILa operando en un entorno SIG. Para las parcelas de 100 ha, la cobertura primaria en las parcelas alrededor de los nidos de las dos especies fue el bosque, 41.4 ± 3.4% para las parcelas de *S. varia* y 45.9 ± 3.4% para las parcelas de *B. lineatus*, seguidas por terreno residencial de baja densidad: 29.8 ± 4.8% para las parcelas de *S. varia* y 29.3 ± 3.7% para las parcelas de *B. lineatus*. Las pasturas comprendieron <15% de la superficie de la parcela para ambas especies y el resto de

[1] The editorial processing and review of this paper were handled by Joseph B. Buchanan.
[2] Email address: cheryldykstra@juno.com

los tipos de cobertura contribuyeron incluso menos. Los valores porcentuales y métricos de la cobertura del suelo no difirieron entre las especies ($P > 0.05$), tanto para las parcelas grandes como para las pequeñas (15 ha). Usando el análisis de regresión logit binario gradual, encontramos que ninguna variable discriminó las parcelas de lechuzas de las de los halcones. Concluimos, en base a nuestra metodología, que el hábitat de los individuos suburbanos de *S. varia* difirió poco del hábitat de los individuos suburbanos de *B. linetaus* en el sudoeste de Ohio.

[Traducción del equipo editorial]

Barred Owls (*Strix varia*) typically have been associated with large tracts of undisturbed mature deciduous or mixed deciduous/conifer forests (Allen 1987, Bosakowski et al. 1987, Bosakowski and Smith 1997, Haney 1997, Mazur and James 2000). Nesting habitats include riparian forests, wooded swamps, and wooded upland areas, often with high canopy closure and located relatively near water (Bosakowski et al. 1987, Laidig and Dobkin 1995, Livezey 2007). Most nesting studies of Barred Owls have been conducted in natural areas such as national and state forests, or national parks. However, Barred Owls also inhabit suburban and urban areas in some regions, although little has been published on the habitat and ecology of these suburban owls. For example, Barred Owls nested in small suburban woodlots in Litchfield, Connecticut (Yannielli 1991), and in urban and suburban Charlotte, North Carolina, in small wooded areas among high-density housing and in larger woodlots near residential and industrial development (Harrold 2003, Mason 2004, Bierregaard et al. 2008).

Red-shouldered Hawks, described as the diurnal equivalent of Barred Owls (Temple and Temple 1976), also nest in undisturbed mature deciduous forests, typically in riparian or upland areas, and often near water (Titus and Mosher 1981, Bednarz and Dinsmore 1982, Armstrong and Euler 1983, Dykstra et al. 2000, 2008). They are similar in size to Barred Owls and both species consume a similar variety of small mammals, amphibians, reptiles, and invertebrates (Livezey 2007, Dykstra et al. 2008, Strobel and Boal 2010). Both species have been considered indicator species for the management of old forests (USDA 1985, 1986, Mazur and James 2000, Hess and King 2002, Crewe and Badzinski 2006).

Red-shouldered Hawks, particularly the western subspecies (*B. lineatus elegans*), also inhabit suburban and urban areas (Bloom and McCrary 1996, Rottenborn 2000). The eastern subspecies, *B. lineatus lineatus,* nests in suburban areas in a variety of regions, including the Cincinnati area of southwestern Ohio (Dykstra et al. 2000, 2001a, 2003) and Charlotte, North Carolina (noted anecdotally by Harrold 2003 and Mason 2004). In southwestern Ohio, Red-shouldered Hawks built nests a mean of 75 m from human residences (Dykstra et al. 2000), and their 90-ha breeding-season home ranges contained an average of 169 residences each (Dykstra et al. 2001b).

Based on published reports of land-cover types inhabited by Barred Owls and Red-shouldered Hawks in remote natural areas and our observations of both species in suburban regions in and near the city of Cincinnati, Ohio (C. Dykstra, M. Simon, and J. Hays unpubl. data), we believed the two species might use similar suburban habitats. However, suburban habitat of the Barred Owl has been little studied. Knowledge of the ecology and habits of these common species will give us insight into some aspects of community dynamics of raptors, which have been studied in various species in natural settings (e.g., Hakkarainen and Korpimäki 1996, Sergio et al. 2003a), but not in urban/suburban regions, to our knowledge. Thus, we studied Barred Owls nesting in suburban and urban settings in and near the city of Cincinnati, Ohio, in southwestern Ohio, and compared land-cover types and environmental features surrounding owl nests to those surrounding Red-shouldered Hawk nests in the same area. Our goal was to evaluate whether any features distinguished owl nest sites from hawk nest sites.

METHODS

Study Area. Southwestern Ohio is a hilly, unglaciated area in the Interior Plateau ecoregion (Omernik 1987). The hills are dissected by many small streams located in ravines and by two large tributaries of the Ohio River, the Great Miami and the Little Miami rivers. Native forests are dominated by second-growth oak-hickory (*Quercus* spp., *Carya* spp.) and American beech-sugar maple (*Fagus grandifolia*, *Acer saccharum*) associations, with lowland riparian forests characterized by American sycamores (*Platanus occidentalis*) and beech.

Our study area centered on the city of Cincinnati, Ohio, and included Hamilton County, Clermont

County, and southwestern Warren County, Ohio, and one owl nest in northern Campbell County, Kentucky. Many of the nests studied were located in the wide band of suburban development surrounding the city of Cincinnati. Suburban areas varied from densely populated (residential lots approximately 20 × 35 m) to sparsely-populated (>2.5-ha residential lots, as well as undeveloped private land); all of these suburban areas were classified as ''low-density residential'' (see below). Human population density in the study area was approximately 480 people/km², based on population in the six suburban townships containing the greatest numbers of nests (Ohio Department of Development 2008, U.S. Census Bureau 2008). Most residences and other buildings were surrounded by lawns and other nonnative vegetation, but residences tended to be located on level ground, with steep slopes and riparian areas left in native vegetation. Areas of public land within the study area contained no residences, but were heavily used for sports and other recreation.

