EXPLORATORY USE OF TRACK AND CAMERA SURVEYS OF MAMMALIAN CARNIVORES IN THE PELONCILLO AND CHIRICAHUA MOUNTAINS OF SOUTHEASTERN ARIZONA

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ABSTRACT—We explored use of non-invasive track and camera surveys to provide baseline information on distribution, activity, and habitat associations of mammalian carnivores within the Chiricahua and Peloncillo mountains of southeastern Arizona. In total, track and camera stations recorded 241 and 149 detections, respectively, of carnivores and other vertebrates in both mountain ranges. In order of frequency of detections, we recorded gray foxes (112 track and camera detections), white-nosed coatis (33), large skunks (25), ringtails (13), domestic dogs (13), coyotes (9), cougars (7), bobcats (3), and western spotted skunks (2) in both the Chiricahua and Peloncillo mountains, and one American black bear was photographed in the Chiricahua mountains. Other vertebrates detected included cattle (12), deer (10), and a variety of small rodents (83), birds (33), lizards (22), and lagomorphs (12). The combination of track and camera data were effective at detecting a variety of species in a range of habitat types, and emphasized the importance of deciduous riparian habitat for carnivores as well as other vertebrates.

RESUMEN—Exploramos el uso de registro de huellas y foto-trampeo como técnicas no invasivas para proveer información básica sobre la distribución, actividad, y asociaciones de hábitat de mamíferos carnívoros en las montañas Chiricahua y Peloncillo del sureste de Arizona. En total, en las estaciones de huellas y de cámaras, se obtuvieron 241 y 149 registros de carnívoros y otros vertebrados, respectivamente, en las dos sierras. Con respecto al orden de frecuencia de detección, registramos 112 zorros grises entre huellas y fotos, coatíes (33), zorrillos grandes (25), cacomixtles (13), perros domésticos (13), coyotes (9), pumas (7), gatos monteses (3), y zorrillos manchados (2) en las montañas Chiricahua y Peloncillo, y un oso negro fue fotografiado en las montañas Chiricahua. Otros vertebrados detectados incluyeron ganado (12), venados (10), y varias especies de roedores (83), aves (33), lagartijas (22) y lagomorfos (12). La combinación de datos de huellas y de fotografías fue efectiva en detectar una variedad de especies en distintos tipos de hábitat, y enfatizó la importancia del hábitat ripario caducifolio tanto para los carnívoros como para otros vertebrados.

Mammalian carnivores are difficult to study because of their low densities, nocturnality, and wariness toward humans, and as such, basic information on their distribution and abundance often is poorly known (Crooks, 2002). Non-invasive techniques such as track stations (Linhart and Knowlton, 1975; Conner et al., 1983; Sargent et al., 1998; Crooks, 2002) and remote cameras (Cutler and Swann, 1999; Carbone et al., 2001) can be useful tools to survey carnivores and other wildlife. Herein, we explored the use of track and camera surveys to provide baseline information on distribution, activity, and habitat associations of mammalian carnivores within the Chiricahua and Peloncillo mountains of southeastern Arizona.

In southeastern Arizona, elevational relief, diverse underlying geology, proximity to the Chihuahuan Desert, and a history of climatic change over geological time have produced a complex and diverse mosaic of distinct biotic communities, including a diversity of mammalian carnivores. The Chiricahua and Peloncillo mountains also form part of the Madrean ''sky

islands,'' isolated ranges that extend disjointed north from their center in the Sierra Madre of Mexico, and might thus be in a position to receive immigrants of Neotropical felids from established populations to the south. As described in detail by Brown (1994), the Chiricahua and Peloncillo mountains support primarily interior chaparral and Madrean evergreen woodlands, surrounded by a matrix of semidesert grassland and Chihuahuan desertscrub. Madrean montane coniferous forests dominate above ca. 2,300 m elevation, and long, sinuous tongues of deciduous riparian forest exist wherever drainages provide predictable subsurface flow during winter and spring. Although semidesert grasslands supported primarily perennial grasses and sparse scrub at the time of European contact, heavy grazing and fire suppression have allowed widespread invasion by shrubby species, creating a short-statured chaparral. The ecological diversity of the Chiricahua and Peloncillo mountains made this an excellent system within which to evaluate use of non-invasive techniques to survey a diverse guild of mammalian carnivores and their prey.

