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INTRODUCED SPECIES DOMINATE THE DIET OF BREEDING URBAN COOPER'S HAWKS IN BRITISH COLUMBIA

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ABSTRACT.—We used collection of prey remains, direct observations of hawks with prey, and video cameras at two nests to assess frequency of occurrence and biomass of prey species taken by breeding Cooper's Hawks (*Accipiter cooperii*) in Victoria, British Columbia, Canada during 1995–2010. Small ($\leq$ 27 g) to medium-size (28–91 g) bird species contributed the majority (79–94%) of prey recorded from collection of 3,231 prey remains, 437 direct observations, and 783 video items at 87 nest sites. Avian prey contributed over half of prey biomass recorded in direct observations and video data (67% and 93%, respectively). One native and two introduced species provided most (> 85%) prey recorded in all samples in which birds were identified to species: American Robin (*Turdus migratorius*), European Starling (*Sturnus vulgaris*), and House Sparrow (*Passer domesticus*). Introduced species were an important component of the diet, contributing over half of items identified in all samples. There was a temporal shift in age of prey used: the early-season diet (Mar–Apr) was comprised of adult birds and subadult mammals, while avian young of the year dominated the diet from late May until the end of the breeding season (70–100% of identifiable items). Mammals were inconsequential in terms of frequency and biomass except at nests (6 of 87) on or near the University of Victoria campus where nearly all European rabbit (*Oryctolagus cuniculus*) prey was recorded. *Received 28 December 2011. Accepted 4 May 2012.*

Urbanization is a major force in changes of global land-use (Ortega-Álvarez and MacGregor-Fors 2011). Urban environments are relatively new habitats for Cooper's Hawks (*Accipiter cooperii*) and other birds of prey (Bird et al. 1996, Stout et al. 2007, Rosenfield et al. 2009). These landscapes vary greatly in size, habitat heterogeneity, prey populations, and other ecological factors that potentially affect reproductive success of raptors (Stout and Rosenfield 2010). Little research has been done on breeding raptors in urban settings and fundamental ecological understanding of these populations is lacking (Stout et al. 2005, Rutz 2008, Stout and Rosenfield 2010).

Some of the highest nesting densities and reproductive success for Cooper's Hawks occur in cities (Rosenfield et al. 2007b, Mannan et al. 2008, Stout and Rosenfield 2010). Investigators have suggested high nesting densities and reproductive success of urban Cooper's Hawks could be related to abundance and type of avian prey in cities (Marzluff et al. 1998, Stout and Rosenfield 2010). However, there are few reports of the diet of urban Cooper's Hawks. A 2-year investigation by Estes and Mannan (2003) in Tucson, Arizona appears to be the only published research that provides a detailed study of the diet of urban breeding Cooper's Hawks. Our objective was to document the diet of Cooper's Hawks breeding at high nesting densities in Victoria, British Columbia, Canada.

METHODS

All data were collected in the city of Victoria, British Columbia, Canada during 1995–2010. This is a 89-km^2 city with a human population of ~300,000. It has a temperate, coastal climate and is comprised of sparsely to heavily wooded habitat dominated by tall coniferous trees including Douglas-fir (*Pseudotsuga menziesii*) and grand fir (*Abies grandis*) (Campbell et al. 1990). Nests were found annually by systematic searches of the entire city and prey reported represent all habitats therein (Stewart et al. 1996).

Direct Observations.—We recorded 437 incidental direct observations of adult Cooper's Hawks with prey items at 87 nest sites from March through August 1995–2010. These observations consisted of direct observations of prey carried by hawks or prey dropped in mist nets by captured hawks. Samples from each breeding stage (pre-incubation, incubation, nestling, and fledgling) for each year were pooled because of small sample sizes and because proportions of avian prey were similar among stages. We noted items as native or introduced to the study area when possible. Avian prey items were initially categorized into size classes (SC) following Storer (1966), Kennedy and Johnson (1986), and Bielefeldt et al. (1992) by known mass and bulk of familiar species: SC 1 $\leq$ 27 g and SC 2 = 28–91 g.

