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EVIDENCE OF RESIDENT JAGUARS (*PANTHERA ONCA*) IN THE SOUTHWESTERN UNITED STATES AND THE IMPLICATIONS FOR CONSERVATION

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Jaguars (*Panthera onca*) remain virtually unstudied in the desert environments at the northern extent of their range. Historic sightings from the United States indicate a declining population of resident jaguars from the late 1800s into the 1940s, after which only occasional jaguars were reported until the present. After 2 sightings of jaguars in 1996, we established a camera monitoring program in southeastern Arizona. From March 2001 to July 2007, we maintained 9–44 trail cameras and conducted opportunistic track surveys. We documented 2 adult males and a possible 3rd unidentified jaguar with 69 photographs and 28 sets of tracks. One jaguar, originally photographed in 1996, was resighted 64 times during 2004–2007. This ≥13-year-old male used habitats from the Sonoran lowland desert at 877 m above sea level to pine–oak woodlands at 1,577 m, and covered 1,359 km^2 in 2 mountain complexes. Despite speculation that recent sightings of jaguars in the United States represented dispersing transients on sporadic forays from Mexico, we documented jaguars in Arizona frequently, continuously, and year-round, and videotaped several scent-marking behaviors, indicating the residency of adult jaguars within Arizona. We outline the importance of maintaining cross-border connectivity for long-term survival of the wide-ranging and thinly distributed binational population of jaguars. We recommend further research and we stress the fragmentation consequences of the proposed United States–Mexico border fence to the northernmost jaguar population, and particularly to jaguars in the United States.

Key words: Arizona, habitat connectivity, jaguar, *Panthera onca*, trail cameras, United States–Mexico border

Jaguars (*Panthera onca*) are typically associated with the rain forests of Central and South America; however, the species historically ranged into the arid southwestern United States (Rabinowitz 1999; Sanderson et al. 2002; Seymour 1989). At risk throughout their range because of habitat loss and overhunting (Swank and Teer 1989), jaguars currently occupy only 46% of their former (pre-1900) range (Sanderson et al. 2002). A general shortage of information on the species in the American Southwest has led to the widely accepted assumption that jaguars observed in Arizona and New Mexico were not residents of the United States, but rather young, dispersing transients (Boydston and López González 2005; Rabinowitz 1999) on sporadic forays from Mexico (United States Fish and Wildlife Service 2006). The common assumption has been that the northernmost breeding population is concentrated at the junction of the Aros, Bavispe, and Yaqui rivers ~200 km south of the United States–Mexico border (López González and Brown 2002; Martínez-Mendoza 2000; Rosas-Rosas 2006), and dispersing offspring occasionally stray north of the border (Brown and López González 2001; United States Fish and Wildlife Service 2006; Hatten et al. 2005; O'Neill and Van Pelt 2004). However, evidence of this type of wandering dispersal has not been documented.

Conversely, the confirmed historical records of jaguars from Arizona and New Mexico suggest a declining population of resident jaguars until the mid-1900s (Fig. 1), with reproduction occurring until 1910 and females documented as late as 1963 (Brown 1983; Brown and López González 2001; Hatten et al. 2005; Hoffmeister 1986; Rabinowitz 1999). Of the 61 historic records of jaguars in the United States from 1880 to 1995, sex was determined for only 25. Of those, 7 (28%) were females, and 3 (43%) of those were with young when killed. Thus, 12% of all known jaguars in Arizona were females raising young, clearly representing a breeding population north of the border.

Three policy changes in the late 1960s and early 1970s led to a sudden decrease in reported records, giving the impression that jaguars had disappeared from the Southwest, even if some persisted in the region. Bounties on predators were removed in

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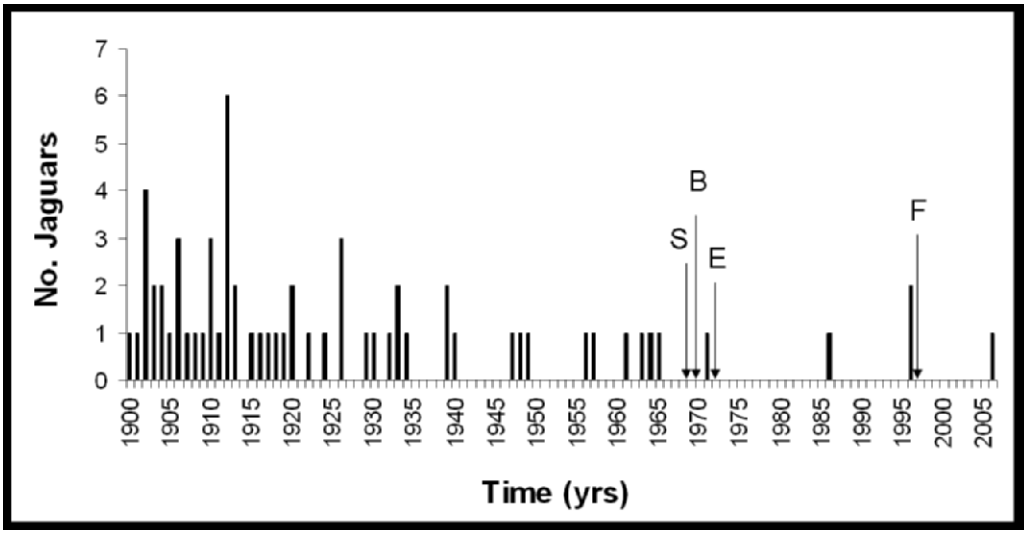

