

# Influence of Natal Experience on Nest-Site Selection by Urban-Nesting Cooper's Hawks

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**ABSTRACT** Exposure to environmental features early in life potentially can influence the kinds of places animals select to live later in life. We examined whether there is evidence that Cooper's hawks (*Accipiter cooperii*) hatched in an urban environment choose sites with features similar to their natal areas when they nest for the first time. The features we examined were the nest tree species and the level of development surrounding the nest tree. We banded nestling and fledgling Cooper's hawks in Tucson, Arizona, USA, from 1994 to 2004. We then monitored nests in Tucson to identify hawks that had been hatched in the city and eventually secured a breeding site. Percent cover of buildings around first breeding nests was not related to percent cover of buildings around natal nests for either sex. There was some evidence that being hatched in a particular tree species influenced choice of tree species at first breeding sites for males, but the influence was weak. In contrast, tree species in which first-time breeders built their nests, and the sites where the trees were located relative to development, were proportional to what was available in the Tucson metropolitan area. Our data suggest that natal experience played a limited role in nest-site selection by Cooper's hawks in Tucson for the features we examined. If learning occurred, it could have been for the general structure of natal sites. Thus, any small grove of large trees planted in Tucson could be used as a nest site by Cooper's hawks regardless of the level of development surrounding the nest. (JOURNAL OF WILDLIFE MANAGEMENT 71(1):64-68; 2006)

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Habitat selection is a behavior, sometimes called a settling response, triggered by features or resources in the environment (Lack 1933, Hilden 1965). Exposure to environmental features early in life potentially can influence the kinds of places animals select to live later in life through a process of learning called habitat imprinting (Stamps 2001), or more recently natal habitat preference induction (NHPI; Davis and Stamps 2004). Individuals learning through NHPI are more likely to select breeding sites with features similar to their natal sites than other areas (Davis and Stamps 2004).

Experiments with a wide variety of organisms, including insects, fish, amphibians, birds, and mammals (Davis and Stamps 2004) have demonstrated that NHPI influences where animals choose to settle. The existence of NHPI also has been suggested from patterns of habitat selection found in field investigations (Stamps 2001). For example, peregrine falcons (*Falco peregrinus*) hatched in a nest on a cliff, building, or bridge generally nested in the same kind of site as breeding adults (Tordoff et al. 1998), but lack of information about availability of nest sites complicated assessment of learning in that study (Stamps 2001). In contrast, some animals settle in places that differ substantially from where they were raised. Rosenfield et al. (2000) found that some Cooper's hawks (*Accipiter cooperii*) hatched in pine plantations nested as

adults in mixed conifer-hardwood stands, and vice versa, suggesting that if NHPI occurred, features learned were general enough to allow considerable flexibility in habitat selection. Understanding the role of early experience in habitat selection could be important when releasing young animals in re-introduction efforts, and when assessing whether environments where conditions are largely dictated by human activities (e.g., urban areas) might be recognized as habitat by a given species.

Cooper's hawks are common breeding birds in the Tucson, Arizona, USA, metropolitan area (Boal and Mannan 1998, 1999), and they usually nest in small groves of relatively large, non-native trees, primarily eucalyptus (*Eucalyptus* spp.) or aleppo pines (*Pinus halepensis*; Boal and Mannan 1998). These tree species differ from each other in many ways, including branch configuration, shape and color of leaves, and texture and color of bark. Furthermore, nest groves are situated in a variety of urban environments, ranging from highly developed areas, such as business complexes and high-density residential neighborhoods, to less-developed sites, such as regional parks, golf courses, and cemeteries (Boal and Mannan 1998). Our objective was to examine whether hawks hatched in nests in particular tree species and in particular urban environments tend to choose similar situations when they settle and breed for the first time. We chose to examine these features because they were among the most prominent structural and compositional elements that differed among nests in Tucson. We predict that if hawks are influenced by

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exposure to these features as nestlings, they should nest in similar situations when they first breed. Alternatively, if they 1) are not influenced by exposure to these features, 2) learn the general structure of trees in their natal sites (e.g., a group of large trees), 3) innately recognize the general conditions of an appropriate nest site, or 4) are limited to nesting in the first available site, then the distribution of their first nest sites relative to these 2 features should be similar to what is available to them.

