

## Home Range and Habitat Use of Cooper's Hawks in Urban and Natural Areas

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*Abstract.* During 2001, we used radiotelemetry to measure home range and habitat use of adult male Cooper's Hawks (*Accipiter cooperii*) in urban and natural areas in Orange County, California, USA. Breeding ( $n = 8$ ) and non-breeding ( $n = 5$ ) season home ranges and core areas were calculated via CALHOME using 95% and 50% adaptive kernel methods, respectively. We used a  $G$ -test of proportions to determine if Cooper's Hawks used the habitat types in their territories in proportion to their availability. We also recorded breeding success of hawks in natural and urban areas. Home ranges did not differ between urban and natural territories in the breeding season. In urban birds, there was a trend of larger territories in the breeding season compared to the non-breeding season. Cooper's Hawks nesting in natural areas used coast live oak and riparian habitat more often

than expected, whereas Cooper's Hawks nesting in urban areas used parks/ornamental plantings and commercial/industrial areas more often than expected. Urban-nesting Cooper's Hawks successfully fledged an average of  $3.75 \pm 0.5$  young per nesting attempt, whereas natural-nesting Cooper's Hawks fledged an average of  $1.5 \pm 1.9$  young per nesting attempt. Our results contribute valuable information on home range and habitat use of urban-breeding Cooper's Hawks. Within urban home ranges this species prefers areas that mimic natural settings. Management for this species in urban areas should emphasize providing this sort of habitat.

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*Key Words:* *Accipiter cooperii*, adaptive kernel, breeding season, habitat use, home range, non-breeding season, radiotelemetry, urban ecology.

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Habitat structure and resource availability are important factors that influence bird communities in both naturally occurring and man-made environments. Predatory birds may be especially sensitive to urbanization because conversion of natural areas can reduce

hunting and foraging habitats (Boal and Mannan 1999), and these species can often be disturbed by human activities near their nests (Fyfe and Olanderoff 1976, Grier and Fyfe 1987, Richardson and Miller 1997). While food is perhaps the most important factor limiting raptor density

(Newton 1979, Pendleton et al. 1987), habitat alteration and/or destruction is recognized as the most important threat to accipiters (White 1974). The conversion of native habitats to agriculture, industry, brush encroachment due to fire control and grazing, wetland drainage, and urbanization has been cited as causes of declines in raptor numbers in the United States (Snyder and Snyder 1975).

However, over the past decade, Cooper's Hawk (*Accipiter cooperi*) populations have increased and range expansions have been observed, especially in the form of breeding birds colonizing urban and suburban areas (Curtis and Rosenfield 2006). Cooper's Hawks have been reported to be tolerant of some levels of human presence and habitat alteration (Beebe 1974; Clark 1977; Rosenfield et al. 1991, 1992) and have been observed nesting in urban environments (Beebe 1974, Stahlecker and Beach 1979, Murphy et al. 1988, Rosenfield et al. 1995, Sureda and Keane 1996, Kapler and Conrads 1997, Boal and Mannan 1998, DeCandido 2005). The ability of this species to colonize certain urban environments suggests that such information can be important for management, especially as urbanization continues (Boal and Mannan 1998). Furthermore, studying these birds in the urban environment, and in particular studying reproductive success, is important because it has been suggested that the urban environment can be an ecological trap for Cooper's Hawks (Boal 1997).

Previous research on Cooper's Hawks has focused on traditional and nontraditional breeding habitat. Traditional habitats consist of extensive forests to small woodlots of deciduous, coniferous, and mixed-pine hardwoods (Meng 1951, Millsap 1981, Titus and Mosher 1981, Reynolds et al. 1982, Moore and Henny 1983, Fischer 1986, Kennedy 1988, Wiggers and Kritz 1991, Trexel et al. 1999, Curtis and Rosenfield 2006). In California, Cooper's Hawks commonly nest in oak woodlands dominated by coast live oak (*Quercus agrifolia*) woodlands (Asay 1987). Nontraditional breeding habitat consists of urban and suburban areas (Beebe 1974, Stahlecker and Beach 1979, Murphy et al. 1988, Rosenfield et al. 1995, Sureda and Keane 1996, Kapler and Conrads 1997, Boal and Mannan 1998, McConnell 2003, Roth and Lima 2003, DeCandido 2005).

Spatial habitat requirements of Cooper's Hawks have been studied in eastern (Craighead

and Craighead 1956, Murphy et al. 1988, Reynolds 1989) and southwestern portions of the species' range (Mannan and Boal 2000, Estes and Mannan 2003, Cartron et al. in press). However, no empirical studies of Cooper's Hawk home ranges and habitat use in California exist. We are aware of seven studies that investigated non-breeding season ecology of this species such as home range size (Craighead and Craighead 1956, Lake et al. 2002), diet (Roth and Lima 2003, 2006), dispersal (Mannan et al. 2004), and wintering locality based on band recoveries (Henny 2004, Knutsen et al. 2004). The Lake et al. (2002) study is the most similar to ours; they found that Cooper's Hawks used forested habitats more often than expected and used edges and open fields less than expected compared to availability. All of these studies have provided important data on home range, habitat use, food habits, and predator-prey interactions of Cooper's Hawks during the non-breeding season and help to fill the data gap in the wintering ecology of this species.