FIG. 1.—Records with confirmed physical evidence of jaguars (*Panthera onca*) from Arizona and New Mexico, 1900–2006 ($n = 64$). B = Predator bounty hunting discontinued. S = State protection in Arizona. E = Endangered Species Act established. F = Jaguar Federally Listed as an Endangered Species. Records are incidental sightings and do not include findings from this study. (Records courtesy of Arizona Game and Fish Department and Brown and López Gonzáles [2001].)

the late 1960s (Brown and López González 2001; Hansen 1994, 2006), and it became illegal to kill jaguars under Arizona State Commission Order 14 in 1969 (Johnson and Van Pelt 1997). Establishment of the Endangered Species Act in 1972 resulted in local fear of federal restrictions on private property and general animosity toward endangered or threatened species (Brook et al. 2003; Haines et al. 2006; Treves and Karanth 2003). Not only did direct persecution of jaguars decrease, but the probability of any jaguars being reported was greatly reduced. This resulted in the appearance that jaguars had been extirpated from the southwestern United States, and there was no way of truly knowing their actual status in the region after 1970. The United States Fish and Wildlife Service, apparently considering the species extirpated, overlooked the jaguar for protection in the United States under the Endangered Species Act of 1973 (Rabinowitz 1999). A jaguar was subsequently killed in the Dos Cabeza Mountains of Arizona in 1986 (Brown and López González 2001), indicating the potential for persistence of jaguars in the region.

On 7 March 1996, mountain lion hunting guide and rancher, Warner Glenn, photographed a live, wild jaguar in the Peloncillo Mountains of southeastern Arizona (Glenn 1996). Six months later, a different jaguar was photographed in the Baboquivari Mountains of south-central Arizona (Childs 1998). Based on body size and conformation, it was determined that the Peloncillo jaguar was an adult male ($\geq$3–5 years old), and the Baboquivari jaguar was a younger male between 2 and 3 years of age (O'Neill and Van Pelt 2004). In February 2006, W. Glenn photographed another male jaguar (different from the Peloncillo jaguar and the Baboquivari jaguar) in the Animas Mountains of southwestern New Mexico (W. Glenn, Malpai Borderlands Group, pers. comm.). Several photographs of the large (approximately 90 kg), snarling jaguar show rounded and yellow teeth, indicating the animal was an adult.

The 2 sightings in 1996 sparked interest in determining the current status of jaguars at the northern extent of their historic range, and reinforced the urgent need to identify and conserve jaguar habitat in the southwestern United States and northern Mexico (Johnson and Van Pelt 1997; O'Neill and Van Pelt 2004; Rabinowitz 1999). State and federal wildlife and land management agencies of the region formed the Arizona–New Mexico Jaguar Conservation Team (JAG Team) to protect and manage the jaguar in the Southwest (Johnson and Van Pelt 1997). The United States Fish and Wildlife Service formally listed the jaguar as an endangered species in 1997 (United States Fish and Wildlife Service 1997).

The conservation of populations at the periphery of a species range is now considered extremely important to the long-term survival of endangered species (Abbitt et al. 2000; Channell and Lomolino 2000; Nielsen et al. 2001); therefore, conservation of jaguars in the northernmost portion of their range (i.e., the borderlands population) deserves attention equal to or greater than that of core populations (Johnson et al. 2007). Furthermore, as global climate trends change toward hotter, drier environments (Karl et al. 1996; Walther et al. 2002), jaguars living in the borderlands may become even more important to the survival of the species. Effective conservation of jaguars will require maintaining sufficient core and connective habitats to avoid population fragmentation and thus reduce the probability of extinction (Quigley and Crawshaw 1992; Sanderson et al. 2002; Weber and Rabinowitz 1996). The Secure Fence Act of 2006 (Secure Fence Act 2006) mandated the United States Department of Homeland Security to physically separate Mexico from the southwestern United States with steel fences 3–4 m high across 1,280 km of the United States–Mexico border, including ~70% of the Arizona border (from Calexico, California, to Douglas, Arizona). Plans to complete the fence before 2009 have been expedited with no apparent regard to wildlife occupying the borderlands region (Segee and Neeley 2006). The border fence may effectively partition the already small, northernmost population of jaguars and isolate jaguars in the United States from the larger source population in northwestern Mexico (Brown 1983; Brown and López González 2001; Rabinowitz 1999; Spangle 2007).

The status, distribution, and basic ecology of jaguars living in the borderlands remain virtually unknown. The only existing data are from historical records of jaguars killed by hunters, trappers, and predator control agents over the past century (Brown 1983), which are considered valid only if accompanied by physical evidence (Tewes and Everett 1986). Several authors have used these records to develop maps of potential habitat for jaguars in the region (Boydston and López González 2005; Hatten et al. 2005; Menke and Hayes 2003). Records are scarce and difficult to verify, however, and this information is of unknown value for delineating the historic or current range and habitat use by jaguars in the region (Hatten et al. 2005; McCain et al. 2006; Sanderson et al. 2002).