## STUDY AREA

We monitored Cooper's hawks in and near Tucson, Arizona (32°N, 111°W). The Tucson metropolitan area encompassed about 146,000 ha with an estimated human population of about 600,000 residents. Tucson was located in the Sonoran Desert and supported remnants of lower and upper Sonoran vegetation types and riparian corridors (Brown et al. 1979), but much of the natural vegetation had been removed and replaced with non-native plants.

## METHODS

We located nests of Cooper's hawks during the breeding season (Feb–Jul) from 1994 to 2004 by searching in historical nest sites, areas where Cooper's hawks had been seen and reported by interested persons, sites from which injured nestlings or adults were collected by wildlife rehabilitators, and groves of large trees (Boal and Mannan 1998). We defined a nest site as occupied when we observed a pair of hawks present in the area building a nest, and we plotted locations of nests on a digital coverage of the streets and land-use categories in Tucson (Shaw et al. 1996). We visited nests at least once per week from the time we found them until the young fledged or the nest failed. When nestlings were  $\geq 15$  days old, we climbed nest trees and banded each nestling with a United States Geological Survey aluminum band. If nest trees were unsafe to climb, we waited until fledglings were beginning to hunt on their own (about 50 d after hatching) in their natal area and attempted to capture them with bal-chatri traps (Bloom 1987). We banded captured fledglings and released them at the capture site. We used diameter of the tarsometatarsus to distinguish male and female hawks ( $< 5$  mm = M;  $\geq 5$  mm = F).

We captured breeding hawks with bal-chatri or dho-gaza traps (Bloom 1987) and marked each hawk with an aluminum band on one leg, and a plastic colored band etched with a unique alpha code on the other leg. We could see letters on the plastic bands from the ground with a 15–45 $\times$  spotting scope or 20 $\times$  binoculars. We identified marked hawks each year when we revisited nest sites. Hawks we found breeding that had only an aluminum band on one leg were individuals that had been banded as nestlings or fledglings and had secured a breeding site. We captured these hawks, marked them with coded-plastic bands (as above), and identified their natal site by the number on the aluminum band. All field methods we used were approved by the University of Arizona Institutional Animal Care and Use Committee (IACUC Protocol Approval no. 03-119).

We used ArcView Version 3.2. to measure distances between natal sites and first breeding sites for all marked hawks recruited into the breeding population. We calculated an index of site fidelity of breeding hawks by dividing the number of times breeding hawks moved from one territory to another by the number of instances when we knew where an individual nested in one year and the subsequent year (i.e., a bird-year). We defined a territory as the area within 500 m of an occupied nest, an area corresponding roughly to the average home range size of males during the breeding season (Mannan and Boal 2000). Similarly, we calculated the percentage of times pairs of hawks changed tree species by dividing the number of consecutive years a territory was occupied (territory-yr) by the number of times any pair in that territory nested in different tree species.

### Comparison of Natal Sites to First Breeding Sites

We recorded the tree species in which both natal and first breeding nests occurred and evaluated whether being hatched in a particular tree species influenced choice of nest tree at the first breeding site with chi-square tests for independence (Sokal and Rohlf 1995). We indexed the level of development around both natal and first breeding nests by estimating the percent cover of buildings within 100 m of nests on aerial photographs (2.5 cm = 366 m). We calculated this index by counting squares on a grid (100 squares/cm<sup>2</sup>) that overlapped buildings and dividing the count by the total number of squares within the sampled area. The photographs were taken in 2001, but nests were primarily in areas where developments were completed before we initiated our study; thus, level of development was accurately depicted in the photographs. We assessed whether percent cover of buildings around first breeding nests was related to percent cover of buildings around natal nests and sex with multiple regression (Ramsey and Schafer 2002).

