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DISTRIBUTION AND HABITAT OF GREATER ROADRUNNERS IN TUCSON, ARIZONA

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TABLE OF CONTENTS

INTRODUCTION

In 1990 the metropolitan area of Tucson, Arizona had a population of >666,900 people living in 23,700 km^2. By 1997 the metropolitan area had grown to >780,100 people and in 2010 the population is projected to be about 889,600 (Bureau of the Census 1998). Urbanization such as this has a variety of effects on wildlife populations. Exotic species such as the house sparrow (*Passer domesticus*) prosper in urban environments (Lowther and Cink 1992), while species such as bighorn sheep (*Ovis canadensis*) are negatively affected (Harris et al. 1995). Construction of houses, commercial buildings, and parking lots displaces wildlife and patches of native vegetation can become isolated islands within city limits (Shaw et al. 1991, Germaine et al. 1998). As urbanization increases these islands become farther away from the native vegetation surrounding the city. This separation can mean loss of genetic diversity or genetic isolation in species with low vagility (Germaine 1995).

Urban areas may act as ecological traps for some species. These areas contain the cues necessary for the organism to settle but also contain some source of mortality associated with urbanization that can reduce reproductive success or survival. For example, historically Cooper's hawks (*Accipiter cooperii*) occupied riparian areas in and around Tucson. Today, Cooper's hawks inhabit small groves of tall trees in various locations throughout the city and feed primarily on inca doves (*Columbina inca*) and mourning doves (*Zenaida macroura*). Trichomoniasis (*Trichomonas gallinae*) is a protozoan disease common in doves and transmittable to Cooper's hawk nestlings. It

appears that the cues to settle are present in the small tree groves in Tucson, but trichomoniasis severely limits Cooper's hawk nesting success (Boal 1997).

Effects of urbanization on greater roadrunners (*Geococcyx californianus*) have not been studied, and roadrunner tolerance for many habitat variables associated with urban areas such as traffic and housing density is unknown. Roadrunners nest on urban structures such as houses (Rylander 1972) and eat urban wildlife such as the introduced European snail (*Helix pomata*) (Wright 1973) and house sparrow (Zimmerman 1970).

Urban habitat features of importance to roadrunners have not been described, nor has a distribution pattern in an urban area been documented. This project will attempt to answer questions about the distribution and key habitat features for roadrunner occupancy in an urban-suburban area. Our objectives are to (1) examine the status and distribution of roadrunners in and around Tucson, (2) describe habitat use by roadrunners in an urban-suburban environment, and (3) compare the distribution and prevalence of human-created (e.g., housing densities, golf courses, etc.) and natural (e.g., washes, native vegetation, etc.) landscape features as predictors of roadrunner distribution.

STUDY AREA

Tucson is located in southeastern Arizona at 32°1' north latitude and 110°9' west longitude (Turner and Brown 1982). In 1990 it covered 404 km^2 (Bureau of the Census 1993) and is surrounded by mountains to the north, east, and west, and Tucson International Airport and the Tohono O'Odham Nation to the south. Tucson is part of the Arizona Upland subdivision of the Sonoran Desert. Elevation averages 787 m and annual rainfall is about 280 mm/yr, 30-60% falling from June to August and 10-40% falling during winter (Turner and Brown 1982). Our study area covered 601 km^2 divided into

232 contiguous 2.6-km^2 (1-mi^2) blocks in the city of Tucson. Each block was covered with man-made features such as roads, buildings, and parks over at least 25% of the area.

METHODS

The project consisted of 6 parts: a public survey, walking surveys, bird identifications skills test, use/availability analysis, description of nest variables, and evaluation of variables in the area surrounding nest sites.

Public Survey

We used a public survey to document roadrunner sighting locations in Tucson. We solicited information from the public on sightings of roadrunners via fliers, newspaper articles (Arizona Daily Star), a 90-second television news segment (KOLD Ch. 13), radio broadcasts (KUAT), and word-of-mouth. We designated a phone number and voice messaging system for callers to leave information about their sightings. Variables of interest included the name, phone number and address of the caller; the exact location, time, and date of the roadrunner sighting; and location and status of nests. We entered this information into a computer database and acquired a streets coverage (an address database and digital map of the streets in Pima County) from Pima County Government offices. Using the Geographic Information Systems (GIS) available at the University of Arizona, we combined the roadrunner sightings database and streets coverage to construct a distribution map of roadrunner sighting locations in metropolitan Tucson. We eliminated sighting locations outside the study area and duplicate sighting locations. Duplicate sightings of roadrunner locations were those sightings reported by the same person or family at similar locations on or near the same day. People who voluntarily called with roadrunner sighting locations will be referred to as callers in this report.

Walking Surveys

Biases often exist with information acquired from the public. To evaluate possible bias in the information we received on roadrunner sightings, we conducted our own surveys for roadrunners. We divided the city into 232 2.6-km^2 (1-mi^2) blocks as defined on 7.5 minute topographic maps. Each block was divided into 4 0.65-km^2 (0.25-mi^2) square sections. Days were divided into 3 parts: AM = sunrise-1000 hrs, MD = 1000-1400 hrs, and PM = 1400 hrs-sunset. Each survey consisted of a randomly selected block, section within that block, day of the week (1 of 7), and time of day.

Surveys were conducted by skilled bird watchers. Each survey covered a distance of 3-5 km or 50-60 minutes of walking, whichever came first. Observers searched for roadrunners and asked the available public about roadrunners in the area. Observers drove at about 15-25 kph in those survey areas deemed unsafe for walking. If a survey landed on inaccessible property (e.g., gated community), the surveyor selected the available plot closest to their current location. A data form was completed immediately upon seeing a roadrunner or at the end of each survey and the data were entered into a computer database. We produced a distribution map of roadrunner sightings resulting from the walking surveys.