We conducted a retrospective study of habitat and space use by Cooper's Hawks in Orange County, California, USA, using radiotelemetry. One step in assessing the quality of an urban environment as habitat for a species is to compare that species' breeding ecology and productivity in urban versus natural areas (Gehlbach 1988, Frimer 1989). Therefore, we also assessed reproductive success. The objectives of our study were to determine home range and core area size of adult male Cooper's Hawks in areas with two levels of human disturbance (urban and natural) and to compare use of habitat types during the breeding and non-breeding seasons. Based upon our objectives, we hypothesized that the following:

- Home range size and core areas of Cooper's Hawks in urban and natural areas will differ in size. Specifically, we predicted that home ranges and core area sizes will be smaller in urban environments.
- Home range size and core areas of Cooper's Hawks in urban and natural areas will differ in the breeding and non-breeding season. Specifically, we predicted that home range and core area will be larger in the breeding season compared to the non-breeding season.
- Habitat use by Cooper's Hawks will be distributed unequally across the entire home range. We predicted that in natural areas,

hawks will use oak woodland habitat in greater proportion than what is available in the home range and that urban hawks will use mature ornamental landscaping in greater proportion than what is available in the home range.

- Reproductive success in urban- and natural-breeding Cooper's Hawks will differ. We predicted that natural hawks will fledge more young than urban hawks.

## METHODS

### Study Area

The study area encompasses 648 km<sup>2</sup> of urban and natural areas in Orange County, California, USA (Fig. B.1). Orange County has an estimated human population of 2.94 million residents and is located in Southern California along the Pacific Ocean, south of Los Angeles. The county covers approximately 2,066 km<sup>2</sup>, which includes 65 km of coastline and extends inland approximately 30 km. The climate is Mediterranean, with an average annual rainfall of 36 cm, most of which occurs in February. Average annual relative humidity is 56%, with an average temperature of 22°C. Topography includes rolling hills and other low-elevation areas that are primarily urbanized, and canyons constituting remnant natural areas.

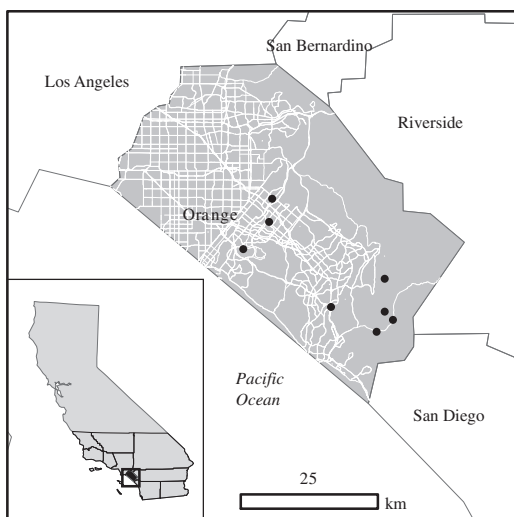


Figure B.1. Southern California study area located in Orange County. Urban territories were primarily located in the central portion of the county and natural territories were located in the southern portion of the county.

Elevation ranges from sea level to 1,710 m above mean sea level (County of Orange 2005).

The county contains local and neighborhood parks, greenbelts, windrow-lined streets, and channelized creeks interspersed throughout the urban environment, which provides mature landscaping conducive to some urban-adapted wildlife like Cooper's Hawks. Although the majority of ornamental trees are nonnative eucalyptus (*Eucalyptus* spp.), some parks and greenbelts contain fragmented remnants of natural vegetation comprised of mature willows (*Salix* spp.), coast live oaks, and western sycamore (*Platanus racemosa*) trees.

At the time of this study, we were aware of 74 Cooper's Hawk territories in natural settings, 11 along the urban-rural interface, and 40 in urban areas, from which we selected four urban and four natural based on accessibility. We considered territories as sampling units.

Principal land uses in urban territories include residential, commercial, and local parks. Permanent and intermittent water sources within urban territories include channelized waterways, man-made water features such as pools or fountains, artificial ponds, and a few natural drainages. Three of the four urban territories are located in park-like settings comprised of mature ornamental trees associated with schools and university campuses. One of our urban territories is located in a semi-fallow agricultural area next to a small park.

Principal land uses in natural territories include agriculture, cattle ranching, nurseries, gravel mining, and open space. Perennial and intermittent water sources within natural territories include natural streams, drainages (Bell Canyon, Verdugo Canyon, and San Juan Creek), and stock ponds. With the exception of dirt roads, utility poles, and scattered buildings, vegetation communities in the natural territories are relatively intact; certain areas are more heavily grazed than others, and therefore are more disturbed. However, in general, the natural territories represent a contiguous tract of open space.

### Telemetry

All hawks were captured using dho-gaza traps with a Great Horned Owl (*Bubo virginianus*) as a lure (Bloom 1987, Bloom et al. 1992), or using bal-chatri traps baited with house mice (*Mus*

*musculus*, Berger and Mueller 1959). Each hawk was weighed, measured, and banded with a U.S. Fish and Wildlife Service aluminum band and a plastic color band (Haggie Engraving). Age and sex were determined by plumage and molt characteristics, body size, mass, and presence or absence of a brood patch. We fitted male hawks with a 6-g backpack-mounted radio transmitter (Model RI-2C, Holohil Systems, Ltd.; Dunston 1972), attached with a 4-mm-wide Teflon strap harness. Backpacks weighed less than 3% of the birds' body weight and transmitters had a life expectancy of 12 months. We observed each radio-tagged hawk immediately following transmitter attachment and within 48 hours of release; each appeared to exhibit normal behaviors.