### Comparison of First Breeding Sites to Available Nest Sites

We assessed the availability of potential nest sites by identifying 100 random locations in the Tucson metropolitan area. Tucson is a rapidly growing city and can be divided roughly into 2 areas relative to the abundance of potential nest sites. The central core of Tucson ( $> 40\%$  of the metropolitan area) is composed mostly of older developments where trees were planted  $> 40$  years ago. Trees in this part of Tucson were large enough to be used by Cooper's hawks as nest sites, and this was where the majority of occupied nests (about 80%) were located. Neighborhoods surrounding this core were newer and existing trees generally were too small to be used as nest sites. To sample approximately the same proportion of potential nest sites in both areas, we stratified our random locations by age of development; we selected 80% of the locations from older developments in the central portion of the city and 20% from newer developments on the outskirts of the city. At each location, we located the closest potential nest site. We identified potential nest sites as  $\geq 3$  eucalyptus, aleppo pine, or other tree species  $\geq 10$  m tall clustered in a 0.08-ha area

**Table 1.** Number of nests of Cooper's hawks monitored, nestlings banded, and recruits<sup>a</sup> located between 1994–2004 in Tucson, Arizona, USA.

Yr	No. nests monitored	No. M nestlings banded	No. M recruits located	No. F nestlings banded	No. F recruits located
1994	23	19	0	14	0
1995	43	30	2	27	0
1996	46	58	2	36	1
1997	43	30	1	23	3
1998	42	43	4	35	1
1999	50	59	12	49	1
2000	61	48	9	52	4
2001	65	62	8	52	4
2002	82	97	10	77	6
2003	82	35	11	47	3
2004	82	59	7	68	3

<sup>a</sup> Hawks hatched and banded in Tucson that subsequently nested in Tucson.

(about 32-m-diam circle; Boal and Mannan 1998). Also,  $\geq 1$  tree in the cluster had to have a diameter at breast height greater than the minimum for nest trees in Tucson (e.g., 55 cm for eucalyptus, 44 cm for aleppo pine; Boal and Mannan 1998). We identified the tree with the largest diameter at breast height in each potential nest site as the potential nest tree and recorded its species.

We identified the dominant form of development (i.e., highest percent coverage) within 100 m of each potential nest site from the digital coverage of land-use categories (Shaw et al. 1996). We assigned each potential nest to 1 of 2 categories based on level of development: developed (i.e., high-density residential areas [ $\geq 7.4$  residences/ha] and commercial sites); and relatively undeveloped (i.e., golf courses, parks, cemeteries, natural open space, and low-density residential areas [ $< 7.4$  residences/ha]). We also categorized each first breeding site as either developed or relatively undeveloped based on counts of buildings and zoning. We compared proportion of first breeding sites and potential nest sites in the 2 categories of development with chi-square tests (Sokal and Rohlf 1995). We conducted all statistical analyses with JMP IN software (Sall et al. 2001).

## RESULTS

### Patterns of Recruitment

We monitored between 23 and 82 breeding pairs each year (Table 1). We found that 10.3% of nestlings banded (92/893) through 2003 were recruited into the breeding population by 2004; the proportion was higher for males (13.7%; 66 recruits/481 banded) than females (6.3%; 26 recruits/412 banded;  $\chi^2 = 9.06$ ,  $P < 0.01$ ; Table 1). Percent of breeders that were locally produced in a population is another measure that, in the short-term, may reflect differential rates of recruitment of males and females. In the 2004 breeding season, 39% (32/82) of observed breeding males and 17% (14/82) of observed breeding females were known to have been hatched in Tucson. Most females and males secured a breeding site in their first or second years of life, but more females than males nested in their first year (F: yr 1 = 42.3%, yr 2 = 42.3%, yr 3+ =

15.4%; M: yr 1 = 13.6%, yr 2 = 60.6%, yr 3+ = 25.8%;  $\chi^2 = 13.19$ ,  $P < 0.0001$ ).

