

Nest Sites of Five Raptor Species Along an Urban Gradient

R. W. Mannan, C. W. Boal, W. J. Burroughs, J. W. Dawson, T. S.
Estabrook and W. S. Richardson

ABSTRACT

We surveyed the metropolitan area of Tucson, Arizona, USA, from 1993-1997 for breeding Cooper's Hawks *Accipiter cooperii*, Harris' Hawks *Parabuteo unicinctus*, Red-tailed Hawks *Buteo jamaicensis*, Great-horned Owls *Bubo virginianus*, and Burrowing Owls *Athene cunicularia*, and found 227 nests. We were interested in determining whether these five species nested in identifiable and different environments along the gradient of developed to undeveloped land. Therefore, we randomly selected 20 nests of each species and plotted their locations on aerial photographs (scale: 2.5 cm = 360 m) taken in 1995. Within 200 m of each nest, we counted the number of houses and non-commercial buildings, and estimated the percent cover of major roads and commercial buildings, native vegetation, land developed for public activity (e.g., parks and golf courses), and undeveloped land from which native vegetation had been removed. We also measured the distance from each nest to the centre of the nearest square block of undeveloped land ≥ 16 ha in size. We compared the means of each variable among species with one-way analysis of variance. Mean values of all variables, except percent cover of commercial buildings and roads, differed among species ($P < 0.001$). In general, Cooper's Hawks nested in high density residential areas or parks and golf courses, Harris' Hawks nested in moderate density residential areas interspersed with native vegetation, Red-tailed Hawks and Burrowing Owls nested in areas dominated by undeveloped land, and Great-horned Owls nested in a variety of environments. The distribution of nesting hawks and owls in Tucson appeared to be influenced by the distribution of nest structures or sites (e.g., large trees, burrows), favoured prey species, and environments in which the raptors are adapted to hunt.

INTRODUCTION

Urbanization generally creates a gradient of environments with highly developed land on one end of the continuum and moderately developed or undeveloped land on the other (Blair 1996). For example, towns and cities frequently have on their outskirts a mixture of native vegetation, agricultural fields, and a few private residences or other buildings. In contrast, centres of urban environments often are almost wholly covered by buildings and pavement, and vegetation, if present, is dominated by exotic species. The gradient of environments created by urbanization provides an array of resources (e.g., food, cover, nest sites, water) required by birds for nesting. Not surprisingly, species composition

of breeding birds changes markedly along this gradient (e.g., Batten 1972, Emlen 1974, Beissinger & Osborne 1982, Rosenberg *et al.* 1987, Mills *et al.* 1989, Blair 1996).

Hawks, owls, and falcons also should respond to the gradient of resources created by urbanization, but information about the distribution of raptor species in urban settings is lacking for two reasons. First, standard survey methods for birds do not effectively estimate raptor abundance; raptors are, therefore, often excluded from bird counts in urban environments. And second, most reports of raptors nesting in urban environments focus on a single species and many describe only a few nests (see Adams 1994 for review). We report, herein, on urban-nesting by five species of hawks and owls in an urban centre in the southwestern United States, and identify and compare the environments in which they nest.

STUDY AREA

We studied the distribution of nesting raptors in the greater Tucson metropolitan area (32° 12'N, 110° 57'W) in southeastern Arizona, USA, from 1993 to 1997. The area encompasses about 70,000 ha, with an approximate human population of 800,000. Tucson includes developments ranging from commercial districts and high density housing to suburban areas with low density housing. Tucson is located in the Sonoran Desert. Vegetation communities common in the area prior to development were lower and upper Sonoran vegetation types and riparian corridors (Brown *et al.* 1979). Remnants of these vegetative communities are still found within Tucson, particularly in the suburban developments, but much of the native vegetation has been removed and replaced with exotic species.