Cooper's Hawks exhibit sexual dimorphism and may consequently hunt different areas and take differently sized prey items. Male Cooper's Hawks are the primary food provider during nest building, incubation, and brooding periods (Jones 1979); therefore, we used point locations obtained from males to estimate territory metrics. Consequently, our results are more applicable to adult male Cooper's Hawks than to Cooper's Hawks in general. We used a hand-held radio receiver with a three-element Yagi antenna (Communications Specialists, Inc.) to locate tagged hawks during 2001. A total of 1,685 hours were spent radio-tracking adult male Cooper's Hawks during the breeding season (March–July) and non-breeding season (July–November). In most cases, birds were tracked all day from morning roost (1 hour before sunrise) to night roost (1 hour after sunset) (Bloom 1989), with locations recorded at approximately half-hour intervals. In order to minimize dependency between successive locations, we removed all location points within 30 minutes of each other; 30 minutes was easily longer than the amount of time required for a Cooper's Hawk to fly from one end of its home range to the other (White and Garrott 1990, Otis and White 1999). We developed an ArcView script to randomly filter 30-min locations from the data set equally throughout our survey period, and night and morning roost locations from consecutive observation days were removed. The total number of locations used to generate home range estimates was 2,559 points. We determined the locations of radio-tagged hawks by direct observation accompanying radio locations (18.6%) and triangulation (81.4%). Care was taken not to

disturb hawks while radio-tracking. Two to four bearings were taken to determine triangulated locations, and most bearings were taken from a distance of 100–150 m. However, hawks occupying urban territories were considerably more tolerant of human activity and often flew to perches located <20 m from observers, which resulted in exact location points. Location points for natural territories were mapped on U.S. Geological Survey (USGS) 7.5-minute topographic quadrangles, and locations for urban territories were mapped on Thomas Brothers Quad-page maps (Thomas Brothers Maps 2001 and 2008).

To determine error associated with location estimates, we conducted error tests in natural ( $n = 15$  with two bearings) and urban locations ( $n = 15$  with two bearings and  $n = 15$  with three to four bearings). We had an independent party place a transmitter in habitat and topographic conditions where Cooper's Hawks would be found. The test transmitter locations were recorded with a Global Positioning System (GPS) unit, and the triangulated locations in natural habitats were mapped on USGS topographic maps while the triangulated positions in urban habitats were mapped on Thomas Brothers Quad-page maps. Triangulated positions were then digitized and converted to Universal Transverse Mercator (UTM) coordinates using ArcGIS software (ver. 9.2, ESRI, Redlands, CA). Distances between test transmitters and triangulated locations were measured by comparing UTM coordinates. The average distance between the actual and the triangulated locations was what we considered to be the average error associated with triangulated locations and mapping ( $44.5 \pm 22.0$  m in natural areas with two bearings,  $43.7 \pm 26.3$  m in urban areas with two bearings,  $28.4 \pm 16.6$  m in urban areas with three to four bearings).

#### Analysis

Home range estimates were calculated using CALHOME (Kie et al. 1994) via the adaptive kernel (AK) method (Worton 1989), using the 95% contour level and 50 m  $\times$  50 m grid size. Core areas were calculated via the AK method with a 50% contour level and 50 m  $\times$  50 m grid size. The estimated optimum bandwidth (least-squares cross-validation score; Worton 1989) was used as the smoothing parameter for all home range estimates.

In order to determine if enough location points were obtained to adequately describe home ranges, home range estimates were plotted against sample sizes. Area-observation curves for the UCI territory ( $n = 206$ ) showed that an adequate number of locations was collected when approximately 95 points were obtained (Odum and Kuenzler 1955). However, area-observation curves for the smallest sample size revealed that an inadequate number of locations was collected (S. Preusker,  $n = 81$ ). However, due to the small sample size of the study, this territory was still included in the home range analysis. As such, home range size for S. Preusker should be considered a minimum estimate. Consequently, combined home range estimates for natural territories may also be underestimated.

We determined if home range sizes differed between natural and urban birds in the breeding and non-breeding season by comparing means and 99% confidence intervals (CI) of 95 AK and 50 AK home range sizes. Assessing differences with confidence intervals is appropriate in observational studies with low sample sizes (Johnson 1999). We used 99% CI (instead of 95% CI) as a correction for multiple comparisons. If confidence intervals were overlapping, we interpreted this as a lack of statistical difference. However, if confidence intervals did not overlap the mean, we interpreted this as support for a trend toward statistical difference (Ramsey and Schafer 2002).

#### Reproductive Success

In addition to radio-tracking, general nest observations were made throughout the breeding cycle, including nestling development, timing of fledging, and reproductive success. Reproductive success was determined by the number of young that successfully fledged the nest.

#### Habitat Use

We used the Orange County Habitat Classification System as the basis for our habitat classifications (County of Orange 1992). Descriptions of natural plant communities follow the categories set forth by Holland (1986) and are described in detail in Chiang (2004). We categorized natural habitat into one of nine communities based on dominant vegetation and physiognomic features of the landscape: (1) coastal sage scrub, (2) chaparral,

(3) grassland, (4) riparian, (5) coast live oak, (6) aquatic, (7) agriculture, (8) developed, and (9) ornamental landscaping. We categorized urban habitat into one of ten types based on Orange County Habitat Classification Maps: (1) urban, (2) rural residential, (3) commercial/industrial, (4) transportation, (5) parks/ornamental plantings, (6) cleared or graded areas, (7) natural areas, (8) agriculture, (9) other developed, and (10) other disturbed.

We overlaid 50% AK and 95% AK home range estimates onto Orange County GIS vegetation data with a ground resolution of 1 m (County of Orange 1992) using ArcView and ArcGIS software (ESRI 1998, 2002). The resulting polygons were overlaid onto orthophotos to ground-truth vegetation data. A G-test of proportions (Sokal and Rohlf 1995) was used to test whether hawks used habitat within their territories in proportion to the available habitat.