Rabinowitz (1999) stressed the need to gather basic information on jaguars in the southwestern United States. In 2001, we initiated efforts to obtain data on jaguars in southern Arizona by implementing presence–absence surveys with trail cameras and track surveys in areas considered potentially suitable for the species (Brown and López González 2001; Hatten et al. 2005). The objectives of our study were to examine the current status and distribution of jaguars in southeastern Arizona, and to obtain baseline information on general habitat associations and travel corridors to guide meaningful conservation of the jaguar in the borderland region.

Materials and Methods

Study site.—The study area included mountain ranges in southern Arizona with potential jaguar habitat as identified by the JAG Team's Habitat Subcommittee and the Arizona Game and Fish Department, and in proximity to verified historic sighting locations (Brown and López González 2001; Hatten et al. 2005). The study extended from the crest of the Baboquivari Mountains east to the San Rafael Valley and approximately 80 km north of the international border, encompassing portions of Coronado National Forest, Buenos Aires National Wildlife Refuge, lands managed by the Bureau of Land Management and the state of Arizona, and several private ranches (Fig. 2). Exact locations and location names are withheld for the protection of the jaguars and their habitat, as requested by the Arizona Game and Fish Department and the JAG Team (T. Johnson, Arizona Game and Fish Department, pers. comm.; W. Van Pelt, Arizona Game and Fish Department, pers. comm.).

The borderlands region encompasses biotic communities of Madrean evergreen woodland and semidesert scrub grassland (Brown 1994). The oak woodland–oak grassland community is the dominant vegetation type between 1,100 m and 2,000 m. Below 1,100 m, mesquite–Sonoran desert scrub predominates (Brown 1994; Hatten et al. 2005; Toolin et al. 1979). The climate is semiarid with approximately 400 mm annual rainfall, half of which occurs between July and September (Hass 2002).

Trail camera surveys.—Based on population sampling techniques for tigers (*Panthera tigris*—Karanth 1995; Karanth and Nichols 1998; Karanth et al. 2004), we implemented a series of systematic surveys with automatic trail cameras arranged in grids. We placed at least 1 trail camera along the most probable travel route within each 5-km^2 grid and maintained >1 km between cameras (Karanth et al. 2004; Silver et al. 2004). We recorded only the 1st detection when >1 photograph was taken of the same animal at a given camera site within 60 min (Bridges et al. 2004).

We focused our surveys on major travel routes and natural funnels through core and connective habitats in the mountain ranges within our study area. Movement patterns and habitat use by jaguars were unknown in this region, but we assumed jaguars would use the landscape and travel routes similarly to pumas (*Puma concolor*), the other large felid in the area. Cameras were placed on likely travel routes along washes, trails, dirt roads, ridges, and canyon bottoms (Karanth et al. 2004; Silver et al. 2004), and in areas where wildlife travel was naturally directed by landscape features.

We employed an "adaptive cluster sampling" scheme, which builds on a simple or stratified sampling design by sampling all cells bordering those where presence had previously been recorded until the cluster is surrounded by cells that fail to detect presence (Karanth and Nichols 1998; Karanth et al. 2004). Where jaguars were photographed, we placed a 2nd camera on the opposite side of the trail to record the patterns of spots on both sides of the animals, following methodologies for unambiguous identification of individuals (Karanth et al. 2004; Silver et al. 2004; Wallace et al. 2003).

We used trail camera systems designed for continuous surveillance of medium to large mammals. We used 2 types of cameras: digital (Cuddeback Digital; Non Typical, Inc., Park Falls, Wisconsin) and film (CamTrakker; Camtrak South, Inc., Watkinsville, Georgia). All cameras were fully automatic and used passive infrared motion sensors that detect heat-in-motion. We attached camera units to trees, aimed approximately 0.3 m above the level of the trail or travel route. Cameras monitored activity 24 h per day with a 5-min delay between photographs to avoid multiple photographs of the same individual (Main and Richardson 2002). We serviced cameras approximately every 6 weeks to replace batteries and film or memory cards.

Activity patterns.—We examined daily activity patterns of jaguars using the time stamp on each photograph (Bridges et al. 2004; Pierce et al. 2000). We divided the 24-h day into eight 3-h time categories: 0131–0430 h = LateNight; 0431–0730 h = Dawn; 0731–1031 h = EarlyDay; 1031–1330 h = MidDay; 1331–1630 h = LateDay; 1631–1930 h = Dusk; 1931–2230 h = EarlyNight; and 2231–0130 h = MidNight.

