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DISPERSAL AND MORTALITY OF RED-SHOULDERED HAWKS BANDED IN OHIO

CHERYL R. DYKSTRA[1]
U.S. Environmental Protection Agency, National Exposure Research Laboratory, Cincinnati, OH 45268 U.S.A.

JEFFREY L. HAYS
RAPTOR, Inc., 1586 Covered Bridge Road, Cincinnati, OH 45231 U.S.A.

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

JOHN B. HOLT, JR.
858 Johnson Street, North Andover, MA 01845 U.S.A.

G. RONALD AUSTING
P.O. Box 428, Dillsboro, IN 47018 U.S.A.

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

ABSTRACT.—We banded nestling Red-shouldered Hawks (*Buteo lineatus*) in southwestern Ohio and northern Kentucky (SW OHIO, hereafter) to examine movements and determine causes of mortality in this suburban population. For comparison, we examined band recovery records for nestling Red-shouldered Hawks banded in rural northern Ohio. Of 899 nestlings banded in SW OHIO from 1955–2002, 43 (4.8%) were encountered (dead or alive) some time after fledging. Mean distance from natal nest at time of encounter was 38.5 ± 13.6 km and was not correlated with hawk age ($P > 0.58$). Distance from natal nest did not differ for hawks of three age classes or between those encountered in the breeding and nonbreeding seasons ($P > 0.13$). Cumulative exponential distribution (CED) analysis of distance from natal nest at time of encounter indicated that 50% of SW OHIO Red-shouldered Hawks were found <15 km from their natal nest, 75% were <29 km away, and 95% were <62 km away. Mean age of hawks recovered dead was 1.9 ± 0.4 yr ($N = 31$). CED analysis of age at recovery indicated that 50% of Red-shouldered Hawks were dead by age 1.2 yr, 75% by 2.4 yr, and 95% by 5.2 yr. SW OHIO hawks did not differ from hawks banded in northern Ohio in either distance from natal nest or age at recovery.

KEY WORDS: *Red-shouldered Hawk*; Buteo lineatus; *natal dispersal*; *survival*; *banding*; *urban.*

DISPERSION Y MORTALIDAD DE *BUTEO LINEATUS* ANILLADOS EN OHIO

RESUMEN.—Anillamos pichones de *Buteo lineatus* en el sudoeste de Ohio y norte de Kentucky (SO de Ohio, en adelante) para examinar los movimientos y determinar las causas de mortalidad en esta población suburbana. De modo comparativo, examinamos datos de anillos recuperados de pichones de *Buteo lineatus* anillados en áreas rurales del norte de Ohio. De 899 pichones anillados en el SO de Ohio entre 1955 y 2002, 43 (4.8%) fueron encontrados (muertos o vivos) algún tiempo después de abandonar el nido. La distancia al nido natal en el momento del encuentro fue de 38.5 ± 13.6 km y no estuvo correlacionada con la edad del ave ($P > 0.58$). La distancia al nido natal no difirió entre águilas de tres clases de edad ni entre aquellas encontradas en la estación reproductiva y no reproductiva ($P > 0.13$). Los análisis de la distribución exponencial acumulativa (DEA) de la distancia desde el nido natal en el momento del encuentro indicaron que el 50% de las águilas del SO de Ohio fueron encontradas

[1] Present address: 7280 Susan Springs Dr., West Chester, OH 45069 U.S.A.; E-mail address: cheryldykstra@juno.com

a <15 km del nido natal, 75% a <29 km de distancia y 95% a <62 km de distancia. La edad media de las aves recobradas muertas fue de 1.9 ± 0.4 años (N = 31). Los análisis de DEA de la edad en el momento del encuentro indicaron que el 50% de los individuos ya habían muerto a una edad de 1.2 años, 75% a una edad de 2.4 años y 95% a una edad de 5.2 años. Las águilas del SO de OHIO no se diferenciaron de las anilladas en el norte de Ohio en la distancia desde el nido natal ni en la edad al momento de recuperación del anillo.

