Contributed Paper

Relationships between Human Disturbance and Wildlife Land Use in Urban Habitat Fragments

LISA MARKOVCHICK-NICHOLLS,* HELEN M. REGAN,*‡§ DOUGLAS H. DEUTSCHMAN,* ASTRID WIDYANATA,* BARRY MARTIN,† LANI NOREKE,† AND TIMOTHY ANN HUNT†

*Department of Biology, San Diego State University, 5500 Campanile Drive, San Diego, CA 98192-1416, U.S.A.
†San Diego Tracking Team, P.O. Box 502345, San Diego, CA 92150-2345, U.S.A.
§Department of Biology, University of California, Riverside, CA 92521, U.S.A.

Abstract: *Habitat remnants in urbanized areas typically conserve biodiversity and serve the recreation and urban open-space needs of human populations. Nevertheless, these goals can be in conflict if human activity negatively affects wildlife. Hence, when considering habitat remnants as conservation refuges it is crucial to understand how human activities and land uses affect wildlife use of those and adjacent areas. We used tracking data (animal tracks and den or bed sites) on 10 animal species and information on human activity and environmental factors associated with anthropogenic disturbance in 12 habitat fragments across San Diego County, California, to examine the relationships among habitat fragment characteristics, human activity, and wildlife presence. There were no significant correlations of species presence and abundance with percent plant cover for all species or with different land-use intensities for all species, except the opossum (*Didelphis virginiana*), which preferred areas with intensive development. Woodrats (*Neotoma *spp.) and cougars (*Puma concolor*) were associated significantly and positively and significantly and negatively, respectively, with the presence and prominence of utilities. Woodrats were also negatively associated with the presence of horses. Raccoons (*Procyon lotor*) and coyotes (*Canis latrans*) were associated significantly and negatively and significantly and positively, respectively, with plant bulk and permanence. Cougars and gray foxes (*Urocyon cinereoargenteus*) were negatively associated with the presence of roads. Roadrunners (*Geococcyx californianus*) were positively associated with litter. The only species that had no significant correlations with any of the environmental variables were black-tailed jackrabbits (*Lepus californicus*) and mule deer (*Odocoileus hemionus*). Bobcat tracks were observed more often than gray foxes in the study area and bobcats correlated significantly only with water availability, contrasting with results from other studies. Our results appear to indicate that maintenance of habitat fragments in urban areas is of conservation benefit to some animal species, despite human activity and disturbance, as long as the fragments are large.*

Keywords: animal movement, animal tracks, habitat fragmentation, habitat remnants, human disturbance, urban open space, urbanization

Relaciones entre Perturbación Humana y Uso de Suelo para Vida Silvestre en Fragmentos de Hábitat Urbano

Resumen: *Los remanentes de hábitat en áreas urbanizadas típicamente conservan la biodiversidad y sirven para los propósitos de recreación y espacios urbanos abiertos de las poblaciones humanas. Sin embargo, estas metas pueden entrar en conflicto si la actividad humana afecta negativamente a la vida silvestre. Por lo tanto, cuando se considera a los remanentes de hábitat como refugios de conservación es crucial entender como afectan las actividades humanas y usos de suelo al uso de esas áreas por la vida silvestre. Utilizamos datos de huellas (huellas de animales y sitios de descanso y madriguera) de 10 especies de animales y la información sobre la actividad humana y los factores ambientales asociados con la perturbación antropogénica en 12 fragmentos de hábitat en el Condado de San Diego, California (E.U.A.) para examinar las relaciones entre las características del fragmento de hábitat, la actividad humana y la presencia de vida silvestre. No hubo*

‡*Address correspondence to H. M. Regan, email helen.regan@ucr.edu*
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correlaciones significativas de la presencia y abundancia de especies con el porcentaje de cobertura de plantas par todas las especies o con diferentes intensidades de uso de suelo para todas las especies, excepto Didelphis virginiana*, que prefirió áreas con desarrollo intensivo.* Neotoma *spp. y* Puma concolor *se asociaron significativa y positivamente y significativa y negativamente, respectivamente, con la presencia y prominencia de servicios.* Neotoma *spp. También se asociaron negativamente con la presencia de caballos. Los mapaches (*Procyon lotor*) y coyotes (*Canis latrans*) se asociaron significativa y negativamente y significativa y positivamente, respectivamente, con el volumen y permanencia de plantas.* Puma concolor *y* Urocyon cinereoargenteus *se asociaron negativamente con la presencia de caminos. Los correcaminos (*Geococcyx californianus*) se asociaron positivemente con basura. Las únicas especies que no tuvieron correlaciones significativas con alguna variable ambiental fueron* Lepus californicus *y* Odocoileus hemionus*. Se observaron huellas de* Lynx rufus *más frecuentemente que de* Urocyon cinereoargenteus *y* L. rufus *se correlacionó significativamente solo con la disponibilidad de agua, lo que contrastac con los resultados de otros estudios. Nuestros resultados parecen indicar que el mantenimiento de los fragmentos de hábitat en áreas urbanas tiene beneficios de conservación para algunas especies de animales, no obstante la actividad y perturbación humana, siempre y cuando los fragmentos sean grandes.*

