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ABSTRACT: Increasingly, coyotes are becoming common residents of urban areas in the western United States, including Tucson, Arizona. The authors' objectives were to determine the home-range size of coyotes in Tucson, the habitat encompassed by the home ranges of these coyotes compared with the habitat available in Tucson, and the use of habitats within the home range, compared to their availability in the home range. To address these objectives, the authors trapped, radiocollared, and followed 13 coyotes via radiotelemetry in Tucson, Arizona. Seven coyotes were in less-densely populated areas (<1 house/0.4 ha, called rural) of Tucson; six coyotes were in densely populated areas (>1 house/0.4 ha, called urban) of Tucson. The authors used RANGES V to determine home-range size and the geographic information system ARC/INFO to analyze habitat use. The home-range size of Tucson coyotes varied from 129 to 3,279 ha (95% MCP). Coyote home ranges in rural areas included a greater proportion of natural habitat and a smaller proportion of residential habitat than was available in the study area. Coyote home ranges in urban areas included a greater proportion of vacant areas and a smaller proportion of natural areas and parks than was available in the study area. Within the home range, coyotes in rural areas preferred (used greater than available) parks and washes, and avoided (used less than available) all other habitats. Within the home range, coyotes in urban areas preferred residential habitat; they avoided commercial areas and vacant areas. Coyotes may have been preferring areas where food and cover was most abundant.

KEY WORDS: *Canis latrans*, coyotes, habitat use, urbanization

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INTRODUCTION

Since the 1980s, urbanization has added new dimension to the study of coyote ecology. Coyotes persist in urban habitats (Howell 1982; Quinn 1991), and this adaptability makes them ideal animals with which to study the affects of urbanization on wildlife (Bekoff and Wells 1986), as well as the effects of wildlife on urban areas. To date, however, no studies have investigated the way in which coyotes use urban areas. Some studies have investigated coyotes on the outskirts of urban areas (Shargo 1988; Bounds 1993), but have not concentrated on their presence in urban centers. Researchers recorded the presence of coyotes in Los Angeles, California (Gill and Bonnett 1973; Howell 1982) and in Seattle, Washington (Quinn 1991), but did not quantify or explain their findings.

The authors' objectives were to determine home-range size, evaluate the habitat encompassed by the home range compared to habitat availability in Tucson, and quantify habitat use compared to its availability within the home range. Three questions relative to this objective were asked: What is it home-range size of Tucson coyotes and how does it compare to the home-range size of coyotes obtained by other researchers in rural settings? Do home ranges encompass certain habitats out of proportion to their availability in Tucson? And finally, are certain areas within the home range used more than others?

STUDY AREA

The area in which the coyotes were captured and collared encompassed most of the city of Tucson, Arizona, and a few urbanized areas directly outside of the city limits. Tucson, which is in eastern Pima County, currently encompasses 493 km^2 with an estimated population of 456,100 (Tucson Planning Department 1996). Tucson is situated in the Sonoran Desert, the most varied and the hottest of the North American deserts. The elevation is 745 m in midtown Tucson, and increases toward the foothills of the Santa Catalina Mountains to the north, the Tucson Mountains to the west, and the Rincon Mountains to the east. The climate in Tucson is characterized by low, unevenly distributed rainfall (about 28 cm annually; Sellers and Hill 1974), low humidity, high air temperatures and periodic strong winds (Hastings and Turner 1965).

Determination of Study Areas within Tucson

Although the authors concentrated their trapping efforts on urban areas of Tucson, some coyotes were trapped in less-densely populated areas than others. In addition, some coyotes ranged from the areas in which they were trapped to less-densely populated areas. To deal with the variability in habitats used by coyotes, the collared animals were divided into two groups, each with its own study area. Six coyotes were located in less-densely populated areas of Tucson (<1 house/0.4 ha, called rural); seven coyotes were located in more-densely populated areas of Tucson (>1 house/0.4 ha, called urban).