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Relatively few items were larger than SC 2 and were categorized as >SC 2. We estimated biomass of each prey item. Biomass refers to live mass of an item, not the mass delivered to the nest or consumed by nestlings. We removed the data collected at nests on or within 0.5 km of the University of Victoria property (n = 31 items) from biomass estimates due to a site bias; nearly all (8 of 9) European rabbits (*Oryctolagus cuniculus*) were recorded at these few nest sites. Each rabbit provided about five times the biomass of a single avian item, inflating the biomass proportion contributed by mammalian items and inaccurately representing the extent of mammal consumption at the majority of nests in Victoria.

We identified 189 (46%) of 408 avian prey items to species. Adult masses of these items were from Dunning (2008). The age of avian prey items, when possible, was identified from feather sheathing in nestlings and recent fledglings, distinctive juvenal plumages, or the color of the tarsi for some species. We estimated mass of avian items identified by species and age from the literature on growth rates (Clench and Lieberman 1978). Most species in SC 1 fledge at ≥90% of adult mass and we ignored age in these cases. Altricial, open-nesting species in SC 2 were divided into two categories of smaller (28–59 g) and larger (60–91g) species. We calculated mass at 70, 90, and 95% of adult mass for smaller species at nestling, juvenal, and unknown ages, respectively; and for larger species at 65, 85, and 90%, respectively. Juvenal and unidentifiable items larger than SC 2 were calculated at 90% of adult mass to be conservative in our estimates. We used assumed averages of 25 g and 65 g for unidentified birds in SC 1 and SC 2, respectively. Only one unidentified partial item was larger than SC 2 and was not assigned a mass. Other unidentified items that could not be assigned a size class were not included in mass estimates.

We identified 27 of 29 mammalian items (93%) to genus or species; most were Eastern cottontail (*Sylvilagus floridanus*) or European rabbits, and Norway rats (*Rattus norvegicus*). A mean mass estimate of 350 g for the two rabbit species was obtained from measurements of semi-intact prey remains; all rabbits were less than or about half-grown. We estimated adult mass of Norway and black rats (*R. rattus*) from Nowak (1999); juveniles and unidentified individuals were estimated at 90% of adult mass to be conservative. Rats only identified to genus were assumed to be less than or about half-grown Norway rats based on general observations and we estimated biomass of each at 220 g. Adult masses of one deer mouse (*Peromyscus maniculatus*) and one Eastern gray squirrel (*Sciurus carolinensis*) were estimated from Wilson and Ruff (1999).

Prey Remains.—We tabulated remains of 3,231 prey items from 44 active nest sites during the pre-incubation through fledging stages in 1995–1998. The items were mainly pluckings, and legs, tails, or partial carcasses. We identified prey to the lowest taxonomic class by comparing remains to a reference collection of locally common prey-sized species and the Royal British Columbia Museum's vertebrate collection. We included items from reoccupied nest sites but treat the data as independent because no single nest site contributed >7% of the total items over the 4 study years. We combined all stages of breeding (pre-incubation through fledgling) and pooled data from all years because proportions of avian prey were similar (94–98%). Avian items identified to species were categorized, based on adult masses (Dunning 2008), into the same size classes from Storer (1966), Kennedy and Johnson (1986), and Bielefeldt et al. (1992). We classified prey items as native or introduced to the study area when possible.

Video Analysis.—We used video cameras to record prey deliveries in different years to two arbitrarily selected nests >2.5 km from the University of Victoria property. The custom-made camera fed into two VHS video recorders and an Axis brand video server that recorded a still image every minute. We placed cameras at an oblique angle, 80 to 100 cm from the center of the nest platform. The Torquay nest was recorded from 2 June through 21 July 2001. Recording start time varied between 0800 and 0930 hrs from 2 June to 4 June, 0430 hrs during 6–15 June, and 0500 hrs the rest of the days. Recording continued until ~2100 hrs, when the videotape ran out each day. Ten of the 50 days had incomplete recordings. The Burnside nest was recorded from 4 June through 5 July in 2002. We recorded from 0500 to ~2100 hrs each day (excluding 6 incomplete days). Complete days for both nests averaged ~16 hrs of footage and incomplete days ranged from 6 to 12 hrs of footage. We obtained 750 and 467 hrs of video from the Torquay and Burnside nests, respectively.