Track-survey transects were established within a variety of habitat types across the Chiricahua and Peloncillo mountains, including oak-pine forest, Madrean evergreen forest, deciduous riparian forest, chaparral, Madrean evergreen woodland-semidesert grassland boundary, and chaparral-semidesert grassland boundary. We focused track surveys within the southern one-half of the Chiricahua Mountains as well as the western side of the Peloncillo Mountains. We established one track-survey transect in each of six canyons in the study areas; Red Rock, Cottonwood, Tex, and Price canyons in the Chiricahua Mountains, and the main and South Fork of Skeleton Canyon in the Peloncillo Mountains. Transects followed the major drainage of each canyon surveyed and stations were set near the primary streambed and in animal trails wherever possible. All streams near transects were dry during our surveys, although some supported bands of riparian vegetation. Each transect in the Chiricahua Mountains contained at least one remnant pool of water or artificial water source. No obvious water sources were located in the main or South Fork of Skeleton Canyon.

Each track transect was comprised of 10 tracking stations set 400 m apart. Following Linhart and Knowlton (1975) and Crooks (2002), each track station consisted of a circle of sifted gypsum powder ca. 1 cm deep and 1 m in diameter, set on firm substrate cleared of dust and debris. A flat rock daubed with two scent lures (Russ Carman's Pro's Choice and Canine Call, New Milford, Pennsylvania) was placed in the middle of each station and rebaited every other day. We intended to attract felids if present, and due to the visual orientation of felids, we supplemented some track stations with one of a variety of visual lures, including hanging feathers, dead birds, or small balls of white cheesecloth. Preliminary analyses for gray foxes and skunks, for which we had adequate samples, did not reveal any effect of visual lures on rate of visitation; therefore, we pooled our data across type of lures for subsequent analyses. Nevertheless, use of different lures and attractants may have influenced visitation rates among species, survey stations, and habitats, potentially limiting comparison of rates of visitation among these groups.

Each track station was checked daily for 5 consecutive days during 1 March–21 May 1999 (5 of 7 days in the case of Cottonwood Canyon, where rain precluded use of gypsum powder for 2 days). Identification of native carnivores, domestic dogs (*Canis familiaris*), and other wildlife was based on Murie (1954), Halfpenny (1986), and Rezendes (1992). Among carnivores, striped (*Mephitis mephitis*), hooded (*M. macroura*), and hognose (*Conepatus mesoleucus*) skunks could not be distinguished by tracks alone; track data from these three species were pooled as large skunks for analysis. We also pooled track data within each of the following groups: mule (*Odocoileus hemionus*) and white-tailed (*O. virginianus*) deer, rodents, lagomorphs, lizards, and birds. For each transect, the track index was expressed as total number of visits recorded for each taxon divided by total sampling effort (i.e., track nights = number of stations times number of nights set; Linhart and Knowlton, 1975; Crooks, 2002). Note that our track surveys yielded information on presence, but not necessarily absence, in an area, particularly given relatively low sample effort. Further, because individual animals were not identified, track surveys provide a relative measure of activity in an area, but do not allow for estimation of population sizes (Wilson et al., 1996; Sargeant et al., 1998; Crooks, 2002).

Remotely triggered cameras (CamTrakker, Watkinsville, Georgia) also were posted at 18 different stations for a total of 150 camera days (mean/station = 8.9 days; *SD* = 3.11). Survey sites included Red Rock Canyon, Coal Pit Tank Trail, Price and Brushy canyons, South Fork of Cave Creek, and Horseshoe Pass in the Chiricahua Mountains, and Skeleton Canyon in the Peloncillo Mountains. We chose these sites on the basis of available water (South Fork of Cave Creek, springs at Price and Red Rock canyons), presence of riparian vegetation (South Fork of Cave Creek and Skeleton Canyon), or presence of thick cover (Coal Pit Tank Trail, Brushy Canyon, Horseshoe Pass). Habitats surveyed by cameras included Madrean evergreen woodland, oak-pine forest, chaparral, Madrean evergreen woodland-chaparral boundary, and areas with a deciduous riparian forest component.

Cameras were stationed along probable routes traveled by carnivores, including riparian corridors, intersections of well-used animal trails, animal trails to water or through thick, brushy habitat, and mountain passes between major drainages. Whenever possible, we set cameras where movement of animals would be restricted naturally by topography or vegetation. In most cases, scent lure was placed on a rock 2–3 m in front of the camera. As with track stations, visual lures, including strips of white plastic, feathers, or balls of white cheesecloth, often were hung near the camera to attract felids. Cameras were triggered each time a passive, infrared sensor detected both heat and motion, although a timer rendered the camera inactive for 3 min following each picture to avoid multiple exposures of a single animal. Cameras were equipped with an automatic focus and flash, were active both day and night, and included a digital reading of date and time on each picture. Indices were calculated as number of times a species was photographed divided by number of 24-h days a camera was stationed at that location. Days during which a camera was set but had run out of film were not included in calculations of sampling effort. Camera surveys, like track surveys, yielded information on presence and activity, and use of different lures and attractants likely influenced rates of visitation among species, stations, and habitats.