Determination of Land-use Categories in Study Areas

The WHIPS database (Shaw et al. 1996) was used as a basis for creating habitat categories in the study area. The WHIPS database assigned all of eastern Pima County, including Tucson, to one of 33 land-use categories at a resolution of 0.4 ha. The authors collapsed across WHIPS land-use categories to create seven habitat categories. The new habitat categories were formed based on information from Shaw et al. (1996) on the amount of native and non-native vegetation present,

the amount of human activity present, and on obvious structural differences and similarities among WHIPS land-use categories.

Natural habitat included residential areas with low-density housing (< 1 house/0.4 ha), state and federal parks, privately-owned natural open space, and cropland. Commercial habitat included industrial areas, malls and other shopping centers, public buildings, and office buildings. Park habitat included schools, military grounds, cemeteries, zoos, golf courses, neighborhood, district and regional parks, and stables or pens with horses or cows. Vacant habitat included mines, landfills, graded vacant land, abandoned agricultural lands, and railway yards. Residential habitat included neighborhoods with > 1 house/0.4 ha. Wash habitat included major and minor rivers and washes. Road habitat included only roads with ≥ 4 lanes; smaller roads were incorporated into the surrounding habitat categories.

Vegetative Characteristics of Habitat Categories

To construct the land-use categories for their database of eastern Pima County, Shaw et al. (1996) sampled vegetation from their land-use categories. They found that golf courses and neighborhood parks (the authors' parks habitat) had the highest total vegetative cover (Table 1). Areas equivalent to the natural habitat had the highest percentage of native plants, and the most vegetation that was dense enough to serve as escape cover. Structural diversity of vegetation was higher in human-designed urban landscapes such as medium-density residential areas (1 to 3 houses/2.5 ha), zoos, schools, and cemeteries (the authors' residential and park habitat) than in areas with native vegetation. Based on these vegetative characteristics, Shaw et al. (1996) ranked natural open spaces, federal/state parks, and low-density housing (the authors' natural habitat) as the most valuable wildlife habitat in Tucson. The next highest-ranked group of land use categories included medium density housing, schools, parks, golf courses, and cemeteries (the authors' residential and park habitat). The least valuable land use categories for wildlife included landfills, abandoned agricultural lands, and railways (the authors' vacant habitat).

METHODS

Trapping and Radiocollaring

The help of a professional trapper was enlisted to live-trap coyotes using padded leg-hold traps (#3 Victor Softcatch Coilspring). Fourteen coyotes were trapped and radiocollared from October 1996 through March 1997, and five coyotes from December 1997 through January 1998. The data from 13 of these coyotes is presented here. The authors tried to trap in locations that represented a variety of areas and human population densities within Tucson. They were not able to trap everywhere they chose, however, because some landowners would not allow them to trap on their property; other areas were too often traversed by dogs and people that might step in a trap. The traps were closed at dawn and opened at dusk daily to minimize the time that a coyote spent in a trap, and to minimize the chances of trapping non-target animals. Each trapped coyote was immobilized with a noose rod, muzzle, and nylon stockings to tie its legs (Woolsey 1985). The coyote was then fit with a radiocollar (Telonics Inc., Mesa, Arizona). Each trapped coyote was weighed, its sex and reproductive condition determined, and its age approximated (< 12 months, > 12 months, > 24 months) by looking at tooth wear (Gier 1968) and, for young of the year, by looking at the condition of the coat and tail. Finally, the animal's general health was evaluated by checking for external parasites, wounds, or other obvious signs of ill heath. The coyote was then released at the trapping site.

Radiotelemetry

The authors worked with technicians to locate coyotes by homing with hand-held Yagi antennas (White and Garrott 1990). They attempted to visually locate animals, if possible, without trespassing or disturbing the animal. Each technician's error was tested in locating coyotes by placing radiocollars at locations, known to the tester, in various habitats and having technicians estimate collar locations via their usual homing procedure (e.g., Litvaitis and Shaw 1980; Bounds 1993).

Table 1. Characteristics and ranking (based on vegetative characteristics) of wildlife habitats in Tucson, Arizona (Shaw et al. 1996).