We identified prey to the lowest taxonomic level possible, age, and categorized them into size

TABLE 1. Percent frequency of avian and mammalian prey items by three sampling schemes at Cooper's Hawk nests in Victoria, British Columbia, 1995–2010.

	% Frequency		
	Prey remains (n = 3,231)	Direct observations (n = 437)	Video analysis (n = 783)
Avian			
SC 1	32	46	62
SC 2	61	33	32
>SC 2	3	3	0
Unidentified	1	11	2
Totals	97	93	96
Mammalian	3	7	1
Unidentified	0	0	3

classes. We also estimated biomass for items observed in the video with the same methods used in direct observations. Data from the two nests were pooled because proportions of avian prey were similar (96% at both nests).

RESULTS

Small (≤ 27 g) to medium-size (28–91 g) birds provided most of the diet in terms of frequency (79–94%) and biomass (67–93%) among all three sampling schemes; mammalian items were a small component of the diet at typical Victoria nests (Tables 1, 2). There was a site bias concerning one species of mammalian prey; nearly all European rabbits (26 of 27) were recorded from nest sites associated with the University of Victoria campus (6 of 87 nest sites over 16 years). Introduced species were a major component of the diet, contributing >50% of the items in terms of frequency and a similar proportion of the biomass of items identified as introduced or native (Tables 3, 4). The most prevalent avian prey species were House Sparrow (*Passer domesticus*), European Starling (*Sturnus vulgaris*), and American Robin (*Turdus migratorius*) (Table 5). These three species combined represented 85, 88, and 97% of the avian items identified to species in direct observations, prey remains, and video analysis, respectively. These species contributed a majority of the avian biomass (69% in direct observations and 91% in video analysis).

TABLE 2. Percent biomass of avian and mammalian prey items by direct observations and video at Cooper's Hawk nests in Victoria, British Columbia, 1995–2010. Total biomass in grams is provided below sampling scheme headings.

	% Biomass	
	Direct observations[a] (g = 21,086)	Video analysis (g = 30,379)
Avian		
SC 1	23	40
SC 2	44	53
>SC 2	14	2
Totals	81	95
Mammalian	19	5

[a] Estimates do not include data from nests on the University of Victoria campus due to site bias.

Young of the year represented a majority of identifiable avian items, contributing 76% of prey remains, 63% of direct observations, and 92% in video analysis. These young of the year also contributed a majority of biomass in direct observations (69%) and video (97%). The identifiable mammalian items in the prey remains and direct observations were mostly subadults (100 and 80%, respectively). Only one mammalian item was classified to age in the video analysis; a subadult rat. Avian young of the year were taken with increased frequency in the prey remains and direct observation samples as the breeding season progressed. All identifiable items recorded before late April were adult or subadult mammals, while avian young of the year dominated in the diet from late May to the end of July (Fig. 1). Nest video data documented that high proportions of young of the year prey (92%) were captured in June and July, corresponding to similarly high proportions of young prey recorded in the same months by direct observations and prey remains (Fig. 1).

DISCUSSION

Small and medium-size birds (≤ 27 g and 28–91 g, respectively), and especially introduced species, were the primary prey taken by Cooper's Hawks breeding in the city of Victoria, British Columbia. Mammals were taken at low frequencies and did not contribute substantial biomass at typical Victoria nests.

High variability of urban environments should cause variation in the ecology of a raptor species that inhabits different cities, which appears to be the case for several investigations of the diet of urban breeding Cooper's Hawks. This species preyed mainly on small and medium-size birds in Victoria, many of which were introduced. Estes and Mannan (2003) in Tucson, Arizona reported nesting Cooper's Hawks mainly taking native

TABLE 3. Percent frequency of introduced and native prey items recorded by three sampling schemes at Cooper's Hawk nests in Victoria, British Columbia, 1995–2010.

	% Frequency		
	Prey remains (n = 2,893)	Direct observations (n = 217)	Video analysis (n = 155)
Introduced			
Avian	50	52	54
Mammalian	3	12	4
Totals	53	64	58
Native			
Avian	47	35	42
Mammalian	0	1	0
Totals	47	36	42

dove species and introduced species had little role in the diet (7.3% frequency, 4.6% biomass). Bielefeldt et al. (1992) found Eastern chipmunks (*Tamias striatus*) contributed a majority of the biomass at a semi-urban nest near a rural town in Wisconsin and the Eastern chipmunk is a common prey item of breeding Cooper's Hawks in and around the city of Stevens Point, Wisconsin (Nicewander and Rosenfield 2006; RNR, unpubl. data). We found local variation within our study population; only Cooper's Hawks nesting on the University of Victoria campus preyed upon European rabbits in addition to the avian prey commonly taken at nests elsewhere in the study area. The variation in diet among populations and opportunistic use of locally abundant prey within Victoria underscores the plasticity of Cooper's Hawk feeding behavior. This plasticity may in part explain this hawk's ability to occupy a wide variety of habitats across North America (Rosenfield et al. 2007b, 2010; Sonsthagen et al. 2012). A commonality in age of prey taken by Cooper's Hawks underlies these variations in prey species used across cities. Bielefeldt et al. (1992) and this study report young of the year birds are major components of the urban breeding season diet; Estes and Mannan (2003) did not report the ages of the avian prey taken by urban Cooper's Hawks in Arizona.

TABLE 4. Percent biomass of introduced and native prey items by two sampling schemes at Cooper's Hawk nests in Victoria, British Columbia, 1995–2010. Total biomass in grams is provided below sample scheme headings.

	% Biomass	
	Direct observations[a] (g = 14,397)	Video analysis (g = 9,390)
Introduced		
Avian	41	38
Mammalian	24	14
Totals	65	52
Native		
Avian	35	48
Mammalian	0	0
Totals	35	48

[a] Estimates do not include data from nests on the University of Victoria campus due to site bias.

The type and availability of prey can (or has the potential to) deleteriously affect reproductive success of Cooper's Hawks. Boal et al. (1998) recorded high levels of trichomoniasis, an upper digestive tract disease, among urban Cooper's Hawk nestlings in Tucson, Arizona, likely due to high consumption of abundant columbid (Columbidae) prey infected with the protozoan *Trichomonas gallinae*. Boal and Mannan (1999) found relatively lower reproductive rates at urban versus rural nests, largely the result of nestling mortality due to trichomoniasis; this led them to suggest the city of Tucson was an 'ecological trap' for Cooper's Hawks (but see Mannan et al. 2008). The diet of Cooper's Hawks in Victoria was low in columbids and this disease has not been documented in hawks there (Rosenfield et al. 2002). Rosenfield et al. (2009) reported a low prevalence of *T. gallinae* (7%), but no evidence of the disease (or deaths) in nestling urban Cooper's Hawks in Grand Forks, North Dakota. However, sampling there in 2011 found ~30% prevalence of *T. gallinae* (n = 70 hawks at 13 nests), but no documented deaths of nestlings due to trichomoniasis (T. G. Driscoll, unpubl. data). Both the Victoria and Grand Forks populations exhibit some of the highest nesting densities and production indices recorded for Cooper's Hawks in North America (Rosenfield et al. 2007a), although the Grand Forks population could potentially be affected by trichomoniasis in future years (~ 14% of the diet of Cooper's Hawks in Grand Forks is columbid prey; T. G. Driscoll, unpubl. data).

Bielefeldt et al. (1992) challenged the assumption that birds were the most frequent prey of Cooper's Hawks as reported in pre-1990 studies of the biology of this species. They indicated mammals provided a majority of biomass in some studies and argued that previous studies could have overestimated avian prey in the diet due to

TABLE 5. Prey species constituting ≥1% frequency in any of three sampling schemes at Cooper's Hawk nests in Victoria, British Columbia, 1995–2010. Total sample size of items identified to species is provided below sampling scheme headings.

Prey species		% Frequency		
		Prey remains (n = 2,896)	Direct observations (n = 217)	Video analysis (n = 155)
American Robin	*Turdus migratorius*	34.6	29.5	40.0
European Starling	*Sturnus vulgaris*	28.3	15.2	18.7
House Sparrow	*Passer domesticus*	18.8	31.8	34.8
Varied Thrush	*Ixoreus naevius*	1.1	0.5	0
Pine Siskin	*Spinus pinus*	0.9	0.5	0
Spotted Towhee	*Pipilo maculatus*	1.0	0.5	0
House Finch	*Carpodacus mexicanus*	5.6	2.8	0
Northwestern Crow	*Corvus caurinus*	0.4	0	1.3
Chestnut-backed Chickadee	*Poecile rufescens*	0.7	0.5	0.6
Rock Pigeon	*Columba livia*	1.8	4.1	0
Northern Flicker	*Colaptes auratus*	0.6	0	0
Gray squirrel	*Sciurus carolinensis*	0.3	0.5	0
Black rat	*Rattus rattus*	0	0.9	1.3
Norway rat	*R. norvegicus*	1.3	5.1	2.6
Eastern cottontail	*Sylvilagus floridanus*	0.8	1.4	0
Deer mouse	*Peromyscus maniculatus*	0.1	0.5	0
European rabbit	*Oryctolagus cuniculus*	0.6	4.1	0

methodological biases. Our samples of prey remains, direct observations, and nest video each show that avian species are the most frequent items and provide the majority of biomass in the diet of Cooper's Hawks in Victoria.

Other recent urban and rural studies have also shown birds are the most frequent prey (Estes and Mannan 2003; Roth and Lima 2003, 2006) and provide the majority of biomass (Estes and Mannan 2003), and it is likely that birds are also important prey in other cities. The lack of mammalian and other 'low agility' prey may be due to reduced abundance or availability of such prey in the areas at the time of those studies. Hawks nesting on the University of Victoria campus preyed upon European rabbits that were present in large numbers (about 18–20 rabbits/ha in non-forested habitats), yet elsewhere in the city mammals were recorded infrequently. Bielefeldt et al's (1992) suggestion that much of the breeding Cooper's Hawk diet consists of vulnerable, inexperienced, and ground-foraging individuals is supported by our results. The three most common avian species taken in Victoria (American Robin, House Sparrow, and European Starling) would be classified as frequent or primarily ground-foraging species by Bielefeldt et al. (1992), and inexperienced young of the year were the most commonly recorded prey when they become available in the season. Cooper's Hawks seem to be opportunistic predators but it is unknown whether they target vulnerable prey or that prevalence of these items in our samples was due to higher attack success rates.

Roth and Lima (2003) reported introduced bird species, especially European Starlings and Rock Pigeons (*Columba livia*), were important prey of seven female and one male radio marked Cooper's Hawks wintering in Terre Haute, Indiana. They indicated small birds ($<$ 70 g) such as House Sparrows were rarely attacked despite being numerous in their urban study area; smaller bird species in their study area were at low risk of predation from Cooper's Hawks. It is possible that differences in size class used by Cooper's Hawks between our study and others may reflect disparity in size of hawks and prey used. Breeding males captured most of the prey documented in our study, and males often take smaller prey than females (Rosenfield and Bielefeldt 1993). It is also possible that smaller, sparrow-sized birds have a greater risk of predation from smaller Cooper's Hawks in the western half of this hawk's North American distribution. Smaller body size of breeding Cooper's Hawks in some western populations (including in Victoria) appears to be influenced by selective pressures of size and agility of their relatively small avian prey

