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PREDATORY BEHAVIOR AND DIET OF WINTERING MALE COOPER'S HAWKS IN A RURAL HABITAT

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The behavior of North American Accipiter hawks during the nonbreeding season is largely unknown. While several studies have focused on the winter ecology of the Northern Goshawk (*Acciptier gentilis*, e.g., Widen 1987, Boal et al. 2003, Drennan and Beier 2003), very little information exists about the smaller Cooper's (*A. cooperii*) and Sharp-shinned (*A. striatus*) Hawks. Even basic natural history information about these smaller species such as home range use, diet (but see Roth and Lima 2003, Roth et al. 2006), activity and foraging patterns is unavailable for the winter (Rosenfield and Bielefeldt 1993, Dunn and Tessaglia 1994, Bildstein and Meyer 2000). However, wintering Eurasian Sparrowhawks (*A. nisus*) have been studied by Newton (1986) and Cresswell and colleagues (Cresswell 1994, 1996, Whitfield et al. 1999). Although innovative in many respects, much of this work examines sparrowhawks in unusual habitats, e.g., mudflats, and may not be applicable to the more typical situation of Accipiters hunting in wooded habitats (but see Newton 1986).

We studied wintering Accipiters in part because of the importance of these hawks in conceptual models of behavioral predator-prey interactions (Bertram 1978, Pulliam and Caraco 1984, Houston and McNamara 1999), especially those addressing the ''small bird in winter'' research paradigm (see Roth et al. 2006). Such studies of small bird behavior typically base predator behavior largely on simplifications and guesswork rather than observation (Lima 2002).

Here, we report the hunting behavior and diet of male Cooper's Hawks as part of a broader study on Accipiters and avian predator-prey interactions in order to assess their similarity to that of Sharp-shinned Hawks. We focused on males because the much larger female Cooper's Hawks were known (in our study area) to take large prey (Roth and Lima 2003) and were uncommon in our rural study site where Sharp-shinned Hawks were frequent (Roth et al. 2005). Although our observations of male hawks were not extensive and sample sizes were small, the information below on diet, hunting success, and general hunting behavior represent the first such published data on wintering Cooper's Hawks in a rural environment.

STUDY AREA AND METHODS

We studied Cooper's Hawks during the winters of 2001–2004 in rural Vigo County, Indiana, U.S.A. The site was composed primarily of small residential clusters, peripheral city suburbs, agricultural land, and fragmented forest.

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Trapping was conducted from late November to late January in all years using constantly monitored bal-chatri traps (Berger and Mueller 1959) and bow nets baited with European Starlings (*Sturnus vulgaris*) and House Sparrows (*Passer domesticus*). Traps were positioned conspicuously in open areas or flight corridors such as open fields, roadsides, powerline corridors, bird feeders, and potential roost sites. All trapping and marking procedures adhered to the guidelines for the use of animals in research, were reviewed and approved by the Institutional Animal Care and Use Committee at Indiana State University (No. 00-19:TR/SL and 08-21-2003:TR/SL), and followed all federal and state regulations for the collection and marking of wild animals.

We used radiotelemetry to track hawks. We fitted each hawk with an appropriately-sized position-sensitive radiotransmitter (Holohil, Inc., Ontario, Canada; <3% total body mass; 4.2–5.8 g) using the pelvic harness of Rappole and Tipton (1991). The position-sensitive transmitters provided information on the activity of the hawks. A slow pulse rate indicated a perched, stationary hawk. A stationary, rapid pulse rate or fluctuations in pulse rate were indicative of prey consumption: hawks were in a prey-consumption posture with alternating bouts of feeding and vigilance. A steady rapid pulse rate indicated flight; a sudden switch to flight prompted our attention to a possible attack.