METHODS

1. Surveys

Nests examined in this study were located over a period of five years (1993-1997) in a series of different surveys. In 1993, Dawson and Mannan (1994) attempted to find all Harris' Hawk nests in Tucson. From 1994 to 1997, Boal and Mannan (1998) attempted to locate all Cooper's Hawks nests in Tucson, and in 1997, Estabrook and Mannan (1998) searched for Burrowing Owls nests there. The effort to find nests in each of the above studies was maximized in a specific area where the subject species was most abundant. The areas did not overlap and totalled about 65,000 ha. Nests of all raptor species were noted in each of the study areas.

Beginning in 1993, W. Burroughs began to locate and map nest sites of all raptor species in Tucson, independent of the surveys conducted by Dawson and Mannan (1994), Boal and Mannan (1998), and Estabrook and Mannan (1998). Burroughs located nests partly from reports of injured or sick birds made to wildlife rehabilitators. A sample of nests ($n=50$) from this survey was revisited each year (1994-1997) by personnel from the Urban Raptor Conservation Project or the Arizona Game and Fish Department. In all of the surveys described above, except Estabrook and Mannan (1998), the general public was encouraged through newspaper articles and television news programmes to report the locations of nesting raptors.

Nests from all survey efforts described above were combined to form our overall sample. We believe the sample of nests for each species is representative of the kinds of environments which they occupy because most of the city was thoroughly searched at some time during the study, the general public aided in the location of nests, many nests were located independently in different surveys, and occupancy of a sample of nests was tracked over time.

2. Selection and Measurement of Nest Sites

We randomly selected 20 nests of five common species of raptors found in Tucson: the Cooper's Hawk, Harris' Hawk, Red-tailed Hawk, Great-horned Owl, and Burrowing Owl. We restricted our sample within a species to nests that were separated by at least 400 m to avoid sampling the same area more than once (see below). We plotted the locations of all nests on aerial photographs (scale: 2.5 cm = 360 m) taken in 1995. Within 200 m of each nest, we counted the number of houses and non-commercial buildings, and estimated the percent cover (by counting grid points) of major roads

and commercial buildings, native vegetation, land developed for public activity (e.g., parks and golf courses), and undeveloped land from which native vegetation had been removed. We also measured the distance from each nest to the centre of the nearest square block of undeveloped land ≥ 16 ha in size and outside the 200 m radius. These measurements characterized the level of development surrounding nests and were selected to help identify where nests were positioned along the urban gradient.

Variance among variables was unequal (i.e., standard deviations often were positively correlated with means), and the distributions of our samples were skewed. We therefore transformed our count and distance measures with "log y" and our proportion measures with " $\log[y/(1 - y)]$ " (Sokal & Rohlf 1995). We then compared the means of each variable among species with one-way analysis of variance (Sokal & Rohlf 1995); $P < 0.001$ was used to determine significance because of the number of tests conducted ($n=6$). For ease of interpretation, means and standard deviations are presented in their untransformed states.

Table 1. Means and standard deviations (SD) (untransformed) of variables describing conditions within 200 m of nests of five species of raptors ($n=20$ nests/species) in Tucson, Arizona, USA, 1993-1997. Species are ranked (high to low values) under each variable to facilitate assessment of their position along the urban gradient. Variables were estimated or counted from aerial photographs taken in 1995. P values are from one-way analyses of variance.

<i>Number of Houses/Bldgs¹</i>			<i>Percent Commercial Bldgs/Roads²</i>			<i>Percent Land For Public³</i>		
<i>Sp⁴</i>	<i>Mean</i>	<i>SD</i>	<i>Sp</i>	<i>Mean</i>	<i>SD</i>	<i>Sp</i>	<i>Mean</i>	<i>SD</i>
CH	32.7 (2.6)	44.7	GO	14.9	27.6	CH	31.7	36.7
HH	14.1 (1.1)	16.9	BO	11.5	13.4	GO	25.6	40.5
GO	10.7 (0.9)	12.8	RH	9.9	14.2	RH	7.9	23.5
BO	6.7 (0.5)	13.6	CH	7.9	10.5	BO	3.9	10.3
RH	4.5 (0.4)	5.6	HH	2.4	7.0	HH	1.3	5.6
$P < 0.0001$			$P > 0.05$			$P < 0.0004$		

¹Number of houses and non-commercial buildings within 200 m of nests; number/ha in parentheses.