Track surveys.—We conducted track surveys opportunistically, especially while traveling to service cameras. We searched for tracks in promising areas where substrates were favorable for track detection, such as along trails, dirt roads, sandy washes, canyon bottoms, and around ponds and water holes. Jaguar tracks were differentiated from those of pumas in the following ways: plantar pad is proportionally larger, wider, and more rounded without pronounced lobes at the base;

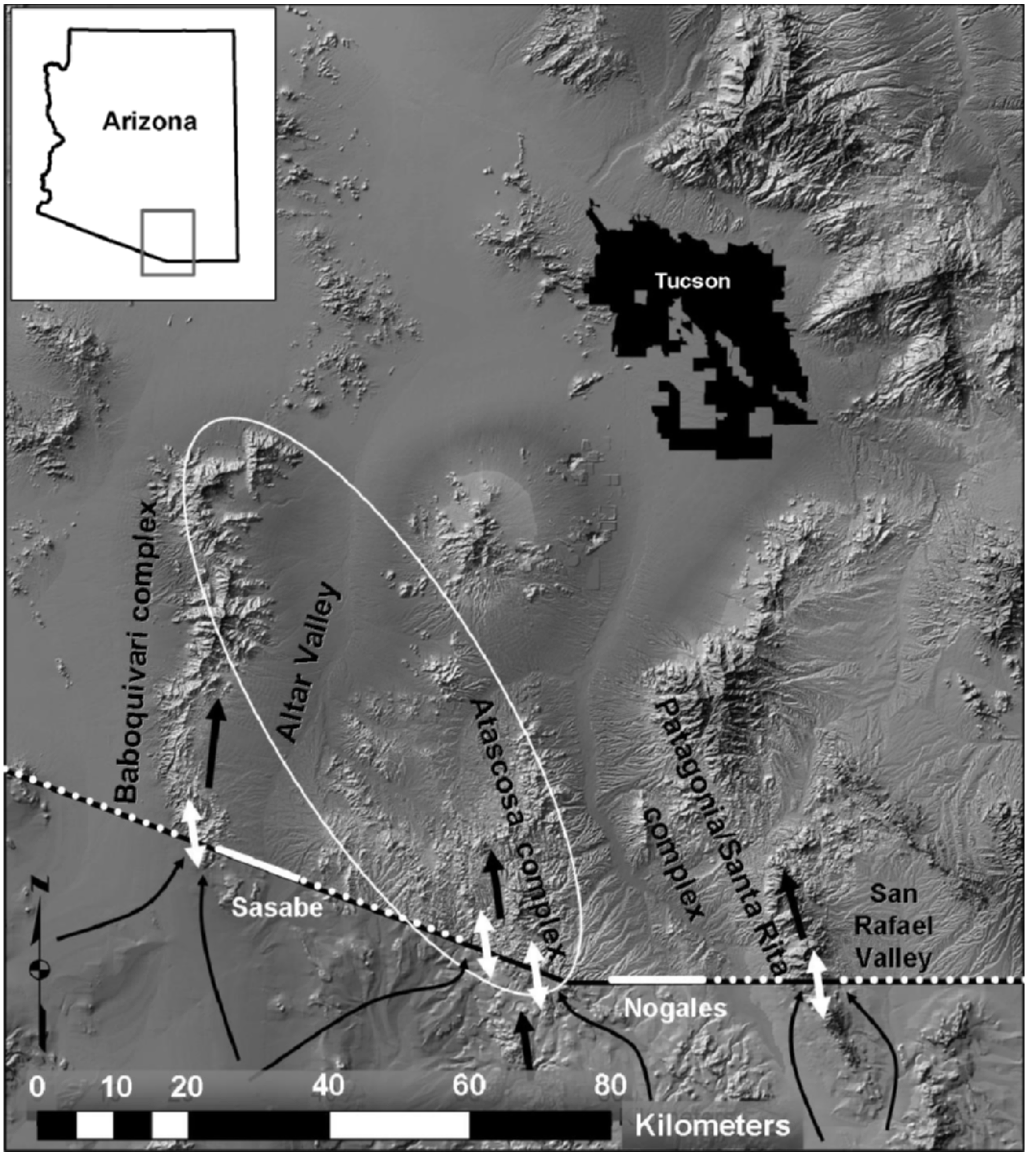

Fig. 2.—Topographic relief map of the study area, showing United States–Mexico border (solid black line), general observed minimum ''range'' of adult male jaguar Macho B from May 2006 to April 2007 (white oval), important cross-border corridors for jaguars and other wildlife (heavy white double-arrows), 4- to 5-m-tall steel pedestrian fences (existing or under construction; solid white lines), increased border security with vehicle barriers, chain-link fences, virtual fencing, surveillance towers, and agent patrols (white dashed lines), and funneled illegal immigrant and resulting law enforcement traffic (black arrows).

plantar pad extends forward to the base of the toes, giving the overall track a compact or filled-in appearance, with little negative space between the toes or between the plantar pad and toes; toes are proportionally larger and more rounded; and front feet exhibit broad straddle, whereas hind feet have narrower straddle and fall inside front feet on overstep (Aranda 2000; Childs 1998).

Mapping.—Locations of photographs and tracks were recorded on handheld global positioning system units and imported into ARC-GIS 9.0 (ESRI, Redlands, California) for mapping and analyses of areas of use based on minimum convex polygons.

Animal care and use guidelines.—All field methodologies were approved by Humboldt State University Institutional Animal Care and Use Committee (IACUC nos. 04/05.W.43.A and 06/07.W.133.E) and followed the guidelines approved by the American Society of Mammalogists (Gannon et al. 2007). All fieldwork was permitted by the United States Fish and Wildlife Service, Arizona Game and Fish Department, United States Department of Agriculture Forest Service, and Buenos Aires National Wildlife Refuge.