### Natal and Breeding Dispersal

Mean distance between natal sites and sites where we found hawks breeding for the first time was greater for females ( $\bar{x} = 9.7$  km, SE = 0.86, range = 1.1–24.0 km) than for males ( $\bar{x} = 7.4$  km, SE = 0.53, range = 1.3–18.8 km;  $t = 2.28$ ;  $P = 0.025$ ), but the ranges overlapped considerably. Also, our search for nests was truncated at the edge of the urban environment; thus, we likely missed the longest movements made by both sexes. After hawks settled in a breeding territory, site fidelity was 96.6% in males ( $n = 354$  bird-yr) and 90.6% in females ( $n = 320$  bird-yr). Pairs of hawks changed tree species within territories 18.2% of consecutive years of occupancy ( $n = 367$  territory-yr).

### Comparison of First Breeding Sites to Natal Sites and Available Sites

We found that when male and female hawks were analyzed together, they nested for the first time in tree species independently of the tree species in which their natal nests were placed for pine and eucalyptus trees (Table 2). Males hatched in eucalyptus trees tended to place their first nests in eucalyptus trees more frequently than males not hatched in eucalyptus trees (Table 2), and there was weak evidence for a similar trend for males hatched in pine trees (Table 2). Percent cover of buildings around first breeding nests was not related to sex or percent cover of buildings around natal nests (whole model analysis of variance,  $F$ -Ratio = 0.01,  $P = 0.99$ ); neither percent cover of buildings around natal nests ( $F$ -Ratio = 0.02,  $P = 0.88$ ; Fig. 1) nor sex ( $F$ -Ratio = 0.001,  $P = 0.97$ ) contributed significantly to the model. Tree species in which first-time breeders (both M and F) built nests, and the level of development at sites where nest trees were located, were proportional to what was available in the Tucson metropolitan area (Figs. 2, 3).

## DISCUSSION

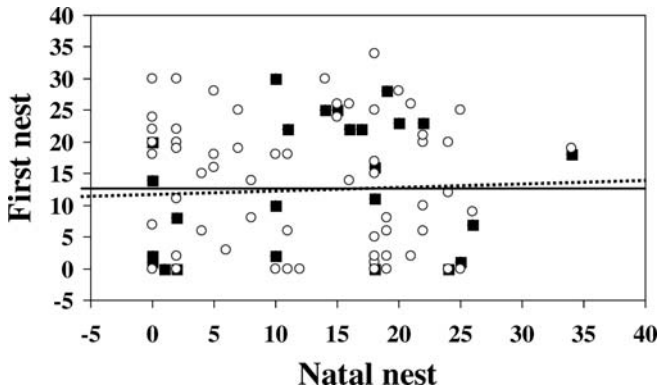
Our data suggest that Cooper's hawks in our study area were not influenced by level of development surrounding their natal nests when choosing their first nest sites as breeders.

**Table 2.** Percentage of Cooper's hawks that built their first nests as breeders in the same tree species in which their natal nests had been placed, Tucson, Arizona, USA, 1994–2004.

Natal tree species ( $n_{m+f} = M$ and F, $n_m = M$ only)	% M and F combined <sup>a</sup>	% M only <sup>b</sup>
	First nest pine	
Pine ( $n_{m+f} = 46$ , $n_m = 33$ )	41.3	48.5
Not pine ( $n_{m+f} = 46$ , $n_m = 33$ )	34.8	30.3
	First nest eucalyptus	
Eucalyptus ( $n_{m+f} = 42$ , $n_m = 29$ )	57.1	65.5
Not eucalyptus ( $n_{m+f} = 50$ , $n_m = 37$ )	48.0	40.5

<sup>a</sup> Pine:  $\chi^2 = 0.42$ ,  $P = 0.5$ ; eucalyptus:  $\chi^2 = 0.77$ ,  $P = 0.38$ .