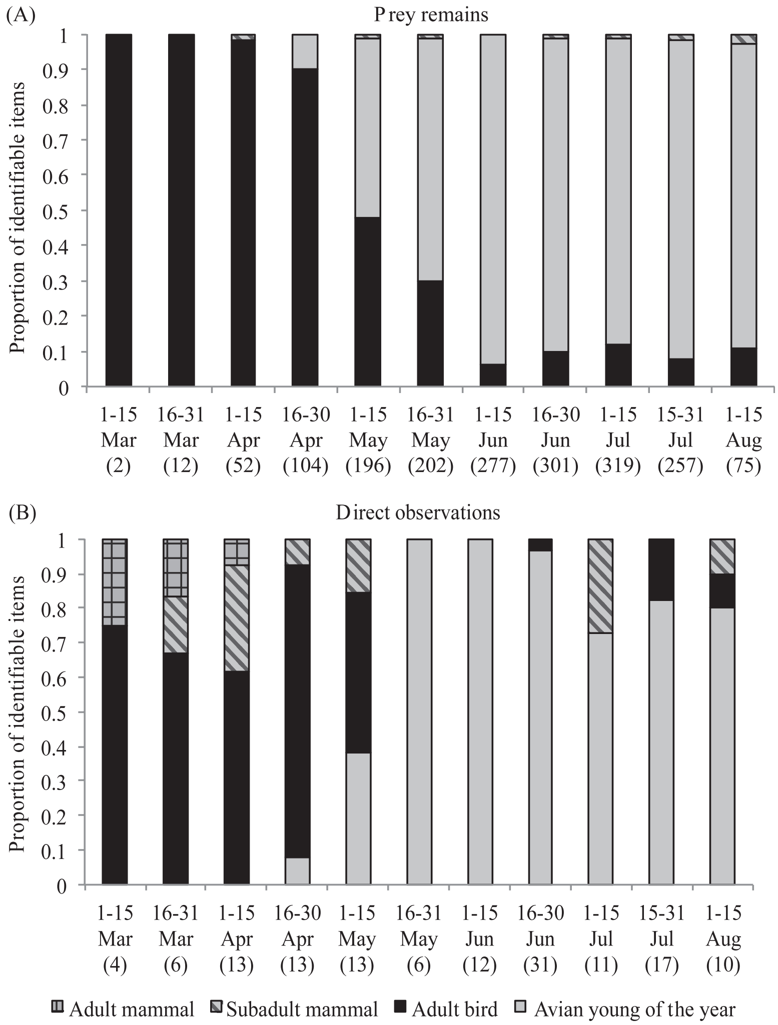

FIG. 1. Semi-monthly proportions of identifiable items recorded during 1995–2010 at Cooper's Hawk nests in Victoria, British Columbia by prey remains (A) and direct observations (B). The number of identifiable items recorded in each time period is in parentheses. Pre-incubation, incubation, nestling, and fledgling stages occur in March to early-April, mid-April to late-May, late-May to late-June, and July to August, respectively.

(Rosenfield et al. 2010, Sonsthagen et al. 2012). Larger and less agile prey are taken by Cooper's Hawks in some eastern populations where Cooper's Hawks are larger (Rosenfield et al. 2010). Roth and Lima's (2003) data mostly (141 of 179 attacks) were observations of wintering female hawks in an eastern population. Wintering male and female Cooper's Hawks capture House Sparrows in Victoria, but males do so more than females (ACS, unpubl. data).

Ours is the first study to describe introduced species as a major component of the diet of urban breeding Cooper's Hawks. Introduced species are known for causing damage to native ecosystems and species (e.g., Mack et al. 2000, Chace and Walsh 2006), but they can provide potential benefits to ecosystems (Schlaepfer et al. 2011). The introduced bird species in our study area are a benefit as they provide a valuable resource for native, breeding Cooper's Hawks in Victoria. Introduced bird species, particularly House Sparrows and European Starlings, are predominant avifauna in many cities (e.g., Marzluff et al. 1998), and it appears these species are important prey for many nesting populations of urban Cooper's Hawks. House Sparrows and starlings are common prey of Cooper's Hawks breeding in Milwaukee, Wisconsin (W. E. Stout and RNR, unpubl. data), and Grand Forks, North Dakota (T. G. Driscoll, unpubl. data). House Sparrows are also common prey of breeding Cooper's Hawks in Albuquerque, New Mexico (European Starlings are mostly absent from Albuquerque; B. A. Millsap and R. K. Murphy, unpubl. data). Apparent widespread use of House Sparrows and European Starlings in association with generally higher densities of birds in cities could in part be responsible for urban Cooper's Hawks (including the Victoria Cooper's Hawk population) attaining some of the highest nesting densities and reproductive success known for this raptor (Rosenfield et al. 1996; Marzluff et al. 1998; Rosenfield et al. 2007a; ACS, unpubl. data). There is evidence that some cities serve as population sources for Cooper's Hawks and prey availability has been suggested as having a key role in this demographic progress (Mannan et al. 2008, Stout and Rosenfield 2010).