²Percent cover of commercial buildings and major roads.

³Percent cover of land developed for public activity (e.g., parks, golf courses).

⁴Species: CH=Cooper's Hawk; HH= Harris' Hawk; RH=red-tailed Hawk; GO=Great-horned Owl; BO=Burrowing Owl.

<i>Percent Undeveloped Land/Disturbed¹</i>			<i>Percent Undeveloped Land/Native²</i>			<i>Distance to Undeveloped Land (m)³</i>		
<i>Sp</i>	<i>Mean</i>	<i>SD</i>	<i>Sp</i>	<i>Mean</i>	<i>SD</i>	<i>Sp</i>	<i>Mean</i>	<i>SD</i>
BO	75.3	18.3	RH	55.6	36.9	CH	1541	1153
RH	12.7	21.9	HH	50.6	32.6	GO	1534	1201
HH	9.8	22.2	GO	23.8	29.8	HH	1001	816
GO	6.2	14.0	CH	11.7	22.6	RH	799	484
CH	6.1	14.1	BO	3.0	7.9	BO	526	526
$P < 0.0001$			$P < 0.0001$			$P < 0.0001$		

¹Percent of undeveloped land from which native vegetation had been removed.

²Percent of undeveloped land supporting native vegetation.

³Distance from nest to the centre of the nearest square block of undeveloped land ≥ 16 ha in size. The block had to be outside the 200 m radius.

⁴Species: CH=Cooper's Hawk; HH= Harris' Hawk; RH=Red-tailed Hawk; GO=Great-horned Owl; BO=Burrowing Owl.

RESULTS

We selected our sample of 100 nests from a total of 227 nests (Cooper's Hawks [$n=46$], Harris' Hawks [$n=53$], Red-tailed Hawks [$n=23$], Great-horned Owls [$n=32$], and Burrowing Owls [$n=73$]). Cooper's Hawks generally nested in neighbourhoods where housing density was relatively high ($n=11$ nests; $\bar{x}=4.5$ houses/ha), or in lands developed for public activity (e.g., parks and golf courses; $n=9$ nests; Table 1). The sites where they nested had little undeveloped land around them and were relatively far from large blocks of undeveloped land (Table 1). Harris' Hawks nested in neighbourhoods where housing density was moderate to low ($\bar{x}=1.1$ houses/ha), and the areas between houses often supported native vegetation (Table 1). Both Red-tailed Hawks and Burrowing Owls nested in areas with undeveloped land where housing density was low (<0.5 houses/ha; Table 1). Red-tailed Hawks however, generally nested in areas dominated by native vegetation, whereas Burrowing Owls nested in areas where the native vegetation had been removed (Table 1). Great-horned Owls nested in a variety of environments, although they selected areas near the most urbanized end of the gradient most frequently. Coverage of major roads and commercial buildings around nests was variable and did not differ among species (Table 1).

DISCUSSION

All species of hawks and owls we examined, except Great-horned Owls, generally nested in identifiable places along the urban gradient. The gradient in this study was characterized at its most developed end by high-density residential neighbourhoods and parks and golf courses, and at its opposite end by low-density housing and undeveloped land. Cooper's Hawks nested in areas near the most urbanized end of the gradient, Harris' Hawks in moderately developed areas, and Burrowing Owls and Red-tailed Hawks in places with the least development. We speculate that selection of nest sites along the urban gradient by hawks and owls is influenced by the availability of nest structures, the abundance of favoured prey species, and the structure of vegetation as it relates to hunting behaviour.