## RESULTS

Nine male Cooper's Hawks were fitted with radio transmitters. However, one urban male did not establish a territory, left the area within two weeks of transmitter attachment, and was excluded from the study. Breeding-season home range estimates were subsequently determined for eight hawks. Non-breeding season home range estimates were determined for five hawks. Two males (S. Preusker and Starr Mesa) vacated the area following nest failure, while a third male (Verdugo Canyon) fledged young but vacated the area following post-fledging. Subsequent attempts to relocate hawks via hiking, driving, and aerial surveys via small fixed-wing plane were unsuccessful; all three males left before enough non-breeding season points could be collected and were excluded from non-breeding season analysis. Approximately one-quarter of non-breeding season location points for The Nature Conservancy (TNC) male were obtained via direct observation after we discovered that the antenna had been pulled out.

#### Home Range

Breeding-season home ranges in natural areas ranged between 378.0 ha and 1,080.0 ha (Table B.1). Breeding-season home ranges in urban areas ranged between 344.0 ha and 630.6 ha

TABLE B.1  
*Seasonal core areas (50% AK) and home range (95% AK) estimates (ha) of adult male Cooper's Hawks  
in Orange County, March through November 2001.*

Territory	Breeding			Non-breeding		
	<i>n</i>	50% AK	95% AK	<i>n</i>	50% AK	95% AK
Natural						
Amantes Camp <sup>a</sup>	214	40.63	378.00	104	20.03	221.10
Verdugo Canyon <sup>b</sup>	277	62.65	1,080.00	—	—	—
Starr Mesa <sup>b</sup>	92	62.98	557.00	—	—	—
S. Preusker <sup>b</sup>	81	47.90	419.60	—	—	—
Urban						
TNC	295	12.56	351.10	101	21.39	159.30
UCI	206	63.77	344.00	230	54.61	294.30
Saddleback	207	40.10	595.50	272	15.78	128.60
Venado	306	23.91	630.60	174	25.95	368.00

<sup>a</sup> Data for the Amantes Camp non-breeding season were not included in any statistical analysis. The data are included here for completeness.

<sup>b</sup> Vacated territory before sufficient non-breeding season data was collected and was therefore excluded from non-breeding season analysis.

(Table B.1). Only one home range was found for a non-breeding territory in a natural area (221.1 ha). Non-breeding home ranges in urban areas ranged between 128.6 ha and 368.0 ha (Table B.1). Average home range size for Cooper's Hawks in natural territories during the breeding season was  $609 \pm 416$  ha (mean  $\pm$  99% CI), and average home range for urban territories was  $481 \pm 198$  ha. Home ranges did not differ between urban or natural territories in the breeding season. In urban birds, there was a trend (CI do not overlap the means) of larger territories in the breeding season compared to the non-breeding season (Fig. B.2a). Comparisons between non-breeding birds in urban versus natural habitats and non-breeding versus breeding in natural habitats could not be made due to lack of sample size in non-breeding birds in natural habitats.

Mean distance of roost sites from the nest during early and middle stages of the breeding season (incubation through pre-fledging) was  $296 \pm 132$  m (mean  $\pm$  95% CI). As the breeding season progressed and fledglings approached independence, half of the males (Verdugo Canyon, TNC, UCI, Venado) used different roosts located

further away from the nest. Mean distance of roost sites during the latter portion of the breeding season through the non-breeding season was  $608 \pm 361$  m (mean  $\pm$  95% CI). The other four males (Amantes Camp, Starr Mesa, S. Preusker, Saddleback) used several different roosts throughout the breeding and non-breeding seasons.

#### Core Areas

On average, core areas represented  $9.0 \pm 3.5\%$  and  $12.4 \pm 4.7\%$  (mean  $\pm$  95% CI) of the overall breeding and non-breeding home ranges, respectively. Breeding-season core areas in natural areas ranged between 40.6 ha and 63.0 ha. Breeding-season core areas in urban areas ranged between 12.6 ha and 63.8 ha. Only one core area was found for a non-breeding territory in a natural area (20.0 ha). Non-breeding core areas in urban areas ranged between 15.8 ha and 54.6 ha. In the breeding season, there was evidence that core areas were larger for birds in natural areas compared to urban areas (Fig. B.2b). In urban birds, there was no trend between breeding and non-breeding birds. Comparisons between non-breeding birds in urban versus natural habitats

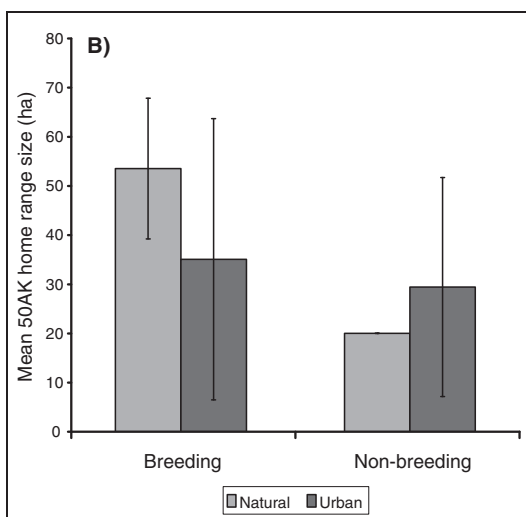
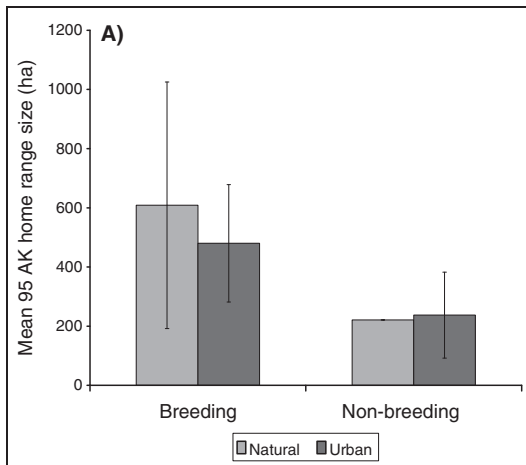


Figure B.2. Comparison of (a) 95% AK breeding and non-breeding home ranges between natural and urban territories and (b) 50% AK breeding and non-breeding core areas between natural and urban territories.

and non-breeding versus breeding in natural habitats could not be made due to lack of sample size in non-breeding birds in natural habitats.

### Reproductive Success

All four urban Cooper's Hawks successfully fledged young ( $3.75 \pm 0.5$ ; mean  $\pm$  95% CI); however, only two natural Cooper's Hawks successfully fledged young ( $1.5 \pm 1.9$ ). The other two natural nests failed because of unknown causes. However, in both cases the eggs were scavenged.

Uneven overlap of confidence intervals indicates a trend for higher reproductive success in urban versus natural-breeding hawks.

### Habitat Use

Percentages of habitat types, especially percentage of developed areas, varied considerably between urban and natural territories. Developed areas included shopping plazas, parking lots, residential units, industrial buildings, schools, and university campuses. Developed areas were the most abundant habitat type in urban territories, often accounting for more than 50% of available habitat, whereas developed areas only represented at most 15% of available habitat within natural territories. In contrast, coastal sage scrub was the most abundant habitat type in natural territories, often accounting for more than 20% of available habitat.

Habitat used by hawks differed significantly from what was available within home ranges for breeding birds in both urban ( $G = 22.9$ ,  $df = 9$ ,  $P < 0.05$ ) and natural ( $G = 17.1$ ,  $df = 9$ ,  $P < 0.05$ ) habitats. Urban breeding birds used parks/ornamental plantings and commercial/industrial areas more often than expected, and transportation and natural areas less than expected (Fig. B.3). However, confidence intervals are large and demonstrate trends. Natural-breeding birds used coast live oak and riparian areas more than expected and chaparral, agriculture, and developed areas were used less than expected (Fig. B.4). Non-breeding birds in urban habitat did not use habitat within home ranges differently ( $G = 6.6$ ,  $df = 7$ ,  $P > 0.05$ ). Non-breeding birds in natural habitats could not be tested because telemetry data was collected on only one bird.

All nests in natural territories were located in coast live oaks. Three of the four urban nests were located in eucalyptus trees, and the fourth was in a Fremont's cottonwood (*Populus fremontii* ssp. *fremontii*). All urban nest groves contained tall, mature trees that were predominantly eucalyptus.

Nest height was measured during nestling banding or with a clinometer; nests averaged  $15.4 \pm 3.46$  m (mean  $\pm$  95% CI) above ground and were typically located in the upper one-third of the nest tree. Average diameter at breast height (DBH) for all nest trees was  $254.0 \pm 92.16$  cm (mean  $\pm$  95% CI).

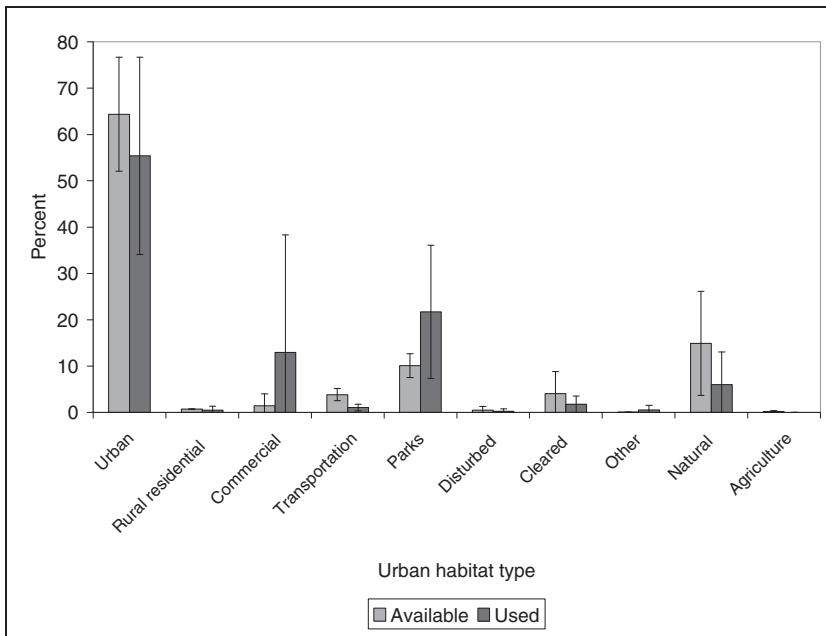


Figure B.3. Available versus used habitat for urban breeding birds. Urban-breeding birds used parks/ornamental plantings and commercial/industrial areas more often than expected.

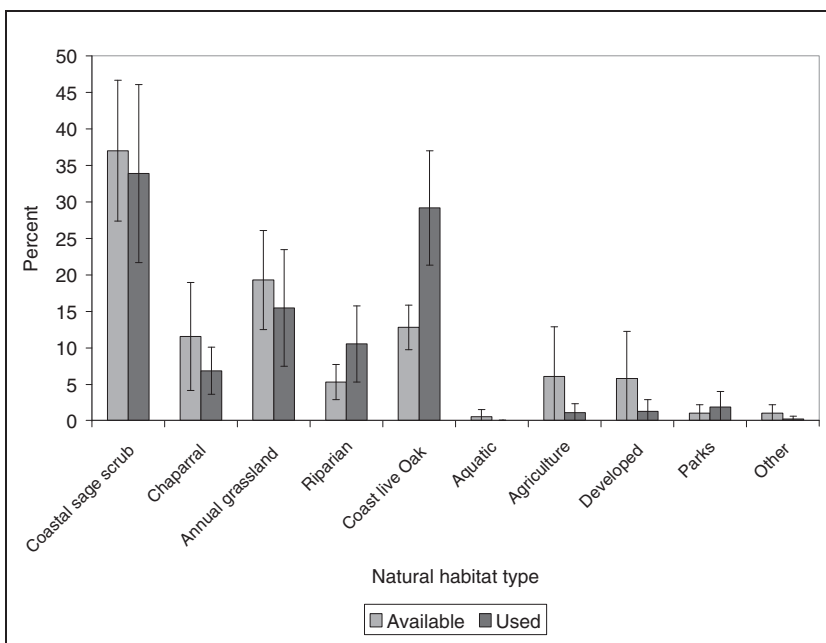


Figure B.4. Available versus used habitat for natural breeding birds. Natural-breeding birds used coast live oak and riparian habitat more often than expected.