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LITERATURE CITED

BIELEFELDT, J., R. N. ROSENFIELD, AND J. M. PAPP. 1992. Unfounded assumptions about the diet of the Cooper's Hawk. Condor 94:427–436.

BIRD, D. M., D. E. VARLAND, AND J. J. NEGRO (Editors). 1996. Raptors in human landscapes. Academic Press, London, United Kingdom.

BOAL, C. W. AND R. W. MANNAN. 1999. Comparative breeding ecology of Cooper's Hawks in urban and exurban areas of southeastern Arizona. Journal of Wildlife Management 63:77–84.

BOAL, C. W., R. W. MANNAN, AND K. S. HEDELSON. 1998. Trichomoniasis in Cooper's Hawks from Arizona. Journal of Wildlife Diseases 34:590–593.

CAMPBELL, R. W., N. K. DAWE, I. M. COWAN, J. M. COOPER, G. W. KAISER, AND M. C. MCNALL. 1990. The Birds of British Columbia. Volume 2. Nonpasserines. Mitchell Press, Vancouver, British Columbia, Canada.

CHACE, J. F. AND J. J. WALSH. 2006. Urban effects on native avifauna: a review. Landscape and Urban Planning 74:46–69.

CLENCH, M. H. AND R. C. LIEBERMAN. 1978. Weights of 151 species of Pennsylvania birds analyzed by month, age, and sex. Bulletin Number 5. Carnegie Museum of Natural History, Pittsburgh, Pennsylvania, USA.

DUNNING, J. B. 2008. CRC handbook of avian body masses. Second Edition. CRC Press Inc., Boca Raton, Florida, USA.

ESTES, W. A. AND R. W. MANNAN. 2003. Feeding behavior of Cooper's Hawks at urban and rural nests in southeastern Arizona. Condor 105:107–116.

KENNEDY, P. L. AND D. R. JOHNSON. 1986. Prey-size selection in nesting male and female Cooper's Hawks. Wilson Bulletin 98:110–115.

MACK, R. N., D. SIMBERLOFF, W. M. LONSDALE, H. EVANS, M. CLOUT, AND F. BAZZAZ. 2000. Biotic invasions: causes, epidemiology, global consequences and control. Issues in Ecology 5:1–22.

MANNAN, R. W., R. J. STEIDL, AND C. W. BOAL. 2008. Identifying habitat sinks: a case study of Cooper's Hawks in an urban environment. Urban Ecosystems 11:141–148.

MARZLUFF, J. M., F. R. GEHLBACH, AND D. A. MANUWAL. 1998. Urban environments: influences on avifauna and challenges for the avian conservationist. Pages 283–299 *in* Avian conservation: research and management (J. M. Marzluff and R. Sallabanks, Editors). Island Press, Washington, D.C., USA.

NICEWANDER, J. AND R. N. ROSENFIELD. 2006. Behavior of a brood of post-fledging Cooper's Hawks: non-independence of sibling movements. Passenger Pigeon 68:321–343.

NOWAK, R. M. 1999. Walker's mammals of the world. Sixth Edition. Volume 2. Johns Hopkins University Press, Baltimore, Maryland, USA.

ORTEGA-ÁLVAREZ, R. AND I. MACGREGOR-FORS. 2011. Spreading the word: the ecology of urban birds outside the United States, Canada, and western Europe. Auk 128:415–418.

ROSENFIELD, R. N. AND J. BIELEFELDT. 1993. Cooper's Hawk (*Accipiter cooperii*). The birds of North America. Number 75.

ROSENFIELD, R. N., J. BIELEFELDT, J. L. AFFELDT, AND D. J. BECKMANN. 1996. Urban nesting biology of Cooper's Hawks in Wisconsin. Pages 41–44 *in* Raptors in human landscapes (D. M. Bird, D. E. Varland, and J. J. Negro, Editors). Academic Press, London, United Kingdom.