Our track surveys recorded ≥8 species of carnivores (in decreasing order by number of stations visited); gray fox (*Urocyon cinereoargenteus*), large skunk (striped, hooded, and hog-nose), domestic dog, coyote (*Canis latrans*), ringtail (*Bassariscus astutus*), white-nosed coati (*Nasua nasua*), cougar (*Puma concolor*), and western spotted skunk (*Spilogale gracilis*; Table 1). Deciduous riparian forest, represented by 26 tracking stations within three different transects (Tex Canyon, Skeleton Canyon, South Fork of Skeleton Canyon), yielded seven species of mammalian carnivores (cougar, coyote, gray fox, large skunk, western spotted skunk, white-nosed coati, ringtail). The cougar, coyote, and western spotted skunk were represented only in deciduous riparian forest. Madrean evergreen woodland, represented by 26 tracking stations within four different transects (Cottonwood, Red Rock Canyon, Tex Canyon, Price Canyon), yielded four species of carnivores (gray fox, large skunk, ringtail, white-nosed coati). Deer were only represented in Madrean evergreen woodland. Other mammals detected on track stations included mule deer, white-tailed deer, or both, domestic cattle (*Bos taurus*), desert (*Sylvilagus audubonii*) and eastern (*S. floridanus*) cottontail, black-tailed jackrabbits (*Lepus californicus*), squirrels (*Spermophilus* and *Sciurus*), cliff chipmunks (*Tamias dorsalis*), mice (*Perognathus*, *Reithrodontomys*, *Peromyscus*), kangaroo rats (*Dipodomys*), and shrews (*Sorex*, *Notiosorex crawfordi*, or both). Lizards could not be identified to species, although one probable Gila monster (*Heloderma suspectum*) crossed a station in Tex Canyon. Avian species included owls (Strigidae), greater roadrunner (*Geococcyx californianus*), wild turkey (*Meleagris gallopavo*), and Gambel's quail (*Callipepla gambelii*). Passerines also landed on stations, but were not recorded due to difficulty in identifying species.

Mammalian carnivores detected by our remotely triggered cameras included, in decreasing order by number of pictures, gray foxes, white-nosed coatis, ringtails, cougars, large skunks (including both striped and hog-nosed skunks), bobcats, coyotes, and American black bears (*Ursus americanus*; Table 2). Gray foxes were recorded within every habitat type surveyed by cameras (Table 2). Cougars and white-nosed coatis were photographed within oak-pine forest and deciduous riparian forest, and bobcats and deer were photographed within Madrean evergreen woodland and deciduous riparian forest. Ringtails were photographed in chaparral, deciduous riparian forest, and oak-pine forest, and

TABLE 1—Summary of track station surveys, by species and transect location, conducted March–May 1999 within the Chiricahua and Peloncillo mountains. Track data are expressed as number of visits to transect divided by sampling effort (50 track nights/transect). Species richness of carnivores does not include domestic dog.

	Chiricahua Mountains			
Species	Cottonwood	Red Rock Canyon	Tex Canyon	Price Canyon
Gray fox	0.34	0.10	0.32	0.18
Large skunk		0.08		0.04
Domestic dog				0.06
Coyote			0.02	
Ringtail		0.02		
White-nosed coati	0.04			
Cougar				
Western spotted skunk				
Deer		0.02		
Cattle	0.12	0.06		
Lagomorph			0.04	
Rodent	0.02	0.04	0.08	0.08
Lizard			0.04	
Bird			0.06	0.04
Species richness of native carnivores	2	3	2	2

	Peloncillo Mountains			
Species	Skeleton Canyon	South Fork Skeleton Canyon	Number of transects detected	Total number of visits
Gray fox	0.20	0.20	6	67
Large skunk	0.22	0.08	4	21
Domestic dog		0.20	2	13
Coyote	0.02	0.12	3	8
Ringtail	0.08	0.04	3	7
White-nosed coati	0.02		2	3
Cougar	0.02	0.02	2	2
Western spotted skunk	0.04		1	2
Deer			1	1
Domestic cattle		0.04	3	11
Lagomorph	0.04	0.08	3	8
Rodent	0.26	0.38	6	43
Lizard		0.40	2	22
Bird	0.06	0.50	4	33
Species richness of native carnivores	7	5		

large skunks were recorded only in one station within riparian forest. The photographs of a coyote and an American black bear was recorded in Madrean evergreen woodland and deciduous riparian forest, respectively. Cameras also recorded photographs of deer (including both white-tailed and mule deer), domestic cattle, lagomorphs, and rodents (including *Tamias dorsalis*, *Spermophilus*, *Sciurus, Perognathus*, *Reithrodontomys*, *Peromyscus*).

Within several weeks of field surveys, the combination of non-invasive track and camera methods detected a diversity of mammalian carnivores, and their vertebrate prey, in a range of habitat types in the Chiricahua and Peloncillo mountains. In total, track and camera stations recorded 241 and 149 detections, respectively, of carnivores and other vertebrates in both mountain ranges. Although these species have been

TABLE 2—Summary of camera surveys, by species and camera station (numbered within each site), conducted March–May 1999 within the Chiricahua and Peloncillo mountains. Camera data are expressed as number of times a species was photographed divided by number of sampling days.

	Chiricahua Mountains														
	Red Rock Canyon			Coal Pit Tank Trail	Price Canyon				Brushy Canyon		South Fork Cave Creek				Horseshoe Pass
Camera station	1	2	3	1	1	2	3	4	1	2	1	2	3	4	1
Number of sampling days	5	6	6	5	9[a]	9	9	8	6	8	14	10	16	10	8
Habitat type[b]	OP/w	MEW	MEW	MEW	OP/w	OP	MEW/CH	CH	CH	MEW	MEW/w	MEW	R/w	R/w	MEW/CH
Species															
Gray fox	0.40	0.33		2.80		0.44	0.56	0.38	1.17	0.50					
White-nosed coati	4.00												0.31		
Ringtail						0.11		0.25					0.13		
Cougar						0.11									
Large skunk															
Bobcat				0.20											
Coyote				0.20											
American black bear													0.06		
Deer			0.33							0.13	0.07		0.31		
Domestic cattle		0.17													
Lagomorphs									0.17						0.13
Rodents	2.00	0.50						0.25	0.17	0.13	0.57		0.31	0.10	
Species richness of carnivores	2	1	0	3	0	3	1	2	1	1	0	0	3	0	0

TABLE 2—Continued.

	Peloncillo Mountains				
	Skeleton Canyon				
Camera station	1	2	3		
Number of sampling days	11	11	5[a]	Number of stations detected	Total number of pictures
Habitat type[b]	R	R	R		
Species					
Gray fox	0.18	0.18		10	45
White-nosed coati	0.45			3	30
Ringtail	0.09			4	6
Cougar	0.09	0.27		3	5
Large skunk	0.36			1	4
Bobcat		0.09	0.27	3	3
Coyote				1	1
American black bear				1	1
Deer				4	9
Domestic cattle				1	1
Lagomorphs		0.18		3	4
Rodents		0.82		9	40
Species richness of carnivores	5	3	1		

[a] Cameras malfunctioned; accurate indices are therefore unobtainable for these sites.

[b] OP (oak-pine forest); MEW (Madrean evergreen forest); CH (chaparral); R (deciduous riparian forest); w (water present at or near camera).

documented previously in this area (e.g., Findley et al., 1975; Hoffmeister, 1986), our survey yielded preliminary information on distribution, activity, and habitat associations for a variety of species that might serve as guidance or baseline data for future surveys in the region. Future surveys that incorporate non-invasive field techniques such as track and camera surveys with methods such as occupancy modeling (MacKenzie et al., 2006), identification of man-made (Mace et al., 1994; Jacobson et al., 1997) or natural (Karanth, 1995; Karanth and Nichols, 1998; Heilbrun et al., 2006) marks of photographed animals, or statistical analyses of spatial correlation of visits among stations (Kauffman et al., 2007), would improve estimates of probability of detection and thus presence-absence and population estimates. Although our field surveys did not yield evidence of Neotropical felids, this clearly does not eliminate the possibility that they occur within the Chiricahua or Peloncillo mountains or visit periodically, especially given the low density of these carnivores and our relatively limited sampling effort; indeed, verified sightings of jaguars have occurred recently within the region (Brown and Lopez-Gonzalez, 2000, 2001; Grigione et al., 2007). Finally, our frequent detections of carnivores and other species within deciduous riparian forest emphasize the important role of riparian areas as resident and travel habitat for a variety of wildlife including carnivores (Hilty and Merenlender, 2004), particularly in the arid Southwest, where riparian zones function as linear oases for many organisms (Johnson, 1989; 1998; Noss, 2006; A. Martinez and R. Valdez, in litt.).

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