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BEHAVIOR AND PREY OF NESTING RED-SHOULDERED HAWKS IN SOUTHWESTERN 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 Rd., Cincinnati, OH 45231 U.S.A.

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

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

ABSTRACT.—We used direct observations to quantify prey types, prey delivery rate, and adult and nestling behavior at nests of Red-shouldered Hawks (*Buteo lineatus*) in suburban southwestern Ohio. Twenty-one nests were observed for 256 hr in 1997–2001. Small mammals made up the largest percentage of the identified prey (31.5%), followed by reptiles (22.7%), invertebrates (18.8%), amphibians (17.7%), birds (6.9%), and fish (2.5%). Season-long prey delivery rate averaged 3.4 ± 0.6 prey items delivered per 4-hr observation period, or 116 ± 19 g biomass delivered per 4-hr observation period. Weekly prey delivery rate showed no correlation with the age of the nestlings ($P > 0.05$). Adult attendance at the nest and time adults spent brooding nestlings both were negatively correlated with nestling age ($P < 0.05$). Time adults spent feeding nestlings was negatively correlated with nestling age ($R^2 = 0.92$, $P = 0.002$), while time nestlings spent feeding themselves was positively correlated with nestling age ($R^2 = 0.92$, $P = 0.003$). These data may serve as a baseline for assessing prey delivery rates and behavior of populations of Red-shouldered Hawks throughout the lower Midwest.

KEY WORDS: *Red-shouldered Hawk*; Buteo lineatus; *behavior*; *diet*; *prey*; *raptor*.

CONDUCTA Y PRESAS DEL GAVILAN DE HOMBROS ROJOS DURANTE SU ANIDACIÓN EN EL DEL SUROESTE DE OHIO

RESUMEN.—Utilizamos observaciones directas para cuantificar las presas, su tasa de entrega y la conducta de adultos y polluelos en nidos de gavilanes de hombros rojos (*Buteo lineatus*) en las localidades suburbanas del suroeste de Ohio. Se observaron veintiún nidos durante 256 horas entre 1997–2001. El porcentaje más grande de presas identificadas estuvo representado por mamíferos pequeños (31.5%), seguido por reptiles (22.7%), invertebrados (18.8%), anfibios (17.7%), otros pájaros (6.9%) y peces (2.5%). El promedio de la tasa de entrega de presas a lo largo de la temporada fue 3.4 ± 0.6 ítems de presa entregados en un período de 4 horas de observación, o 116 ± 19 g de biomasa entregada, en un período de 4 horas de observación. La tasa semanal de entrega de presa no mostró correlación con la edad del polluelo ($P > 0.05$). La asistencia de los adultos en el nido y el tiempo empleado por los adultos empollando, estuvieron correlacionados negativamente con la edad del polluelo ($P < 0.05$). El

[1] Present address: 7715 Mitchell Park Dr., Cleves, OH 45002 U.S.A.; e-mail address: cheryldykstra@juno.com

tiempo que los adultos emplearon alimentando al polluelo tuvo una correlación negativa con la edad del polluelo (R^2 = 0.92, P = 0.002), mientras que el tiempo que gastaron los polluelos alimentándose a si mismos tuvo una correlación positiva con su edad (R^2 = 0.92, P = 0.003). Estos datos pueden servir como una base para valorar las tasas de entrega de presa y la conducta de poblaciones de gavilanes de hombros rojos a través del Medio Oeste bajo.

[Traducción de César Márquez]

The diet of Red-shouldered Hawks (*Buteo lineatus*) has been documented in several locations using either observational data or prey remains in pellets or nests (Craighead and Craighead 1956, Portnoy and Dodge 1979, Bednarz and Dinsmore 1985, Howell and Chapman 1998), but only a few researchers have attempted to measure prey delivery rate by adult Red-shouldered Hawks to nestlings (Snyder and Wiley 1976, Portnoy and Dodge 1979, Penak 1982), and only one study has quantified and reported other behaviors of adults and nestlings during the breeding season (Portnoy and Dodge 1979).

Quantitative information on food delivery rates and adult and nestling behaviors is of particular interest because productivity may be related to prey delivery rate. Prey delivery rates are usually indicative of prey availability in the environment (Newton 1979, Collopy 1984) and food supply is generally the most significant factor determining breeding rates for raptors (Newton 1979). Adult and nestling behavior also may be influenced by prey availability, in that time spent foraging is a function of prey availability, and nestling growth and development may be related to food provisioning rate (Dykstra 1995).

Because of its restricted distribution due to habitat loss within the state of Ohio, the Red-shouldered Hawk is currently a "Species of Special Interest" in the state (Ohio Department of Natural Resources pers. comm.) and is similarly classified in other midwestern and eastern states (Titus et al. 1989, Castrale 1991). Prey delivery rates and other behavioral data for the Red-shouldered Hawk may be useful in evaluating the viability and conservation status of this species, particularly if they can be used as indicators of the adequacy of prey availability within an environment.

Our objectives were to quantify the prey delivery rate and other behaviors of adult and nestling Red-shouldered Hawks in southwestern Ohio from hatching through fledging. This information may be useful for comparison to other populations in the lower Midwest and other parts of the breeding range.

STUDY AREA AND METHODS

Study Area. The study area in 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 rivers, the Great Miami River and the Little Miami River. 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. Elevation ranges from ca. 140–270 m.

The study area consisted of Hamilton County, Clermont County, and southwestern Warren County, Ohio, however, the nests studied were actually located in a wide band of suburban development surrounding the city of Cincinnati, Ohio. Suburban areas 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. Areas of public land within the study area contained no residences, but were heavily used for sports and other recreation.

Nests and Nest Selection. Nests in this study were selected from those known from a larger study of suburban Red-shouldered Hawk productivity and nest site selection (Dykstra et al. 2000a). We selected nests based on their visibility from a suitable blind location and their accessibility. Nests were selected for study after nestlings had hatched. We studied six nests in 1997, six nests in 1998, five nests in 1999, four nests in 2001 (Table 1). We observed for two or three breeding seasons at some nests (or at alternate nests within the same territory): two territories were each monitored in two years and two were each monitored in three years. Thus, we studied a total of 15 independent territories (Table 1); of these, five were located within or very near (225 m away, N = 1) the floodplain of the Little Miami River, and 10 were in upland locations, primarily near small streams. Observed nests were built primarily in sycamores (N = 12; 67%), but also in red oak (*Quercus rubra*; N = 2), white ash (*Fraxinus americana*; N = 1), sugar maple (*Acer saccharum*; N = 1), and common locust, (*Robinia pseudoacacia*; N = 1), and one nest was built on the roof of a three-story apartment building in a busy complex of such buildings (Hays 2000, Dykstra et al. 2001a). Mean height of the nests was 15.2 ± 0.8 m above the ground (N = 17 measured nests).

Nest Observations. At most sites, nests were observed from blinds made of camouflage-colored canvas and native plant materials, erected 31–85 m ($\bar{x}$ = 49 m) from the nests (N = 12). At other nests, we used temporary

Table 1. Observation schedules and reproduction at Red-shouldered Hawk nests studied 1997 to 2001.

NEST NAME	YEAR	NUMBER OF 4-hr OBSERVATION BLOCKS	AGE OBSERVED (wk)	BROOD SIZE[a]	NUMBER OF YOUNG FLEDGED
Birch Rail Run	1999	4	2–6	2	2
Cones	1998	2	4	3	0
Fields-ertel	1997	4	2–6	2	2
Gaines	2001	2	6	2	2
Lake Bern	1999	4	2–5	4	3
Mapleknoll	2001	2	4	2	2
Maryknoll	1997	2	2–3	2	0
Nisbet	1997	4	2–6	3	3
Nisbet	1998	4	3–6	3	3
Nisbet	1999	4	1–5	3	3
North Wesselman	2001	3	2–6	4	4
Pineview	1998	3	1–6	3	3
Pineview	1999	3	1–4	3	3
Roof	1998	3	2–4	4	4
Sheed	1997	2	5–6	4	4
Sheed	1998	4	2–6	3	3
Sheed	1999	4	1–5	3	3
Tanager Hills	1997	2	1–2	4	0
Twin Willow	2001	1	5	2	2
Woodsong	1997	3	1–4	3	0
Woodsong	1998	4	1–5	1[b]	1

[a] Brood size during most observation periods. Brood size during wk 1 may have been smaller if not all chicks had hatched, or, possibly, larger.
[b] Brood size during wk 1 was 2 or 3 young.

blinds created from patio furniture ($N = 3$) or sat inside a vehicle parked on a driveway ($N = 4$). At two nests where birds were very accustomed to humans, no blinds were used. Where possible, we placed blinds upslope from the nests, improving the view of nest contents. We conducted observations during the brood-rearing periods, between 1 May and 3 June 1997, 27 April and 1 June 1998, 27 April and 5 June 1999, and 4 May and 10 June 2001. Each observation period lasted 4 hr; "morning" observations were conducted between 0700 and 1300 H ($N = 35$), "afternoon" observations were conducted between 1130 and 1800 H ($N = 28$), and a single observation was conducted 1000–1400. We observed most nests ($N = 14$) 3–4 times, approximately once per wk from the time of hatching until the first nestling fledged. Because three nests failed partway through the nestling period, we were unable to complete studies on them, and we added four nests partway through the season; these nests were observed 1–2 times each ($N = 7$; Table 1). We chose to observe fewer times at many nests rather than make intensive studies of a few nests in order to minimize the influence that individual birds/pairs might have on the behavior data.

We monitored and recorded behaviors of nestlings and adults, with the time of occurrence and duration (nearest min). The specific behaviors quantified were: adult attendance at the nest, adult prey delivery to nest, adult feeding nestlings, adult brooding nestlings, and nestlings feeding themselves. We defined adult attendance at the nest as the total amount of time at least one adult was present in the nest itself. Adult feeding nestlings included all the time an adult fed one or more nestlings and all the time an adult fed itself and nestlings. Brooding behavior was defined as an adult covering 50% or more of the total number of nestlings. Nestlings feeding themselves included all time that 50% or more of the nestlings in the brood were feeding themselves.

We recorded prey deliveries by adults to the nestlings. We attempted to identify the taxonomic class and the size of each prey item. Prey were categorized into one of eight classes: amphibian, reptile, fish, bird, mammal, insect, crustacean, or oligochaete. Further identification to species or species-group was recorded if possible. Prey were also categorized to one of four size-classes: 0–15 cm, 16–30 cm, 31–46 cm, >46 cm; smaller size categories were recorded when possible.

Hatch date was estimated by back-calculating from the approximate age at banding, based on secondary length (Penak 1982), or by observation of adult behavior. The date of hatch of the oldest nestling was used when assigning nestling ages for data analyses. We defined Day 1 as hatch date and Week 1 as 1–7 d post-hatch.

Data Summary and Analyses. Total minutes spent in brooding, feeding, and adult presence at the nest were tallied, and reported as a percent of total time observed (240 min/session). Adult and nestling behaviors were reported as a function of approximate nestling age in weeks. At five nests, we observed twice within a single week of nestling age; behavioral data at these sites were averaged to provide a single mean value for each week. Multiple years of data from territories observed in more than one year were considered to be independent for purposes of data analyses. We observed a total of 256 hr, 64 4-hr sessions.

We tallied the prey delivery rate at each nest each week (prey deliveries/nest/4-hr observation period), and pooled study nests by nestling age for a study-wide weekly prey delivery rate. We also calculated a season-long mean prey delivery rate for each nest.

Records of prey type and size were combined for all nests and all years. In addition, we included data on prey deliveries recorded during shorter observation periods (1–3.5 hr) totaling 44 hr, at eight nests 1998–2001. (Other behavioral data from these shorter observations were not included in the above analyses). Biomasses of prey items were estimated based on published data on Red-shouldered Hawk diet (Craighead and Craighead 1956, Howell and Chapman 1998) and other measures of prey item masses (Hiles and Jones 1941, Mohr 1947, Steenhof 1983, Jayne and Bennett 1990, Sibley 2000), as well as field measurements on prey items captured within the study area (C. Dykstra and J. Hays, unpubl. data). When the species of a prey item was unknown, but the genus or genus and size were known (e.g., *Microtus* vole, medium *Rana* frog), we used the mass of an appropriate species known to be present in the study area. For calculation of biomass-delivery rates, unidentified prey of the 0–15 cm size ($N = 20$) were assigned the mean mass for all identified prey size 0–15 cm (28 g), unidentified prey of the size 16–30 cm ($N = 2$) were assigned the mean mass for identified prey of size 16–30 cm (52 g), and unidentified prey of unknown size class ($N = 24$) were assigned the overall mean mass for all known prey items (36 g). Distributions of prey-size classes for identified and unidentified prey did not differ (Pearson Chi-square, $P >$ 0 05).

Nestling and adult behaviors, including prey delivery rates, were reported as a function of nestling age (wk). Weekly values for each behavior at each nest were log-transformed to account for non-normality, then averaged to produce a study-wide weekly mean value. Study-wide weekly values were compared to nestling age using linear regression.

Season-long mean prey delivery rates, calculated in both numbers of prey items and estimated biomass, were log-transformed and compared to brood size using linear regression. Taxonomic classes of prey delivered at riparian zone nests and upland nests were compared using a Chi-square test for independent distribution; we combined prey items in classes Crustacea, Insecta, and Oligochaeta into the category "invertebrates," because the numbers of items in some of these classes were very small. When distribution of prey types differed, we used Bonferroni *Z*-test to examine which prey types were delivered more or less often than expected at the two habitats: flood plains or upland (Neu et al. 1974, Byers et al. 1984).

Results are presented as mean ± SE. All statistical tests were conducted using SYSTAT (Wilkinson 1988) and were considered significant at the $P < 0.05$ level.

RESULTS

Reproductive Rate. Red-shouldered Hawks at observed nests had reproductive rates of 2.2 ± 0.3 young per nest where eggs hatched ($N = 21$; Table 1) and 2.8 ± 0.2 young/successful nest ($N = 17$), which was similar to the rate we measured for the entire study area (2.7 ± 0.2 young per successful nest, 1997–99, Dykstra et al. 2000a).

Prey Deliveries. There was no difference in the number of prey items or estimated biomass delivered in morning observations and in afternoon observations (number of items: $t = 0.73$, df = 61, $P = 0.47$; estimated biomass: $t = 0.10$, df = 61, $P = 0.92$), so data from both observation periods were combined for analyses below. Sample sizes were insufficient to test for differences between years, so data from all observation years were combined. Weekly prey delivery rate showed no correlation to the age of the nestlings (number of prey items, $R^2 = 0.27$, $P = 0.29$, $N = 6$ wk, and estimated biomass, $R^2 = 0.23$, $P = 0.34$, $N = 6$ wk; Fig. 1). Season-long prey delivery rate averaged 3.4 ± 0.6 prey items delivered per 4-hr observation period, or 116 ± 19 g biomass delivered per 4-hr observation period ($N = 21$ nests). Season-long prey delivery rate was weakly correlated to brood size when delivery rate was measured as number of prey items ($R^2 = 0.14$, one-tailed $P = 0.048$, $N = 21$; Fig. 2); however, the relationship was dependent on one datum (which included an unusual day when 21 items, mostly earthworms, were delivered in 4 hr) and was not significant when that datum was removed ($R^2 = 0.07$, one-tailed $P = 0.14$, $N = 20$). Season-long prey delivery rate was not correlated to brood size when delivery rate was measured as estimated biomass ($R^2 = 0.07$, one-tailed $P = 0.13$, $N = 21$).

Eighty-two percent of all prey items delivered were identified to taxonomic class (203 of 249 deliveries). Small mammals (Class Mammalia) made up the largest percentage of the identified prey, in terms of numbers of items and biomass (Table 2) Thirty-two percent (65 of 203 deliveries) of identified prey items were further classified to species or genus (Table 2).

The types of prey items delivered to riparian nests differed significantly from those delivered to upland nests ($\chi^2 = 22.04$, df = 5, $P = 0.001$). Specifically, riparian nests received fewer invertebrates

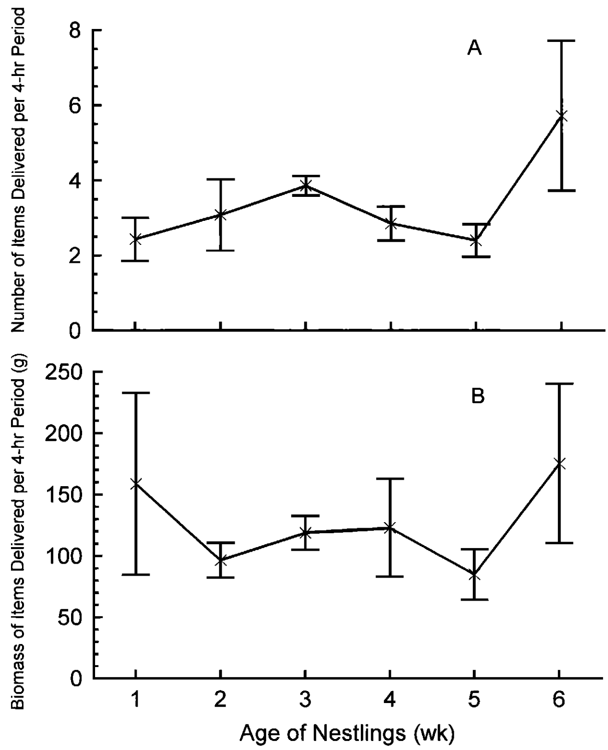

Figure 1. Prey delivery rate to nests by adult Red-shouldered Hawks as a function of nestling age. (A) Prey delivery rate measured as the number of items delivered per 4-hr observation period. (B) Prey delivery rate measured as the estimated biomass of prey delivered per 4-hr observation period. Mean ± SE.

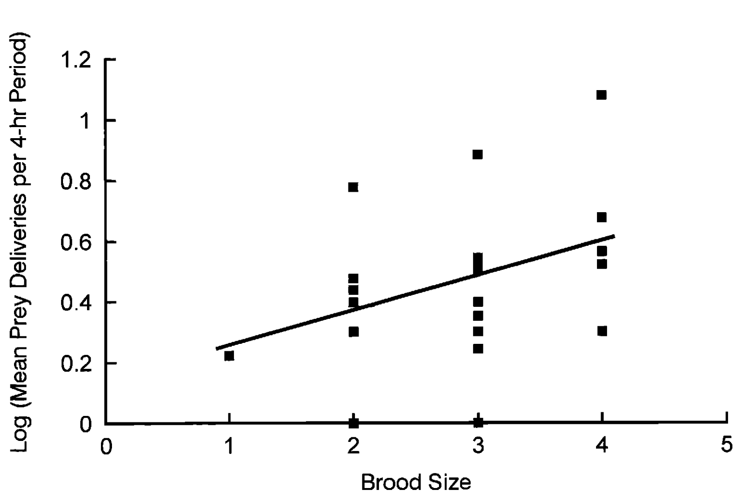

Figure 2. Prey delivery rate by adult Red-shouldered Hawks as a function of brood size. Each point represents the mean season-long prey delivery rate for a single nest. Prey delivery rate was weakly correlated with brood size (R^2 = 0.14, one-tailed P = 0.048, but see text for details).

Table 2. Prey items delivered to Red-shouldered Hawk nests in southwestern Ohio and identified to taxonomic class or species, 1997 to 2001.

PREY TYPES	NUMBER IDENTIFIED TO SPECIES OR GENUS	NUMBER IDENTIFIED TO CLASS (%)[a]	BIOMASS OF PREY IDENTIFIED TO CLASS IN g (%)[b]
Class Mammalia		64 (31.5)	4084 (55.9)
Vole (*Microtus* spp.)	12		
Mice (*Peromyscus* spp.)	4		
Chipmunk (*Tamias striatus*)	5		
Eastern gray squirrel (*Sciurus carolinensis*)	4		
Eastern mole (*Scalopus aquaticus*)	1		
Eastern cottontail (*Sylvilagus floridanus*)	1		
Class Reptilia[c]		46 (22.7)	549 (7.5)
Garter snake (*Thamnophis sirtalis*)	4		
Class Amphibia		36 (17.7)	1731 (23.7)
Bullfrog (*Rana catesbeiana*)	4		
Other frogs (*Rana* spp.)	29		
Class Aves		14 (6.9)	506 (6.9)
Class Osteichthyes		5 (2.5)	253 (3.4)
Yellow perch (*Perca flavescens*)	1		
Class Oligochaeta[d]		32 (15.8)	160 (2.2)
Class Crustacea[e]		4 (2.0)	28 (0.4)
Class Insecta		2 (1.0)	2 (<0.1)
Total	65	203	7313

[a] Percent of 203 total prey items that were identified to class.
[b] Percent of 7313 total g of prey items that were identified to class.
[c] Prey consisted entirely of snakes.
[d] Prey consisted entirely of unidentified earthworms.
[e] Prey consisted entirely of unidentified crayfish.

than expected, based on the overall distribution of prey types.

Adult Behavior. Adult attendance at the nest was negatively related to nestling age ($R^2 = 0.96$, $P = 0.001$, $N = 6$ wk; Fig. 3A). Similarly, time adults spent brooding nestlings declined significantly as nestlings aged ($R^2 = 0.94$, $P = 0.001$, $N = 6$ wk; Fig. 3B). Time adults spent feeding nestlings also was negatively correlated with nestling age ($R^2 = 0.92$, $P = 0.002$, $N = 6$ wk; Fig. 4).

Nestling Behavior. Time nestlings spent feeding themselves was positively correlated with nestling age ($R^2 = 0.92$, $P = 0.003$, $N = 6$ wk; Fig. 4), but time nestlings spent at all feeding behaviors (being fed and feeding themselves) did not vary as nestlings grew ($R^2 = 0.07$, $P = 0.61$, $N = 6$ wk).

DISCUSSION

Prey Types. Diet of eastern Red-shouldered Hawks (*B. l. lineatus*) has been documented in several locations using either observational data or prey remains in pellets or nests (Craighead and Craighead 1956, Portnoy and Dodge 1979, Bednarz and Dinsmore 1985, others). For Red-shouldered Hawks, observational data provide a more accurate and quantitative description of diet than prey remains in pellets, due to the prevalence in the diet of highly-digestible amphibians, which frequently are under-represented in pellets or nest remains (Portnoy and Dodge 1979, Bednarz and Dinsmore 1985, Welch 1987). Diet of Red-shouldered Hawks varies widely from location to location, and from year to year at the same location (Bednarz and Dinsmore 1985), underscoring the ability of this species to adapt to available conditions. In published studies, mammals comprised 17–72% of nesting Red-shouldered Hawks' diet (by number of prey items), amphibians 12–46%, reptiles 3–24%, birds 0–8%, fish 0–3%, and inverte-

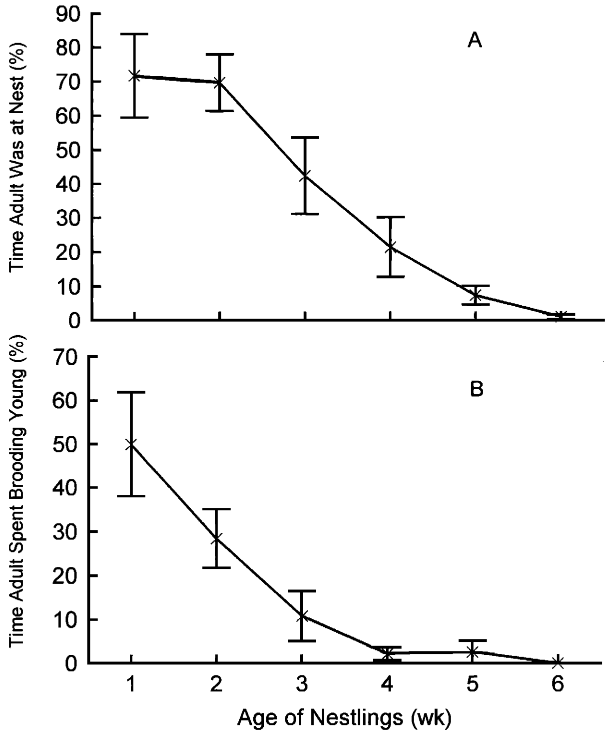

Figure 3. (A) Adult attendance at nests of Red-shouldered Hawks as a function of nestling age. Adult attendance was negatively related with nestling age (R^2 = 0.96, P = 0.001). (B) Brooding behavior of adult Red-shouldered Hawks as a function of nestling age. Time adults spent brooding nestlings declined significantly as nestlings aged (R^2 = 0.94, P = 0.001). Mean ± SE.

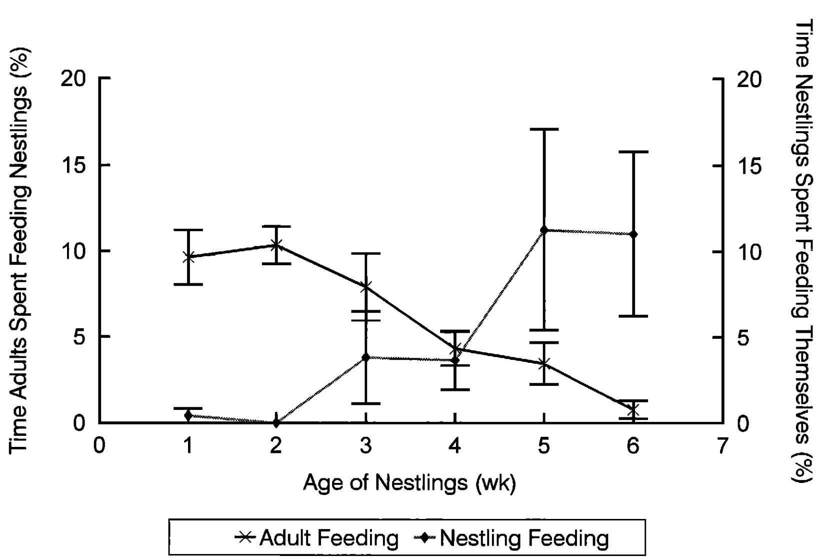

Figure 4. Feeding behavior of adult and nestling Red-shouldered Hawks as a function of nestling age. Time adults spent feeding nestlings was negatively related with nestling age (R^2 = 0.92, P = 0.002) and time nestlings spent feeding themselves was positively related with nestling age (R^2 = 0.92, P = 0.003). Mean ± SE.

brates 0–26% (observational studies only: Portnoy and Dodge 1979, Penak 1982, Bednarz and Dinsmore 1985, Parker 1986, Welch 1987, Howell and Chapman 1998, this study). The abundance of aquatic prey in the Red-shouldered Hawk diet can be as high as 60% of the diet (Howell and Chapman 1998), a factor that is likely related to the preference of this species for nesting near wetlands, ponds or streams (Woodrey 1986, Bosakowski et al. 1992, Moorman and Chapman 1996, Dykstra et al. 2000a, 2001b). The hawks we observed in southwestern Ohio delivered more mammalian prey and fewer aquatic prey items than those observed in bottomland forests further south in Missouri and Georgia (Parker 1986, Howell and Chapman 1998). This is likely due to the primarily upland nature of our study site; even birds nesting in the floodplain of the Little Miami River had access to only a narrow corridor (150–300 m) of river and bottomland forest, surrounded by slopes and upland habitats. The only difference in diet between upland sites and floodplain sites, fewer earthworms delivered at floodplain sites, was probably due to the paucity of suburban development within the floodplain itself. We observed that earthworms were delivered in rapid succession (10 worms in 61 min at one nest, 10 worms in 70 min at another nest) at nest sites in lawns or adjacent to lawns, following a rain.

Prey species observed and identified were generally similar to those reported in other studies of Red-shouldered Hawks, consisting primarily of voles and mice, garter and other snakes, and *Rana* frogs, with a few exceptions. On one occasion, an adult delivered a small nest containing two unidentified passerine nestlings, which were removed individually from the nest materials and eaten by a nestling; delivery of nests containing nestlings has been reported for Swallow-tailed Kites (*Elanoides forficatus*; Coulson 2001), but not for Red-shouldered Hawks, to our knowledge. Unusual prey species found as prey or prey remains in nests (visited in a related study) included Eastern Screech-Owl (*Otus asio*) and southern flying squirrel (*Glaucomys volans*). We also observed Red-shouldered Hawks feeding on an unidentified road kill within the study area, and on the carcass of a deer (*Odocoileus virginianus*) lying beside a road in the Hocking Hills region of south-central Ohio, about 180 km east of Cincinnati.

Prey Delivery Rate. It was unclear whether Red-shouldered Hawk food delivery rates increased with increasing brood size in this study. Although the number of prey deliveries per 4-hr was weakly correlated with brood size, the estimated biomass of those deliveries was not. These data should be interpreted with caution, because our study design was such that each nest was observed for a limited amount of time (3–4 4-hr periods at most nests; Table 1), so the mean (season-long) prey delivery rate at each nest had a fair amount of variance.

The mean 4-hr prey delivery rate for all Red-shouldered Hawk nests, 3.4 prey items per 4-hr or 116 g biomass per 4-hr, was somewhat higher than that measured in 220 hr of observation at eight nests in southwestern Quebec, 2.5 items per 4-hr or 91.1 g per 4-hr for broods of 1–4 nestlings (Penak 1982). However, hawks in southwestern Quebec were nesting at the northern limit of their range and had low nesting success (only 13% of the pairs observed fledged all the young that hatched; Penak 1982), so it is possible that these feeding rates were suboptimal.

The 4-hr prey delivery rates we documented also may be used to estimate prey delivery rates/d (14–15 hr daylight). Because we detected no difference between morning and afternoon delivery rates, the mean 4-hr rate is likely representative of all hours we observed, 0700–1800 H. However, prey delivery rates were likely lower in very early morning and in the evening (Portnoy and Dodge 1979), so we estimated that daily prey delivery rates were approximately three times our measured 4-hr rates, or 10.2 items per d and 348 g biomass/d. This was slightly higher than rates measured at two California nests each containing two nestlings, 19.6 g/hr or about 294 g/d (Snyder and Wiley 1976). As a caveat, we note that we were unable to identify or even classify to size a small number (10%) of the prey deliveries we observed, so our estimation of prey biomass was not exact and may be biased in some way.

Prey delivery rate to nestlings may be an indicator of the adequacy of the prey base (Newton 1979), an important component of habitat quality for raptors. Individual raptors or populations of raptors living in marginal habitat with low prey availability may have lower prey delivery rates to their nestlings, which can result in nestling mortality and, hence, lower adult productivity (Dykstra et al. 1998). Lower prey delivery rates also may result from aberrant parental behavior due to contamination of the adults by toxins, such as organochlorines (Fox et al. 1978, McArthur et al. 1983, Kubiak et al. 1989). Thus, lower prey delivery rates may be an early indicator of subtle problems in a population or its environment.

However, it is important to have baseline information on prey delivery rates from a productive population in order to make any assessments of other populations. In the absence of other data, nesting behaviors alone cannot indicate whether a population is viable, but we have investigated several other aspects of the ecology of Red-shouldered Hawks in southwestern Ohio. Despite their somewhat atypical suburban habitat, the population does not appear to be compromised in any way that we have measured. Compared to more rural populations in south-central Ohio and elsewhere, the suburban birds reproduce at relatively high, consistent rates (Dykstra et al. 2000a, 2000b), nest at a high nest density (Dykstra et al. 2000a), choose suitable nest sites similar to those in rural areas (Dykstra et al. 2000a), and inhabit home ranges that are typical in size for Red-shouldered Hawks, although they are less forested than those measured elsewhere (Howell and Chapman 1997, Dykstra et al. 2001a). Unfortunately, we have only limited data on some aspects of population dynamics such as post-fledging survival and long-term population stability. Preliminary analysis of post-fledging survival using banding data indicated that about 50% of the fledglings survived the first year (C. Dykstra, J. Hays, and M. Simon, unpubl. data), which was similar to the survival rate determined by Henny (1972) using banding data. However, in the long term, the population may be decreasing; anecdotal data suggest that the suburban birds of southwestern Ohio may have lost nesting habitat in the past 20–30 yr, as urbanization has proceeded (Dykstra et al. 2000a). Thus, with the exception of long-term population stability, which is unknown, most evidence suggests that the Red-shouldered Hawks in the southwestern Ohio study area probably comprise a productive population inhabiting a suitable environment at this time and, hence, data from this population may serve as a baseline for evaluating prey delivery rates and nesting behaviors of other populations throughout the Midwest and elsewhere.

Other Behaviors. The nestling period of Red-shouldered Hawks may be divided into three distinct behavioral stages (Newton 1979), as evidenced by our behavior data (Figs. 3 and 4). In the early nestling stage, wk 1 and 2 after hatch, adults were present in the nest ca. 70% of the day, and much of that time was spent brooding, particularly in wk 1. Nestlings were inactive, and unable to feed themselves; feeding was done by the adults and comprised about 10% of the day. In the middle nestling stage, wk 3 and 4 after hatch, behaviors were transitional. Adult attendance declined rapidly, as did brooding, which had nearly ceased by wk 4. There was no change in the overall amount of time spent feeding, but the time adults fed nestlings declined to 4–8% of the day, and nestlings fed themselves for 4% of the day. In the late nestling stage, wk 5 and 6 after hatch, brooding had ceased and adults were present in the nest primarily to deliver food. Nestlings were active and fed themselves most of the time, on average about 11% of the day.

Behaviors measured in our study were quite similar to those documented in central Massachusetts using a time-lapse movie camera in 1974. In that study, adult attendance rates were >80% in wk 1, then declined rapidly to <5% by the end of wk 3 (Portnoy and Dodge 1979); this was consistent with our study except that southwestern Ohio birds still attended the nest 42% of the day during wk 3 and 21% during wk 4.

Time adults spent feeding nestlings and nestlings spent feeding themselves in the Massachusetts study also were similar to those recorded in this study. In wk 1 and 2, adults fed chicks for ca. 7% of the day (estimated from graphical data, Portnoy and Dodge 1979), compared to 10% of the day in southwestern Ohio. In wk 3 and 4, Massachusetts nestlings fed themselves for about 6% of the day while adults fed them for only 4% of the day (Portnoy and Dodge 1979), compared to 4% for self-feeding and 6% for adult-feeding in southwestern Ohio. In wk 5 and 6, nestlings at both locations fed themselves for about 11% of the day (Portnoy and Dodge 1979, this study). It is not known whether the slightly higher rates of adult attendance and adult-feeding in wk 3 and 4 recorded in southwestern Ohio were statistically significantly different from those in Massachusetts, or, if so, whether they represent real behavioral differences or are artifacts caused by differences in study designs (e.g., camera vs. direct observation, number of hours and times of day recorded).

Summary. Aberrant food delivery rates or other nesting behaviors may be an early indicator of subtle problems in a raptor population or its environment. Measurements of prey delivery rates and nesting behaviors, as well as measurements of productivity, can be used to compare data from marginal populations to benchmark data from a healthy population. We measured prey delivery rates and other nesting behaviors in an apparently productive population of suburban Red-shouldered Hawks inhabiting a suitable environment in southwestern Ohio. These data may serve as a baseline for evaluating behaviors of other populations throughout the Midwest and elsewhere, particularly where the Red-shouldered Hawk is classified as a species of special concern because of habitat loss.

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