Habitat Category	Vegetative Characteristics	Ranking
Natural	Most native vegetation; Most escape cover	Most valuable
Residential	High structural diversity	Intermediate Value
Parks	High structural diversity; Most vegetation overall	Intermediate Value
Vacant	None of the above	Low Value

Data was collected throughout the year. Each coyote was located ≥2 times/week, once during the day and once at night. Day and night were divided into two, six-hour blocks, and an equal number of locations during each block were made. Coyote locations were recorded on enlarged sections of a Tucson street map. The locations were then entered into Arc/View (desktop mapping system, ESRI, Redlands, California) as a coverage that overlaid the WHIPS database (Shaw et al. 1996). Finally, the coyote locations were converted into ARC/INFO (geographic information system, ESRI, Redlands, California) coverages to assign the locations UTM coordinates.

Home-range Size Estimation

The ARC/INFO coverages of coyote locations were imported to the home-range package RANGES V to estimate home-range size. Two methods of home-range estimation were used: 1) the minimum convex polygon (MCP) method (Mohr 1947); and 2) the adaptive kernel method (Worton 1989). For both methods 95% of all points to estimate home-range size were used. The MCP method is commonly used in coyote research (e.g., Litvaitis and Shaw 1980; Althoff and Gipson 1981; Andelt 1985; Bekoff and Wells 1986; Bounds 1993); this method was used to compare the data with that of other studies. The adaptive kernel method is a nonparametric method of estimating home-range size that allows one to determine core areas of activity, an important factor in urban areas where coyotes habitat may be fragmented. The adaptive kernel home-range estimations was used in the analyses of habitat use.

Determination of Use Versus Availability of Habitats

Home range versus study area. The habitats that were encompassed by each home range were determined by importing the 95% adaptive kernel home ranges from RANGES V to ARC/INFO as polygons that were the shape and size of each home range. These polygons were used to clip out the habitat categories in each home range, and then the amount of each habitat category that was within the home range was determined. The amount of each habitat category that was in the study area (either rural or urban) was also determined. The proportion of each habitat category that was within the home range was compared with the proportion of each habitat category that was in the study area by using Chi-square tests of homogeneity (Daniel 1991) on all home ranges and on individual home ranges. It was determined which habitat categories were encompassed by home ranges more or less than they were available in the study area by constructing simultaneous 95% confidence intervals with Bonferroni corrections on the proportions (Manly et al. 1993).

Locations within the home range versus the home range. It was determined if certain habitats within the home range were being used out of proportion to their availability in the home range by comparing the number of coyote locations in each habitat category within the home range with the number of locations that would be expected in each habitat category within the home range if the habitat categories were being used in proportion to their availability. The number of locations that were in each habitat category was determined by intersecting the coverage with the coyote locations with that of the coyote's home range polygon. The previously determined proportion of each habitat category in each home range was used to determine the number of expected coyote locations in each category. Chi-square tests of homogeneity (Daniel 1991) were used on all home ranges and on individual home ranges to compare the actual number of locations in each habitat category with the expected number, if use equaled availability within the home range. Which habitat categories were used more or less than they were available in the home range was determined by constructing simultaneous 95% confidence intervals with Bonferroni corrections on the proportions (Manly et al. 1993).

RESULTS

Home-range Size Estimates

Preliminary estimates of technician error ranged from 0 to 100 m. The MCP (95%) home-range estimates of coyotes ranged from 129 ha to 3,279 ha in size. The home-range size of rural coyotes ranged from 312 to 3,279 ha, and the home-range size of urban coyotes ranged from 129 to 1,637 ha. Although rural coyote home ranges were larger than those of urban coyotes, both groups of coyotes contained three individuals with home ranges under 500 ha.

Habitat Encompassed by Home Range versus Study Area

Within each study area, the pooled home ranges of coyotes encompassed habitat categories out of proportion to the availability of the habitat categories ($P < 0.0001$). Each individual home range also encompassed habitat categories out of proportion to their availability in the study area ($P < 0.0001$). Overall, coyotes home ranges in rural areas contained a greater proportion of natural areas than available, and a smaller proportion of residential areas than available; all other habitat categories were used in proportion to their availability. Overall, coyote home ranges in urban areas contained a greater proportion of vacant areas and roads than available, and a smaller proportion of natural areas and parks than available. All other habitat categories were used in proportion to their availability. Individual coyotes, however, showed a great deal of variation in their preferences for various habitat categories (Figure 1 and Figure 2).