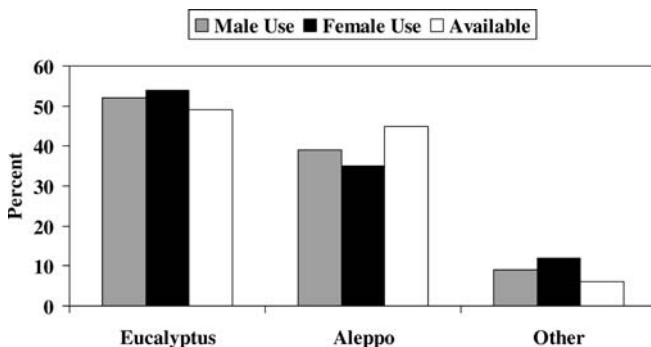
<sup>b</sup> Pine:  $\chi^2 = 2.30$ ,  $P = 0.13$ ; eucalyptus:  $\chi^2 = 4.11$ ,  $P = 0.04$ ; we did not test females due to small sample size.



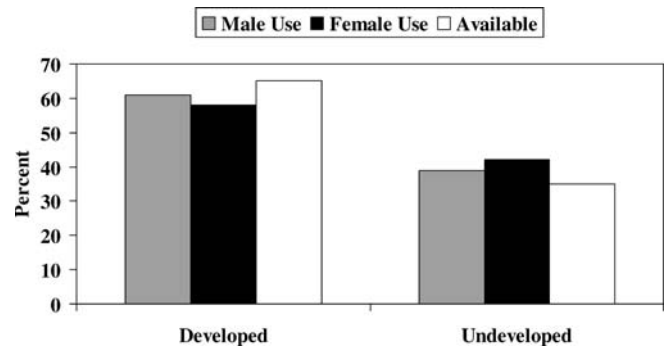
**Figure 1.** Effects leverage plot (Sall et al. 2001) of percent cover of buildings within 100 m of natal nests and first breeding nests for Cooper's hawks in Tucson, Arizona, USA, 1994–2004. Open circles represent males ( $n = 66$ ); solid squares represent females ( $n = 26$ ). The dotted line represents the fitted regression line; the solid line represents a slope of zero at the mean percent cover of buildings for first nests. Slope of the regression line did not differ from zero ( $F$ -Ratio = 0.02,  $P = 0.88$ ).

Evidence was equivocal about the role of natal experience when Cooper's hawks selected tree species at their first breeding site. Analyses of males and females combined indicated that selection of nest trees was independent of the tree species in which they were hatched. However, if male Cooper's hawks select territories and nest sites, and females select mates that successfully supply food, as evidenced in sparrowhawks (*Accipiter nisus*; Newton 1986), patterns of selection in females may reflect only male choice. Our analyses for males alone suggested that exposure to eucalyptus trees, and to a lesser extent pine trees, as nestlings may have influenced their choice of nest trees as breeders. The influence, however, was relatively weak, as the match between natal tree species and tree species at the first breeding site was 48.5% and 65.5% for pine and eucalyptus, respectively. Evidence of nonrandom mating based on age (Boal 2001) and mass (Rosenfield and Bielefeldt 1999) suggests that factors other than habitat features also may play a role in determining where Cooper's hawks settle.

If young Cooper's hawks in Tucson take the first breeding site made available by the death of a resident breeder, or if



**Figure 2.** Use of tree species (eucalyptus, Aleppo pine, and all others) as nest sites by male and female Cooper's hawks in their first breeding attempt, and availability of potential nest trees in the Tucson metropolitan area, Arizona, USA, 1994–2004. Chi-square tests for males ( $n = 66$ ):  $\chi^2 = 1.47$ ,  $P = 0.48$ ; females ( $n = 26$ ):  $\chi^2 = 1.84$ ,  $P = 0.40$ .