Bird Identification Skills Test

Most of our roadrunner sighting information came from the public; therefore, we evaluated the ability of the public to correctly identify roadrunners. We tested 20 callers (i.e., people who called voluntarily to report roadrunner sightings) to evaluate their identification skills. We called each person and asked if he or she would be willing to take a short quiz on bird identification. The participant did not know that we were specifically

testing for roadrunner identification skills. We also asked 20 people from the general public; 10 at a Fry's grocery store near 22nd Street and Alvernon Way and 10 at A & M Texico gas station near Speedway Boulevard and Craycroft Road. We approached only those people who made eye contact with us and seemed interested. We assumed that people who did not make eye contact did not want to be approached. We did not reveal the subject of the test immediately and asked only if the person was willing to help a University of Arizona student with a research project by participating in a 1-2 minute quiz. We asked each participant to identify 6 bird species. In addition to the roadrunner, we chose 5 common urban species that might be confused with a roadrunner: cactus wren (*Campylorhynchus brunneicapillus*), great-tailed grackle (*Quiscalus mexicanus*), curve-billed thrasher (*Toxostoma curvirostre*), rock dove (*Columba livia*), and Gambel's quail (*Callipepla gambelii*). One color photo of each of these 6 species was displayed on the same poster board. After the survey was completed participants were given the correct answers and the opportunity to ask about our research project.

Use/Availability Analysis

We evaluated the difference between distribution of roadrunner sighting locations from callers and distribution of randomly generated locations using the technique described by Neu et al. (1974). We calculated the number of locations in both distributions that fell within each of 30 land-use covers (Appendix A) in the Wildlife Habitat Inventory Pilot Study (WHIPS) database (Shaw et al. 1996). We eliminated the roadways cover from this analysis because many of the roadrunner sighting locations (21%) that fell within that cover were an artifact of geocoding. Many of these locations likely fell within a land-use cover adjacent to the roadways cover, but we had no way to

determine into which land-use cover each location fell. We tested for differences between the distributions of sightings vs random points with a chi-square test. We then used a Bonferroni test to check for significant differences in 4 individual land-use covers. We chose those covers that had the greatest difference between number of sighting locations from the public and randomly generated locations.

We also evaluated proximity of roadrunner sighting locations and randomly generated locations to 3 groups of similar land-use covers and 4 individual land-use covers within the study area. Groups of land-use covers for comparison included major and minor washes, areas of open space with a high probability of containing abundant non-native landscaping (cemeteries, golf courses, and neighborhood, regional, and district parks), and areas of open space with a high probability of containing abundant native vegetation (natural open space and State and Federal parks and forests). Individual land use covers were housing densities of <1 residence per acre (RAC), >1-3 RAC, >3-6 RAC, and >6 RAC. We used a Student's t-test to compare roadrunner sighting locations to randomly generated locations at distances for these land-use covers. Distances were at 50 m intervals from 25 to 1,000 m for wash and vegetation land-use cover groups and 25 to 400 m for housing density land-use covers.

Description of Nest Variables

We measured nest structure variables on roadrunner nests located through the public survey. Nest variables of interest included outside nest diameter and nest thickness, inside cup diameter and cup depth, nest rim height above ground, and distance of nest from tree bole. We averaged measurements and described mean nest dimensions.

Evaluation of Nest Area Variables

We measured variables surrounding nests and nest sites. These variables included type of nest supporting structure (native vegetation, non-native vegetation, or man-made structures); tree species, height, crown dimensions, and diameter at breast height (dbh); percent cover surrounding nest, and presence or absence of dogs and daily available water.

RESULTS

Public Survey

Between January 1997 and August 1998, the public survey generated 1,449 phone calls with roadrunner sighting locations throughout metropolitan Tucson. Of these calls approximately 1,230 callers responded to 3 newspaper articles, 140 to fliers, 40 to a KOLD (Channel 13) news segment, 30 to 3 KUAT radio broadcasts, and 9 to word-of-mouth. From the total 1,449 locations we eliminated 248 locations that fell outside the study area and 8 duplicate sighting locations. Exactly 1,015 sighting locations (70%) fell within the study area (Fig 1). Most sighting locations were from callers phoning from home to report a roadrunner in their yard (75%). The highest density of sighting locations occurred in northeast Tucson in an area bounded by Snyder Road to the north, Sabino Canyon Wash to the east, Tanque Verde Wash to the south, and Sabino Canyon Road to the west. Data also revealed a smaller concentration of sighting locations in the southwest part of the city. The approximate boundaries of this area, were Grant Road to the north, Interstate 10 to the east, Ajo Way to the south, and Tucson Mountain County Park to the west. The fewest sighting locations were in 3 separate areas: (1) east and west of Interstate 10 north of Ft. Lowell Road, (2) an area in the center of Tucson bounded by Ft. Lowell Road to the north, Alvernon Way to the east, Speedway Boulevard

to the south, and 1st Avenue to the west, and (3) a long, narrow strip of land on the south side of the city west of Wilmot Road (Fig. 2).

Walking Surveys

We completed 281 walking surveys for roadrunners from February 1997 to January 1999. We were unable to conduct 10 (3.5%) of our planned surveys on the original plots because these plots landed on inaccessible property; however, each was relocated to the next nearest accessible plot.

Fifty-two roadrunners were seen on 39 different survey blocks (Fig. 3). Highest concentrations of sightings occurred in 4 areas (Fig 4). The first 2 areas were golf courses, the El Conquistador-Oro Valley Country Clubs on the north side of the city and the Fred Enke Golf Course on the south side of Tucson. The third and largest concentration occurred on the northeast side of the city in an area bounded by Coronado National Forest to the north, Wentworth Road to the east, Speedway Boulevard to the south, and Swan Road to the west. The fourth concentration occurred on the southwest side of Tucson. The approximate boundaries of this area were 36th Street to the north, 12th Street to the east, Irvington Road to the south, and La Cholla Boulevard to the west. These areas of high concentration form a rough circular pattern of distribution around the periphery of the city with a void near the center.

The fewest sightings occurred in 3 areas. The largest was near the city center in an area bounded by Ft. Lowell Road to the north, Swan Road to the east, 22nd Street to the south, and Interstate 10 to the west. The second area was on the northwest side of Tucson in an area bounded by Ina Road to the north, La Cholla Boulevard to the east, Goret Road to the south, and Camino de Oeste to the west. The third area occurred on

the east side of Tucson. Its boundaries were Speedway Boulevard to the north, Tanque Verde Way to the east, Golf Links Road to the south, and Camino Seco to the west.

Bird Identification Skills Test

We conducted a bird identification skills test during 7-12 December 1998. We randomly selected and contacted 25 callers to take the test. Four people did not return our phone calls and 1 person declined, thus 20 callers took the test. We also approached approximately 55 people from the general public for the test. Fifteen people declined. Of the 20 people who agreed to participate, none declined when they learned that the test was on bird identification.