Results

We operated between 9 and 44 trail cameras in southeastern Arizona from March 2001 to July 2007 for a total of 30,260 camera ''trap'' nights (Table 1). We obtained 69 photographs of jaguars (including 5 video clips) and documented 28 sets of jaguar tracks and 1 calf (*Bos taurus*) killed by a jaguar (Fig. 3). We photographed 2 adult male jaguars, dubbed Macho A and Macho B, and a possible 3rd individual that we were unable to identify or determine as to sex. In 2001–2004 we obtained 3 right-side profile photographs of Macho A; however, we were unable to photograph the spot pattern on his left side. We photographed Macho B 65 times during 2004–2007, recording his spot patterns on both sides with multiple simultaneous images from paired cameras. Shortly before and after we last photographed Macho A, we obtained 2 photographs of the left profile of a jaguar. These pictures may have been from the left side of Macho A (not observed in previous photos) or of a different, unknown jaguar. The 2 jaguars photographed by Glenn (1996; W. Glenn, Malpai Borderlands Group, pers. comm.) were different from the individuals photographed in this study.

Photographs and detection rates of jaguars (jaguars/100 trap nights) increased over the course of the study as monitoring intensified (Table 1). Detections were temporally clumped, with several photographs or tracks or both occurring over several months, followed by periods with no detections (Fig. 3), suggesting that jaguars were moving outside the area we surveyed. Nevertheless, photographs and tracks of jaguars were detected during every month of the year, indicating that movements outside of the study area were not seasonal. Jaguars were almost exclusively nocturnal, with most photographs (86.6%) taken between Dusk (1631–1930 h) and LateNight (0131–0430 h; $\chi^2 = 39.63$, $d.f. = 7$, $P < 0.005$).

Based on body size and conformation, the JAG Team Scientific Advisory Group estimated ages of the 2 known jaguars. In 2001, Macho A was fully grown and estimated to be at least 3–5 years old (H. Quigley, Hornocker Wildlife Institute, pers. comm.), which meant he was 6–8 years old when photographed in September 2004. The pattern of spots on Macho B matched pelage features of the jaguar that was photographed in 1996 in the Baboquivari Mountains (Childs 1998). In 1996, this jaguar from the Baboquivari Mountains was fully grown and at least 2 years old, indicating that Macho B was 13–14 years old when photographed in July 2007 (Fig. 4).

Macho B was resighted 89 times between August 2004 and July 2007 including 60 photographs, 5 video segments, and 25 sets of tracks (which were attributed to Macho B based on track measurements [Childs 1998] and spatial and temporal association with photographic records). Also, in 2 of the 5 video segments Macho B exhibited territorial scent-marking behavior with backward urine-spraying, cheek-rubbing, and claw-raking.

Although our study design was insufficient to estimate true home-range or habitat selection, knowledge of the wide-ranging movements by Macho B through diverse habitat types is important for conservation of the species. The most continuous 12 months of detections for Macho B were between May 2006 and April 2007; 33 separate sightings were recorded for this jaguar. A minimum convex polygon assessment of these locations yielded an estimated area of use for Macho B to be 1,359 km^2 (Fig. 2). The most continuous sequence of locations occurred from 4 October to 5 October 2005, in which Macho B crossed the border into the United States and traversed a 20-km straight-line distance northward along the Atascosa Mountain complex in 25.5 h. Jaguars used areas from 1,577 m elevation in the Baboquivari and Atascosa mountain complexes to flat lowland desert floor of the Altar Valley at 877 m (Fig. 5). The average elevation for the 89 different locations where jaguars were detected during the study was 1,159 m.

Table 1.—The survey effort (measured by the number of trail cameras and working camera ''trap''-nights) increased over time, as did detections of jaguars (*Panthera onca*; photographs only), and detection rates (detections/100 trap-nights) from March 2001 to May 2007 for each year in southeastern Arizona.

Year	Camera sites	Camera trap-nights	Jaguar photographs	Jaguar detection rates (photos/100 ''trap'' nights)
2001	9	1,390	1	0.07
2002	14	2,842	0	0.00
2003	14	3,291	1	0.03
2004	42	5,739	13	0.23
2005	41	6,567	12	0.18
2006	44	7,587	27	0.36
2007	30	2,844	15	0.53
Total		30,260	69	0.23

Discussion

Our data on the presence–absence of jaguars provides valuable new information on the current status and distribution, basic habitat associations, travel patterns, longevity, and activity patterns of jaguars in the borderlands region. Although the types of data we generated likely underestimated actual animal movements (Soisalo and Cavalcanti 2006), the information does begin to describe core and connective habitats in the border region between the United States and Mexico. Examination of these data identifies high-priority areas for conservation of jaguars in the transborder region between these 2 countries (Fig. 2).

Of the 4 recent jaguars confirmed in the United States since 1996, none were dispersing or ''transient'' juveniles. Macho A and Macho B and the 2 different jaguars photographed by Glenn (in 1996 and 2006) near the Arizona–New Mexico border were all adult-aged animals well beyond the age of dispersal (15 months to 2 years—Nowak 2005; Seymour 1989; Sunquist and Sunquist 2002). Macho B was photographed north of the border over 11 total years, and he evidently resided in Arizona continuously and year-round from 2004 to 2007. These data clearly demonstrates the presence of resident, adult jaguars with at least some portion of their home ranges or territories within the continental United States.