## DISCUSSION

### Home Range

Average home range size for Cooper's Hawks in natural territories during the breeding season was  $609 \pm 416$  ha and average home range for urban territories was  $481 \pm 198$  ha. Our findings for home range size of Cooper's Hawks during the breeding season in Orange County falls within the lower range of previous studies. Previous home range estimates for breeding Cooper's Hawks range from 400 to 1,800 ha based on nest density studies in natural areas without the benefit of telemetry (Craighead and Craighead 1956, Reynolds 1989) and from an average of 65.5 ha to 1,206 ha based on telemetry studies in urban and natural areas (Murphy et al. 1988, Mannan and Boal 2000, Cartron et al. in press). The data from S. Preusker, which did not meet the minimum required locations, likely lowered our overall mean for home range size due to its more conservative estimate. However, the home range estimate for this individual was neither the smallest nor the largest estimate. Therefore, we believe that the average home range calculated is an accurate estimate. Furthermore, the home ranges we calculated fit within the known range of areas for this species; therefore, we believe our data are reflective of the home range for this species in this area.

The average home range ( $481 \pm 198$  ha) for urban Cooper's Hawks during the breeding season in Southern California falls within the middle range of other urban telemetry studies. Average home range was smaller than the 784-ha average in Wisconsin (Murphy et al. 1988) and considerably larger than the 65.5-ha average in Tucson, Arizona (Mannan and Boal 2000).

A variety of factors influence space use of raptors, including prey abundance, habitat availability, foraging behavior, and territoriality (Newton 1979, Bloom et al. 1993). Beissinger and Osborne (1982) suggested that urban areas support a higher total density of birds than non-urban areas. Based on such evidence, urban Cooper's Hawks would be expected to have smaller home ranges due to a higher biomass of birds within the area, as was the case in Tucson (Boal 1997, Estes and Mannan 2003). Home ranges did not differ between urban and natural territories in this study; however, confidence intervals are large

and our sample size is small. Further studies with increased sample sizes are needed to understand the relationship between urban and natural home ranges of Cooper's Hawks in Orange County.

### Core Areas

It is not surprising that urban Cooper's Hawks tended to have smaller core areas, because an urban hawk has a limited number of suitable mature nest groves of adequate size compared to natural settings that have essentially intact habitat with a mosaic of woodlands and tree groves. Cooper's Hawks in urban settings are limited by an inconsistent number and more random location of landscaped trees that are tall enough and provide adequate canopy cover. Smaller urban core areas could also result in a higher abundance of prey within the immediate vicinity of the nest. Urban Cooper's Hawks were often seen hunting at backyard bird feeders and bird baths immediately surrounding the nest grove throughout the breeding and non-breeding seasons.

### Reproductive Success

Although based on a small sample size, we believe that the high reproductive success rate of urban Cooper's Hawks may be attributed, in part, to the fact that there are few, if any natural nest predators such as gray fox (*Urocyon cinereoargenteus*) or bobcat (*Lynx rufus*) in the urban home ranges in our study area (P. H. Bloom, unpubl. data). Similar findings have been observed in Eastern Screech-Owls (*Megascops asio*) in Texas (Gehlbach 1994) and urban Cooper's Hawks in Pennsylvania (McConnell 2003), where these species apparently benefited from decreased nest predation in the urban setting. Raccoons (*Procyon lotor*) occasionally occur in the urban home ranges of our study area, but their numbers were believed to be low and occurrences localized compared to natural areas. Therefore, we assume they do not pose a substantial threat to nestling Cooper's Hawks. Furthermore, the presence of domestic dogs within the immediate vicinity of urban Cooper's Hawk nests probably contributes significantly to reduced predation risk by mammals. Nest predation by Great Horned Owls is a major cause of nestling mortality (Rosenfield 1988). Despite the fact that three of the four urban Cooper's Hawk

territories were located in the vicinity of Great Horned Owl nests (Bennett 1999, P. H. Bloom, unpubl. data), all of these territories successfully fledged young. We acknowledge that many urban Cooper's Hawks in other portions of the species' range must contend with the previously mentioned nest predators; however, Cooper's Hawks in our urban study area may have benefited from low numbers and localized occurrences.

#### Winter Residency and Non-breeding Season Ecology

Relatively little data exist on winter residency among accipiters, and on Cooper's Hawks in particular, during the non-breeding season. Banding data in Wisconsin based on winter recaptures of marked birds indicate that some of that state's Cooper's Hawks may overwinter within 1 to 2 km of their previous nest sites (Bielefeldt et al. 1998). Band recoveries in Michigan also indicate winter site fidelity (Knutsen et al. 2004). Data on winter home range size of unmarked Cooper's Hawks range from 2.4 to 3.2 km in diameter (Craighead and Craighead 1956) to an average of 771 ha for marked fledglings (Mannan et al. 2004) and 331 to 836 ha for marked juveniles and adults (Lake et al. 2002). Our findings follow winter residency patterns of Cooper's Hawks in Wisconsin (Bielefeldt et al. 1998), Michigan (Knutsen et al. 2004), and Arizona (Mannan et al. 2004), and suggest that Cooper's Hawks in Southern California appear to be year-round residents and remain close to their nest stands during winter (Chiang 2004). Average home range size of Cooper's Hawks in Orange County during the non-breeding season was 237 ha (urban) and 221 ha (natural), which is much smaller than the average of 771 ha for fledgling Cooper's Hawks in Tucson, Arizona (Mannan et al. 2004), and moderately smaller than the range of 331 to 836 ha for juvenile and adult Cooper's Hawks in southwestern Tennessee (Lake et al. 2002).

Cooper's Hawks feed primarily on birds during winter (Craighead and Craighead 1956), especially medium-large birds >70 g in urban areas (Roth and Lima 2003) and small birds such as sparrows in rural areas (Roth and Lima 2006). Southern California has an abundant wintering bird population on which Cooper's Hawks may be able to subsist in smaller home ranges. The trend of smaller non-breeding season home ranges in urban territories can also be attributed,

in part, to sedentary behavior exhibited by male Cooper's Hawks following nestling independence. This sedentary behavior was also observed during fledgling dispersal of urban Cooper's Hawks in Arizona (Mannan et al. 2004). Whereas Cooper's Hawks during the breeding season were constantly moving from perch to perch actively foraging and defending the territory (Fischer 1986, Kennedy 1991), it was common for a Cooper's Hawk during the non-breeding season to remain perched in the same location for several hours at a time (up to 8 hours; Chiang 2004). The change in daily activity pattern is a function of parental responsibility. During the breeding season, adult male Cooper's Hawks are active because they must constantly hunt to feed the female during incubation and brooding, feed the young, and defend the territory. During the non-breeding season, adult male Cooper's Hawks need only hunt for themselves. Activity beyond what is necessary for survival increases the risk of mortality.

#### Habitat Use

Habitat used by hawks differed significantly from what was available within home ranges in both natural and urban environments. Cooper's Hawks in natural areas of our study area used coast live oak and riparian areas more than expected. Specifically, the coast live oak habitat often occurred in association with riparian areas, suggesting this species' strong association to riparian woodland vegetation. Other studies have documented Cooper's Hawks in undeveloped, extensive forests to small woodlots of deciduous, coniferous, and mixed-pine hardwoods, and coast live oak woodlands (Meng 1951, Asay 1980, Millsap 1981, Titus and Mosher 1981, Reynolds et al. 1982, Moore and Henny 1983, Fischer 1986, Kennedy 1988, Wiggers and Kritz 1991, Curtis and Rosenfield 2006). Breeding Cooper's Hawks in urban sites within our study area used parks/ornamental plantings and commercial/industrial areas within their home ranges more often than expected. It is likely that parks/ornamental plantings and commercial/industrial areas within the urban home ranges adequately mimicked natural woodlands in terms of habitat structure. Studies of non-traditional breeding habitat have shown Cooper's Hawks to be successful breeders in a variety of urban settings with different

levels of human disturbance (Stahlecker and Beach 1979, Murphy et al. 1988, Rosenfield et al. 1995, Sureda and Keane 1996, Boal 1997, Boal and Mannan 1998, DeCandido 2005). However, habitat data were evaluated for a relatively small number of birds ( $n = 4$  for natural hawks during the breeding season and  $n = 4$  for urban hawks during each season, breeding and non-breeding). Therefore, it is important that more studies of habitat use by Cooper's Hawks be conducted, particularly in urban areas where habitat use is not as well documented. Regardless, our results provide valuable information about the types of habitat in which Cooper's Hawks may be found.

### Urban Ecology of Cooper's Hawks

Habitat use by raptors is greatly influenced by prey abundance, habitat structure, and perch availability in relation to foraging technique (Craighead and Craighead 1956, Newton 1979, Newton et al. 1979, Janes 1985). Cooper's Hawks use a combination of prey-capture methods that include brief perch-and-scan episodes to locate prey, followed by a sudden burst of speed in addition to hunting from higher flight (Meng 1951, Mead 1963, Beebe 1974, Clark 1977, Fischer 1986). Kennedy (1991) described this hunting technique as saltatory foraging, which is characterized by a stop-and-go pattern, where the animal repositions itself frequently to scan from a new location (Evans and O'Brien 1988). Other hunting techniques employed by Cooper's Hawks in urban areas include the use of visual obstructions such as buildings, fences, and hedgerows for surprise-ambush attacks on prey (Roth and Lima 2003). All of the aforementioned foraging techniques were observed during radio-tracking. Due to the fact that Cooper's Hawks typically rely on concealment and take prey from the ground, in flight, or from perches, it is not surprising that Cooper's Hawks used woodland habitats more than non-woodland habitats. Woodland habitats provide numerous perch sites and cover necessary for successful hunting by a predator that relies on concealment. Cooper's Hawks in the study area were seen hunting and feeding on avian prey more often than mammalian or reptilian species, and urban Cooper's Hawks were regularly seen hunting within hedgerows and from fences above hedgerows. Unlike other raptor species such as Red-shouldered Hawks (*Buteo lineatus*)

that hunt exclusively from perches (Bloom et al. 1993), Cooper's Hawks employ a variety of hunting techniques and therefore are not limited by perch availability.

Previous studies of urban-nesting raptors in Southern California include Red-shouldered Hawks (Bloom and McCrary 1996) and Great Horned Owls (Bennett and Bloom 2005). Additional raptor species that have been thoroughly monitored in Southern California include Red-tailed Hawk (*Buteo jamaicensis*), Northern Harrier (*Circus cyaneus*), and White-tailed Kite (*Elanus leucurus*; P. H. Bloom, unpubl. data, Niemela 2007). Of these species, Cooper's Hawks and Red-shouldered Hawks have been successful in the urban environment in similar ways. Behaviorally, both urban Cooper's Hawks and Red-shouldered Hawks seemed undisturbed by human presence.