All people surveyed (100%) were able to identify a roadrunner correctly. There was no difference in ability to identify a roadrunner between callers and the general public. Most people correctly identified the Gambel's quail (88%) and the rock dove (63%) but only half correctly identified Arizona's state bird, the cactus wren (53%). Only a few people correctly identified the curve-billed thrasher (20%) and the great-tailed grackle (10%) (Table 1).

Use/Availability Analysis

As expected, we found a significant difference in distribution between 802 roadrunner sighting locations from callers and 1,200 randomly generated locations ($\chi^2 = 382.66$, df = 29, $P < 0.001$). However, significant differences existed for 4 land-use covers tested with the Bonferroni test. Roadrunners were reported more frequently than expected in <1 RAC and >1-3 RAC and less than expected in natural open space and graded vacant land (Table 2).

Using a Student's t-test on distances from groups of similar land-use covers and 4 individual housing density covers, we found a significant difference in only 1 land-use cover; roadrunner observations were concentrated in areas with housing densities of >1-3 RAC (t = -3.364, P = 0.004) (Table 3).

Description of Nest Variables

We took measurements of nest variables on 23 roadrunner nests (Table 4). Roadrunners build nests with average outside dimensions of 28 cm wide and 15 cm thick and average inside cup dimensions of 17 cm wide and 4 cm deep. Nests were most often built 1.5-4.5 m above the ground. We also measured distance to bole for 14 nests. Most (79%) nest were against the bole of the tree or atop the point of branching from the bole. Four nests (21%) were built away from the bole at distances of 0.51 m, 1.52 m, 1.65 m, and 5.49 m.

Evaluation of Nest Area Variables

We located 23 nests and 7 locations where nests previously existed. Nineteen (63%) of these were in non-native vegetation, 6 (20%) were on man-made structures, and 5 (17%) in native vegetation. The most common supporting structure of nests was man-made roofed structures (17%), followed by citrus trees (13%), Italian cypress (*Cupressus sempervirens*) (13%), and vines against walls (13%) (Table 5). We measured dimensions of trees in which roadrunners built their nests. Trees were usually as high as they were wide with the exception of Italian Cypress (Table 6). Percent cover surrounding nests in each of 6 directions (above, below, north, south, east, west) averaged 73% (SE = 9.4%). Percent cover was greatest above the nest (84%), least below the nest (57%), and averaged 73% in the 4 horizontal directions (Table 7). Only 30% of properties with

roadrunner nests had at least 1 dog living on the property and 80% of the properties had daily water available.

DISCUSSION

We conducted a public survey for roadrunner sighting locations because we could have many more people simultaneously looking for roadrunners than what we could accomplish ourselves. On our walking surveys we averaged 1 roadrunner sighting in 7 surveys. To get the same number of sightings as acquired from the public survey (1,449) we would have had to look for roadrunners 8 hrs/day 7 days/week for 3.5 years. Time and funding made a survey this extensive impossible.

We received an overwhelming response from the public. Many callers made favorable comments about roadrunners and were glad that research was being conducted. They were very willing to help by providing sighting information, indicating a high public interest in roadrunners.

The number of roadrunners that exist in Tucson is unknown. Some population estimates average 2.8 individuals/km^2 (Folse and Arnold 1978), 3.1 individuals/km^2 (Calder 1968), 4 individuals/km^2 (Bryant 1916), and 10 individuals/km^2 (Hughes 1996) in undeveloped areas. Population estimates in disturbed sites are <6 individuals/km^2 and suburban subdivisions are <5 individuals/km^2 (Hughes 1996). The study area is developed over >75% of its area. Using Hughes' estimate of <5 individuals/km^2 we estimate the population to be <3000 birds. Our public survey of 1449 sightings may represent only ½ of the population.

Density of calls varied throughout the city. The highest concentration of calls came from the northeast part of Tucson and from the southwest part of the city. There

were also areas from which we received very few or no calls. These voids occurred on the west side of the city along Interstate 10, near the city center, and along the southern border of the study area.

Reporting bias was our greatest concern with using a public survey. Most callers responded to articles published on Thursdays in the Arizona Daily Star. This means that most callers were people who could read, afford the newspaper, bought the newspaper on Thursdays, had time to read the newspaper, and chose the Arizona Daily Star over the other daily paper, The Tucson Citizen. Our requests for information were always in English thus biasing the survey towards people who speak English. Subsequently, those people who speak only Spanish may not have known about the project. Other social influences include income level and cultural values. People with higher incomes may have more leisure time or 1 spouse may stay at home. This may allow more time to see roadrunners especially around the home. Cultural values may affect interest levels and willingness to participate.

These social influences may in part explain some of the variations in density. Most calls came from the northeast side of Tucson. People who live in that area may have higher incomes, which allows more leisure time to see roadrunners. These people may also own larger house lots which may contain more wildlife. The void along Interstate 10 may exist because there are few people in that area available to see roadrunners. The area near the city center has many people, but they may be largely working class with less leisure time to see birds. The void at the southern part of Tucson may result from a language barrier. The Hispanic community makes up approximately 28% of Tucson's population (Bureau of the Census 1998) and many live in the southern part of the study

area. If many of these people speak only Spanish they may not have understood our requests for information because the requests were in English.

We conducted our own walking surveys to reveal possible biases in the public survey. The distribution of sighting locations from the walking surveys was similar to the distribution of sighting locations from the public survey in that there were high densities in both the northeast and southwest parts of Tucson. This indicates that callers may have reported sightings from these areas because there were indeed more roadrunners. The distribution of sighting locations from the walking surveys differed from the distribution of sighting locations from the public survey in areas including golf courses. Walking surveys showed high densities in these areas, the public survey did not. Golfers may have seen roadrunners but did not call with the information, because a phone was not readily available.