Nest Location Techniques. We defined ''nests'' as locations with a known nest and ''nest sites'' as areas where preflighted owl young (''branchers'') were present but no nest was identified. We assumed that preflighted owl young were still located relatively close to their natal nest. For our analyses, we included only nests and nest sites where pairs attempted breeding. We considered that a breeding attempt occurred if there was evidence that eggs had been laid (i.e., observations of an incubating adult, presence of small down feathers on the edges of nest or cavity, broken eggshells below nest, nestlings in nest, or preflighted owl young; Steenhof and Newton 2007).

Barred Owl nests. We found nests and nest sites between 17 April and 1 June, 2006–09, using primarily two techniques. We received reports of nests or sightings from members of a local raptor-rehabilitation association, RAPTOR, Inc. (''RAPTOR reports''). We solicited information on nest locations and owl sightings from birders and others by word-of-mouth and by announcements at meetings of local ornithological societies, nature centers, county parks, and on a local birding list-serve (''public reports''). We also found three Barred Owl pairs using stick nests that had been previously occupied by Red-shouldered Hawks. We visited all reported locations to find owl nests and confirm breeding attempts. Locations of nests were confirmed by our observation of an incubating owl, an owl flying from the nest cavity, nestlings in the nest, or broken eggs on the ground below a nest cavity.

Red-shouldered Hawk nests. Nests included in this study were previously known to us from an ongoing long-term study (Dykstra et al. 2009). We originally found the nests in that study primarily between February and early April, using several techniques (Dykstra et al. 2000). As for Barred Owls, we received reports of nests or sightings from members of a local raptor-rehabilitation association (RAPTOR reports), and we solicited and received information on nest locations and hawk sightings from birders and other members of the general public (public reports). Other nests were found as a result of our own searches and observations (Dykstra et al. 2000). We visited all known nest areas at least twice (and sometimes three or more times) between mid-February and mid-April and viewed nests from the ground using 8× or 10× binoculars or a 20–60× spotting scope.

For this investigation, we selected all nests in 2007 that were originally found as a result of reports from the raptor-rehabilitation association (RAPTOR reports), or from birders and other members of the general public (public reports). All Red-shouldered Hawk nests found by other methods were excluded from our analyses, in order to minimize bias resulting from differing nest-location techniques. Although it is preferable statistically to find nests in an unbiased way by walking transects through a specific region of habitat, that time-consuming technique probably would not be efficacious in fragmented suburban areas. We believe that our methodology ensured that any potential bias should be roughly equivalent for both species.

Habitat Variables. Coordinates of nests and nest sites were recorded using a handheld GPS unit and these coordinates were entered into a geographic information system (GIS; ArcView 3.3 with Spatial Analyst 2.0; ESRI, Redlands, California, U.S.A.). We selected one plot size of 100 ha (radius of 564 m) based on the home-range size of Red-shouldered Hawks in this study area (90 ha in the breeding season; Dykstra et al. 2001b) and the home-range size of suburban Barred Owls in Charlotte, North Carolina (113 ha for males in the breeding season; Harrold 2003). We also created smaller plots of 15 ha (radius = 219 m) around the nests, based on the core areas used by Red-shouldered Hawks (13 ha for seven breeding-season males; Dykstra et al. 2001b) and suburban Barred Owls (18 ha for five breeding-season males; Harrold 2003). Both

sets of plot circles were overlaid on selected geographic coverages: the National Land Cover Dataset (NLCD) 2001 (for 30-m resolution land-cover metrics; Homer et al. 2007); the National Hydrography Dataset (NHD) 2009 (for the 1:24 000 scale stream length and densities; Simley and Carswell 2009); and official state roadway coverages from the Ohio and Kentucky Departments of Transportation (M. Thompson, D. Zourarakis pers. comm.) for the road length and densities. Desired metrics were computed using ATtiILa software (USEPA 2004) operating within the GIS environment.

Based on published reports of habitat selection in our study species, we selected land-cover metrics that represented habitat we believed important for nesting and foraging (forests, streams, fields) and those that represented features that might be deterrents (such as residential areas and roads; Appendix).

Statistical Analyses. Data were not normally distributed. Thus, we first used Mann-Whitney *U*-tests for the univariate comparison of habitat variables between species. We then examined the Pearson correlation matrix. For all pairs of variables with $r > 0.70$, we selected one variable of the pair, choosing those that were most basic (least derivative). For multivariate analysis, all variables in the reduced dataset were used in stepwise binary logit regression analysis (SYSTAT 11.0), with forward and backward steps, to select the combination of variables that best discriminated nest sites/areas of the two species.

RESULTS

Nests and Nest Sites. We found 21 nests and nest sites of Barred Owls in the study area (14 nests and 7 nest sites; Fig. 1). Nine of these were reported to us by the public, nine by the raptor-rehabilitation group, and three were open stick nests found by us because they were formerly occupied by Red-shouldered Hawks. One of the nests was in a nest box erected 8 m from a cavity nest that had been used by the owls in the previous season, but then usurped by raccoons (*Procyon lotor*); for all analyses, we included only the nest in the nest box. The remaining 13 nests were in trees. Of 10 nest trees for which species was recorded, five (50%) were American sycamores, and one each were American beech, northern red oak (*Quercus rubra*), eastern cottonwood (*Populus deltoides*), ash sp. (*Fraxinus americana* or *F. pennsylvanica*), and willow sp. (*Salix* sp.; 10% each). Of 11 nest trees for which tree condition was recorded, six (55%) were alive (four sycamores [36%], one eastern cottonwood [9%], and one willow sp. [9%]) and five (45%) dead (one each of beech, northern red oak, ash sp., sycamore, and unknown sp. [9% each]).