[Traducción del equipo editorial]

The breeding habitat of the Red-shouldered Hawk (*Buteo lineatus*) in some areas of North America has been described as remote (Johnson 1989, Bosakowski et al. 1992, Bosakowski and Smith 1997). However, the species also inhabits suburban areas, at least in California (Bloom and McCrary 1996, Rottenborn 2000) and in southwestern Ohio near Cincinnati (Dykstra et al. 2000, 2001a, 2003). In southwestern Ohio, Red-shouldered Hawks built nests a mean of 75 m from human residences (Dykstra et al. 2000), and their 90-ha home ranges contained a mean of 169 residences each (Dykstra et al. 2001b). Two pairs of southwestern Ohio Red-shouldered Hawks have nested on rooftops and one pair on a gas grill on the deck of a residence (Hays 2000, Dykstra et al. 2001b).

Suburban-nesting raptors may experience different threats than those encountered by their rural-nesting conspecifics (Love and Bird 2000). They may endure repeated human disturbance (Preston and Beane 1996) and risk of collision with vehicles and buildings (e.g., Peregrine Falcons [*Falco pergrinus*]; Sweeney et al. 1997). They also may face a higher risk of other kinds of human-induced mortality, such as electrocution on power lines (e.g., Harris's Hawks [*Parabuteo unicinctus*]; Dawson and Mannan 1995) and persecution.

Although suburban areas can provide significant breeding habitat for species facing habitat loss in more traditional natural and rural settings, suburban areas also are subject to rapid development that may displace even the most tolerant raptor species. The continual conversion of forested areas to lawn and other nonnative vegetation may reduce prey populations to levels inadequate to sustain raptor populations, even if suitable nest sites are available. As urbanization proceeds and habitat deteriorates, fledglings able to disperse long distances from their natal nest may have the best opportunity to locate suitable breeding habitat. Fledglings of species with short natal dispersals may be less likely to find adequate breeding sites, which eventually may result in regional population decline.

We banded nestling Red-shouldered Hawks in southwestern Ohio to examine natal dispersal and determine causes of mortality in this suburban population. For comparison, we obtained band-recovery records from the Bird Banding Lab for nestlings banded in rural areas of northern Ohio. We anticipated that suburban hawks from southwestern Ohio and northern Kentucky have longer natal-dispersal distances than rural hawks because the fragmented-habitat mosaic of the suburbs might result in suitable nesting habitat interspersed among highly-developed, unsuitable space.

STUDY AREA

We banded nestling Red-shouldered Hawks in southwestern Ohio and northern Kentucky (SW OHIO, hereafter), in Hamilton, Clermont, and southwestern Warren Counties, OH, and northern Boone and Kenton Counties, KY, <27 km south of the Ohio-Kentucky border. Most nests at which nestlings were banded occurred in a wide band of suburban development and semirural areas surrounding the city of Cincinnati.

SW 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 rivers, the Great Miami and the Little Miami. Native forests are dominated by second-growth oak-hickory (*Quercus* spp.-*Carya* spp.) and beech-maple (*Fagus grandifolia-Acer saccharum*) associations, with lowland-riparian forests characterized by sycamores (*Platanus occidentalis*) and beech. Suburban areas in SW OHIO varied from densely populated (residential lots ca. 20 × 35 m) to sparsely populated (>2.5-ha residential lots, as well as undeveloped private land). 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. Public land within the study area consisted primarily of native vegetation, with some developed areas for sports and other recreational uses.

METHODS

Banding. Red-shouldered Hawk nestlings in SW OHIO were banded with U.S. Fish and Wildlife Service (USFWS)/ U.S. Geological Survey (USGS) bands between 1955–59, 1963–77, and 1996–2002. Most nestlings banded between May 1998 and June 2002 were also banded with colored-plastic bands (Haggie Engraving, Crumpton, MD U.S.A.) inscribed with individual alpha-numeric codes large enough to be observed from the ground with

binoculars or a spotting scope. Nestlings were banded at ca age 2–5 wk.

Band Recoveries and Encounters. We defined a band recovery as a report of a hawk that had died, and a band encounter as any report of a banded hawk, dead or alive. Most reports were further investigated by contacting the individual who had reported the band.

We also encountered color-marked hawks in the course of other fieldwork. Color bands were read with a spotting scope or binoculars, or the marked bird was captured using a bal-chatri trap baited with a mouse (Bloom 1987). Other banded birds ($N = 2$) encountered by birders were reported directly to the bander. Four banded birds that were injured were brought to RAPTOR, Inc., a local rehabilitation organization. Additional bands recovered in nests or on the ground under nests were not included in this study.