A void occurred near the city center in both the public and walking surveys. Tweit and Tweit (1986), Hughes (1996), and Unitt (1985) report that roadrunners are absent from highly developed areas with solid urbanization. Our results concur with these observations. Roadrunners do not avoid suburban areas as demonstrated by public sighting locations well within city limits nor do roadrunners leave areas of new development (Wright 1973). Some surveys indicate that roadrunners are absent from suburban areas (Rosenberg et al. 1987). We suggest that roadrunners might have been seen during Rosenberg et al.'s survey if more searching time had been available. We compared the lack of sightings in a small area of Tucson by Emlen (1974) to our public and walking surveys. Roadrunners were absent from this location in both our surveys,

however, 1 sighting from the public occurred within 160 m of Emlen's study area and 8 sightings occurred with 1000m.

The distribution of sighting locations from the walking surveys was closer to what we expected with most sighting locations at the periphery of the city and a void in the middle. This indicates that, if enough time is spent in Tucson (i.e. if one lived in Tucson) a roadrunner can be seen almost anywhere. However, the best chance of seeing a roadrunner in a short time is at the edges of the city, specifically on golf courses that have easy public access. We documented 3 roadrunner sighting locations in 1 hour on Fred Enke Golf Course from a least 2 different birds (1 bird was distinctively injured). Although the highest concentration of roadrunner sightings occurred on the northeast side of Tucson in both the walking surveys and the public survey, this area is extensive and mostly private property so seeing roadrunners in a short time is difficult.

The results of the bird identification skills test gave us confidence that callers were seeing roadrunners and not confusing roadrunners with other bird species. Some people confused a Gambel's quail with a parrot and only 53% of participants were able to identify Arizona's state bird, the cactus wren. But, all 40 participants correctly identified the roadrunner. An informal bird identification survey was recently conducted in Washington, D.C. (J. W. Cornett, Palm Springs Desert Museum, personal communication). When asked to identify a bald eagle (our national symbol) and a roadrunner, 34% correctly identified a bald eagle and 66% correctly identified a roadrunner. The nearest roadrunner to Washington, D.C. is about 1500 km away.

A chi-square test revealed a difference in distribution between roadrunner sighting locations from the public and randomly generated locations among all land-use covers.

The Bonferroni test identifies the presence and degree of differences in specific land-use covers. Roadrunners were seen more than expected in housing densities of <1 RAC and >1-3 RAC. This indicates that people most often see and report roadrunners around their homes, more specifically in areas with the lowest housing densities. Roadrunners were sighted less often than expected in natural open spaces and graded vacant land. This lower incidence of sightings is likely due to lack of people available to see roadrunners in both areas. It may also be more difficult to see a roadrunner in natural open space because vegetation may be too dense. The chance of seeing a roadrunner on the caller's property is greater because the caller likely spends more time on their own property than out in non-residential natural open space. Graded vacant land may not contain enough people available to see roadrunners and may not be attractive to roadrunners because of the lack of vegetation.

There is a significantly higher probability of receiving a roadrunner sighting location from the public in areas with >1-3 RAC. Ohmart and Anderson (1982) describe the roadrunner as a facultative riparian species, one inhabiting riparian areas but also occurring in urban, desert and agricultural environments. Roadrunners likely exist in washes, cemeteries, and parks, and our walking surveys revealed roadrunners on golf courses. The public, however, may not report sighting from these places because they visit them infrequently or a phone is not readily available. Areas with housing densities of <1 RAC may contain roadrunners, but there are not enough people in the area to report seeing the birds. In areas with >3-6 RAC, and >6 RAC, many people may be available to report roadrunners, but housing density may reduce the number of birds in the area. Areas

with >1-3 RAC may contain the optimum combination of number of people available to see roadrunners and abundance of roadrunners.

The sighting location distribution resulting from the public survey technically represents the distribution of people who see roadrunners and not the true distribution of roadrunners. However, because of the large number of locations reported by the public, the comparison with our walking surveys and the positive results of the bird identification skills test, we believe that the public survey accurately represents the distribution of roadrunners in Tucson.

Christmas bird counts (CBC) conducted in the Tucson valley report low numbers of roadrunner sightings in the early 1970's and the 1990's and a peak in the 1980's (Christmas Bird Count 1970-1971, 1994-1996; Christmas Bird Count 1971-1993). Root (1998) discusses controversy over error in CBSs but believes that they adequately represent abundances of most birds reported. Since urbanization has increased since the 1970's the changes in roadrunner sightings may be due to natural population fluctuations or other factors rather than increased urbanization.

Roadrunners build a fairly large and distinctive nest. It is typically made of sticks and twigs, pencil size and smaller, and sparsely lined with finer materials such as grass and pine needles. The nests we measured were the same dimensions or slightly smaller than those measured in other studies. Hughes (1996) reported an average nest outside diameter of 28 cm, range 19-41 cm and Sutton (1940) reported 30 cm. Both of these studies are similar to our average of 28 cm. Dawson (1923) reported wider nest outside diameters ranging from 30-45 cm. Our nest outside thickness of 15 cm fell at the lower range of both Sutton's (1940) measurements of 15-20 cm and Dawson's (1923)

measurements of 10-30 cm. The 4 cm inside cup depth of nests in our study area was much more shallow than that described by Hughes (1996) which ranged from 5-10 cm. Average nest height above ground was much higher in our study but was within the range described in other studies. Our nests averaged 2.3 m, range 1.3-4.5 cm above ground while others averaged 1.44 ± 0.37 m, range 1.0-2.5 m (Hughes 1996); $x = 2.0$ m, range 0.9-6.1 m (Bryant 1916); $x = 1.3$ m, range 0.4-2.5 m (Ohmart 1973); $x = 1.4$ m, range 0.6-3.1 m (Folse and Arnold 1978); range 1-4.6 m (Sutton 1940); and range 0.6-6.0 m (Sutton 1967). Differences in dimensions may be due to differences in structure of available nest sites.

In undeveloped areas near Tucson nests are reported most often in native vegetation such as cholla cactus (*Opuntia* sp) (Dawson 1923, Ohmart 1973) and palo verde (*Cercidium floridum*) and desert hackberry (*Celtis pallida*) (Ohmart 1973). Nests from other areas are reported in trees such as elm (*Ulmus* sp), willow (*Salix* sp), juniper (*Juniperus* sp), and oak (*Quercus* sp) and thorny bushes (Sutton 1967, Folse and Arnold 1978) as well as sandstone cliffs (Dawson 1923). In developed areas nests were reported in neglected farm machinery (Sutton 1967) and under the eaves of a house (Rylander 1972). We expected roadrunners to select native vegetation but we discovered that most nests were built in non-native vegetation and man-made structures, despite readily available and abundant native vegetation. Most of the nests we measured were close to daily human activity such as under carports that were used daily or just outside the often used front door of a house.

Non-native trees and man-made structures may provide more cover than native vegetation. A number of nests were built in Italian cypress and citrus trees which both

have dense foliage. Roadrunner movements into and out of these trees is often the only indication that a nest exists. Man-made structures provided 100% cover from the sun. Hughes (1996) describes nests that are well concealed by vegetation, but Ohmart (1973) and Lowe and Hinds (1969) report nests built in fairly open vegetation, unprotected or weakly protected from solar radiation. These observations warrants further investigation through a comparison of percent cover provided by non-native vegetation and man-made structures to native vegetation.

Nest trees had a common shape with the exception of Italian cypress. Most were circular in shape and as high as they were wide. Hughes (1996) reports a similar shape for shrubs used for nesting ($x = 2.8 \pm 1.1$ m, range 1.0-5.2 m). Roadrunners nests built in trees were most often at the center of the crown near the bole and Hughes (1996) reports nests built in shrubs near the center of the shrub.

Only 30% of the properties with roadrunner nests had resident dogs. Domestic dogs can kill wildlife and may kill roadrunners, despite this, roadrunners nested on properties with large, unrestricted dogs. One nest was built directly above a dog house occupied by 2 large dogs. The roadrunner used this dog house as a launching pad from which to reach a shed and then its nest. Water was available daily on 80% of properties with roadrunner nests. In captivity roadrunners drink about 2 times per week (Bryant 1916, Dawson 1923), therefore, it may not be necessary for roadrunners to be near daily available water. Percent occurrence of these and daily water on properties with nests may not be different from average for that area of Tucson in which the nests were found. These aspects of roadrunner habitat warrant further investigation.

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Table 1: Percent correct answers 40 participants in the bird identification skills test in Tucson, Arizona, 7-12 December 1998.

Species	% Correctly identified by callers	% Correctly identified by general public	Average
roadrunner	100	100	100
Gambel's quail	90	85	87.5
rock dove	60	75	62.5
cactus wren	60	45	52.5
curve-billed thrasher	30	10	20
great-tailed grackle	20	0	10

Table 2: Percent of expected and observed greater roadrunner locations in 4 land-use covers in Tucson, Arizona, 1 January 1997 - 30 August 1998.

Land-use cover	% randomly generated locations (expected)	% sighting locations from callers (p_i) (observed)	Confidence interval on % sighting locations of callers (p_i) (90% family confidence coefficient)
>1-3 RAC[a]	12.7	30.9	$27.3 \leq p_1 \leq 34.6$
natural open space	23.3	11.3	$8.8 \leq p_2 \leq 13.9$
graded vacant land	7.2	3.5	$2.1 \leq p_3 \leq 5.0$
<1 RAC	13.7	17.1	$14.1 \leq p_4 \leq 20.1$

[a] RAC = residence per acre

Table 3: Results of Student's t-test analysis on 1,015 greater roadrunner sightings from the public and 1,200 random points in groups of similar land-use covers in Tucson, Arizona, 1 January 1997 - 30 August 1998.

Land-use Cover Groups	*t* statistic	*P*-value
major rivers and wash/riparian area	0.091	0.9280
cemeteries; golf courses; neighborhood, regional, and district parks	0.204	0.8401
natural open space and State/Federal parks and forests	0.105	0.9172
<1 RAC[a]	-0.225	0.8242
>1-3 RAC	-3.364	0.0035
>3-6 RAC	0.228	0.8226
>6 RAC	-0.381	0.7079

[a] residents per acre

Table 4: Values (cm) of nest structure variables from 23 greater roadrunner nests in Tucson, Arizona, February 1997 - January 1999.

Nest Structure Variable	n[a]	$\bar{x}$	SE	Range
outside nest diameter	12	28	1.4	18-35
outside nest thickness	14	15	1.7	4-24
inside cup diameter	16	17	0.8	10-28
inside cup depth to rim	12	4	0.6	0.5-6
height above ground to rim	19	230	21.2	127-478

[a]Not all variables could be measured on all nests.

Table 5: Percent support structure types of 30 greater roadrunner nests found in Tucson, Arizona, February 1997 - January 1999.

Support Structure	Percent of Total
roofed structure	17
citrus tree	13
Italian cypress	13
wall/vine	13
palo verde[a]	7
mesquite[b]	7
pine tree[c]	7
other[d] (7)	3 each

[a]*Cercidium* sp., [b]*Prosopis* sp., [c]*Pinus* sp.

[d]prickly pear (*Opuntia* sp.), African sumac (*Rhus lancea*), flowering plumb (*Prunus* sp.), window sill, saguaro (*Carnegiea gigantea*) skeleton/bougainvillea (*Bougainvillea* sp.), oleander (*Nerium oleander*)/pomegranate (*Punica granatum*)complex, mulberry tree (*Morus* sp.).

Table 6: Dimensions (m) of trees with greater roadrunner nests in Tucson, Arizona, February 1997 - January 1999.

Variable	n	x	SE
DBH[a]	10	0.2	0.04
crown width	17	4.5	0.9
crown length	17	4.3	0.9
tree height	17	4.9	0.6

[a] diameter at breast height

Table 7: Percent cover surrounding 30 greater roadrunner nests in Tucson, Arizona, February 1997 - January 1999.

Direction from nest	Percent cover	SE
above	84	5.3
below	57	7.9
north	70	7.5
south	80	5.9
east	72	7.4
west	71	7.3
Average	72.5	9.4

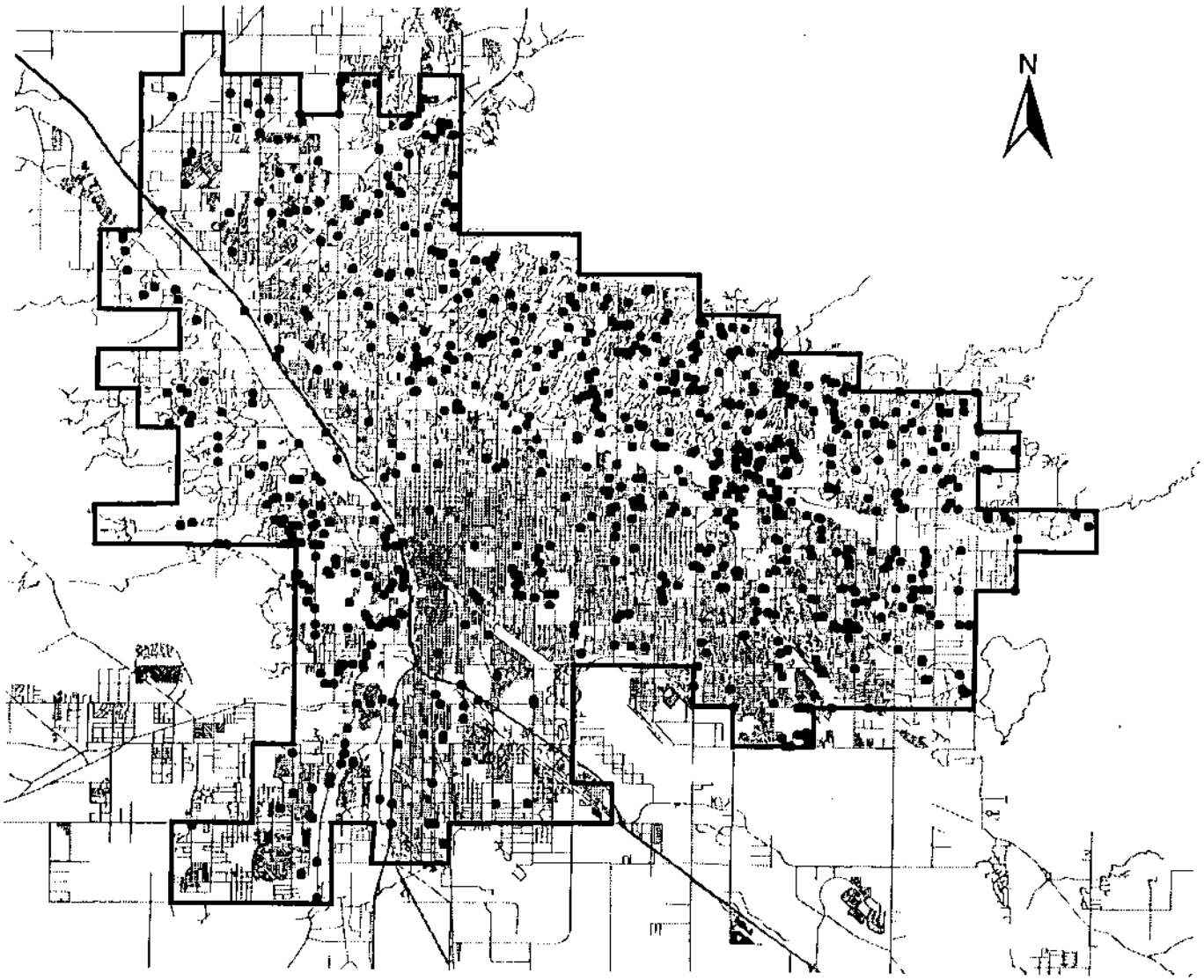

Fig. 1. Sighting locations of greater roadrunners from a public survey in Tucson, Arizona, January 1997 - August 1998.

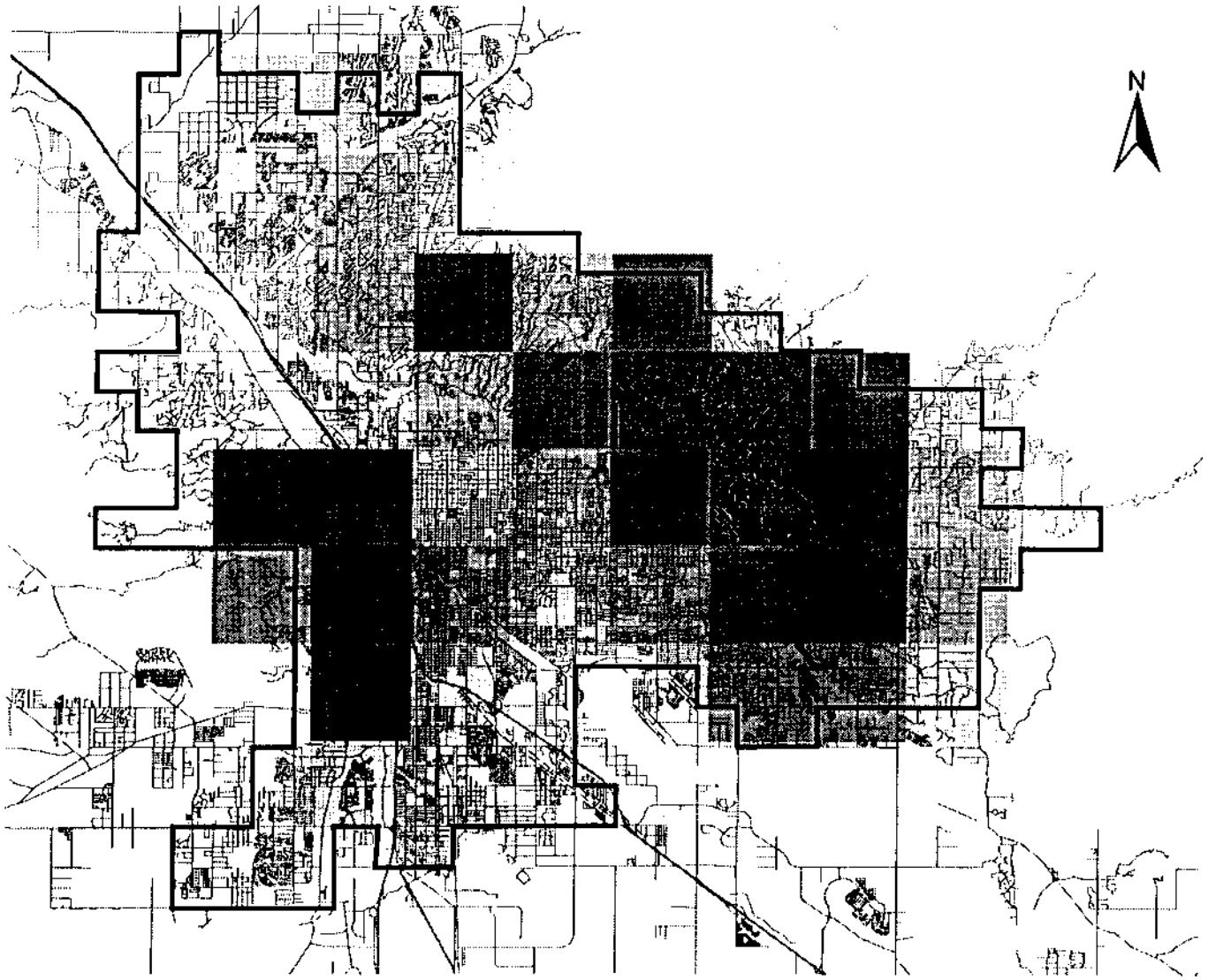

Fig. 2. Relative distribution of greater roadrunner sightings from a public survey in Tucson, Arizona, January 1997 - August 1998, from lowest (white = 0) to highest (black = 3.5) number of sightings per 25 sq. km.

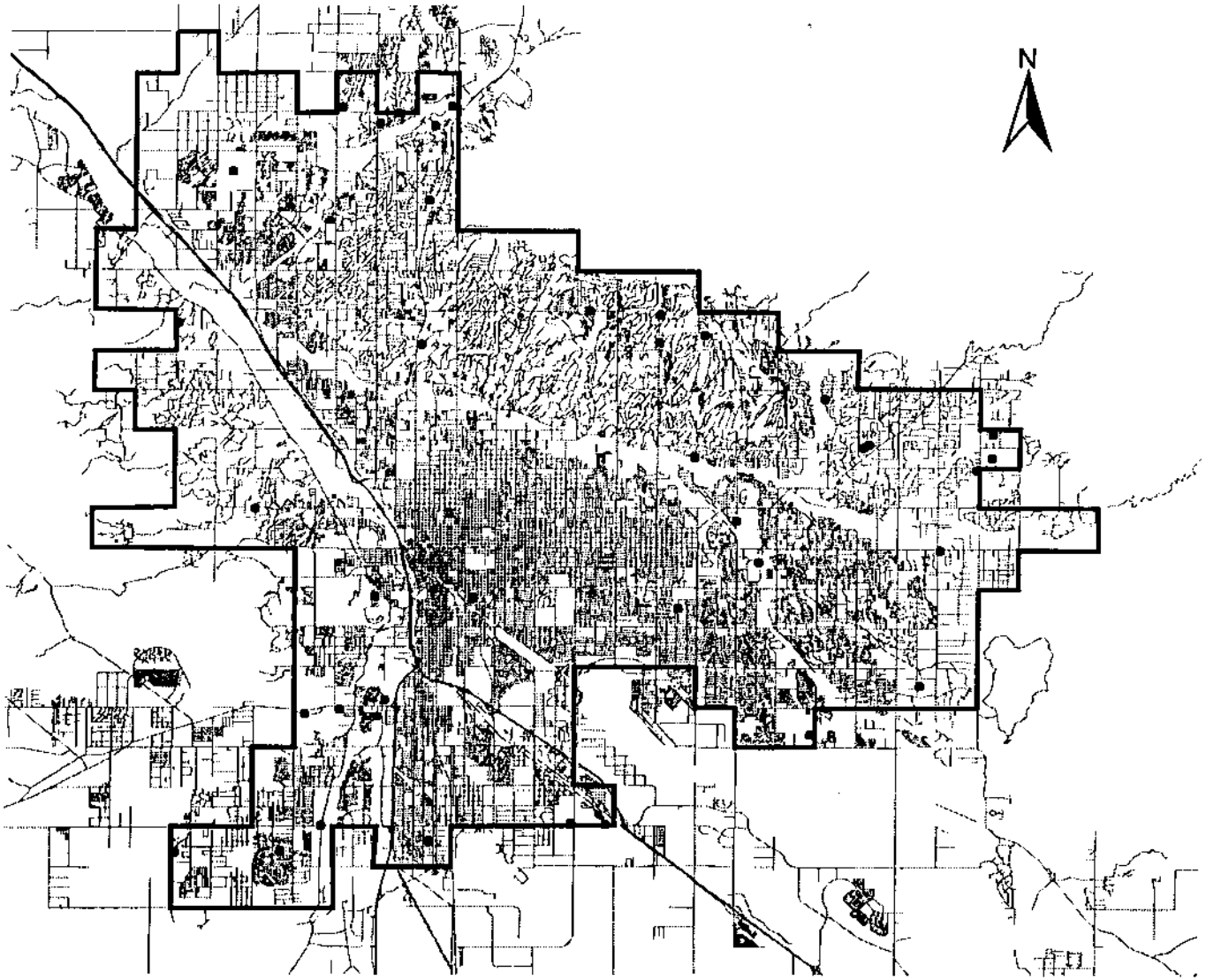

Fig. 3. Sighting locations of greater roadrunners from walking surveys in Tucson, Arizona, February 1997 - January 1999.