We found 103 nests of Red-shouldered Hawks in the study area in 2007. Of these, 29 were originally reported to us by the public, 22 by the raptor-rehabilitation association, and 52 were found by us as a result of our own searches and observations. For all analyses, we included only the 51 nests in the first two categories. Of these, 11 of 51 Red-shouldered Hawks nests were in sycamores (22%), five were in northern red oak (10%), five in ash spp. (10%), three in tuliptree (*Liriodendron tulipifera*; 6%), three in white oak (*Q. alba*; 6%), three in pin oak (*Q. palustris*; 6%), three in unidentified oaks (*Quercus* spp.), two each (4%) in shingle oak (*Q. imbricaria*), burr oak (*Q. macrocarpa*), shagbark hickory (*Carya ovata*), sugar maple, silver maple (*A. saccharinum*) and unidentified maples (*Acer* spp.), and one each in black cherry (*Prunus serotina*), cottonwood, red maple (*A. rubrum*), black walnut (*Juglans nigra*), elm (*Ulmus* sp.), and hickory (*Carya* sp.). All these nest trees were alive.

Habitat Around Nests and Nest Sites. *Large 100-ha plots.* The primary cover type surrounding nests and nest sites of both species was forest, 41% for Barred Owl nests and nest sites, and 46% for Red-shouldered Hawk nests (Table 1), but low-density residential land made up 30% of the Barred Owl plots and 29% of the Red-shouldered Hawk plots. Pasture composed <15% of the plot area for both species and the remainder of the cover types contributed even less (Table 1). Total road length within the plots was 4899 m for owls and 4070 m for hawks, more than three times the total stream length within the plots. Univariate comparisons indicated no differences in cover types and other attributes between Barred Owl plots and Red-shouldered Hawk plots (Table 1; all $P > 0.2$).

Small 15-ha plots. As in the larger plots, the primary cover type surrounding nests and nest sites was forest, followed by low-density residential land. We found no differences in any cover-type variables between hawk and owl plots (Table 2; all $P > 0.2$).

Multivariate Analyses. For the 100-ha plots, road length and number of forest patches were correlated with other variables and were excluded from the analysis (Table 1); the other 11 variables were used in the logit regression model. However, no variables were retained in the final model, indicating that

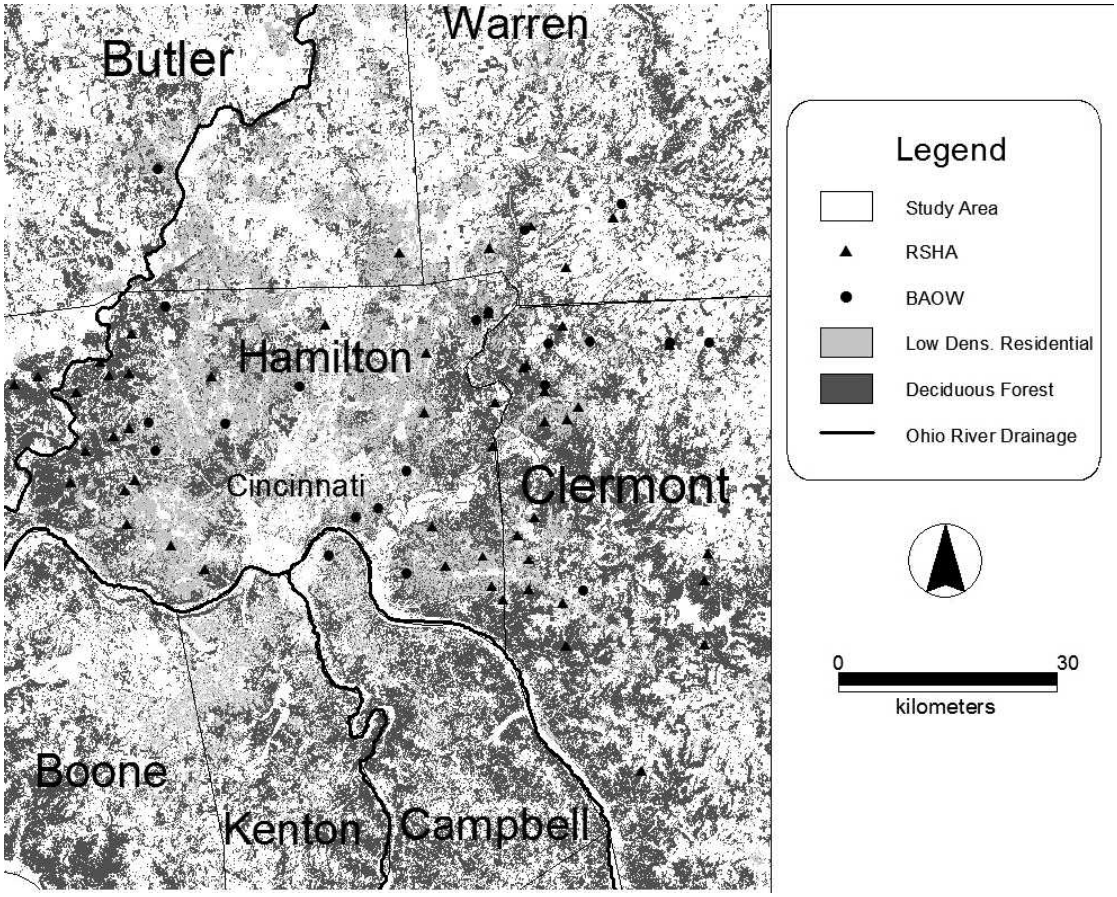

Figure 1. Locations of nests and nest sites of Barred Owls and nests of Red-shouldered Hawks in the suburban areas surrounding the city of Cincinnati, Ohio. Butler, Warren, Hamilton, and Clermont counties are in Ohio; Boone, Kenton, and Campbell counties are in Kentucky. Two land-cover types are shown in gray, low-density residential in light gray, and deciduous forest in dark gray.