Further evidence of residency within the United States was demonstrated in 2 video recordings of Macho B in which he scent-marked in the form of backward urine-spraying, cheek-rubbing, and claw-raking. Scent-marking in free-ranging felids serves as important chemical communication among conspecifics to display territoriality and to defend an established home range (Hornocker 1970; Rabinowitz 1986; Schaller 1967; Seidensticker et al. 1973; Smith et al. 1989).

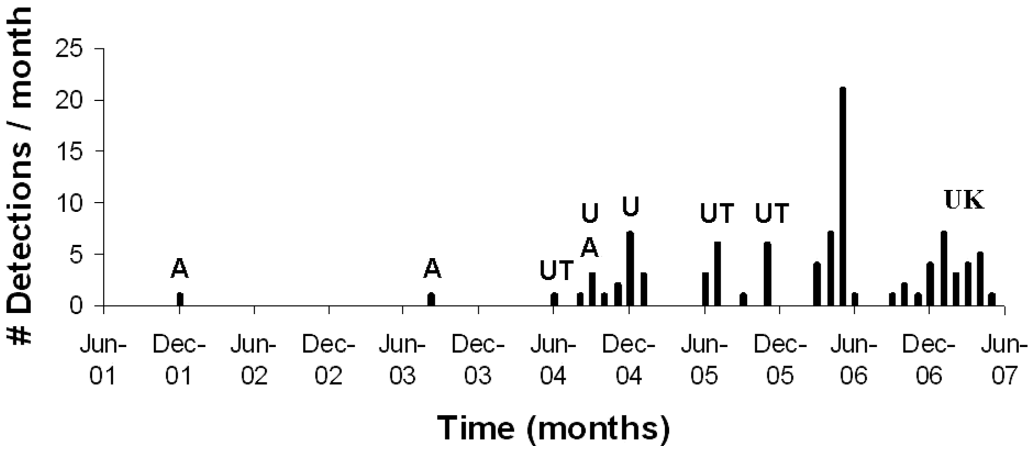

FIG. 3.—Detections of jaguars (*Panthera onca*; photographs, tracks, and kills) during each month from March 2001 to May 2007 in southeastern Arizona ($n = 97$). All of the detections are of Macho B ($n = 88$) except those identified by A (photographs of Macho A, $n = 3$), U (photographs of unidentified jaguar, $n = 2$), UT (tracks of unidentified jaguar, $n = 3$), and UK (kill by unidentified jaguar, $n = 1$).

Scent-marking behavior has not been well studied in jaguars (Rabinowitz 1986); however, knowledge of this behavior in other felids (Hornocker 1970; Schaller 1967; Seidensticker et al. 1973; Smith et al. 1989) suggests that Macho B was a territorial resident attempting to communicate with 1 or more jaguars in the area. Studies of this behavior in tigers in Nepal, for example, demonstrated that transient individuals did not begin to scent-mark until after they had established a territory (Smith et al. 1989). Also, both male and female tigers scent-marked, a behavior that increased for both sexes when females were in estrus (Smith et al. 1989).

Movements and habitat associations.—The arid environment in of the borderlands region of Arizona and Sonora, Mexico, contains resources and environmental conditions that are more variable than those in tropical habitats (Hass 2002). Because of this, we would expect jaguars to have larger home ranges and