We determined causes of death for recovered birds from USGS Bird Banding Laboratory (BBL) records ("How obtained" codes) or by carcass examination. We determined gender of dead hawks, when possible, by examination ($N = 4$), and gender of live hawks by behavior (i.e., copulation observed) or the presence/absence of a brood patch ($N = 5$).

For comparison, we obtained from the BBL reports of band recoveries and encounters for birds banded at various rural locations in northern Ohio (>40°N latitude) by seven banders. The birds represented were banded from 1940–72.

Data Analyses. Banding locations in SW OHIO were defined by street addresses in most cases ($N = 37$) and plotted on USGS 7.5′ topographic maps. Encounter locations in SW OHIO were defined by street addresses in most cases ($N = 27$) or by the nearest town as indicated on the BBL "Report to the bander" data card ($N = 9$). Specific location data were lacking for some older banding locations ($N = 6$), encounters ($N = 7$), and for all banding and encounter locations in northern Ohio, so we designated these locations as the center of the 10-minute block indicated in BBL records.

To estimate age of hawks at the time of the encounter, we assumed that all nestlings hatched on 23 April, the mean hatch date for SW OHIO 1997–99. We classified encounters into three categories based on age at the time of encounter: <298 d, 298–663 d, and >663 d. Birds <298 d were those encountered before 15 February in the year following the year in which they were banded, and thus, were not breeding birds. We selected 15 February as a cut-off date because by that date most birds in SW OHIO had begun breeding activities, such as territory occupancy and nest-building (Dykstra et al. 2000, 2001a). Birds 298–663 d were those encountered between 15 February of the year following that in which they were banded and the subsequent 15 February, and thus, were in immature plumage and possibly breeding. Birds >663 d were those in mature plumage and were probably breeding birds. We also classified encounters according to the season in which they occurred. We considered 15 February–31 July to be the breeding season (Dykstra et al. 2001b), and 1 August–14 February the nonbreeding season.

Although Red-shouldered Hawks normally begin breeding in their third spring at 2 yr, they may breed first as immature-plumaged yearlings in their second spring (Wiley 1975, Crocoll 1994). Natal dispersal has been defined as the movement from birthplace to the site of the first breeding attempt (Greenwood 1980, Greenwood and Harvey 1982). However, because adult Red-shouldered Hawks in SW OHIO apparently are year-round residents (Dykstra et al. 2001a, 2001b), any bird encountered at age >663 d or older was likely located at or very near its breeding site, regardless of the season. For simplicity, we assumed this location to be the first breeding site. Thus our measure of natal dispersal included all birds >663 d encountered in any season, as well as yearling birds known to be breeders.

Results are shown as mean ± 1 standard error of mean. Because of skewed distributions, the distance from natal nest and age at encounter data were log-transformed before statistical analysis. We used *t*-tests, analysis of variance (ANOVA), and analysis of covariance (ANCOVA) to test for differences in distance from natal nest, and linear regression to examine the relationship between distance from natal nest and age at encounter.

We examined age at recovery using cumulative exponential distribution (CED) following Harmata et al. (2001) and Harmata (2002). Age in years (x) of each recovered hawk from SW OHIO was listed in order from youngest to oldest and the cumulative proportion of recoveries calculated for each. For the purposes of calculation, the proportion of 1.0 was expressed as 0.9999999. We fitted cumulative proportion of recoveries by age to the CED function $y = 1 - e^{bx}$. The predicted proportion of recoveries (y) generated from this function were used in the transformed function $bx = \ln(1 - y)$. The $\ln(1 - y)$ was calculated and regressed with the observed x (with zero intercept) to determine the coefficient (β) of age variable x. We also examined distance from natal nest at time of encounter using CED analysis following Harmata et al. (2001).