Palabras Clave: espacio urbano abierto, fragmentación de hábitat, huellas de animales, movimiento animal, perturbación humana, remanentes de hábitat, urbanización

Introduction

Habitat loss and fragmentation are the most serious threats to biodiversity worldwide (Dobson et al. 1997; Wilcove et al. 1998; Czech et al. 2000). Habitat loss and fragmentation due to urban development may have the most serious consequences to wildlife because it results in permanent and unmanaged changes to the environment that do not support biodiversity and for which there is little chance of restoration and recovery. Furthermore, habitat loss due to urbanization brings with it myriad other threats to remnant habitat fragments that exacerbate impacts on biodiversity (Saunders et al. 1991; McKinney 2002). In the United States urbanization is more widespread and endangers more species than any other human activity (Czech et al. 2000).

In response to urbanization, wildlife have adapted or moved to other habitat, their fitness has been reduced (Gill et al. 2001*a*; Frid & Dill 2002) or their movement restricted, and in some cases they have been extirpated (Woodroffe 2000). With the introduction of habitat conservation plans to offset incidental take of species listed under the Endangered Species Act (Harding et al. 2001; Rahn et al. 2006), remnant habitat patches are currently incorporated into multiple-species conservation plans in the United States. This is despite the fact that little attention is paid to the conservation value such remnants provide (e.g., Pressey et al. 1996; Scott et al. 2001; Mendel & Kirkpatrick 2002). To determine the likely success of conservation plans in urbanized areas, however, an understanding of the effects of ongoing direct and indirect human activities on wildlife in these areas is crucial. We used available data on animal tracks and survey data on human activity and habitat condition to investigate the effects of human disturbance on animal species' occurrences across a range of habitat fragments, home range sizes, behaviors, and life-history types. In particular, we asked whether species' occurrences are positively or negatively associated with different human activities and land-use intensities within habitat fragments in an urban matrix.

The effects of ongoing human disturbance to wildlife in habitat remnants is a major conservation concern (reviewed in Sutherland [1998] and Frid & Dill [2002]). Although human activity in a patch affects habitat condition (Stenhouse 2004), animal behavior and demographic rates can also be affected dramatically by human disturbance (Hockin et al. 1992; Frid & Dill 2002). Animals respond to human disturbance in the same way they respond to predation, by avoiding highly disturbed areas or underutilizing them (Sutherland & Crockford 1993; Gill et al. 1996; Beale & Monaghan 2004), but the strength of this response is different for different species (Gill et al. 2001*b* and references therein). Many wildlife species shift habitat under long-term, intense human activity at the risk of reduced access to resources (Frid & Dill 2002). Nevertheless, this will not occur if other habitats are unavailable or unsuitable.

Conversely, some wildlife species maintain population sizes (Weaver et al. 1996; Gill et al. 2001*b*) or become more prevalent in urbanized areas with high levels of human activity; nevertheless, the proportion of species affected negatively by urbanization is much higher than those that benefit from it (e.g., Grubb & Greenwald 1982; Bowers & Breland 1996; McKinney & Lockwood 1999). In addition to outcompeting other wildlife species for resources, species that are adapted to urban habitats can also directly interfere with other species (e.g., Kristan & Boarman 2003).

Given the myriad human activities that occur in urbanized areas, determining the characteristics and human activities associated with wildlife presence and behavior is critically important for effective conservation planning (Sutherland 1998). Habitat remnants in urbanized areas typically serve multiple purposes—they must conserve biodiversity and serve the recreation and urban open-space needs of human populations (Ruliffson et al. 2003). Nevertheless, these goals can conflict if human activity impinges negatively on wildlife. Hence, when considering habitat remnants in urbanized areas as conservation refuges, it is crucial to understand how human activities and land uses affect wildlife use of those remnants. This issue is particularly important because habitat remnants may serve as ecological traps. Ecological traps exist but are difficult to identify in the field and are primarily located in areas modified by human activity (Battin 2004). Despite this, ecological traps are often ignored in conservation planning, potentially resulting in overestimation of habitat quality and conservation value of a patch (Battin 2004). We investigated the impact of human activities and environmental factors on the occurrence and abundance of 10 animal species in 12 habitat fragments across a highly urbanized area in San Diego County, California. We determined the extent to which human activities and other indirect anthropogenic effects impinge on or promote wildlife use of this urbanized area.