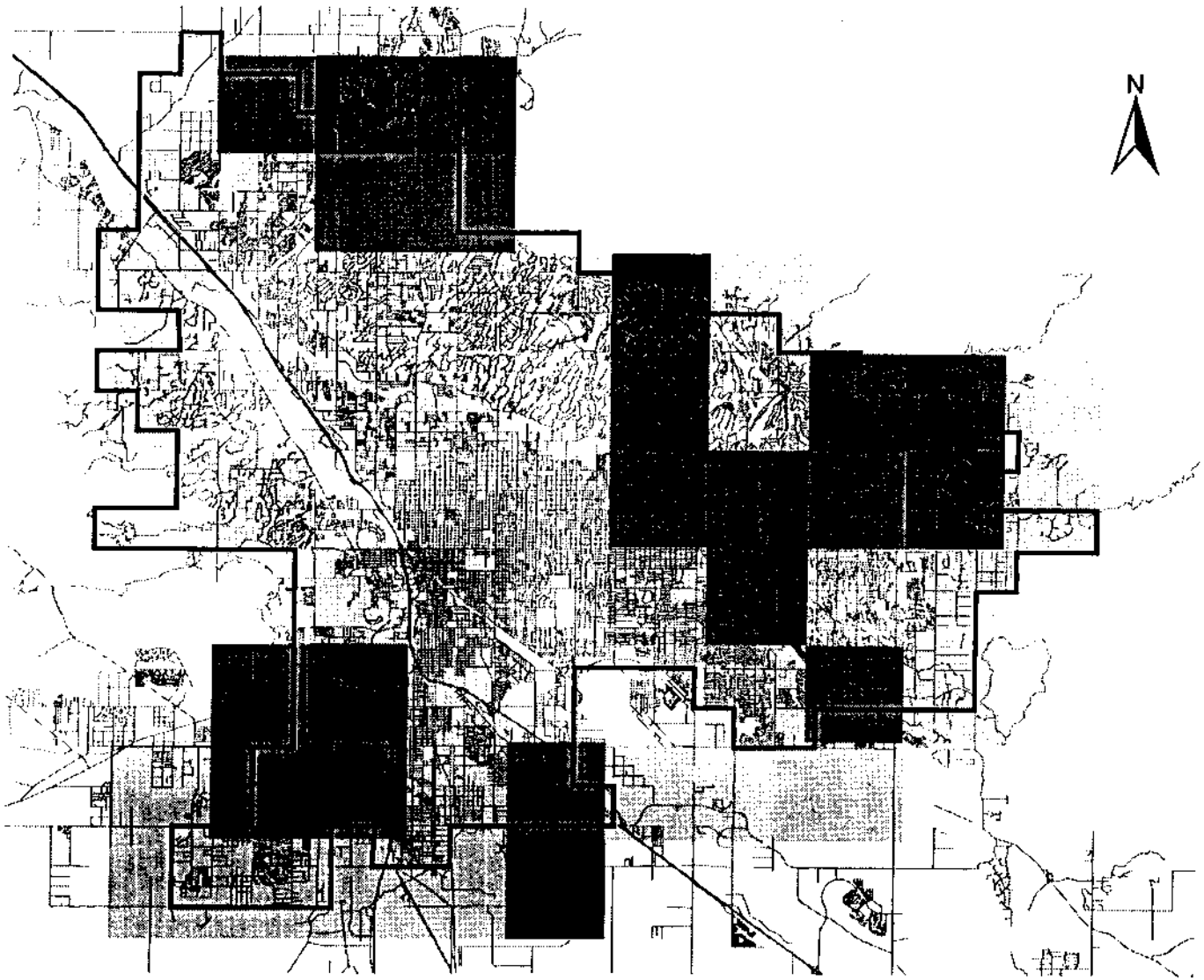

Fig. 4. Relative distribution of greater roadrunner sightings from walking surveys in Tucson, Arizona, February 1997 - January 1999, from lowest (white = 0) to highest (black = 0.1) number of sightings per 25 sq. km.

Appendix A: Land-use cover codes and descriptions in the Wildlife Habitat Inventory Project (WHIPS) database[a].

1.0 Residential

- 1.1 ≤ 1 residence/acre (RAC)
- 1.2 >1-3 RAC
- 1.3 >3-6 RAC
- 1.4 >6 RAC

2.0 Commercial and public facilities

- 2.1 Commercial
- 2.2 Industrial
- 2.3 Regional Mall
- 2.4 Mine
- 2.5 Institutional
  - 2.51 School
  - 2.52 Public Buildings
  - 2.53 Military
- 2.6 Destination Resorts
- 2.7 Offices
- 2.8 Cemetery
- 2.9 Landfill

3.0 Recreation

- 3.1 Zoological Park

3.2 Golf Cours and Associated Recreation Areas

3.3 Parks and Playgrounds

3.41 Neighborhood Park (≤10 acres)

3.42 District Park (11-49 acres)

3.43 Regional Park (≥50 acres)

3.44 State/Federal Park and Forest, and County Preserve

4.0 Water Courses and Ponds

4.1 Major River

4.2 Wash/Riparian Area

4.3 Pond

5.0 Natural Open Space

6.0 Graded Vacant Land

7.0 Agricultural Land

7.1 Animals

7.2 Crops

7.3 Abandoned Agricultural Land

8.0 Major Transportation Route

8.1 Roadway (≥4 lanes or equivalent) (exclude from Use/Availability Analysis)

8.2 Railway Yard

8.3 Airport (excluded from all analyses, out of study area)

*Shaw, W. W., L. K. Harris, M. Livingston, J.P. Carpentier, and C. Wissler. 1996. Pima County Habitat Inventory: Phase II. Arizona Game and Fish Department, Final Report: Contract Number G50028-001, Phoenix, Arizona, USA.

Appendix B: Public presentations and publicity. Distribution and habitat of greater roadrunners in urban and suburban Tucson, Arizona, Arizona Game and Fish Department's Heritage Grant #U97004.

Public Presentations

1. Tohono Chul Park: Lecture Series and Workshops, 11 February 1999, Tucson, Arizona, (85 participants).
2. Pelican Island Audubon Society: Monthly Meeting, 15 March 1999, Vero Beach, Florida, (85 participants)
3. Palm Springs Museum, 16th Annual Natural Science Symposium: The Roadrunner, 17 April 1999, Palm Springs, California, (50 participants).
4. International Urban Wildlife Conference, Tucson, Arizona, 3-4 May 1999.

Publicity

1. Fliers: 800 distributed to libraries and community centers.
2. Newspaper articles: Arizona Daily Star
    - 6 March 1997 (Thursday) - Section C, Page 1
    - 20 March 1997 (Thursday) - Section C, Page 1
    - 20 November 1997 (Thursday) - Section C, Page 2
    - 23 July 1998 (Thursday) - Section B, Pages 1,2
3. Television: KOLD, Channel 13 News - 22 November 1997, 6:20pm.
4. Radio: KUAT (Arizona member of National Public Radio) - 3 20 minute interviews at 6:20am, 8:20am and 9:20am.
5. Student Highlight. 1997. Renew: News and Happenings at the School of Renewable Natural Resources, Issue 1, page 8.

6. Volunteers Needed for Roadrunner Research. March 1998. Vermilion Flycatcher, Tucson Audubon Society, Vol 42(5), page 15.

7. Across the Country: Arizona. 1998. USA Today. 24-26 July.

8. Edmonds, Sharon. 1998. Your Lottery Dollar$ at Work in Pima County. Desert Leaf, September Issue.