Habitat Use within the Home Range

Coyotes in both study areas used habitat categories within the home range out of proportion to their availability ($P < 0.0001$). Overall, coyotes in rural areas preferred (used greater than available) the park and water habitat categories; they avoided (used less than available) all other habitat categories. Overall, coyotes in urban areas preferred residential areas. They avoided commercial areas, vacant areas, and roads, and used natural areas, parks, and water in proportion to their availability. Once again, however, there was much individual variation in the use of various habitat categories by individual coyotes (Figure 3).

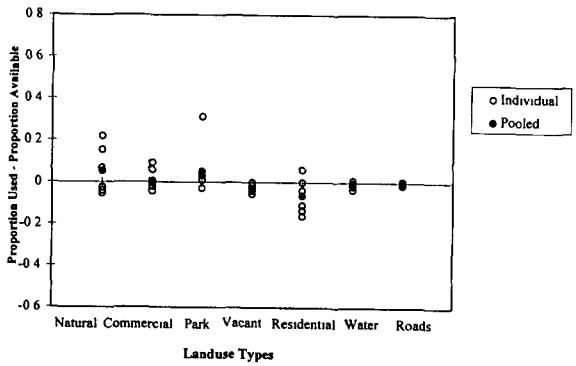

Figure 1. Habitat in home ranges of coyotes versus rural study area. The proportion of each home range containing each habitat category is subtracted from the proportion of that habitat in the study area to illustrate the variation in use of habitats by individual coyotes. The pooled value for each habitat is also shown.

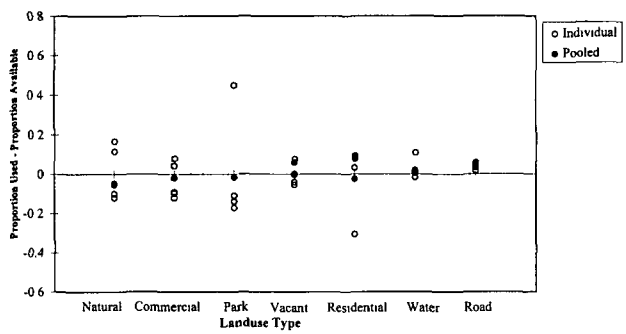

Figure 2. Habitat in home ranges of coyotes versus urban study area. The proportion of each home range containing each category is subtracted from the proportion of that habitat in the study area to illustrate the variation in use of habitats by individual coyotes. The pooled value for each habitat is also shown.

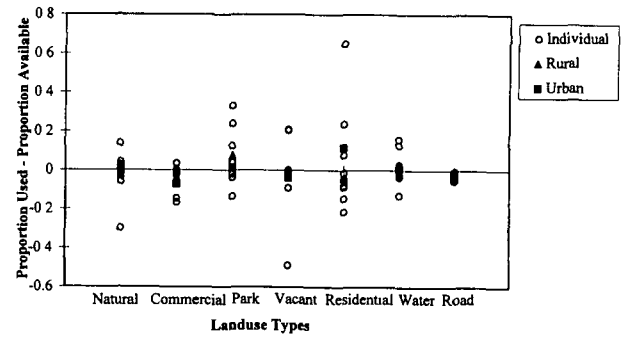

Figure 3. Habitat use versus availability within home ranges. The proportion of locations within each habitat in the home range is compared to the proportion of that habitat that is available within the home range to show the variation in use by individual coyotes. The pooled value for rural and for urban coyotes is also shown.