none of these could be used to differentiate hawk plots from owl plots.

For the 15-ha plots, the low-density residential cover type (%) was correlated with total forest cover (%), so we excluded low-density residential. Similarly, the number of forest patches and mean area of forest patches were excluded (Table 2). The remaining 10 variables were used in the logit regression model, but, as above, no variables were retained in the final model.

DISCUSSION

Habitat Around Nest Sites. Barred Owls nested in suburban areas of Cincinnati, in locations averaging 41–48% forested and 30–31% residential cover type, depending on the spatial scale considered. In some cases, their nests were within about 20 m of suburban and urban residences (C. Dykstra unpubl. data). The cover types and environmental features surrounding owl nests did not differ from those surrounding Red-shouldered Hawk nests in the same study area (Table 1). Although Barred Owl habitat in suburban regions has been little studied, we suspect that Barred Owls are not uncommon in suitable suburban regions of eastern North America (Yannielli 1991, Harrold 2003, Mason 2004, Bierregaard et al. 2008).

Habitat of suburban Barred Owls differed little from that of suburban Red-shouldered Hawks in southwestern Ohio, based on our methodology. The lack of difference was not surprising, as the Barred Owl is sometimes said to be the nocturnal equivalent of the Red-shouldered Hawk (Temple

Table 1. Univariate comparison of habitat variables within 100-ha circular plots for suburban Barred Owls and Red-shouldered Hawks in southwestern Ohio.

VARIABLE	BARRED OWLS		RED-SHOULDERED HAWKS		MANN-WHITNEY	
	MEAN	SE	MEAN	SE	*U*	*P*
Total forest (%)	41.4	3.4	45.9	3.4	479.0	0.48
Wetland (%)	0.2	0.1	0.2	0.1	481.0	0.46
Grassland (%)	3.9	1.4	3.2	1.1	610.0	0.32
Pasture (%)	13.5	3.3	12.9	1.9	486.0	0.54
Cropland (%)	6.9	2.0	5.6	1.0	521.0	0.86
Low-density residential (%)	29.8	4.8	29.3	3.7	568.0	0.69
Other urban (%)	4.1	1.5	2.9	0.6	573.0	0.64
Stream length (m)	1530	177	1328	118	587.5	0.52
Road length (m)	4899	743	4070	360	594.0	0.47
Number of forest patches	20.5	3.5	19.7	2.2	564.5	0.72
Number of low-density residential patches	16.6	2.5	13.0	1.4	629.0	0.25
Mean area of forest patches (m^2)	39 541	9445	107 860	30 460	510.0	0.75
Mean area of low-density residential patches (m^2)	27 183	8283	78 524	25 557	564.0	0.72

and Temple 1976). In more than one case, Barred Owls apparently usurped an occupied Red-shouldered Hawk nest in our study area; owls were found in historical Red-shouldered Hawk nests with fresh green vegetation, indicating that hawks had likely worked on the nest within the previous month. In addition, we often heard Barred Owls calling while we were visiting Red-shouldered Hawk territories (C. Dykstra unpubl. data), although we did not search for owl nests in these areas in order to preserve the independence of the two datasets. Additionally, we found Red-shouldered Hawks or their nests at five sites where we had reports of Barred Owls and were searching for owl nests.

Barred Owls in northern Michigan also apparently used the same forests frequented by Red-shouldered Hawks, because seven of 114 owl breeding attempts were in old Red-shouldered Hawk nests (Postupalsky et al. 1997). Barred Owls and Red-shouldered Hawks also coexist in urban/suburban Charlotte, North Carolina (Mason 2004), and in the second-growth Allegeny hardwood forests of the central Appalachian Mountains, where they are the most common nocturnal and diurnal raptors, respectively (Smith 2003).

Table 2. Univariate comparison of habitat variables within 15-ha circular plots for suburban Barred Owls and Red-shouldered Hawks in southwestern Ohio.

VARIABLE	BARRED OWLS		RED-SHOULDERED HAWKS		MANN-WHITNEY	
	MEAN	SE	MEAN	SE	*U*	*P*
Total forest (%)	47.9	4.4	52.7	4.2	502.0	0.68
Wetland (%)	0.1	0.1	0.1	0.1	561.0	0.56
Grassland (%)	2.2	1.1	2.6	0.9	561.0	0.69
Pasture (%)	14.0	4.2	9.1	2.3	533.0	0.98
Cropland (%)	3.3	1.3	4.1	0.9	464.0	0.36
Low-density residential (%)	31.1	5.9	29.9	4.2	558.0	0.78
Other urban (%)	1.5	0.7	1.5	0.4	509.0	0.71
Stream length (m)	359.0	58.0	261.8	34.7	630.0	0.23
Road length (m)	686.0	92.8	648.2	73.2	599.5	0.43
Number of forest patches	4.5	0.9	3.7	0.4	568.5	0.67
Number of low-density residential patches	3.4	0.7	2.6	0.4	604.5	0.39
Mean area of forest patches (m^2)	45 532	10 052	56 204	7784	488.0	0.56
Mean area of low-density residential patches (m^2)	21 978	6712	28 679	6082	556.5	0.79

Nest-site selection of suburban Barred Owls has been studied in only a single location. In Charlotte, North Carolina, researchers found no variables to distinguish nest plots from randomly placed plots (Harrold 2003), but found that suburban Barred Owl nests were only 11 m from the nearest human dwelling and 41 m from the nearest road (Harrold 2003). In our study area, we did not quantify nest-site selection of Barred Owls. However, suburban Red-shouldered Hawks in our study area selected nest trees that were larger than the surrounding trees, in areas of large trees, and close to permanent or seasonal water (Dykstra et al. 2000). Their nest sites were no further from roads and human residences (primarily single-family homes) than were randomly placed plots, averaging only 86 m from roads and 75 m from houses (Dykstra et al. 2000), suggesting that Red-shouldered Hawks did not alter their use of habitat in response to the presence of houses and roads. The similarity of cover types and other features of the two species in our current study suggests that Barred Owls also may be indifferent to the presence of suburban houses and roads in this study area, as in suburban Charlotte. The nocturnal habits of Barred Owls may serve to increase their tolerance, as they probably interact less frequently with humans than do diurnal hawks.

Home ranges of Barred Owls in the boreal forest in central Saskatchewan consisted of 86% forest (deciduous, mixed, and coniferous), although the entire study area was only 62% forest (Mazur et al. 1998), and these results were typical of telemetry studies in western North America, where Barred Owls used old forests more than expected (Washington; Hamer et al. 2007) and were associated with areas of high canopy closure and large trees (Washington; Singleton et al. 2010). In contrast, home ranges of suburban Barred Owls in Charlotte, North Carolina, consisted of 81% residential land use; although the authors caution that this land-cover value was based on zoning classifications, they also describe the suburban areas as consisting of residential properties including wooded lawns, small woodlots, and city parks (Harrold 2003). We did not investigate home ranges for Barred Owls in this study, so we were unable to quantify home-range habitats, but we can infer that, within the larger landscapes consisting of 41–48% forested land, Barred Owls were able to find sufficient forest, nest sites, and prey to breed.

Our Barred Owl samples included three nests in urban neighborhoods >75 yr old, and closer to downtown Cincinnati than were any of our Red-shouldered Hawk nests. These neighborhoods tended to be relatively densely populated by humans, and often contained large trees, which can develop cavities of appropriate size for Barred Owls. In addition, Barred Owl nests tended to be in sycamores more frequently than did Red-shouldered Hawk nests (50% of all identified nest trees vs. 22%, respectively, in this study), and sycamores are among the most massive trees in the eastern United States (Sibley 2009). The presence of Barred Owls in the older urban neighborhoods, as well as the greater use of sycamores by Barred Owls, may reflect a possible difference in nest-site characteristics between Barred Owls and Red-shouldered Hawks, one that we did not test in this study: nest-tree diameter. The Barred Owl nest trees we measured in this study (n = 7) averaged 77 cm dbh (diameter at breast height; C. Dykstra unpubl. data), whereas Red-shouldered Hawk nest trees in the same southwestern Ohio study area were slightly smaller, averaging 67 cm in 1997–98 (n = 33; Dykstra et al. 2000). Because Barred Owls generally require large trees that contain cavities of appropriate size, unless nesting in an open stick nest, the presence of such trees in older urban neighborhoods may make those areas—in this case, older urban neighborhoods—sufficiently attractive and suitable for Barred Owls. However, we note that the definition of large trees is relative to the habitat; in boreal forests in Saskatchewan, Barred Owl nest-trees averaged only 47 cm dbh, yet these trees were described as relatively large and the surrounding forests as ''mature'' (Mazur et al. 1997). In eastern North America, Barred Owl nest trees averaged 61 cm dbh (Maryland; Devereux and Mosher 1984), and in suburban Charlotte, North Carolina, 79 cm dbh (Harrold 2003).

As a caveat to the above, we emphasize that our study had some limitations. First, we may have failed to measure an important distinguishing feature of the two species' habitat, such as the age of the forest, because we were unable to differentiate forest age from the data in our database. Second, the plots we used for habitat analysis may not include the complete actual home ranges, which likely were not circles centered on the nest sites. Finally, we were unable to draw any quantitative conclusions about Barred Owl nest-site selection compared to the available cover types within the study area, as our study did not include random plots. These caveats do not invalidate our results, but do highlight areas where additional research can further our understanding of Barred Owl ecology in suburban areas.

Conservation and Management Implications. Barred Owls in southwestern Ohio seemed somewhat flexible in their requirements for habitat, and apparently tolerated humans well. Their ability to accept suburban landscapes and, presumably, human disturbance, and their propensity for range expansion (Livezey 2009a, 2009b) suggests that they are a species that should be less susceptible to extirpation than some others. However, we note that different populations seem to have different tolerances for human disturbance (Bosakowski et al. 1987, Bosakowski and Smith 1997), and the ability of some populations to use suburban regions does not necessarily indicate that all populations will be able to do so.