RESULTS

Band Encounter Rate and Circumstances of Encounters. Of 899 nestling Red-shouldered Hawks banded in SW OHIO from 1955–2002, 43 (4.8%) were encountered some time after fledging and before January 2004. Of 28 SW OHIO hawks that were recovered, 14 (50%) were simply "found dead," five (18%) were hit by vehicles, four (14%) were electrocuted, two (7%) were found injured and later died, and one each (4%) were caught in a trap, shot, and found as a band with bone or skeleton only. Three other bands were returned; we assumed these hawks were dead and thus included them with the recoveries. Twelve hawks were encountered alive: nine (75%) of these were color-marked birds that we sighted or trapped in 1999–January 2004, one (8%) was hand-caught during a storm and released, one was trapped by a bander, and one was obtained without information.

Table 1. Movements of Red-shouldered Hawks banded as nestlings in southwestern Ohio and northern Ohio, and encountered after fledging.

Banding Region	Age at Encounter	N	Distance from Natal Nest (km)		
			Mean ± 1 SE	Median	Range
Southwestern Ohio	<298 d	14	68.5 ± 36.5	13.7	3.9–500.0
	298–663 d	11	33.6 ± 23.4	8.5	0.0–266.1
	>663 d	18	18.2 ± 5.4	11.8	0.8–103.2
	Total	43	38.5 ± 13.6	12.3	0.0–500.0
Northern Ohio[a]	<298 d	11	38.4 ± 13.6	18.5	0.0–145.3
	298–663 d	2	40.4 ± 17.2	40.4	23.2–57.6
	>663 d	10	92.6 ± 58.7	28.0	0.0–612.9
	Total	23	62.1 ± 26.2	27.9	0.0–612.9

[a] From USGS Bird Banding Laboratory records, banded 1940–72.

Figure 1. Map of long-distance (>100 km) dispersal of Red-shouldered Hawks banded as nestlings in southwestern OH, 1955–2002. Lines join natal sites and encounter locations. All birds shown were recovered dead and four of the five birds shown were <663-d old at recovery.

Distance from Natal Nest. For SW OHIO birds, mean distance from natal nest at time of encounter was 38.5 ± 13.6 km (Table 1). Most birds moved <30 km, but five birds were recovered 103–500 km from their natal nest (Fig. 1). CED analysis of distance from natal nest at time of encounter indicated that 50% of SW OHIO Red-shouldered Hawks were found <15 km from their natal nest, 75% were <29 km away, and 95% were <62 km away ($R^2 = 0.98$, $\beta = -0.048$, $P < 0.001$, $N = 43$; Fig. 2).

Natal dispersal averaged 18.2 ± 4.9 km, $N = 20$ (males 9.3 ± 2.6 km, $N = 4$; females 16.5 ± 4.7 km, $N = 5$, 11 sex undetermined). One bird was recovered 103 km from its natal nest; the other 19 were encountered <30 km from their natal nests ($\bar{x} = 13.7 \pm 2.0$ km).

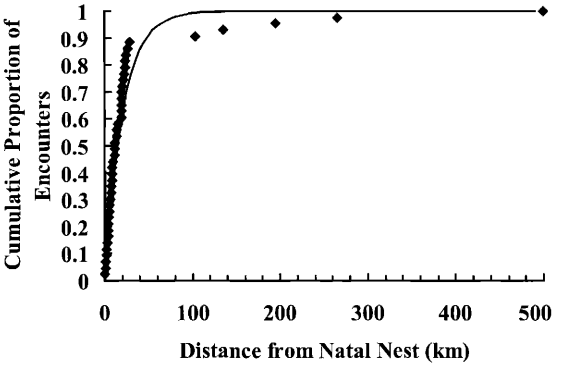

Figure 2. Cumulative exponential distribution of distance from natal area for Red-shouldered Hawks banded as nestlings in southwestern OH and northern KY, 1955–2002.

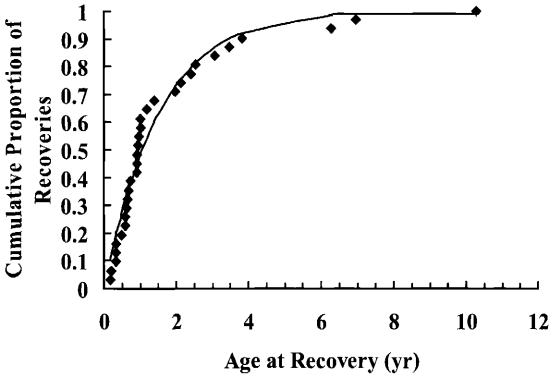

Figure 3. Cumulative exponential distribution of age at recovery for Red-shouldered Hawks banded as nestlings in southwestern OH and northern KY, 1955–2002.