DISCUSSION

Home-range Size Estimates

Many radiotelemetry studies have documented home-range sizes for coyotes in relatively undisturbed areas (Messier and Barrett 1982; Woodruff and Keller 1982; Andelt 1985; Windberg and Knowlton 1988; Mills and Knowlton 1991) and in areas where agriculture or ranching have modified the landscape (Danner 1976; Andelt and Gipson 1979; Fisher 1980; Althoff and Gipson 1981). These areas are less densely inhabited by humans than are urban areas but vary, nonetheless, in regard to their exploitation by man. This variation has been apparent in the wide range of home-range sizes recorded for coyotes. Home-range size of resident coyotes, using the 95% MCP method has been found to vary from around 200 ha (Andelt 1985; Windberg and Knowlton 1988) up to 1,700 to 2,400 ha (Bekoff and Wells 1981). The 95% MCP home ranges for both groups of coyotes are similar to those reported by other studies, although there were coyotes with home ranges that were both larger and smaller than the values found by other researchers. Thus, it is not obvious that living in an urban environment affects the size of an area that a coyote uses during daily activities.

Habitat in the Home Range Versus the Study Area

At the level of the home range, coyotes in rural Tucson preferred the natural habitat category which, because of its vegetation characteristics, was ranked highly as wildlife habitat by Shaw et al. (1996) (Table 1). Thus, coyotes living on the outskirts of Tucson seem to be able to survive by simply avoiding encroaching urbanization. At the level of the home range, coyotes in urban Tucson preferred vacant areas, which Shaw et al. (1996) deemed the least valuable wildlife habitat, and avoided natural areas and parks, which Shaw et al. (1996) ranked higher than vacant areas in their value to wildlife. Although surveys of the vegetation and prey base in vacant areas have not been conducted, two of the collared coyotes were trapped in a landfill, and radiotelemetry observations confirmed that some coyotes do hunt in landfills and vacant agricultural land. Other coyotes have been observed, however, spending most of their time in parks, golf courses, and cemeteries. Although the pooled data from all coyotes do not indicate a preference for parks and residential areas, some individuals undoubtedly prefer these areas.

Habitat Use within the Home Range

The observed preference by coyotes in rural areas for park habitats may, in part, be a result of the fact that four rural coyotes were trapped in a golf course. All of these coyotes were found in the golf course a large proportion of the time soon after they were collared. Only one of these coyotes still resides exclusively in the golf course, however, two of the other three coyotes have not been observed in the golf course in >6 months. Although the home-range estimates for these animals still reflect their earlier use of the golf course, the later locations are concentrated in natural areas. For this analysis, all locations were lumped together to obtain home-range estimates. Later, it is planned to have enough locations for each coyote in different seasons to block the locations by season; this method will allow the authors to observe and quantify shifts in home range size and habitat use within the home range with time. In preferring parks, coyotes in rural areas are showing a preference for what Shaw et al. (1996) considered a valuable wildlife habitat, however.

The preference for residential habitats by coyotes in urban areas coincides with the classification by Shaw et al. (1996) of these areas as good wildlife habitat (Table 1). Natural areas and parks were used in proportion to availability by coyotes in urban areas; both were highly ranked by Shaw et al. (1996). The vegetation in park and residential habitat categories is more structurally diverse than that in natural areas. Other studies have found that coyotes preferred the more structurally diverse forested areas over open areas, and attributed this preference to the availability of prey and cover (Litvaitis and Shaw 1980; Roy and Dorrance 1985). In preferring residential areas, coyotes in Tucson may be showing a preference for structural diversity of vegetation, and possibly a greater prey abundance and availability of cover. Although coyotes may be preferring these aspects in certain habitats, the availability of food, water, or cover was not quantified.

MANAGEMENT IMPLICATIONS

This and other studies (Litvaitis and Shaw 1980; Andelt 1985) indicate that coyotes display a wide variety in home-range size (Andelt 1985; Roy and Dorrance 1985) and in habitat use (Litvaitis and Shaw 1980; Roy and Dorrance 1985). Wildlife managers in Tucson would like to know enough about what influences habitat preference in urban areas to be able to help residents encourage or discourage the presence of coyotes in their neighborhoods. To do this, other questions need to be answered to more fully understand how coyotes are using Tucson. Information is currently being gathered on the health of Tucson coyotes, their activity patterns, and their social structure to better address these issues.

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