The successful range expansion of Barred Owls in the western and northwestern portions of North America (Livezey 2009a, 2009b) has brought them into ranges occupied by the California subspecies of the Red-shouldered Hawk, which is generally more suburban in its habits than the eastern subspecies (Bloom and McCrary 1996, Rottenborn 2000). This subspecies of the Red-shouldered Hawk also has recently expanded its breeding range in the west to include Oregon (Marshall et al. 2003), Arizona (Corman 2005) and east of the Sierra mountains in California (P. Bloom pers. comm.). Nonbreeding Red-shouldered Hawks have also been found in Washington (Tweit 2005). Although it would be unwise to extrapolate beyond our study area in southwestern Ohio, the results of our study suggested that areas suitable for Red-shouldered Hawks, including suburban areas, may also be suitable for Barred Owls, and vice versa.

Barred Owls are known to nest in suburban areas of the Pacific Northwest (J. Buchanan pers. comm.), and if further range expansion continues, may soon come into contact with well-established populations of breeding suburban Red-shouldered Hawks. Their natural colonization may provide a rare opportunity for a preinvasion/post-invasion ''natural'' experiment on the interspecific interactions of these two raptor species in human-dominated landscapes. For raptors, interspecific competition and/or intraguild predation can decrease reproductive success in both competitors (Korpimäki 1987), decrease breeding density (Hakkarainen and Korpimäki 1996), increase egg and nestling mortality (Kostrzewa 1991, Sergio et al. 2003a), delay laying dates (Hakkarainen and Korpimäki 1996), or decrease post-fledging survival (Hakkarainen and Korpimäki 1996). Raptors facing interspecific competition or predation may reduce the effects of these by changing their habitat use (Sergio et al. 2003b), dispersal patterns (Forero et al. 1999), diet (Korpimäki 1987), or other behaviors. The investigation of population responses of Red-shouldered Hawks to the colonizing Barred Owls would give valuable insight into raptor community dynamics, and further illuminate the complex interactions of species coexisting with humans in urban/suburban areas.

ACKNOWLEDGMENTS

We are grateful to Ann Wegman and Sandra Stone for assistance with fieldwork, and to Kent Livezey, Associate Editor Joe Buchanan, and three anonymous reviewers for useful comments on earlier versions of this manuscript. We thank the many private landowners who reported raptor nests to us and allowed us access to their property, and the volunteers at RAPTOR, Inc., of Cincinnati, for reporting hawk and owl nests and territories to us. The original Red-shouldered Hawk study was supported in part by the appointment of CRD to the Postgraduate Research Participation Program at the National Exposure Research Laboratory administered by the Oak Ridge Institute for Science and Education through an interagency agreement between the U.S. Department of Energy and the U.S. Environmental Protection Agency. Additional funding was provided by the Ohio Biological Survey, RAPTOR, Inc., Marilyn Arn, and Brad and Marcia Lindner.

LITERATURE CITED

ALLEN, A.W. 1987. Habitat suitability index models. Barred Owl. USDI Fish and Wildlife Service Biol. Rep. 82, Fort Collins, CO U.S.A.

ARMSTRONG, E. AND D. EULER. 1983. Habitat usage of two woodland *Buteo* species in central Ontario. *Canadian Field-Naturalist* 97:200–207.

BEDNARZ, J.C. AND J.J. DINSMORE. 1982. Nest-sites and habitat of Red-shouldered and Red-tailed hawks in Iowa. *Wilson Bulletin* 94:31–45.

BIERREGAARD, R.O., JR., E.S. HARROLD, AND M.A. MCMILLIAN 2008. Behavioral conditioning and techniques for trapping Barred Owls (*Strix varia*). *Journal of Raptor Research* 42:210–214.

BLOOM, P.H. AND M.D. MCCRARY. 1996. The urban Buteo: Red-shouldered Hawks in southern California. Pages 31–39 *in* D.M. Bird, D.E. Varland, and J.J. Negro [EDS.], Raptors in human landscapes: adaptation to built and cultivated environments. Academic Press Limited, London, U.K.

BOSAKOWSKI, T. AND D.G. SMITH. 1997. Distribution and species richness of a forest raptor community in relation to urbanization. *Journal of Raptor Research* 31: 26–33.

———, R. SPEISER, AND J. BENZINGER. 1987. Distribution, density and habitat relationships of the Barred Owl in northern New Jersey. Pages 135–143 *in* R.W. Nero, R.J. Clark, R.J. Knapton, and R.H. Hamre [EDS.], Biology and conservation of northern forest owls: symposium proceedings. USDA Forest Service Gen. Tech. Rep. RM-142, Fort Collins, CO U.S.A.

CORMAN, T.E. 2005. Supplemental species accounts. Pages 590–603 *in* T.E. Corman and C. Wise-Gervais [EDS.], Arizona breeding bird atlas. University of New Mexico Press, Albuquerque, NM U.S.A.

CREWE, T. AND D. BADZINSKI. 2006. Red-shouldered Hawk and spring woodpecker survey, 2005 final report. Produced for the Ontario Ministry of Natural Resources—Terrestrial Assessment Unit. Bird Studies Canada, Port Rowan, ON Canada.

DEVEREUX, J.G. AND J.A. MOSHER. 1984. Breeding ecology of Barred Owls in the central Appalachians. *Raptor Research* 18:49–58.

DYKSTRA, C.R., F.B. DANIEL, J.L. HAYS, AND M.M. SIMON. 2001a. Correlation of Red-shouldered Hawk abundance and macrohabitat characteristics in southern Ohio. *Condor* 103:652–656.

———, J.L. HAYS, AND S.T. CROCOLL. 2008. Red-shouldered Hawk (*Buteo lineatus*). *In* A. Poole [ED.], The birds of North America online, No. 107. Cornell Lab of Ornithology, Ithaca, NY U.S.A. http://bna.birds.cornell.edu/bna/species/107 (last accessed 26 January 2012).

———, ———, F.B. DANIEL, AND M.M. SIMON. 2000. Nest site selection and productivity of suburban Red-shouldered Hawks in southern Ohio. *Condor* 102:401–408.

———, ———, ———, AND ———. 2001b. Home range and habitat use of suburban Red-shouldered Hawks in southwestern Ohio. *Wilson Bulletin* 113:308–316.

———, ———, M.M. SIMON, AND F.B. DANIEL. 2003. Behavior and prey of nesting Red-shouldered Hawks in southwestern Ohio. *Journal of Raptor Research* 37:177–187.

———, ———, AND ——— 2009. Spatial and temporal variation in reproductive rates of the Red-shouldered Hawk in suburban and rural Ohio. *Condor* 111:177–182.

FORERO, M.G., J.A. DONÁZAR, J. BLAS, AND F. HIRALDO. 1999. Causes and consequences of territory change and breeding dispersal in the Black Kite. *Ecology* 80:1298–1310.

HAKKARAINEN, H. AND E. KORPIMÄKI. 1996. Competitive and predatory interactions among raptors: an observational and experimental study. *Ecology* 77:1134–1142.

HAMER, T.E., E.D. FORSMAN, AND E.M. GLENN. 2007. Home range attributes and habitat selection of Barred Owls and Spotted Owls in an area of sympatry. *Condor* 109: 750–768.

HANEY, J.C. 1997. Spatial incidence of Barred Owl *(Strix varia*) reproduction in old-growth forest of the Appalachian plateau. *Journal of Raptor Research* 31:241–252.

HARROLD, E.S. 2003. Barred Owl (*Strix varia*) nesting ecology in the southern piedmont of North Carolina. M.S. thesis, University of North Carolina—Charlotte, Charlotte, NC U.S.A.

HESS, G.R. AND T.J. KING. 2002. Planning open spaces for wildlife: I. Selecting focal species using a Delphi survey approach. *Landscape and Urban Planning* 58:25–40.

HOMER, C., J. DEWITZ, J. FRY, M. COAN, N. HOSSIAN, C. LARSON, N. HEROLD, A. MCKERROW, J.N. VANDRIEL, AND J. WICKHAM. 2007. Completion of the 2001 National Land Cover Database for the conterminous United States. *Photogrammetric Engineering and Remote Sensing* 73:337–341.

KORPIMÄKI, E. 1987. Dietary shifts, niche relationships and reproductive output of coexisting kestrels and Long-eared Owls. *Oecologia* 74:277–285.

KOSTRZEWA, A. 1991. Interspecific interference competition in three European raptor species. *Ethology, Ecology and Evolution* 3:127–143.

LAIDIG, K.J. AND D.S. DOBKIN. 1995. Spatial overlap and habitat associations of Barred Owls and Great Horned Owls in southern New Jersey. *Journal of Raptor Research* 29:151–157.

LIVEZEY, K.B. 2007. Barred Owl habitat and prey: a review and synthesis of the literature. *Journal of Raptor Research* 41:177–201.

———. 2009a. Range expansion of Barred Owls, part I: chronology and distribution. *American Midland Naturalist* 161:49–56.

———. 2009b. Range expansion of Barred Owls, part II: facilitating ecological changes. *American Midland Naturalist* 161:323–349.

MARSHALL, D.B., M.G. HUNTER, AND A.L. CONTRERAS. [EDS.]. 2003. Birds of Oregon: a general reference. Oregon State University Press, Covallis, OR U.S.A.

MASON, J.S. 2004. The reproductive success, survival, and natal dispersal of Barred Owls (*Strix varia*) in rural versus urban habitats in and around Charlotte, North Carolina. M.S. thesis, University of North Carolina—Charlotte, Charlotte, NC U.S.A.

MAZUR, K.M., S.D. FRITH, AND P.C. JAMES. 1998. Barred Owl home range and habitat selection in the boreal forest of central Saskatchewan. *Auk* 115:746–754.

——— AND P.C. JAMES. 2000. Barred Owl (*Strix varia*). *In* A. Poole [ED.], The birds of North American online. Cornell Lab of Ornithology, Ithaca, NY U.S.A. http://bna.birds.cornell.edu/bna/species/508 (last accessed 17 January 2011).

———, ———, M.J. FITZSIMMONS, G. LANGEN, AND R.H.M. ESPIE. 1997. Habitat associations of the Barred Owl in the boreal forest of Saskatchewan, Canada. *Journal of Raptor Research* 31:253–259.

POSTUPALSKY, S., J.M. PAPP, AND L. SCHELLER. 1997. Nest sites and reproductive success of the Barred Owls (*Strix varia*) in Michigan. Pages 325–337 *in* J.R. Duncan, D.H. Johnson, and T.H. Nicholls [EDS.], Biology and conservation of owls of the northern hemisphere, second international symposium. USDA Forest Service, Gen. Tech. Rep. NC-190, Winnipeg, Manitoba, Canada.

OHIO DEPARTMENT OF DEVELOPMENT. 2008. Policy research and strategic planning. http://www.odod.state.oh.us/research (last accessed 5 October 2010).

OMERNIK, J.M. 1987. Ecoregions of the conterminous United States. *Annals of the Association of American Geographers* 77:118–125.

ROTTENBORN, S.C. 2000. Nest-site selection and reproductive success of urban Red-shouldered Hawks in central California. *Journal of Raptor Research* 34:18–25.

SERGIO, F., L. MARCHESI, AND P. PEDRINI. 2003a. Spatial refugia and the coexistence of a diurnal raptor with its intraguild owl predator. *Journal of Animal Ecology* 72:232–245.