Methods

Study Area

The San Diego metropolitan area is sandwiched between Los Angeles and California's border with Mexico. San Diego's population is almost 3 million and is expected to gain an additional 1 million new residents by 2030 (San Diego Association of Governments 2004). The rapidly expanding human population has led to a substantial loss of native coastal habitats. More than 85% of coastal sage scrub habitat has already been lost to urban and suburban development (Westman 1981; Hobbs & Mooney 1998). Habitat remnants within the San Diego metropolitan area are regarded as vitally important refuges for many species. San Diego County is also home to a multiple-species conservation plan that incorporates many remnant fragments in the urbanized area into a regional reserve system (County of San Diego 1998). We examined 12 habitat patches of various sizes and embedded within various land-use types across San Diego County (Fig. 1; Table 1). Most serve as urban open space and parklands for human use and as habitat patches for plant and animal species. The dominant vegetation types are coastal sage scrub and chaparral. All patches were within 60 miles of the coast.

Animal Tracks

The presence and abundance of animal species was determined based on an existing data set of occurrence of animal tracks and signs observed by volunteer trackers from the San Diego Tracking Team (SDTT). For over 10 years, the SDTT, a nonprofit organization, has conducted quarterly animal-track and sign (scat, claw marks, rub, den/bed site, fur, hair, feathers, predation evidence, prey cache, carcass, animal sighting) surveys for a range of

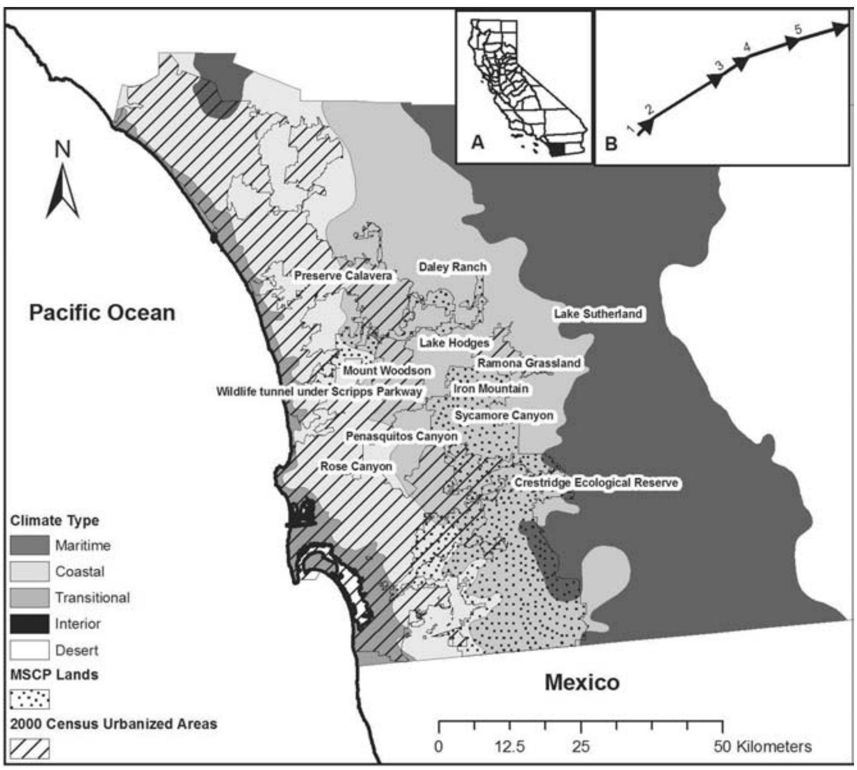

Figure 1. General locations and land context of the12 preserves in which the presence of the 10 animal species was determined through observations of animal sign, where sign refers to tracks for all species and den or bed sites for woodrats. The climate type, multiple-species conservation plan lands and the urbanized areas, as of the 2000 population census, are highlighted. (a) Location of San Diego County within California and (b) a schematic of a transect divided into sections of uneven length.

Table 1. Approximate estimates of area, perimeter, and perimeter-to-area ratio for each preserve used to examine the relationships among habitat fragment characteristics, human activity, and wildlife presence.[a]