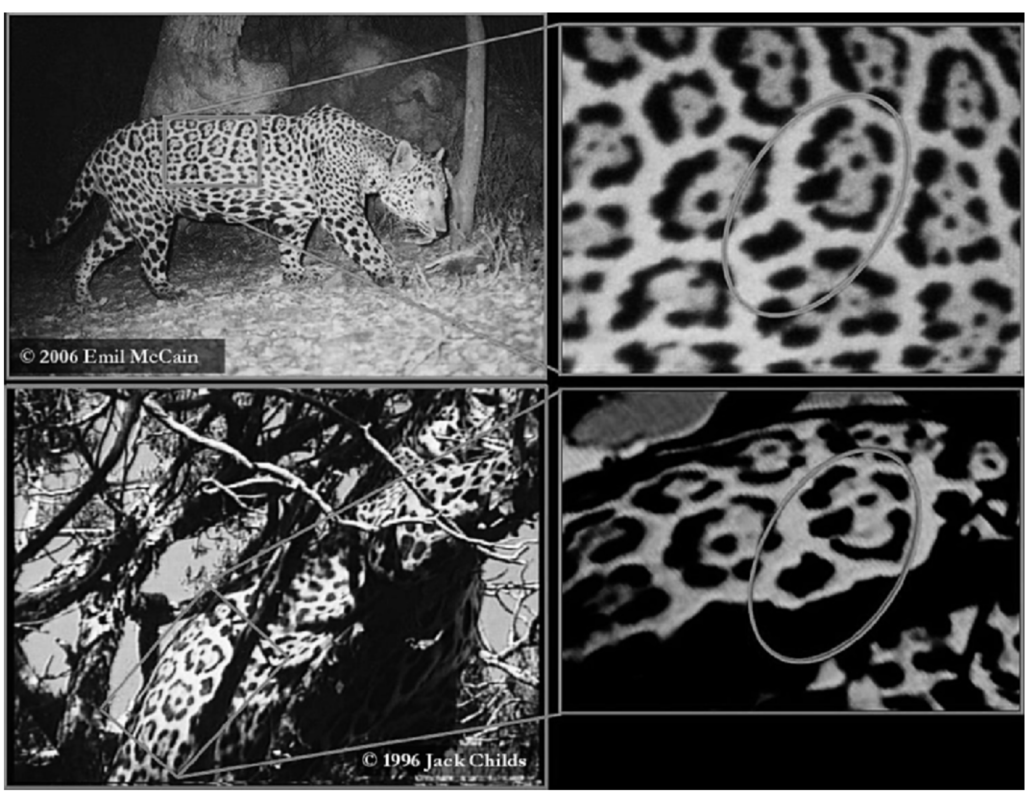

FIG. 4.—Spot patterns on a male jaguar (*Panthera onca*; Macho B) photographed in 1996 (lower left) and 2006 (upper left) in southern Arizona. Rosettes on the right flank are identical (upper and lower right) with conspicuous ''Pinocchio''-shaped rosette (in oval) confirming the same individual jaguar in both photographs.

lower densities in the borderlands than in tropical rain-forest habitat (Rosas-Rosas 2006). Between 2004 and 2007, Macho B used an area of 1,359 km^2 from the Baboquivari Mountain complex in the western part of our study area across the Altar Valley to the Atascosa Mountain complex in the east (Fig. 2).

In general, most locations of jaguars from our study were concentrated in the mountain ranges, which was likely an artifact of our sampling scheme. The majority of monitoring was focused in mountainous areas where landscape features helped direct animal movements and travel (Karanth et al. 2004). Passive monitoring was not done in the relatively featureless open desert flatlands because there were simply too many probable travel routes to monitor. Although Macho B would have crossed the Altar Valley between the Baboquivari and Atascosa mountains, we have no information on the extent of use of desert flatland areas by jaguars in the study area. Notably, however, Hibben (1948) reported following behind a jaguar on horseback more than 2 days as the animal crossed an open desert valley with little or no cover in southern Arizona.

Although the types of data we collected from camera traps and track surveys cannot be used for a quantitative assessment of habitat use by jaguars in the borderlands study area, we do know that Macho B used an extensive area, including habitats of the Sonoran lowland desert, Sonoran desert scrub, mesquite grassland, Madrean oak woodland, and pine–oak woodland. The wide-ranging movements of jaguars through varied habitats and topography evident from our study emphasize the importance of maintaining adequate expanses of intact core and connective habitats for the jaguar in this region.

On 5 occasions we photographed and tracked jaguars as they moved back and forth across the United States–Mexico border. Movements of jaguars across the international border appeared focused in key connective habitats in several mountain ranges and canyon bottoms that span the international border (Fig. 2).

Importance of cross-border connectivity.—Jaguars in Arizona and New Mexico, currently and perhaps historically, are likely neither dispersing transients from Mexico nor members of a distinct United States population. We suggest that jaguars in the United States and those recently documented in northeastern Sonora, Mexico (Brown and López González 2001; Rosas-Rosas 2006), represent small segments of a large but widely distributed, low-density population at the northern extreme of the species range. Although there has been speculation on the existence of a concentration of breeding jaguars in northeastern Sonora, Mexico (Brown and López González 2001; United States Fish and Wildlife Service 2006), Rosas-Rosas (2006) photographed only 5 jaguars over a 400-km^2 area in this region during 5 years of research (estimated density = 1 jaguar/100 km^2). López González (Universidad Autónoma de Queretaro, pers. comm.) estimated the same density and modeled that each jaguar would require approximately 1,800 km^2. Examination of these data suggests that jaguars in northeastern Sonora, Mexico, are actually more sparsely distributed than any other documented population (Rosas-Rosas 2006). With these distributions and movement potentials, we suspect that a single, thinly distributed population likely inhabits the large area from southern Arizona and New Mexico, south through the mountains of eastern Sonora, Mexico.

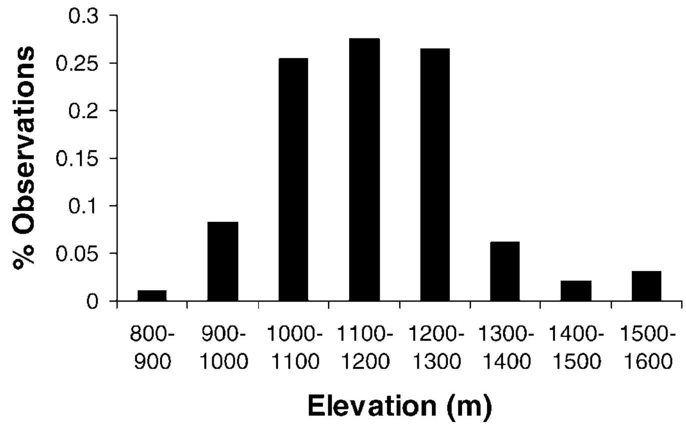

FIG. 5.—Jaguars (*Panthera onca*) were detected (photographs, tracks, and kills) at elevations from 877 to 1,577 m ($\bar{X}$ = 1,159 m) in southeastern Arizona from March 2001 to May 2007 (n = 89).