We tracked all hawks from vehicles using yagi and whip antennae. Observations occurred from approximately 0.5 hr before sunrise to 0.5 hr after sunset. Each hawk was observed continuously for at least 2 but on average 4.5 (SE = 0.5) hr daily. The time of day we began tracking each hawk was systematically chosen so that throughout the study each hawk was tracked during all periods of the day. During radiotracking, we recorded the location and predatory behaviors of hawks. Observed attacks were subjectively classified as ''open'' if made where prey could have detected the approaching hawk at 15 m or more, and ''surprise'' attacks if made using visual obstructions where prey could not readily detect the hawk during the final 15 m of the attack (Newton 1986, Roth and Lima 2003, Roth et al. 2006, but see Dekker 1980). After a hawk had finished consuming its prey and moved well away from the site, trackers would (if possible) intensively search the area for prey remains for at least 30 min. These searches were conducted only when we could determine a precise fix on the hawk location and when we could obtain access to the property. All remains were compared to specimens in the Indiana State University Vertebrates Collection to verify species. Data for all years were pooled and all statistical analyses were performed with Systat 9.0 (SPSS, Inc. 1998) using parametric and nonparametric tests as appropriate. In the determination of diet, we included prey remains found with or without having observed the attack. Consequently, the number of prey eaten did not necessarily correspond to the number of prey attacked.

To assess the relative risk of predation for different prey species, we estimated the relative abundance of avian prey within the study site during the winters of 2002–2004. Unlimited-distance 5 min point counts (Bibby et al. 1992) were conducted weekly from late December through early March at 48 sites positioned in the center of the study site (see Roth et al. 2006). All counts were performed during the same day in good weather (no precipitation, no strong winds). The order of counts was systematically rotated to avoid temporal biases.

RESULTS AND DISCUSSION

We trapped and radiotagged eleven male Cooper's Hawks (2 adults and 9 immatures) during the course of the study. Due to loss of hawks from predation, migration, and accidents (Roth et al. 2005), we were able to collect data on 5 individuals (1 adult and 4 immatures), which were tracked on average 63 (SE = 17.8) d.

The male Cooper's Hawks in this study attacked and killed a wide range of prey species. Of the 72 attacks known to occur, prey species was identified in 31 cases (Table 1), unknown in 31 cases, and identified to unknown sparrow in the remaining cases (10). Of the 31 attacks on known species, three species, House Sparrows (10, 32.3%), Mourning Doves (*Zenaida macroura*; 5, 16.1%), and Dark-eyed Juncos (*Junco hyemalis*; 5, 16.1%), made up over 60% of the species attacked (Table 1). Similarly, larger species such as Mourning Doves (33.3%) and European Starlings (11.1%) were common in the diet, as were small species such as House Sparrows (22.2%; Table 1). The smallest species in the diet were juncos (20 g) and American Tree Sparrows (*Spizella arborea*, 20 g). We observed only one mammal (eastern chipmunk, *Tamias striatus*) in the diet of rural Cooper's Hawks, a marked contrast to their diet during the breeding season in some other study areas (Reynolds and Meslow 1984, Kennedy and Johnson 1986, Bielefeldt et al. 1992, but see Boal 1997, Estes and Mannan 2003). This result probably reflects the lack of small diurnal mammalian prey available during the winter.

With the exception of the Rock Pigeon (*Columba livia*) and Northern Bobwhite (*Colinus virginianus*), the species attacked and/or killed by male Cooper's Hawks overlapped completely with that of Sharp-shinned Hawks tracked simultaneously in the same area (Roth et al. 2006). The extent of the similarity of Sharp-shinned and Cooper's Hawk diets is difficult to determine given our small sample size, but it seems clear that rural male Cooper's Hawks represent a predatory risk for small winter birds such as sparrows. In contrast, small prey in the urban habitat in Terre Haute, Indiana, experienced relatively low risk of attack because the urban habitat was dominated by female Cooper's Hawks whose diet generally lacked birds under 70 g (Roth and Lima 2003), although in other areas, small prey such as sparrows and finches may be attacked in urban sites (Boal 1997).

The hunting strategy of male Cooper's Hawks was similar to their urban female counterparts', but differed somewhat from that of Sharp-shinned Hawks. The overall

Table 1. Relative abundance and mass of prey, number of prey attacked, and diet of five male rural Cooper's Hawks near Terre Haute, Indiana, during the winters of 2001–2004. Species are listed in order of decreasing mass.

			Relative Abundance		Prey Attacked		Prey Eaten[b]	
Prey Species		Mass (g)[a]	*N*	%	*N*	%	*N*	%
Rock Pigeon	*Columba livia*	355	59	0.8	0	0	1	5.6
Northern Bobwhite	*Colinus virginianus*	178	3	<0.1	1	3.2	0	0
Mourning Dove	*Zenaida macroura*	119	172	2.3	5	16.1	6	33.3
Blue Jay	*Cyanocitta cristata*	87	982	12.9	1	3.2	0	0
European Starling	*Sturnus vulgaris*	82	499	6.6	4	12.9	2	11.1
Northern Cardinal	*Cardinalis cardinalis*	45	1211	15.9	3	9.7	1	5.6
House Sparrow	*Passer domesticus*	28	241	3.2	10	32.3	4	22.2
Downy Woodpecker	*Picoides pubescens*	27	238	3.1	1	3.2	1	5.6
Dark-eyed Junco	*Junco hyemalis*	20	536	7	5	16.1	1	5.6
American Tree Sparrow	*Spizella arborea*	20	125	1.6	1	3.2	1	5.6
Other avian species ($N = 27$)[c]		—	3541	46.5	0	0.0	0	0.0
Eastern chipmunk	*Tamius striatus*	—	—	—	—	—	1	5.6
Total			7607		31		18	

[a] Body mass data taken from Dunning (1993).
[b] Includes cases located without observation of the attack as well as cases resulting from observed successful attacks; hence, the number of prey eaten does not necessarily correspond to the number of prey attacked.
[c] Includes only potential prey species <355 g, i.e., smaller than a Rock Pigeon.

success rate of attacks for male Cooper's Hawks was approximately 23% (7 of 31 attacks with known species and known outcome were successful), which is comparable to success rates for other Accipiters (Newton 1986, Wilson and Weir 1989, Cresswell 1996) including rural Sharp-shinned Hawks (23%, Roth et al. 2006) and urban female Cooper's Hawks (20%, Roth and Lima 2003). In addition, 20 of these 31 attacks were classifiable to attack type (surprise or open). Of these, 9 (45.0%) were surprise attacks and 11 (55.0%) were open attacks, which was similar to results for urban Cooper's Hawks (surprise: 49.2%, open: 50.8%; Roth and Lima 2003). The Cooper's Hawks differed greatly, however, from the Sharp-shinned Hawks tracked in the same habitat, which were much more likely to engage in surprise attacks (85.4% surprise, 14.6% open; Roth et al. 2006). However, unlike in previous studies of Accipiter predatory behavior in which surprise attacks were more successful (surprise: 30% successful, open: 7% successful; Roth and Lima 2003), in this study no significant difference in success was observed between surprise (2 of 9 attacks successful) and open attacks (3 of 11 attacks successful; Fisher exact test, $P > 0.90$); however, limited statistical power precluded a firm conclusion.

Much remains to be studied about the winter ecology of Accipiter hawks, but our results suggest that both Cooper's and Sharp-shinned Hawks should be considered when investigating the predatory risk experienced by small birds wintering in rural environments.

COMPORTAMIENTO DE DEPREDACIÓN Y DIETA DE MACHOS DE *ACCIPITER COOPERII* DURANTE EL PERIODO DE INVERNADA EN UN HÁBITAT RURAL

RESUMEN.—El comportamiento durante el invierno de los halcones del género *Accipiter* no ha sido muy estudiado. En este estudio exploramos el comportamiento de caza y la dieta de machos de *A. cooperii* en un hábitat rural (oeste de Indiana, Estados Unidos) durante los inviernos de 2001 a 2004. Seguimos a 11 halcones utilizando radio-telemetría y registramos la identidad de las especies atacadas y depredadas. En este estudio, el halcón *A. cooperii* capturó presas con un amplio rango de tamaño, desde palomas de la especie *Columba livia* hasta aves mas pequeñas como *Junco hyemalis*. El tipo de presas capturadas se sobrepuso ampliamente con las presas capturadas por *A. striatus* en un estudio previo, pero se diferenció marcadamente de las presas capturadas por las hembras de *A. cooperii* en zonas urbanas. Sin embargo, la estrategia de caza de los machos rurales de *A. cooperii* fue similar a la de sus contrapartes hembra en zonas urbanas, y la tasa general de éxito de captura de presas (23%) fue comparable a las tasas de éxito de captura documentadas para otros *Accipiter*.

[Traducción del equipo editorial]

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