Preserve	*Perimeter (m)*	*Area (ha)*	*Ratio (perimeter /area)*	*Main-land use within preserve[b]*	*Main-land use adjacent to preserve*
Preserve Calavera	33541	839	40.0	biking, hiking	urban development, agriculture
Daley Ranch	30072	2246	13.4	recreation, biking, hiking, equestrian	urban development, agriculture, wildlands
Lake Sutherland	174172	48789	3.6	fishing, hiking	wildlands, urban development, agriculture
Lake Hodges	76803	2965	25.9	biking, hiking	urban development, wildlands, agriculture
Ramona Grassland/ Vorhees Lane[c]	1896	14	132.4	hiking, biking, equestrian	ranching, wildland, residential development
Mount Woodson	28042	1979	14.2	hiking	urban development, wildlands
Wildlife Tunnel under Scripps Poway Parkway	29332	909	32.3	hiking, biking, equestrian	urban development, wildlands
Iron Mountain	47179	3798	12.4	hiking, biking	wildland, urban development
Penasquitos Canyon	53293	1388	38.4	hiking, biking, equestrian	urban development
Rose Canyon	11290	113	99.8	hiking, biking	urban development
Crestridge Ecological Reserve	55151	2199	25.1	hiking, biking, equestrian	urban development, agriculture, wildlands
Sycamore Canyon	37425	2973	12.6	hiking, biking, equestrian	urban development, wildlands

[a]Site area and perimeter values were calculated with ArcGIS for site boundaries on aerial imagery interpretation, transect extent and field user knowledge. Main-land use within and adjacent to preserves were based on expert opinion, satellite imagery, maps, and written accounts. Land uses adjacent to preserves were included if they constituted at least 20% of the land surrounding the site boundaries. Land-use layers were provided by the San Diego Association of Governments.
[b]All preserves are open-space preserves except for Wildlife Tunnel under Scripps Poway Parkway, which is an open-space corridor.
[c]A small patch embedded within sparsely residential land use (1 residence/4 ha) in the vicinity of Ramona. It does not refer to the larger Ramona grassland preserve owned by The Nature Conservancy.

animal species (Table 2). We limited analysis to species for which a reasonable amount of variation in presence occurred (e.g., if the species was nearly always present or absent, they were eliminated from further analysis); 10 species fit this criterion (Fig. 2).

The SDTT placed transects on dirt trails and roads within parks and reserves on the basis of ease of access and likelihood of observing the focal species. Transects varied in length and were subdivided into anywhere from 3 to 21 sections, which also varied in length from 6 to 1708 m. Observations were recorded for each section, and trackers discriminated, as much as possible, between animals of the same species within a section. Thus, for example, 20 tracks for mule deer observed within a section, all in a continuous line, were recorded as an observation of one individual mule deer. A group of volunteers completed each survey, led by an experienced transect leader. All observations were verified by the transect leader. Recorded data included species, sign type, sign age (only <2 weeks old signs were included in the analyses), tracking conditions, and number of observations per section. In this analysis we restricted attention to animal tracks for all species. Den or bed sites were also used for woodrats. (Scientific names of animals are provided in Table 2.) Henceforth, *sign* refers to tracks for all of the species considered and for track and den or bed sites for the woodrat.

Because sections within an individual park or reserve varied in length and were too close together for animal sign to be considered indicative of separate individuals with any degree of certainty, we analyzed data in spatial clusters at the level of each preserve (Sargeant et al. 1998, 2003; Fig. 1). Because there was more than one transect within a preserve, we verified that the dependence of sections within a transect was no greater than the dependence of sections across transects within a preserve. Because sections varied in length and section length did not correlate with number of signs or number of observed animals, data were translated into two metrics for each species: the average number of observations per section at a preserve (metric 1) and the proportion of sections at a preserve where the species was seen (metric 2). The first metric relates to abundance (and activity) of each species at a preserve, whereas the second metric captures species presence across preserves. A great deal of debate has centered on the best way to analyze track data for animals, mostly focusing on spatial autocorrelation and behavioral issues that prohibit an easily interpreted correlation between the abundance of animals and the number of tracks (e.g., Allen et al. 1996; Sargeant et al. 1998; Crooks 2002; Gese 2003). Hence, we used both metrics to determine whether results would differ between them. Data on human activity were collected only in 2004, and on the basis of species' occurrence trends over 10 years, 2004

Table 2. Influence of human activity and land use on animal observations as measured by Spearman rank correlation coefficients for environmental variables and animal sign for 10 species across 12 preserves.

Species	*Metric*[a]	*Land-use intensity*	*Horse use*	*Bicycle use*	*Litter*	*Presence/ prominence of utilities*	*Water availability*	*Road intensity*	*Plant cover (%)*	*Plant bulk/ permanence*
Bobcat	avg no.	0.01	-0.19	-0.04	-0.34	-0.04	0.5[c]	-0.34	0.25	-0.19
(*Lynx rufus*)	sections (%)	0.15	-0.23	-0.16	-0.16	0.03	0.63[b]	-0.16	0.38	-0.39
Black-tailed jackrabbit	avg no.	0.36	-0.14	-0.05	0.22	0.50	0.13	0.31	0.22	-0.13
(*Lepus californicus*)	sections (%)	0.36	-0.14	-0.05	0.22	0.50	0.13	0.31	0.22	-0.13
Coyote	avg no.	-0.15	-0.15	-0.26	-0.41	-0.36	-0.29	-0.34	-0.25	0.38
(*Canis latrans*)	sections (%)	-0.12	-0.35	-0.39	-0.28	-0.17	-0.50	-0.19	-0.28	0.63[b]
Cougar	avg no.	-0.07	-0.17	-0.72[b]	-0.37	-0.61[c]	0.02	-0.80[b]	0.05	-0.18
(*Puma concolor*)	sections (%)	0.08	-0.24	-0.72[b]	-0.43	-0.61[c]	-0.09	-0.78[b]	-0.06	-0.23
Gray fox	avg no.	0.09	0.05	-0.39	-0.37	-0.34	-0.05	-0.67[b]	0.23	-0.34
(*Urocyon cinereoargenteus*)	sections (%)	0.09	0.05	-0.38	-0.36	-0.31	-0.11	-0.65[b]	0.19	-0.32
Mule deer	avg no.	-0.23	0.36	0.01	0.02	0.27	-0.22	0.14	0.28	0.21
(*Odocoileus hemionus*)	sections (%)	-0.33	0.38	0.00	0.03	0.22	-0.24	0.07	0.29	0.25
Opossum	avg no.	0.68[b]	-0.51	-0.19	-0.23	0.47	-0.15	-0.05	0.01	-0.21
(*Didelphis virginiana*)	sections (%)	0.63[b]	-0.53	-0.18	-0.26	0.45	-0.16	-0.07	-0.02	-0.17
Raccoon	avg no.	0.29	-0.34	0.00	0.26	0.17	0.44	0.28	-0.01	-0.58[c]
(*Procyon lotor*)	sections (%)	0.24	-0.20	-0.15	0.19	-0.14	0.42	0.15	0.05	-0.68[b]
Roadrunner	avg no.	-0.23	0.47	0.33	0.57[c]	-0.15	0.20	0.33	-0.03	-0.40
(*Geococcyx californianus*)	sections (%)	-0.23	0.47	0.33	0.57[c]	-0.15	0.20	0.33	-0.03	-0.40
Woodrat	avg no.	0.25	-0.60[c]	0.09	0.31	0.76[b]	0.45	0.35	0.35	-0.01
(*Neotoma* spp.)	sections (%)	0.20	-0.60[c]	0.10	0.28	0.75[b]	0.40	0.33	0.29	0.05

[a] *Results are provided for two metrics: the average number of individuals per section within a preserve (avg no.) and the proportion of sections within a preserve with presence data for that species (sections [%]).*

[b] $p = 0.02$.

[c] $p = 0.05$.

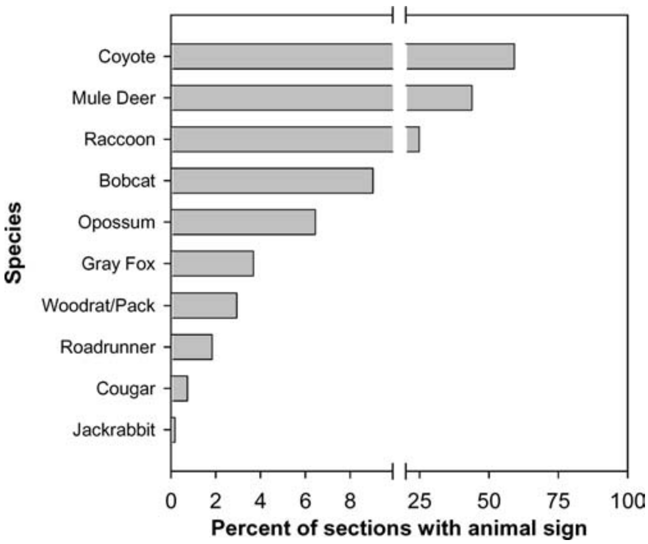

Figure 2. Relative abundance of study species across all sections in 2004 measured as the percentage of all sections across the 12 preserves in which a species' sign was recorded, where sign refers to tracks for all species and den or bed sites for woodrats.

appeared representative of other years (see Results). Thus, we only used animal sign data from 2004. In addition, to compensate for the seasonal differences in preserve use among species, data were summarized across all four seasons within the year 2004.

Human Activity

To determine the human activities and other environmental factors associated with wildlife use of preserves, we asked SDTT trackers to complete a survey on transect sections and their immediate vicinity. We focused on local habitat characteristics that could be assessed by someone in the preserve. Survey questions were intended to provide insight on the status and condition of habitat and were based on similar studies in the literature and agency questionnaires (Bowers & Breland 1996; Crooks 2002; Stenhouse 2004; Bloch et al. 2005). Five transect leaders completed a pilot survey for a representative nonrandom subsample (44 sections) across the study area, and definitions or questions were modified or clarified based on their feedback. This produced a set of questions or categories, with multiple choice options, on the condition of the habitat, the types of human activities and disturbances occurring there, the availability of water, and the extent of plant cover. These categories are henceforth referred to as environmental variables and include land-use intensity, horse use, bicycle use, litter, presence and prominence of utilities, water availability, road intensity, plant cover (%), and plant bulk and permanence.

Surveys were completed for each section within transects so that survey data would be at a spatial scale comparable to the data on animal sign. Surveys were then completed independently by the current transect leader and experienced volunteers across a larger sample of sections. Results for each pair of answers were compared (leader vs. volunteer), and answers that did not have a high degree of agreement between respondent pairs were eliminated from further analysis (either >80% agreement rate or a rate of agreement twice that of random chance). Most fulfilled both criteria. Environmental variables that did not show a reasonable degree of variation across preserves were eliminated from further analysis, resulting in the environmental variables and scoring scheme displayed in Table 3. The final data set included animal sign data (for the 10 species in Table 2) and environmental survey data (nine variables remained after the reliability screening, shown in Table 3) for 213 sections across the 12 preserves.

Multiple-choice (or subcategory) options in the survey were ranked on an increasing (or decreasing) relative scale across their human activity or environmental gradient (whichever was relevant for the particular question), and assigned a score between 0 and 1 (Table 3). Each section received a score for each environmental variable, and the scores for all sections within a preserve were averaged to provide a preserve score for each human-activity and environmental variable.

None of the human or environmental variables had a high degree of correlation with each other (indicating low covariation), which allows the correlation coefficient to be interpreted with less risk of confounding the ranked scores for the environmental variables. Spearman rank correlation coefficients were calculated for all pairs of environmental variable and species on the basis of the average number of observations per section at a preserve and the proportion of sections at a preserve where the species was seen. Three factors led to this choice of analysis: the environmental variables and the species observations were often not distributed normally, the correlations between the two were often not linear, and environmental variables were characterized as ranked scores.

Results

As might be expected, generalist species were more frequently recorded across preserves than specialists (Fig. 2). Coyotes occurred in more sections than any of the other nine species (~60% of sections). Mule deer occurred in the second-most number of sections (~50% of sections) and raccoons in the third most (~25% of sections). Black-tailed jackrabbits, cougars, and Roadrunners occurred in the fewest number of sections (<1%, 1%, and 2% of sections, respectively). Seven species occurred in <10% of sections each.

Table 3. Environmental variables, with subcategories and ranked scores, used in the human-activity survey and subsequent calculation of correlation coefficients.*

Environmental variable	*Ranked score*
Land-use intensity	
natural	0.1
park	0.2
rural residential	0.4
golf course	0.6
cleared or suburban residential	0.8
commercial or paved	1.0
Horse use	
no horse use	0.0
horse use	1.0
Bicycle use	
no bicycle use	0.0
bicycle use	1.0
Litter	
no litter	0.0
moderate litter	0.5
a lot of litter	1.0
Presence/prominence of utilities	
no evidence of utilities	0.0
utilities below ground	0.5
utilities above ground	1.0
Water availability	
no water	0.0
protected artificial water source	0.3
seasonal water	0.7
year-round water	1.0
Road intensity	
no roads	0.0
unpaved roads only	0.2
single-lane paved road	0.4
two-way paved road	0.6
multilane or multiple 2-lane paved road	0.8
highway(s)	1.0
Plant cover (%)	
<25	0.1
25–50	0.4
50–75	0.6
75–100	0.9
Plant bulk/permanence	
none (>30% dirt, cobble, pavement, etc.)	0.0
herbaceous (>30% grasses, annual plants)	0.3
mixed (≤30% dirt and ≤30% herbaceous)	0.5
scrub/shrub (woody plants, multiple stems/plant at ground level)	0.8
trees	1.0

**Each transect section in each preserve received a score from 0 to 1 for each environmental variable.*

Spearman rank correlation coefficients (*R*) were significant ($p = 0.02$ and $p = 0.05$) between several species and environmental variables (Table 2). For our sample size the Spearman rank correlation coefficient was significant at the 0.02 level when $R = 0.612$ and at the 0.05 level when $R = 0.592$ (Haslam & McGarty 1998). Opossum tracks were significantly and positively correlated with increasing intensity of land use. This was the only species that exhibited a significant relationship with intensity of land use. Cougars and gray foxes were significantly and negatively associated with increasing road intensity, and cougars were negatively associated with bicycle use. Woodrats were significantly and positively associated and cougars significantly and negatively associated with the presence and prominence of utilities. Woodrats were also negatively associated with the presence of horses. Raccoons were significantly and negatively and coyotes significantly and positively associated with plant bulk and permanence. Bobcats were the only species significantly correlated with water availability. Roadrunners were positively associated with litter. The only environmental variable for which there were no significant correlations for any species was percent plant cover. Only black-tailed jackrabbits and mule deer had no significant correlations with any of the environmental variables.

Correlations based on the average number of observations per species per section at a preserve and the proportion of sections at a preserve where the species' sign was observed generally produced very similar results for all environmental variables and species (Table 2). There was one exception to this: coyotes and plant bulk and permanence. The percentage of sections with coyote tracks was significant and the average number of coyote tracks per section was not significant.

Discussion

Our results yielded some new findings, confirmed established knowledge about species restricted to habitat fragments, and point to some recommendations for management and monitoring of urban open-space areas as conservation refuges. Although there were increases and decreases in species abundance over the years, the only species that decreased overall was the mule deer, but even this species increased slightly at the end of the time period considered. The fairly stable nature of the abundance trends indicates that these species have already responded to the impacts of habitat loss and fragmentation and that the data we used in this analysis were within the normal range, at least in terms of the number of sections with species occurrences.

Perhaps our most interesting result is the lack of significant correlations of species presence or abundance with percent plant cover for all species and with different land-use intensities for all species except the opossum, which was more often than not found in areas with intensive development (Table 2). We had insufficient evidence to reject the null hypothesis that all species are equally associated with all land-use intensities (except for the opossum) and levels of plant cover. There are a number of reasons this result might have occurred.

First, even though our data set was relatively large, the sample size may have been too small to detect significant differences across all the environmental variables and species. Second, the types of land uses and human activities we considered may be inappropriate for this set of species; nevertheless, based on the literature we think this is unlikely (Bowers & Breland 1996; Stenhouse 2004; Bloch et al. 2005). Third, the trackers' ability to distinguish between land-use intensities and plant cover may not have accurately captured on-the-ground differences, and perceptions of land-use intensities may have been inconsistent across trackers and preserves. Although this is possible, rigorous measures were taken in the construction of the questionnaire and in the multitracker verification procedures to minimize these sources of error. Fourth, the species may genuinely be equally associated with all land-use intensities and levels of plant cover within preserves. If this is the case, then it would appear that species occurring in remnant fragments within urban landscapes are forced to utilize all components of fragments, irrespective of their land-use intensity and land cover. This may occur if animals have nowhere else to go (Frid & Dill 2002). This explanation is supported by Donnelly and Marzluff (2004), who found that total relative abundance of birds was greater in urban and suburban reserves than in exurban reserves. They concluded that density increased because native birds were packed into habitat patches when habitat was rare on the landscape.

Although our results do not allow us to conclude with confidence that species are equally associated with all land-use intensities and levels of plant cover within preserves, they do offer important informed hypotheses for future research and may offer some initial hope for the ability of urban preserves to support native animal populations. Nevertheless, our results need to be considered in light of the species-prevalence results (Fig. 2). Some species were found more commonly in fragments in urban and suburban areas, whereas others rarely occurred in these areas. The rarity of some species will make it difficult to reach solid conclusions about the importance of urban habitat fragments for their persistence.

Mule deer showed no significant relationships with local environmental variables. Coyotes showed a significant relationship with one environmental variable in only one of the metrics used. Because these species were present in many preserves, this supports the notion that mule deer and coyotes are fairly adaptable to urbanization because they occur across a high proportion of sections and they appear not to discriminate among levels of disturbance and human activity, at least in terms of their movement. Mule deer are currently covered under the multiple-species conservation plan, primarily as a focal species to gauge the level of connectivity of the reserve system, and hence status and trend monitoring for this species is mandated. Our results indicate that tracking data are unlikely to be useful in monitoring mule deer for determining the utility of corridors within the reserve system for other species, particularly habitat specialists.

Crooks (2002) suggests that bobcats are a good indicator species and a good gauge of habitat connectivity in southern California. Nevertheless, bobcat tracks correlated positively and significantly only with water availability. This may be due to the fact that bobcats have a large home range relative to the size of most of the preserves in our study. Because we focused on local environmental variables rather than landscape environmental variables, further study at the landscape level may reveal different patterns for species with large home ranges. The fact that cougars were negatively associated with the presence of roads (as were gray foxes) corroborates the work of Dickson et al. (2005), who showed that cougars tend to avoid two-lane roads. It also supports recommendations for the "maintenance and restoration of corridors between large wildlands" to facilitate movement across the landscape (Dickson et al. 2005).