**Figure 3.** Categories of development at sites chosen by Cooper's hawks in their first breeding attempt and availability of categories around potential nest sites in the Tucson metropolitan area, Arizona, USA, 1994–2004. We defined categories as developed (i.e., high-density residential areas [ $\geq 7.4$  residences/ha] and commercial sites) and relatively undeveloped (i.e., golf courses, parks, cemeteries, natural open space, and low-density residential areas [ $< 7.4$  residences/ha]). Chi-square tests for males ( $n = 66$ ):  $\chi^2 = 0.55$ ,  $P = 0.46$ ; females ( $n = 26$ ):  $\chi^2 = 0.59$ ,  $P = 0.44$ .

they choose a breeding site without regard to natal tree species or level of development, then distribution of first breeding sites should approximate what is available relative to tree species and development. Our data indicate that characteristics of first nest sites of both males and females were in proportion to what was available in the metropolitan area. These patterns alone are not evidence against a role of NHPI in nest-site selection because a close match between natal sites and first breeding sites, for the features we examined, could result in similar patterns. But our data indicate that there was no evidence for a match between natal sites and first breeding sites for level of development, and there was only a weak match for males for tree species. We propose 1) that NHPI played a limited role in nest-site selection by Cooper's hawks in Tucson for the features we examined, and 2) that sites selected reflect what is available in the metropolitan area. If learning occurred, it could have been for the general structure of trees in natal sites (i.e., the trees themselves or groves of relatively large trees). Also, it is possible that Cooper's hawks innately recognize appropriate sites, but we cannot separate these possibilities with our data. Our data set also is limited to examining selection within the urban area. We cannot answer the broader question about whether hawks hatched in an urban area choose urban areas over nonurban areas. This question will be difficult to answer for Cooper's hawks hatched in large cities, especially for males, because the movements of many males during dispersal from their natal sites are short enough to be restricted to a large metropolitan area (Mannan et al. 2004). The influence of natal experience on selection also may be different in more natural environments where nestlings are exposed to different sets of environmental features (e.g., native vegetation).

Another potential problem with our data set is that we might have missed the first breeding attempt for some individuals, and they could have moved to sites that differed in level of development and tree species between their first and subsequent breeding attempts (i.e., breeding dispersal).

Because site fidelity by Cooper's hawks in Tucson was high, we think these errors were uncommon. Once we located breeding hawks, the likelihood of them moving to a new territory and building a nest in a different tree species was relatively small. The consistency with which tree species were used within a site could be interpreted as evidence for preference for a particular tree species brought about by NHPI. However, this pattern is better explained by high site fidelity combined with the fact that most groves in Tucson consisted of one or the other of the 2 dominant species of tree (i.e., Aleppo pine or Eucalyptus trees); thus, building a new nest in another tree within the grove did not often result in use of different tree species.

Not being restricted to specific conditions (e.g., a particular tree species) when selecting a nest site could be interpreted as an advantage for an individual in a population at or near saturation, where breeding sites usually are secured by young individuals when a resident adult dies. Rejecting an open nest site because it did not match the exact conditions of a natal site would seem an inefficient reproductive strategy for a young bird seeking to enter the breeding population. Habitat imprinting, or NHPI, by offspring, in combination with site tenacity of adults in an area undergoing modification, has been offered as an explanation for how animals come to occupy novel environments, such as urban areas (Temple 1977). Our data suggest that if Cooper's hawks came to occupy urban areas in this manner and NHPI played a role, juvenile hawks learned the general features of their natal sites, rather than the specific conditions we assessed in this study.

## MANAGEMENT IMPLICATIONS

If Cooper's hawks learn the general features of appropriate nest sites as nestlings, or recognize them innately, almost any small grove of large trees in Tucson could be used as a nest site, regardless of its position along the gradient of intensity of urban development (Blair 1996). Thus, planting trees that eventually will grow sufficiently large invites the presence of nesting Cooper's hawks, at least in urban settings where the species is common and other necessary resources (e.g., food, water) are present. In a broader context, understanding whether natal experience plays an important role in habitat selection could be important in the structure and placement of hacking sites (Barclay 1987) in re-introduction programs for predatory birds.

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