Distance from the natal nest differed between birds recovered dead and those encountered alive (t = 2.455, df = 41, P = 0.018), so the two categories were tested both separately and combined for analyses below; the combined results are presented when there were no differences. Distance from natal nest was not correlated with age at encounter ($P > 0.58$), and did not differ among age classes ($P > 0.18$). Birds encountered during the breeding season were neither nearer nor farther from their natal nests than birds encountered during the nonbreeding season ($P > 0.13$, N = 24 for breeding season, N = 19 for nonbreeding season).

When compared to BBL records for birds banded as nestlings in rural northern Ohio, those banded in SW OHIO moved slightly shorter distances (Table 1), but there were no differences in distance from natal nest for all age classes combined or for birds <298 d or those >663 d ($P > 0.250$; Table 1). Among rural-northern Ohio birds alone, the distance from the natal nest did not differ between birds encountered in the breeding and nonbreeding seasons ($P > 0.583$); however, when adjusted for age class, there was a tendency for birds to be farther from the natal nest during the nonbreeding season than during the breeding season (ANCOVA, age class as covariate, F = 3.719, P = 0.068, R^2 = 0.17, N = 23).

Age at Recovery. Mean age at recovery for Red-shouldered Hawks banded in SW OHIO was 1.9 ± 0.4 yr (N = 31 hawks). CED analysis indicated that 50% of Red-shouldered Hawks were dead by age 1.2 yr, 75% by age 2.4 yr, and 95% by age 5.2 yr (R^2 = 0.96, $P < 0.001$, $\beta = -0.577$; Fig. 3).

SW OHIO birds did not differ from northern Ohio birds in age at recovery (t = 0.038, df = 51, P = 0.97). For northern Ohio birds alone, the mean age at recovery was 2.0 ± 0.4 yr (N = 22). CED analysis indicated that 50% of northern Ohio Red-shouldered Hawks were dead by age 1.1 yr, 75% by age 2.3 yr, and 95% by age 4.9 yr (R^2 = 0.93, $P < 0.001$, $\beta = -0.607$, N = 22).

DISCUSSION

Dispersal from the Natal Nest. Mean dispersal distance was 38.5 km, with 50% of the hawks found <15 km from their natal nest. Natal-dispersal distance, the distance from birthplace to a breeding site, was 18.2 ± 4.9 km. Similarly, Red-shouldered Hawks in other parts of their breeding range also have short natal-dispersal distances. In Wisconsin, 11 banded nestlings that were recaptured as breeding birds had dispersed a mean of 17 km from their natal site (Jacobs and Jacobs 2002). Jacobs and Jacobs (2002) also determined from BBL data that >54% of 99 eastern Red-shouldered Hawks recovered in the breeding season were <30 km from their natal site.

In our study, birds encountered while alive, primarily color-banded birds we sighted or captured, had significantly shorter dispersal distances than those recovered dead. The inclusion of birds encountered alive may have caused the mean dispersal distance to be underestimated because we did not search for color-marked birds outside the study area. Also, birds were more likely to be encountered within the heavily-populated suburban region surrounding Cincinnati than in rural regions outside the study area. Underestimation of dispersal distance is not uncommon in dispersal studies because long-distance dispersers are less likely to be detected than short-distance dispersers (Koenig et al. 1996). Nonetheless, within the study area, we believe that local-dispersal distances were likely correct because, despite ca. equal effort in banding and trapping throughout the study area, we found only two birds that moved as far as the distance from the west side of the study area to the east side, a span of 30–50 km.

We anticipated that young birds <663 d might be encountered farther from their natal nest than those of breeding age (>663-d old), because young raptors of some species tend to move far from the natal nest after they gain independence and before they begin breeding (Walls and Kenward 1998, Forero et al. 2002, Byholm et al. 2003).

Although we did not find significant differences in encounter distance for birds of different ages, we did note that four of the five birds found at long distances from their natal nest were <2-yr old, suggesting that young Red-shouldered Hawks might also wander.