Cooper's Hawks and Harris' Hawks in Tucson build their nests most frequently in aleppo pines (*Pinus halepensis*) and eucalyptus trees (*Eucalyptus* spp.) (Boal & Mannan 1998, unpubl. data). These trees are exotic to the southwestern United States and those used as nest sites are taller than the native trees or cacti in Tucson (e.g., Boal & Mannan 1998). Nest trees in urban settings also are taller than the trees or cacti used as nest sites in undeveloped desert outside the urban environment (e.g., Boal & Mannan 1998). Tall trees may provide the necessary level of security needed by nesting hawks to tolerate human activities in urban settings (Boal & Mannan 1998). However, tall, exotic trees occur in Tucson in a variety of environments, and thus only partly explain the distribution of urban-nesting raptors.

A relatively constant supply of water and green vegetation in Tucson, compared to undeveloped desert, probably increases the abundance of prey species for raptors and reduces fluctuations in prey populations during periods of drought. Availability of water and abundant prey explain, at least in part, why hawks and owls nest in urban environments at all, and why some species (e.g., Cooper's Hawks) nest in higher densities in the city than in exurban areas (Boal & Mannan 1998). Distribution of hawks and owls along the urban gradient likely is determined largely by species-specific prey preferences and hunting strategies. For example, Red-tailed Hawks, although generalists in their selection of prey, hunt in open areas (Monson 1998). We speculate that they nest most frequently along the outskirts of Tucson because undeveloped land with open vegetation is most common there. Minor *et al.* (1993) also attributed the success of Red-tailed Hawks nesting in urban areas in New York to their diet and their ability to move between isolated greenspaces.

Harris' Hawks in the United States hunt in areas with dense ground cover and rely primarily on ground-dwelling prey (Mader 1975), such as Cottontail Rabbits (*Sylvilagus auduboni*) and Gambel's Quail (*Callipepla gambelii*). Emlen (1974) studied birds in a Tucson suburb dominated by exotic vegetation and concluded that urbanization leads to the reduction of ground-dwelling birds, due partly to predation by domestic cats. However, in areas where native species, such as *Opuntia* cacti,

are used as ornamental ground cover, some ground-dwelling birds and mammals persist and even flourish after development. Both rabbits and quail are common in Tucson in areas with desert landscaping or native desert vegetation. Harris' Hawks probably nested most frequently in suburbs with relatively low housing density because their favoured prey were present in these areas and their hunting strategies (Dawson 1988) were effective in the desert vegetation that existed around and between houses.

Cooper's Hawks in Tucson prey primarily on birds, especially Inca Doves (*Columbina inca*) and Mourning Doves (*Zenaidura macroura*) (Boal 1998). We speculate that Cooper's Hawks nest in highly urbanized areas for two reasons. First, they are physically adapted to hunt in forests and shrublands (Rosenfield & Bielefeldt 1993) and thus are capable of capturing birds in structurally complex, urban environments. And second, developed areas generally support higher bird abundance than undeveloped areas (e.g., Beissinger & Osborne 1982, Mills *et al.* 1989). In Tucson, Emlen (1974) reported that the density of birds was 26 times higher in urban areas than in undeveloped desert. Furthermore, numbers of Mourning Doves and Inca Doves, the second and fourth most abundant birds in Tucson, are positively correlated with increasing housing density and exotic vegetation (Germaine 1995).

Great-horned Owls in Tucson appeared to be partly dependent upon diurnal raptors for nest sites and they occupied nests built by all three species of hawks we examined. Minor *et al.* (1993) also found that most pairs of Great-horned Owls in urban/suburban areas in New York nest in vacated hawk nests. We suspect that the tendency of Great-horned Owls in Tucson to nest near the urbanized end of the gradient was a result of the availability of nest structures and not selection for conditions around the nest. Cooper's Hawks and Harris' Hawks were more abundant in Tucson than Red-tailed Hawks; thus, stick nests were most abundant in areas with moderate to high development. We note, however, that Great-horned Owls in Tucson also nested in naturally formed cups at the base of fronds in palm trees (*Phoenix dactylifera*), and on buildings and other man-made structures (unpublished data). The flexibility of Great-horned Owls in selecting nest sites and their catholic diet (Dawson 1998) probably allows them to nest almost anywhere along the urban gradient.

Burrowing Owls in the western United States depend on burrows dug by mammals (e.g., ground squirrels [*Spermophilus* spp.]), or holes created in other ways (e.g., by erosion) as nest sites (Bent 1938, Thomsen 1971, Martin 1973). They usually nest in burrows in areas where vegetation is low or nonexistent (Rich 1986, Green & Anthony 1989, Haug *et al.* 1993, Plumpton and Lutz 1993), ostensibly so that they can see and avoid predators. In Tucson, it appears that even expanses of structurally simple, native, vegetation, such as Creosotebush (*Larrea tridentata*), do not provide the visibility they require. Burrowing Owls in Tucson, therefore, nest most frequently in areas where natural vegetation has been removed and grass or bare ground is maintained (Estabrook & Mannan 1998). These areas in Tucson are most common around airports, along river corridors where flood plains are periodically scraped, in vacant lots, and in new subdivisions where vegetation is removed before development (Estabrook & Mannan 1998). Wesemann and Rowe (1987) also found that Burrowing Owls in urban areas in Florida nest most commonly in places where development is limited.

The conditions which trigger different species of hawks and owls to nest in urban environments potentially could be duplicated and expanded in existing developments, or created in future developments, if hawks and owls are a desired component of urban avifaunas. However, nesting by raptors in towns and cities does not mean that urban environments provide high quality habitats for them. Developed areas present environmental challenges to raptors, such as electrocution, disease, poison, collisions with vehicles and windows, and human disturbance that may preclude self-sustaining populations (e.g., Dawson & Mannan 1994, Boal & Mannan 1999, Love & Bird, this volume). It is incumbent on biologists and city planners to understand the dynamics of populations of urban raptors and their species-specific habitat requirements before extensive habitat management efforts are undertaken.

ACKNOWLEDGEMENTS

We thank the many field technicians and volunteers who assisted in locating nests. We also thank W. Shaw and M. Tuegel for their helpful comments on a draft of the manuscript. The study was funded primarily by the Arizona Game and Fish Department Heritage Fund (Grants U94010, U95009, U96006).

REFERENCES

- ADAMS, L. W. 1994. *Urban wildlife habitats. A landscape perspective*. Univ. Minnesota Press.
- BATTEN, L. A. 1972. Breeding bird species diversity in relation to increasing urbanisation. *Bird Study*, 19:157-166.
- BEISSINGER, S. R. & D. R. OSBORNE 1982. Effects of urbanization on avian community organization. *Condor*, 84:75-83.
- BENT, A. C. 1938. Life histories of North American birds of prey. *United States National Museum Bull.*, 170.
- BLAIR, R. B. 1996. Land use and avian species diversity along an urban gradient. *Ecol. Appl.*, 6:506-519.
- BOAL, C. W. 1997. An urban environment as an ecological trap for Cooper's Hawks. Ph.D. Dissertation. Univ. Arizona, Tucson.
- BOAL, C. W. & R. W. MANNAN 1998. Nest-site selection by Cooper's Hawks in an urban environment. *J. Wildl. Manage.*, 62:864-871.
- BOAL, C. W. & R. W. MANNAN 1999. Comparative breeding ecology of Cooper's hawks in urban and exurban areas of southeastern Arizona. *J. Wildl. Manage.* 63: 77-84.
- BROWN, D. E., C. H. LOWE & C. P. PASE 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples for the Southwest. *J. Ariz.-Nev. Acad. Sci.*, 14 (1, Supplement).
- DAWSON, J. W. 1988. The cooperative breeding system of the Harris' hawk in Arizona. M. S. Thesis, Tucson, Univ. Arizona.
- DAWSON, J. W. 1998. Great-horned Owl. In R. L. Glinski (ed.) *The raptors of Arizona*. Univ. Arizona Press and Arizona Game and Fish Department.
- DAWSON, J. W. & R. W. MANNAN 1994. Population dynamics of Harris' hawks in urban environments. Report to Arizona Game and Fish Department, Phoenix, Ariz. Heritage Grant Program.
- EMLEN, J. T. 1974. An urban bird community in Tucson, Arizona: derivation, structure, and regulation. *Condor* 76:184-197.
- ESTABROOK, T. S. & R. W. MANNAN 1998. Burrow selection by burrowing owls in urban environments. Report to Arizona Game and Fish Dep., Phoenix, Ariz., Heritage Grant U96006.
- GERMAINE, S. S. 1995. Relationships of birds, lizards, and nocturnal rodents to their habitat in the Greater Tucson Area, Arizona. *Arizona Game and Fish Department Technical Report* 20.
- GREEN, G. A. & R. G. ANTHONY 1989. Nesting success and habitat relationships of burrowing owls in the Columbia Basin, Oregon. *Condor* 91:347-354.
- HAUG, E. A., B. A. MILLSAP & M. S. MARTELL 1993. Burrowing owl (*Speotyto cunicularia*). *The birds of North America*, number 61, A. Poole, and F. Gill (eds.) The American ornithologists' Union, Washington, D.C., USA, and the Academy of Natural Sciences, Philadelphia, Pennsylvania, USA.
- MADER, W. J. 1975. Biology of the Harris' hawk in southern Arizona. *Living Bird* 14: 59-85.
- MARTIN, D. J. 1973. Selected aspects of burrowing owl ecology and behavior. *Condor*, 75:446- 456.
- MILLS, G. S., J. B. DUNNING, JR. & J. M. BATES 1989. Effects of urbanization on breeding bird community structure in southwestern desert habitats. *Condor*, 91:416-428.
- MINOR, W. F., M. MINOR & M. F. INGRALDI 1993. Nesting of Red-tailed hawks and Great-horned Owls in a central New York urban/suburban area. *J. Field Ornithol.*, 64:433-439.
- MONSON, G. (ed.) 1998. Red-tailed hawk. In R. L. Glinski. *The raptors of Arizona*. Univ. Arizona Press and Arizona Game and Fish Department.
- PLUMPTON, D. L. & R. S. LUTZ 1993. Nesting habitat use by burrowing owls in Colorado. *J. Raptor Res.*, 27:175-179.
- RICH, T. 1986. Habitat and nest site selection by burrowing owls in the sagebrush steppe of Idaho. *J. Wildl. Manage.*, 50:548-555.
- ROSENFELD, R. N. & J. BIELEFELDT 1993. Cooper's hawk (*Accipiter cooperii*). *The birds of North America*, number 75, A. Poole, and F. Gill (eds.) The American ornithologists' Union, Washington, D.C., USA, and the Academy of Natural Sciences, Philadelphia, Pennsylvania, USA.

- ROSENBERG, K. V., S. B. TERRILL & G. H. ROSENBERG 1987.** Value of suburban habitats to desert riparian birds. *Wilson Bull.*, 99:642-654.
- SOKAL, R. R. & F. J. ROHLF 1995.** *Biometry*. Third edition. W.H. Freeman, New York, New York.
- THOMSEN, L. 1971.** Behavior and ecology of burrowing owls on the Oakland municipal airport. *Condor*, 73:177-192.
- WESEMANN, T. & M. ROWE 1987.** Factors influencing the distribution and abundance of burrowing owls in Cape Coral, Florida. In L. W. Adams and D. L. Leedy (eds.) *Integrating man and nature in the metropolitan environment*. National Institute of Urban Wildlife, Columbia, MD.

R. W. Mannan, J. W. Dawson and T. S. Estabrook
School of Renewable Natural Resources
University of Arizona
Tucson, Arizona
85721, USA

C. W. Boal
Minnesota Cooperative Fish and Wildlife Research Unit
200 Hodson Hall
1980 Folwell Avenue
University of Minnesota
St. Paul, Minnesota
55126, USA

W. J. Burroughs
Urban Raptor Conservation Project
4140 S. Aldon Road
Tucson, Arizona
85735, USA

W. S. Richardson
Arizona Game and Fish Department
555 N. Greasewood Road
Tucson, Arizona
85745, USA