ROSENFIELD, R. N., J. BIELEFELDT, L. J. ROSENFIELD, S. J. TAFT, R. K. MURPHY, AND A. C. STEWART. 2002. Prevalence of *Trichomonas gallinae* in nestling Cooper's Hawks among three North American populations. Wilson Bulletin 114:145–147.

ROSENFIELD, R. N., T. G. DRISCOLL, R. P. FRANCKOWIAK, L. J. ROSENFIELD, B. L. SLOSS, AND M. A. BOZEK. 2007a. Genetic analysis confirms first record of polygyny in Cooper's Hawks. Journal of Raptor Research 41:230–234.

ROSENFIELD, R. N., J. BIELEFELDT, L. J. ROSENFIELD, A. C. STEWART, M. P. NENNEMAN, R. K. MURPHY, AND M. A. BOZEK. 2007b. Variation in reproductive indices in three populations of Cooper's Hawks. Wilson Journal of Ornithology 119:181–188.

ROSENFIELD, R. N., S. J. TAFT, W. E. STOUT, T. G. DRISCOLL, D. L. EVANS, AND M. A. BOZEK. 2009. Low prevalence of *Trichomonas gallinae* in urban and migratory Cooper's Hawks in northcentral North America. Wilson Journal of Ornithology 121:641–644.

ROSENFIELD, R. N., L. J. ROSENFIELD, J. BIELEFELDT, R. K. MURPHY, A. C. STEWART, W. E. STOUT, T. G. DRISCOLL, AND M. A. BOZEK. 2010. Comparative morphology of northern populations of breeding Cooper's Hawks. Condor 112:347–355.

ROTH II, T. C. AND S. L. LIMA. 2003. Hunting behavior and diet of Cooper's Hawks: an urban view of the small-bird-in-winter paradigm. Condor 105:474–483.

ROTH II, T. C. AND S. L. LIMA. 2006. Predatory behavior and diet of wintering male Cooper's Hawks in a rural habitat. Journal of Raptor Research 40:287–290.

RUTZ, C. R. 2008. The establishment of an urban bird population. Journal of Animal Ecology 77:1008–1019.

SCHLAEPFER, M. A., D. F. SAX, AND J. D. OLDEN. 2011. The potential conservation value of non-native species. Conservation Biology 25:428–437.

SONSTHAGEN, S. A., R. N. ROSENFIELD, J. BIELEFELDT, R. K. MURPHY, A. C. STEWART, W. E. STOUT, T. G. DRISCOLL, M. A. BOZEK, B. L. SLOSS, AND S. L. TALBOT. 2012. Genetic and morphological divergence among Cooper's Hawk populations breeding in north-central and western North America. Auk 129:427–437.

STEWART, A. C., R. W. CAMPBELL, AND S. DICKIN. 1996. Use of dawn vocalizations for detecting breeding Cooper's Hawks in an urban environment. Wildlife Society Bulletin 24:291–293.

STORER, R. W. 1966. Sexual dimorphism and food habits in three North American accipiters. Auk 83:423–436.

STOUT, W. E. AND R. N. ROSENFIELD. 2010. Colonization, growth, and density of a pioneer Cooper's Hawk population in a large metropolitan environment. Journal of Raptor Research 44:255–267.

STOUT, W. E., R. N. ROSENFIELD, W. G. HOLTON, AND J. BIELEFELDT. 2007. Nesting biology of urban Cooper's Hawks in Milwaukee, Wisconsin. Journal of Wildlife Management 71:366–375.

STOUT, W. E., A. G. CASSINI, J. K. MEECE, J. M. PAPP, R. N. ROSENFIELD, AND K. D. REED. 2005. Serologic evidence of West Nile virus infection in three wild raptor populations. Avian Diseases 49:371–375.

WILSON, D. E. AND S. RUFF (Editors). 1999. The Smithsonian book of North American mammals. Smithsonian Institution Press, Washington, D.C., USA.