Although not significant statistically, mean dispersal distance for SW OHIO was slightly smaller than for rural northern Ohio hawks (Table 1). This difference might reflect true differences between suburban and rural birds, or it may have resulted from an ecological difference between the two populations. Our age-adjusted analysis indicated that northern Ohio birds encountered in the nonbreeding season tended to be farther from their natal nest than those encountered in the breeding season, suggesting that some northern birds migrate. A more comparable rural population that is likely nonmigratory is located in southeastern Ohio; in this population, we banded 217 nestlings from 1997–2002, but recovered only two bands (0.9%, C. Dykstra and J. Hays unpubl. data).

Mortality. Most mortality for Red-shouldered Hawks in SW OHIO occurred within the first 14 mo of life, as it did for northern Ohio birds. Henny (1972) examined band-recovery data for Red-shouldered Hawks in six regions of North America and determined mortality rate for the first year of life to be 0.58. High first-year mortality is typical of raptors (Newton 1979). The oldest Red-shouldered Hawk recovered in this study was over 10 yr 3 mo old, but Jacobs and Jacobs (2002) report several hawks that were at least 10–14 yr old and one 17 yr old. The oldest wild Red-shouldered Hawk recorded was 19 yr 11 mo (Clapp et al. 1982).

Most SW OHIO hawks died of unknown causes, but of those for whom cause of death was known, 38% were killed by motor vehicles and an additional 31% by electrocution on power lines or electric fences. Although sample sizes are small, these data suggest that interactions with humans and human-made structures may be an important agent of mortality for urban/suburban raptors. Similarly, for urban Harris's Hawks in Tucson, at least 72% of mortality in which cause could be determined was due to electrocution (Dawson and Mannan 1995). Among midwestern Peregrine Falcons, a primarily urban population, 81% of injured falcons admitted to the Raptor Center at University of Minnesota had sustained injuries from collisions with vehicles, buildings or utility lines (Sweeney et al. 1997). Mortality of urban adult Lesser Kestrels (*Falco naumanni*) in southern Spain was ascribed to collision with vehicles (13% of mortalities with known cause), persecution by humans (25%), electrocution (8%), and entanglement in safety nets erected for building restoration work (21%), for a total of 67% of mortality due to interaction with humans (Tella et al. 1996). In contrast, in a species with a typically rural distribution, Red-tailed Hawks (*Buteo jamaicensis*), only 32% of mortalities with known causes were due to collisions with vehicles, electrocution, and gunshot wounds, while the majority were due to poisonings by agricultural pesticides (19%), emaciation (25%), and disease (16%; Franson et al. 1996).

Dispersal and Urbanization. The short natal-dispersal distances for Red-shouldered Hawks, combined with the increasing urbanization of the Cincinnati area and its suburbs, may make it increasingly difficult for young Red-shouldered Hawks fledged in SW OHIO to find suitable breeding habitat. Currently, this suburban population does not appear to be compromised in any way. Compared to more rural populations in Ohio and elsewhere, the SW OHIO birds reproduced well at a fairly high nest density, found suitable nest sites (Dykstra et al. 2000), and maintained home ranges that were typical in size for Red-shouldered Hawks (Dykstra et al. 2001b), although they were less forested than those measured elsewhere (Howell and Chapman 1997). However, anecdotal evidence suggests that hawks may be losing nesting habitat as urbanization proceeds: in a sample of 22 nesting territories, where hawks were banded in 1963–77, only 10 of them still contained nesting hawks by 1997–98 (Dykstra et al. 2000).

Red-shouldered Hawks of SW OHIO may be able to maintain their population if they are able to further adapt to humans and suburban landscapes. Red-shouldered Hawks in southern California may be even more adjusted to urban conditions than those in Ohio; nesting urban birds there tolerated large crowds attending athletic events as well as people camping directly underneath their nest trees (Bloom and McCrary 1996). A few individual hawks in SW OHIO may be similarly tolerant, as evidenced by the two nests located on rooftops and one located on a suburban deck (Hays 2000, Dykstra et al. 2001b). In summary, the suburban Red-shouldered Hawk population of SW OHIO is apparently well-adapted to humans, although it remains uncertain whether these suburban birds

will be able to maintain their numbers in the face of further urbanization and suburban sprawl.

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