Our results for gray foxes and bobcats contrast with a previous study. Riley (2006) showed that foxes reach their highest densities in areas near and including urbanization, whereas bobcats never enter developed areas (although there were reports of bobcats in edge areas). Conversely, in our study bobcats were seen more often than gray foxes, and bobcats were not significantly associated with disturbance variables, whereas gray foxes were negatively associated with roads. We believe that space, diet, and competition are the most plausible explanations for the differences in results in these two studies. In Riley's study the preserve was 30,000 ha, at least an order of magnitude larger than all but one of the preserves we considered. This may indicate that if preserves are large enough, bobcats can avoid developed areas, but in smaller preserves greater proportions of the area are utilized. Riley also concluded that depauperate habitat quality for bobcat prey in the study area was partly responsible for decreased occurrence of bobcats in developed areas. And finally, coyotes, which can cause significant mortality of gray foxes in southern California (Fedriani et al. 2000; Farias et al. 2005), were absent during Riley's study but were the most commonly observed species in our study (Fig. 2).

At face value the lack of significant relationships between animal occurrence and abundance and environmental and human-disturbance variables contrasts with important previous studies conducted on the effects of urbanization on bird and rodent species in coastal sage scrub and chaparral habitats (Soulé et al. 1992; Bolger et al. 1997; Crooks et al. 2001; Crooks 2002). In these studies fragments supported fewer species. Notably, Bolger et al. (1997) found that all native rodents had disappeared from approximately half of the fragments they studied. Our study differs from these in one major way: the preserves we considered were much larger ($\sim$14 to 48,000 ha) than the canyons considered in the other studies (~0.4 to 84 ha). This appears to support the conclusions in these studies that larger reserves are better; nevertheless, until a comparative study that considers preserve area is conducted this remains an informed hypothesis for the species and system we studied.

A comparison of our results and those of similar studies indicates that sweeping conclusions about the effects of urbanization and human activity on wildlife need to be made with caution and are likely to be species specific. Although our results showed that only woodrats were negatively associated with horse use and only cougars were negatively associated with bicycle use, Blair and Launer (1997) found that preserve use by hikers and joggers leads to losses in butterfly diversity. This is not surprising given the sensitivity of butterflies to individual plant species compared with the species in our study. Although butterfly species are promoted as indicators of environmental change they may not be as effective in systems that have a long history of disturbance.

Blair (1996, 1999), Blair and Launer (1997), Germaine et al. (1998), and Donnelly and Marzluff (2004) found that avian species richness peaks at moderately disturbed sites, with most researchers citing the intermediate-disturbance hypothesis as the underlying mechanism (Connell 1978; McDonnell et al. 1993). It is possible that the intermediate-disturbance hypothesis underlies our results. Most of the species we observed could be considered urban adapted (except perhaps for cougars and bobcats). Hence, moderate disturbance may not negatively impinge on their movements and behavior in large fragments and may actually provide them with additional usable habitat while still maintaining sufficient habitat for species that adapt poorly to urbanization. Nevertheless, the level of disturbance that promotes the maximal species richness in this community is currently unknown.

We wish to express some additional caution in interpreting our nonsignificant results. We could not determine from our analyses whether some of the preserves served as ecological traps (Battin 2004). Even though the percentage of sections with observations did not change over 10 years (shown for five species in Fig. 3), there may have been local extinction–colonization events in some preserves that could not be observed with the type of data and analyses we used. The long-term population dynamics of species within preserves warrants further investigation.

It is important that multiple-species approaches to conserving biodiversity in urban and suburban areas take into account the impacts of different types of human activity and land use on wildlife so that the remaining habitat remnants can be evaluated and managed appropriately (Clevenger & Waltho 2000). Barrows et al. (2005) suggest that a hybrid approach of ongoing monitoring of environmental factors and species occurrence is required to understand the drivers of species occurrence and the trade-offs associated with managing multiple species. When considered in the light of previous research, our results indicate that maintenance of habitat fragments in urban areas is of conservation benefit to some animal species despite human activity and disturbance; nevertheless, it is crucial that conservation efforts focus on large reserves and avoidance of further fragmentation.

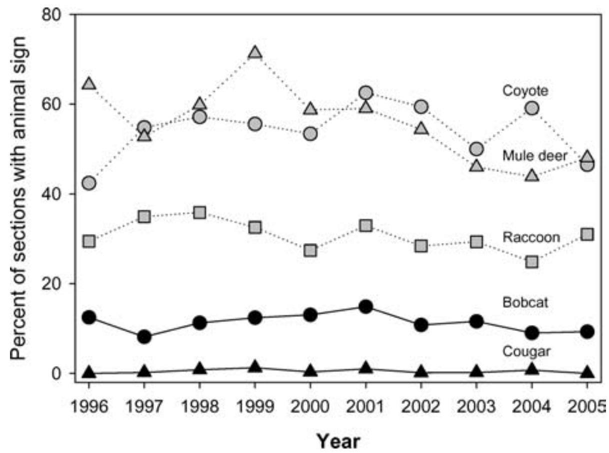

Figure 3. Trends in species observations across the 12 preserves through time as determined by the percentage of all sections with species sign recorded. Data only shown for five species and "sign" refers to tracks for these species.

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