High levels of human activity directly beneath Red-shouldered Hawk nest trees within the same study area did not result in nest abandonment (Bloom and McCrary 1996); however, some individuals were aggressive toward people. In our study, nest groves of all urban hawks were located in densely populated areas. Specifically, the UCI, Saddleback, and Venado nest groves were located on university/school campuses where hundreds of college students and elementary school children regularly walked and played directly below nest trees on a daily basis, often <15 m from perched adults. Aggressive behavior (swooping flights and occasional strikes) in response to human presence was only observed from one pair, but occurs regularly at other urban territories in Orange County. In comparison, Cooper's Hawks in natural settings were skittish and extremely sensitive to human presence. Similar to our findings, Bloom and McCrary (1996) also observed smaller home ranges and higher reproductive success with urban Red-shouldered Hawks than those in natural areas.

Factors that contribute to the success of urban Cooper's Hawks include their foraging technique, characterized by maneuverability in structurally complex habitats, in addition to the fact that their prey base consists primarily of small to medium-sized birds that are abundant in urban areas. Therefore, their surprise-ambush foraging technique (Roth and Lima 2003) is successful in the urban setting. Likewise, the perch-and-wait hunting style of Red-shouldered Hawks is facilitated in the urban landscape through

abundant lampposts, fence lines, and utility poles. Additionally, their prey base consists of small vertebrate and invertebrate species that are abundant in urban areas (Bloom et al. 1993). Although prey species composition differs between urban and natural Cooper's Hawks (Estes and Mannan 2003, Roth and Lima 2006), the urban hawks forage on substitute species that still fit within the parameters of their typical natural prey base. Urban Cooper's Hawks were often seen hunting at backyard bird feeders and bird baths throughout the breeding and non-breeding seasons.

After considering the raptor species that are present and absent from the urban environment in Southern California, we believe that diet and hunting style are two ecological traits that significantly contribute to success in human-altered landscapes. Cooper's Hawks and Red-shouldered Hawks have been able to successfully adapt to the urban environment in our study area because they employ hunting styles that are facilitated by features in the urban setting, in addition to the fact that they are not limited by prey availability.

## MANAGEMENT IMPLICATIONS

A study of Northern Goshawk home ranges within timber management areas placed an emphasis on home range management rather than just nest site protection (Hargis et al. 1994). We fully agree and believe that home range management, especially within urban areas, will become increasingly important for species conservation as development continues. Increasing population demands have led to rapid urbanization in Southern California, resulting in considerable native habitat loss. Estimates of regional coastal sage scrub habitat loss range from 66% to 90% (County of Orange 1996). Oak woodlands are also becoming increasingly rare in Orange County.

Significant conversion of agricultural land to the current urban landscape in Orange County began in the 1940s (County of Orange 2005). It was not until 1998 that P. H. Bloom (unpubl. data) noted the first successful nesting attempt of Cooper's Hawks in the urban setting of his neighborhood. While some older neighborhoods frequently contained Cooper's Hawk nesting territories, vast areas of urban Orange and Los Angeles Counties do not contain nesting Cooper's Hawks. We contend that until approximately ten

years ago, the landscaped vegetation in our urban study area was not mature enough to provide the height and canopy cover that could mimic natural woodlands and groves. Therefore, until that time the urban landscape was not suitable for urban Cooper's Hawks. Even now, after 50 to 70 years of urban forest growth and development, there are many square kilometers of Orange County that do not support nesting Cooper's Hawks because of the short structure of certain tree species that were planted.

Despite the fact that oak woodlands are covered in the Central Coastal Subregion Natural Communities Conservation Plan, a regional plan designed to protect habitat and aid in the recovery of the federally listed Coastal California Gnatcatcher (*Poliophtila californica californica*; County of Orange 1996), a substantial portion of the remaining oak woodlands and surrounding habitat in our natural study area are slated for development over the next 20 years. Although the urban Cooper's Hawk population in Southern California suggests this species' flexibility in an urban setting, urbanization in other portions of the species' range has been detrimental to both urban- and natural-nesting birds (Bosakowski et al. 1993, Boal 1997). For instance, despite the higher fledging success of urban birds, which suggests that urban areas may produce more young, two adult urban Cooper's Hawks died as a result of car collisions after radio-tracking had ended. Roth et al. (2005) cite human-induced mortality factors, including collisions with windows or automobiles (Keran 1981, Klem 1990, Klem et al. 2004), electrocution (Lehman 2001), natural predation by owls and other raptors (Klem et al. 1985, George 1989, Roth et al. 2005), disease (Ward and Kennedy 1996, Boal et al. 1998), and to a lesser degree, gunshot and poison (Boal 1997). A more detailed demographic study including reproductive success and juvenile and adult survivorship in urban and natural areas would provide a more robust analysis of whether the urban setting in Southern California is an ecological trap.

Trend analysis from the North American Breeding Bird Survey (BBS) for 1980 to 2007 indicates a survey-wide increase in Cooper's Hawk populations of 4.6% per year, with a 5.9% increase per year in the United States and a 5.7% decrease per year in Canada (Sauer et al. 2008). Most of the increase has occurred in northern and

eastern portions of the survey area, while declining populations have been observed in western portions of the survey area, including Canada and most of California. Specifically within California and California foothills, trend analyses indicate a 5.2% and 7.1% decrease, respectively, per year for the same time period. Despite the decreasing population trend in California, Cooper's Hawks have recently been downgraded from a California Species of Special Concern to a Watch List Species. Therefore, effective conservation planning and management in California should be actively pursued in light of decreased regulatory oversight and continued habitat loss.

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