———, P. PEDRINI, AND L. MARCHESI. 2003b. Spatio-temporal shifts in gradients of habitat quality for an opportunist avian predator. *Ecography* 26:243–255.

SIBLEY, D.A. 2009. The Sibley guide to trees. Alfred A. Knopf, New York, NY U.S.A.

SIMLEY, J.D. AND W.J. CARSWELL, JR. 2009. The national map—hydrography. USGS Survey Fact Sheet 2009-3054, U.S. Geological Survey, Reston, VA U.S.A. http://pubs.usgs.gov/fs/2009/3054/ (last accessed 26 January 2012).

SINGLETON, P.H., J.F. LEHMKUHL, W.L. GAINES, AND S.A. GRAHAM. 2010. Barred Owl space use and habitat selection in the eastern Cascades, Washington. *Journal of Wildlife Management* 74:285–294.

SMITH, R.D.M. 2003. Raptor assemblages, abundance, nesting ecology and habitat characteristics under intensive forest management in the central Appalachian Mountains. M.S. thesis. West Virginia University, Morgantown, WV U.S.A.

STEENHOF, K. AND I. NEWTON. 2007. Assessing nesting success and productivity. Pages 181–192 *in* D.M. Bird and K.L. Bildstein [EDS.], Raptor research and management techniques. Hancock House Publishers, Blaine, WA U.S.A.

STROBEL, B.N. AND C.W. BOAL. 2010. Regional variations in the diets of breeding Red-shouldered Hawks. *Wilson Journal of Ornithology* 122:68–74.

TEMPLE, S.A. AND B.L. TEMPLE. 1976. Avian population trends in central New York, 1935–72. *Journal of Field Ornithology* 47:238–257.

TITUS, K. AND J.A. MOSHER. 1981. Nest-site habitat selected by woodland hawks in the central Appalachians. *Auk* 98:270–281.

TWEIT, B. 2005. Red-shouldered Hawk (*Buteo lineatus*). Page 116 *in* T.R. Wahl, B. Tweit, and S.G. Mlodinow [EDS.], Birds of Washington: status and distribution. Oregon State University Press, Corvallis, OR U.S.A.

U.S. CENSUS BUREAU. 2008. State and county quick facts. http://quickfacts.census.gov/qfd/states/39000.html (last accessed 5 October 2010).

U.S. DEPARTMENT OF AGRICULTURE (USDA). 1985. Jefferson National Forest land and resource management plan. USDA Forest Service Land Management planning, Roanoke, VA U.S.A.

———. 1986. Allegheny National Forest land and resource management plan. USDA Forest Service, Eastern Region, Warren, PA U.S.A.

U.S. ENVIRONMENTAL PROTECTION AGENCY (USEPA). 2004. Analytical tools interface for landscape assessments (ATtiILA): User Manual. EPA/600/R-04/083. U.S. Environmental Protection Agency, Office of Research and Development, Las Vegas, NV U.S.A.

YANNIELLI, L.C. 1991. Preferred habitat of Northern Barred Owls in Litchfield County, Connecticut. *Connecticut Warbler* 11:12–20.

Received 17 January 2011; accepted 16 November 2011
Associate Editor: Joseph B. Buchanan

Appendix. Habitat variables and patch metrics. Analysis circle sizes were 100 ha and 15 ha.

VARIABLE NAME	DEFINITION
Total forest	Percentage of area that is forested (deciduous, coniferous, and mixed forests; NLCD classifications 41, 41, and 43). Deciduous forest defined as areas dominated by trees where ≥75% of the trees shed foliage seasonally. Coniferous and mixed forests made up <2% each of total forest, on average, in the plots.
Wetland	Percentage of area that is wetland (woody wetlands and emergent herbaceous wetlands, NLCD classifications 91 and 92), where the soil or substrate is periodically saturated with or covered with water.
Grassland	Percentage of area that is grassland: urban and recreational grasses (NLCD classification 85), including parks, golf courses, airport grasses, and lawns, and grasslands/herbaceous (NLCD classification 71), defined as areas dominated by upland grasses and forbs, which may be used for grazing.
Pasture	Percentage of area that is pasture, defined as areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops (NLCD classification 81).

Appendix. Continued.

VARIABLE NAME	DEFINITION
Cropland	Percentage of area that is cropland, defined as areas used for the production of row crops, such as corn, soybeans, vegetables, tobacco, and cotton (NLCD classification 82).
Low-density residential	Percentage of area that is low-density residential land, which includes areas with a mixture of constructed materials (30–80% of the cover) and vegetation (20–70% of the cover), most commonly single-family housing units (NLCD classification 21).
Other urban	Percentage of area that is high-density residential, and industrial/commercial. High-density residential areas (NLCD classification 22) are defined as developed areas where people reside in high numbers, including apartment complexes and row houses, where vegetation makes up <20% of the cover, and constructed materials make up 80–100% of the cover. Commercial/Industrial includes infrastructure and highly developed areas not classified as high-density residential (NLCD classification 23).
Road length	Total length of roads within the analysis circle (m).
Stream length	Total length of streams within the analysis circle (m).
Number of forest patches[1]	Number of forest patches in the analysis circle (units).
Area of forest patches[1]	Average area of forest patches in the analysis circle (m^2).
Number of low-density residential patches[1]	Number of low-density residential patches in the analysis circle (units).
Area of low-density residential patches[1]	Average area of low-density residential patches in the analysis circle (m^2).

[1] Patches were defined as areas of land cover greater than or equal to two pixels (i.e., $2 \times [30\ m \times 30\ m] = 1800\ m^2$) that are separated by at least one pixel of other land-cover types.