The interdependence of the American and Mexican portions of the population of jaguars in the borderlands region has important implications for conservation. In Sonora, Mexico, jaguars are seriously threatened by loss of habitat, reduced prey populations, and hunting (Brown and López González 2001; Rosas-Rosas 2006; Valdez 1999). In contrast, jaguars in the United States occupy large expanses of public lands where federal protection for jaguars is enforced (United States Fish and Wildlife Service 1997), native prey are managed at healthy numbers (Arizona Game and Fish Department 2006), and a program to compensate producers for losses of livestock to jaguar depredation has alleviated concerns of local stakeholders (O'Neill and Van Pelt 2004; Sayre 2005). According to Spangle (2007), the overall area of potential habitat for jaguars in Arizona and New Mexico is equal to or greater than the area of suitable habitat for jaguars in Sonora, Mexico. Thus, the availability of suitable habitat for jaguars in the southwestern United States will be increasingly important for the long-term survival of the species in the borderlands region. Furthermore, with no known breeding north of the border since 1910, jaguars in the United States also are dependent on reproduction in Mexico.

Current threats.—The most critical and imminent threat to jaguars in the United States is the proposed border fence. The border fence will separate the small segment of the borderlands population in Arizona from those in northeastern Sonora, Mexico, thereby eliminating dispersal and preventing recovery in jaguar numbers or range north of the border. In August 2007, the Department of Homeland Security initiated construction of the border fence within the study area. Among the 1st areas to be fenced were 11 km across the southern boundary of Buenos Aires National Wildlife Refuge in the Altar Valley and a 4-km extension of the existing fences in Nogales, Arizona, west to the Atascosa Mountain complex. The United States Fish and Wildlife Service Biological Opinion on the border fence detailed the combined direct and indirect impacts to jaguars, emphasizing large-scale risks associated with fragmentation of an already small population related to loss of gene flow (Spangle 2007). The biological opinion also warned that migrant traffic and associated law enforcement activities will likely shift from the desert floor into mountainous habitats where disturbance by humans and habitat degradation will have greater negative effects on jaguars than before (Spangle 2007). This is important for jaguars because the mountainous Baboquivari and Atascosa Mountain complexes appear critically important for maintaining connectivity between the Arizona and Sonora, Mexico, portions of the jaguar population in the borderlands (Fig. 2). An extensive fence along the United States–Mexico border would likely effectively fence jaguars out of the United States, preventing dispersal and gene flow from northern Mexico, and bring an end to naturally occurring jaguars in the United States.

Direct killing of jaguars in predator control efforts is another very serious threat, especially in Mexico (Brown and López González 2001; Rosas-Rosas 2006). Also in the United States, recent debates over designation of Critical Habitat and federal restrictions on local land-use practices have alienated important local conservation stakeholders (Brook et al. 2003; Curtin 2002; Rabinowitz 1999), causing greater animosity toward jaguars that further threatens the safety of jaguars (United States Fish and Wildlife Service 2006). On a broader scale, Arizona has the fastest-growing human population in the United States (Bernstein 2006), and housing developments are severing connective habitats (Abbitt et al. 2000; Curtin 2002; Spector 2002). Finally, large-scale, open-pit mines threaten known core habitat of jaguars in the Atascosa Mountain complex (Ahern 2007) and potential habitat in the Patagonia/Santa Rita Mountain complex (Gunzel 2006a, 2006b; Hardy 2007a, 2007b).

Research and management recommendations.—There is an urgent need for greater understanding of jaguars in the northern extent of their range, especially regarding cross-border connectivity. In Arizona and New Mexico there are 7 different mountain ranges with potentially suitable habitat for jaguars (Hatten et al. 2005; Menke and Hayes 2003) that have not yet been surveyed for jaguars (McCain et al. 2006). Jaguars have been recorded in 3 of these mountain ranges in the last 2 decades (Brown and López González 2001; Glenn 1996; Rabinowitz 1999; W. Glenn, Malpai Borderlands Group, pers. comm.). The current population of jaguars in the borderlands region, and particularly the United States portion of that population, appears to be dependent on large expanses of core and connective habitats for dispersal and cross-border movements within the bioregion of southern Arizona and New Mexico and eastern Sonora, Mexico. If this cohesive habitat and gene flow throughout the region are disrupted by the proposed fence along the border, it is our belief that the population of jaguars in the borderlands will be at great risk and that jaguars will not persist in the United States.

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Literature Cited

Abbitt, R. F. J., J. Scott, M., and D. S. Wilcove. 2000. The geography of vulnerability: incorporating species geography and human development into conservation planning. Biological Conservation 96:169–175.

Ahern, R. 2007. Scoping notice/opportunity to comment: proposed exploratory drilling at the Margarita Mine. United States Department of Agriculture Forest Service, Nogales Ranger District, Tucson, Arizona.

Aranda, M. 2000. Huellas y otros rastros de los mamiferos grandes y medianos de México. Instituto de Ecología, A. C., Xalapa, