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An Initial Carnivore Survey of Griffith Park, Los Angeles, California

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Abstract.—We established 42 carnivore detection stations in Griffith Park, Los Angeles, CA, in June 2007 to gather baseline information about wildlife species in the park. We documented the widespread presence of coyotes (*Canis latrans*), striped skunks (*Mephitis mephitis*), and raccoons (*Procyon lotor*), and the localized presence of bobcats (*Lynx rufus*), gray foxes (*Urocyon cinereoargenteus*), and Virginia opossums (*Didelphis virginiana*). Carnivore diversity and detection rates were greatest at the park's borders and along wooded canyons. Our data suggest a possible avoidance of areas heavily used by hikers and dogs, despite the presence of suitable habitat. This represents Griffith Park's first formal mammal survey.

Introduction

Griffith Park, at 1,700 ha the nation's largest municipally-owned park, is a natural oasis for both human and wildlife populations of Los Angeles. Despite being surrounded by urban development, Griffith Park has remained in large part a natural environment. The park lies within the California Floristic Province, a biome considered one of 34 biodiversity hotspots for conservation worldwide due to its high levels of diversity, endemism, and the degree to which it is threatened (Myers et al. 2000). Griffith Park itself has become increasingly isolated from other nearby open areas and their extensive wildlife habitat due to development. Two major roadways (US 101 and Interstate 405) separate the park from the rest of the Santa Monica Mountains and its large areas of protected and undeveloped land, which include the Santa Monica Mountains National Recreation Area (the eastern-most arm of which extends to ~3 km west of the park) and several state parks. Griffith Park is also separated from the Verdugo (~5 km to the north) and San Gabriel Mountains (~10 km to the northeast) by continuous residential and commercial development. In spite of its location within this highly urbanized landscape, there are frequent wildlife sightings and reports from the park that indicate permanent habitation within the park by at least some large mammal species. However, to date, no formal studies of wildlife presence and/or distribution have been conducted, inhibiting proper management of the park's natural resources.

Carnivores are good indicators of the park's overall ecological health as their survival is contingent upon diverse and reliable food sources. Given their low densities and large home ranges, they may also be considered "umbrella" species, as management and conservation efforts targeted at carnivores also encompass many other species (Fleish-

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man et al. 2001). We focused on mid-sized carnivores, or mesocarnivores, for this study. These species have a much more generalized ecology than their larger counterparts and are less likely to be extirpated from areas of high human density and fragmentation (Parks & Harcourt 2002, Crooks 2002).

This study presents the first survey of Griffith Park's mammals. We established 42 tracking stations at seven sampling areas June 2007 and quantified detection frequency, species richness and species diversity of seven target species. We also gathered preliminary data on the effects of habitat type and human disturbance in limiting carnivore distribution in the park. The target species included all of the large and mid-sized carnivores that have been reported in the park, including mountain lions (*Puma concolor*), coyotes (*Canis latrans*), bobcats (*Lynx rufus*), gray foxes (*Urocyon cinereoargenteus*), raccoons (*Procyon lotor*), and striped skunks (*Mephitis mephitis*). The Virginia opossum (*Didelphis virginiana*) is also included as a target species because its generalist ecology is similar to that of mesocarnivores, and it can be detected by the same methods employed to detect carnivores in this study (e.g. Boydston 2004). In addition to the target species, other mammalian carnivores possibly present in the park [e.g., long-tailed weasels (*Mustela frenata*)] would also likely be detected by these methods.

Methods

Study area

Griffith Park is located entirely within the city of Los Angeles. It is situated on the eastern end of the Santa Monica Mountains, and elevations within the park range from just over 100 m along the Los Angeles River to more than 500 m above sea level along the highest ridges. An ecologically similar area of undeveloped, privately-owned land abuts the northwestern portion of the park, and Forest Lawn Cemetery adjoins the park's northern border. The rest of the park is separated from other nearby open areas by dense urban development. The average housing unit density to the west towards open space in the Santa Monica Mountains is nearly 1000 houses per square mile, and the density north, east and south of the park exceed 3000 houses per square mile (U.S. Census 2000). Though Griffith Park contains several golf courses and museums, an observatory, a zoo, and numerous picnic areas and playing fields, its rugged interior has remained largely undeveloped aside for a network of trails and fire roads. The natural landscape consists of native vegetation types (mixed chaparral, mixed scrub, oak-sycamore riparian, oak woodland and walnut woodland) and areas of introduced or altered vegetation (including pine and eucalyptus plantations), the latter particularly in the eastern portion of the park (Meléndrez 2004) (Fig. 1). A wildfire in May 2007 burned approximately 20% of the park at its southeastern corner.

Detection stations

We assembled and monitored 42 carnivore detection stations from June 6–24, 2007. These detection stations were placed along sampling lines, which consisted of 3–10 stations set at least 150 meters apart along existing access roads and hiking trails. These sampling lines were set up in seven areas of the park representing a cross-section of the habitat types found in the park. Sampling lines included both burned and unburned sites (Fig. 1).

In each sampling line we alternated between tracking stations and experimental hair snares. Tracking stations consisted of powdered gypsum spread smoothly in a 1.5 m diameter circle that had been cleared of vegetation. Several drops of a commercial

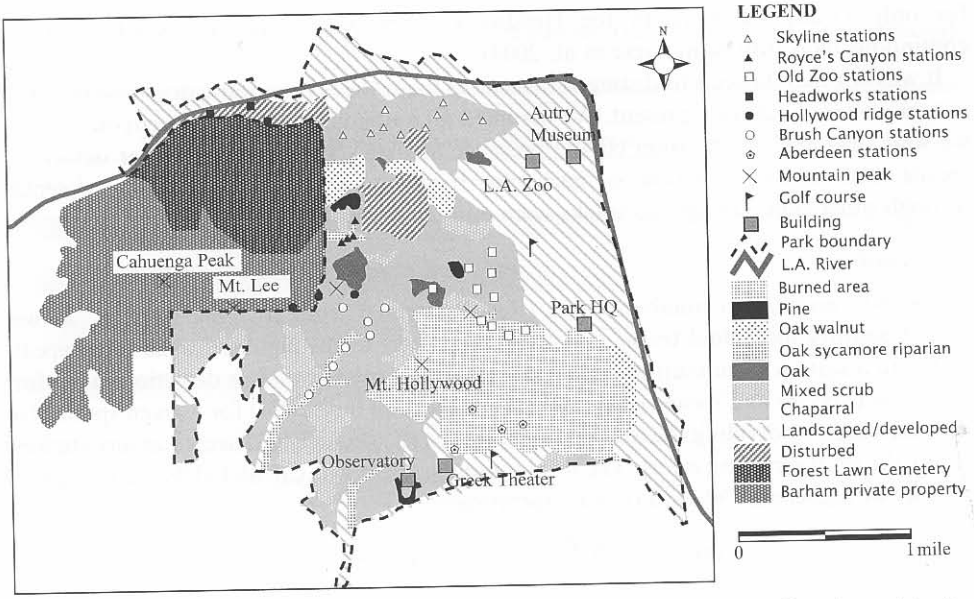

Fig. 1. Vegetation types in Griffith Park, Los Angeles, CA., with locations of carnivore detection stations. Vegetation types were based on Melendrez (2004) and drawn from digital orthoquadrant images without a formal ground-truthing effort. All boundaries should be considered approximate.

trapping lure (Gusto, Minnesota Trapline Products, Pennock, MN) were placed in the center of the circle to entice animals to enter the station and leave tracks. This lure has proven effective in attracting numerous carnivore species (e.g., Long et al. 2007). Reflective aluminum takeout containers and carpet squares scented with trapping lure were hung with fishing line nearby to further attract target species (following McDaniel et al. 2000).

Hair snare station design followed Harrison (2006) and consisted of a 10 cm by 10 cm square of commercial carpeting with 12 10 mm-long staples driven through the back. The carpet squares were scented with approximately 15 ml of trapping lure with several drops of imitation catnip oil and sprinkled with crushed dried catnip and placed approximately 40 cm off the ground. A 0.8 m radius semicircle of ground at the base of the snares was cleared and tracking substrate was spread. The hair snares were employed as an experimental test method for use in future studies that would require individual animal identification through genetic markers found in hair samples. All species identifications from hair snare stations for this study were made from tracks found at the base of the snares.

All animal sign present in the immediate vicinity of each station was noted during assembly to ensure that subsequent detections during the study were new. Stations were checked each day for the first four days, and every other day for the following eight days (Schauster et al. 2002, Gese et al. 2004, Manley et al. 2005). All identifiable tracks were measured, noted, and photographed, and new scat and other animal sign in the vicinity of the stations were recorded. After each examination, the tracking substrate was smoothed, and additional substrate and lure were added as necessary. Heavy machinery work and access restrictions prohibited us from visiting stations at one site (Aberdeen) on the second day of monitoring; those stations were monitored for an additional day. The sampling line along Hollywood Ridge was set up one day late, and was thus monitored for only 11 days; stations in the Headworks area were only monitored for four continuous days (following Gese et al. 2004).

It was at times difficult to distinguish between the tracks of domestic dogs and coyotes in areas where both were present. We assumed all ambiguous tracks were coyote only if we were also able to ascertain coyote presence at that station through other detection means such as scat, urination, or hair rubs. If we could not confirm coyote presence through other sign, ambiguous tracks were omitted from the dataset.

Data analysis

Absolute population numbers cannot be ascertained from tracking stations, as we cannot identify individual tracks and there is no way to distinguish tracks of a repeat visitor to a station from multiple visitors. Instead, we used a relative detection index for each target species as a means of analysis. The detection index (DI) for a given species (i) was calculated by dividing the total number of times a species was detected at any station (d_i) by the total sampling effort. The total sampling effort was calculated by summing the number of nights each station (j) was operating:

$$DI_i = d_i \Big/ \sum \left(\text{station}_j \times \text{days operated}\right)$$

The detection index ranged from 0 (species not found at any station) to 1 (species found at every station every night), and can be used to compare the ease with which different species are detected; from this, relative abundance can be inferred (Crooks 2002). Similar calculations can be made when grouping stations by sampling area to compare relative abundance in different areas of the park.

In order to quantify target species biodiversity more completely than simply looking at species richness, we used the Shannon diversity index. This index takes into account the relative abundance of species within a sample, as well as how evenly species are distributed within that sample. It is not affected by sample size, allowing comparison across unequally sampled areas. The Shannon diversity index (H) is calculated by taking the proportion of a given species (i) out of all species present and multiplying it by the natural log of this proportion. This is done for all species in the sample, and the products are summed and multiplied by −1. Greater H values indicate a higher level of species diversity:

$$H = -\sum (p_i \times \ln(p_i))$$

A species evenness value, which measures how evenly study species are distributed in a given area, can then be calculated. The Shannon index (H) is divided by the log of the total number of species in the sample (S):

$$E_H = H/\log(S)$$

Evenness (E_H) approaches 0 as a sample becomes dominated by a single species and approaches 1 as a sample has similar proportions of all species.

Results

The 42 detection stations were monitored for a total survey effort of 491 nights. We detected six of seven target species; only mountain lion presence could not be confirmed. Coyotes were the most easily detected and widespread species, its tracks accounting for nearly 80% of all carnivore tracks detected (Table 1). Coyotes had the highest detection

Table 1. Number of mammal species detections at all stations. The shaded rows indicate stations with hair snares.

Station	Coyote	Fox	Bobcat	Raccoon	Skunk	Opossum	Deer[1]	Rabbit[1]	Domestic Dog[2]
Skyline 1	7	—	—	1	1	—	—	1	X
2	1	—	1	1	—	1	—	—	X
3	8	—	—	1	—	—	—	—	X
4	—	—	—	—	—	—	1	—	—
5	5	—	—	—	—	—	—	—	—
6	8	—	—	—	—	1	—	—	X
7	6	—	—	—	—	—	—	—	—
8	3	—	—	1	1	—	1	—	—
9	1	—	—	—	—	—	—	—	—
10	6	—	—	1	2	—	3	1	X
Brush 1	—	—	—	—	—	—	—	—	—
2	4	—	—	—	—	—	—	—	X
3	5	—	—	—	—	—	—	—	X
4	8	—	—	—	—	—	—	2	—
5	4	—	—	—	—	—	—	1	—
6	3	—	—	—	—	—	—	—	X
7	7	—	—	—	—	—	—	—	X
8	7	—	—	1	1	—	1	2	—
Royce 1	4	—	1	1	—	—	—	—	—
2	4	—	—	2	—	—	1	—	—
3	3	—	2	—	—	—	1	—	—
4	—	—	—	—	—	—	2	—	—
Old Zoo 1	7	—	—	—	2	—	1	1	—
2	1	—	—	—	—	—	2	—	—
3	3	—	1	—	1	—	1	2	—
4	4	1	1	1	2	—	—	—	—
5	7	—	—	—	2	—	3	3	—
6	8	1	1	—	2	—	—	1	—
7	5	—	—	1	—	—	—	—	—
8	4	—	—	2	1	—	2	—	—
9	8	2	—	1	—	—	2	—	X
10	2	—	—	—	1	—	—	—	—
Aberdeen 1	5	—	—	—	—	—	4	—	X
2	4	—	—	1	—	—	—	—	—
3	5	—	—	—	—	—	—	2	X
4	5	—	—	—	—	—	—	—	X
Hollywood 1	6	—	—	—	—	—	3	1	X
2	2	—	—	—	—	—	1	—	—
3	5	—	1	—	—	—	—	—	X
Headworks 1	1	—	—	—	1	—	—	1	X
2	1	—	—	3	—	—	—	3	—
3	1	—	—	—	—	—	1	1	—
Total	**178**	**4**	**8**	**18**	**17**	**2**	**30**	**22**	**N/A**

[1] *Odocoileus hemionus* and *Sylvilagus* spp.; nontarget wildlife species. These are likely coincidental detections and are not used in analyses.

[2] *Canis familiaris* tracks detected at scent stations. Only presence/absence recorded; an "X" indicates presence. Data not used in analyses.

Table 2. Detection indices for mammalian carnivore species in different sample areas.

	Coyote	Fox	Bobcat	Raccoon	Skunk	Opossum
Skyline	0.375	—	0.008	0.042	0.033	0.017
Brush	0.396	—	—	0.010	0.010	—
Royce	0.229	—	0.063	0.063	—	—
Old Zoo	0.377	0.031	0.023	0.038	0.085	—
Aberdeen	0.365	—	—	0.019	—	—
Hollywood	0.394	—	0.030	—	—	—
Headworks	0.250	—	—	0.250	0.083	—
Total	**0.363**	**0.008**	**0.016**	**0.037**	**0.035**	**0.004**

index of all target species; its presence was identified in all seven sample areas and at all but three detection stations.

Raccoons were detected at six of the seven sample areas, and both striped skunks and bobcats were found in four of the seven areas each, with skunks detected at nearly twice as many stations as bobcats and at a much higher detection index (Table 2). Opossums and gray foxes had the lowest detection index of the target species; both were only detected in a single area each (Table 2).

A maximum of five carnivore species was detected at two survey areas (Skyline and Old Zoo); the Aberdeen area exhibited the lowest species richness with only two target species detected (Table 3). When carnivore diversity was calculated using the Shannon diversity index, Old Zoo also had the highest diversity level (Table 3). While Royce Canyon and Brush Canyon had the same species richness (n=3), Royce Canyon had a much higher diversity index; only one station in Brush Canyon detected any carnivore species other than the coyote (Tables 1 and 3).

Because of the recent fire, only certain trails in the park were open to the general public at the time of the study. Three sample areas, Skyline, Brush Canyon, and Hollywood Ridge, coincided with areas of high human usage. We grouped stations by (subjective) levels of human use, and present detection rates for each target species in each group. While the same number of carnivore species were detected in both groups, stations in areas of high human use recorded a significantly lower level of carnivore diversity (Mann-Whitney U test, $U=119$, $p=0.047$), about half that of areas where humans were excluded (Table 3).

Table 3. Carnivore richness, diversity, and evenness in different sample areas in Griffith Park, Los Angeles, CA.

Area (#stations)	Species Richness	Shannon Index (H)	Evenness (E_H)
Skyline (10)	5	0.78	0.16
Brush (8)	3	0.23	0.05
Royce (4)	3	0.89	0.18
Old Zoo (10)	5	1.03	0.21
Aberdeen (4)	2	0.20	0.04
Hollywood (3)	2	0.26	0.05
Headworks (3)	3	1.00	0.20
Total (42)	**6**	**0.82**	**0.14**
High Human Use (21)	5	0.57	0.11
Low Human Use (21)	5	0.98	0.20
Ridgetops (14)	4	0.42	0.10
Lower Altitude (28)	6	0.97	0.16

The distribution of vegetation types in Griffith Park was found to coincide with elevation, with wooded habitats (e.g., oak-sycamore riparian, oak woodland) typically found below 300 m (particularly along canyon bottoms), and scrub and chaparral habitats above 300 m, including along the higher ridges. Because several habitat types were sampled at a very small number of stations, we divided the stations into two groups by elevation for a preliminary habitat analysis. Low-elevation stations recorded significantly higher levels of species diversity (Mann-Whitney U test, $U=99$, $p=0.026$; Table 3), and the coyote was the only carnivore species detected on more than one occasion at high-elevation stations.

To assess potential effects of the recent wildfire, one may compare results from the one sample area located entirely within the burn zone (Aberdeen) with the others. Three stations in the Old Zoo sample area were also set in a burned area, but were adjacent to unburned habitat (Fig. 1). Aberdeen had the lowest carnivore detection rate, carnivore species richness, and species diversity of all areas sampled. With the exception of a single raccoon, all carnivore detections at Aberdeen were of coyotes. The Old Zoo stations set at the edge of the burned area had much higher detection rates, species richness, and diversity than the Aberdeen stations (Tables 1 and 3).

Discussion

Coyotes

Coyotes appear to be the most abundant and widespread carnivore in the park, found in all sample areas at similar detection rates. Previous studies have demonstrated that coyote home range size is quite elastic and highly variable depending on food abundance and degree of surrounding development (Gehrt 2004). A study of coyote home range size in and around the Santa Monica Mountains National Recreation Area immediately west of Griffith Park found that home range size varied between 125 ha to 324 ha (Tigas et al. 2002). Given home ranges of similar size, the park could support around ten pairs of coyotes, assuming overlapping territories of the males and females of a pair. It is also likely that additional coyotes residing in the surrounding urban areas regularly visit the park, augmenting park numbers. Feeding of coyotes by park visitors and nearby residents is a frequently encountered problem (G. Randall, City of Los Angeles, pers. comm.).

Bobcats

Bobcats were found in four areas within the park; two of these areas see high levels of human use (Hollywood Ridge and Skyline), but the area that had by far the highest detection index—Royce Canyon (tracks noted on four separate occasions)—sees low levels of human activity. Previous bobcat studies in southern California have found both spatial and temporal displacement of bobcats in response to high levels of human activity (Tigas et al. 2002, George and Crooks 2006). Tigas et al. (*Ibid*) reports mean home range sizes of 149.8 and 125.2 ha for male and female bobcats, respectively, in unfragmented southern California habitat, and reported that home range size did not increase with fragmentation. This suggests that Griffith Park is large enough to support as many bobcat pairs as coyote pairs; however, the distribution of this species may be limited by human disturbance, particularly along canyon bottoms popular with hikers (e.g., Brush Canyon).

Raccoons and striped skunks

We found that raccoons and striped skunks had similar detection indices in the park; both were found at approximately one-third of all detection stations (Table 1), particularly at low-elevation areas and within canyons. It is unclear why skunks were not as widespread as raccoons and absent from seemingly high-quality habitat areas such as Royce Canyon. It is unlikely that raccoons are outcompeting skunk in the park; Gehrt (2004) describes differential foraging habits that allow skunks and raccoons to coexist with minimal competition despite the two species being omnivorous and similarly sized. Human activity—in particular deliberate feeding by park visitors (G. Randall, City of Los Angeles, pers. comm.)—may influence the distribution of skunks in Griffith Park, keeping them close to developed areas at the park's border.

A recent study of mammal home range size in San Francisco's Presidio, another urban park, reported a mean home range size of both raccoon and skunk to be 21–25 ha, with a significant amount of overlap between individual home ranges (Boydston 2004). These home range sizes are much smaller than those reported in non-urban studies (e.g., Fritzell 1978, Gehrt 2004), but may be representative of home range sizes of raccoon in Griffith Park, especially given the likelihood of anthropogenic food sources reducing resource competition and need for larger ranges. The data reported by Boydston (2004) suggest that Griffith Park may support dozens of both raccoon and skunk pairs, with numbers likely augmented by animals moving back and forth between the park and the surrounding residential area.

Gray foxes

Gray foxes in Griffith Park appear to be localized, with all detections during this study from the center of the park along the interface between picnic areas and the interior (Old Zoo area). This region of the park, which includes Spring Canyon, supports ample native tree cover and a diversity of habitat types (including oak woodland, sycamore woodland, sumac scrub) as well as permanent water. A study in areas of the Golden Gate National Recreation Area adjacent to cities reported home range sizes of 100.3 ha and 85 ha for female and male gray foxes, respectively (Riley 2006). This suggests that Griffith Park has the potential to support at least as many fox pairs as coyote pairs. However, like bobcats, foxes may be limited by habitat type, human activity, and competition with coyote. Foxes are much less often seen in urban areas than coyotes and, based on track evidence and anecdotal reports from park rangers, appear to be genuinely scarce here.

Opossums

Surprisingly, opossums, frequently observed in urban Los Angeles, had the lowest detection index of any target species in Griffith Park (Table 3). Raccoons have been reported to outcompete opossums (Ladine 1997, Ginger et al. 2003), which could explain the low detection of the species. It is also likely that the opossum has become so urban-adapted in this area that it prefers developed areas to the park due to ease of foraging, as suggested by Boydston (2004) for San Francisco's Presidio. This preference has also been reported for some urban-adapted bird species (Cooper 2002).

Habitat preference

Certain vegetation types, particularly woodland habitats along streams and residential gardens, may be preferred by carnivores to the arid scrub and chaparral of the park; this could explain the higher carnivore diversity found in the low elevation stations. Additionally, proximity to water sources may be especially important for species with small home ranges, especially during periods of seasonal water shortage. This study was conducted at a time of record drought, with only three inches of rainfall between July

2006 and July 2007 (Becerra & Blankstein 2007). Skunks and raccoons were rarely detected at higher elevations; their ranges are relatively small and they may have been limited by access to water sources. Wildlife may have been attracted to food and water sources found in adjacent residential areas and golf courses found on the edges of the park or to the horse troughs and natural springs found at lower elevations.

Low elevation stations may also provide more cover and shade to large mammals than ridges, providing relief from the heat. The increased cover in these areas may be attractive to prey species (e.g., rodents) seeking protection, which in turn would draw predators. Further studies, particularly during the wet season, should be conducted to determine what, if any, seasonal movement shifts are found in the park's wildlife.

Human disturbance

Human disturbance in Griffith Park's interior comes in a variety forms, including hikers, joggers, dog-walkers, and horseback riders, as well as loiterers and transients who set up small encampments in the park's canyons and near parking lots. Numerous studies have documented the impact of human recreation on wildlife (e.g., Whittaker & Knight 1998, Taylor & Knight 2003, George & Crooks 2006). Mammalian carnivores are particularly susceptible to human disturbance because of their low densities and large home ranges, and studies have found that carnivores shift distribution and change behavior in response to human recreation (e.g., White et al. 1999, Ray et al. 2005). A southern California study reported that bobcats and coyotes showed no displacement from equestrian use, but both were affected by hikers with dogs (George & Crooks 2006).

The effect of companion dogs—particularly unleashed dogs—on wildlife is well-documented (reviewed by Lenth et al. 2006). Dogs are reported to disturb wildlife through barking, chasing, scent marking, and disease transmission through defecation. They have also been implicated in disrupting wildlife behavior and habitat use, as well as causing reduced reproductive success for some wildlife (e.g., Yalden & Yalden 1990, Mainini et al. 1993, Miller et al. 2001). While a leash law does exist (L.A.M.C. 53.02), it appears to be rarely obeyed. A casual count by the authors while checking the detection stations in Brush Canyon and Hollywood Ridge on three visits of three hours each totaled 37 dogs off-leash and 18 dogs on-leash.

Brush Canyon, which appeared to be the study area most heavily used by visitors during the study (pers. obs.), exhibited the lowest species diversity, aside from the completely burned Aberdeen sample area. These results are surprising, given that the other oak-sycamore woodland areas of the park (Royce Canyon, Old Zoo) had high carnivore detection rates. Results from our study suggest that current levels of human activity may be limiting the distribution of at least some carnivores within the park. The low carnivore diversity in the Brush Canyon area in particular may reflect an avoidance by large and mid-sized carnivores of an area heavily used by humans. The Skyline trail also has regular hikers and horseback riders, but casual observation during this study indicated that while both areas had comparable equestrian use, Brush Canyon receives many more hikers than Skyline, especially hikers with dogs. This suggests that it may be the presence of hikers accompanied by dogs that is most disruptive to wildlife.

Finally, it should be stressed that this study was conducted only once and over a short period of time. It represents only a snapshot in time within the park, providing baseline information on the presence and distribution of mammalian carnivore species and their habitat needs throughout Griffith Park. Lack of detection by this study does not necessarily mean that other carnivores are not present in the park. Similar studies of wildlife presence and distribution should be conducted several times a year to obtain a more complete understanding of wildlife distribution and account for any possible seasonal movement and dispersal by wildlife. Furthermore, Griffith Park provides a unique opportunity for outdoor recreation within Los Angeles and is thus an invaluable resource for local residents. With this in mind, we recommend that studies on human usage in different areas of the park also be conducted. With a better understanding of the location and distribution of high levels of human recreation, as well as what type of recreation is occurring, we can better study, understand, and mitigate the effects of human activity in the park on resident wildlife.

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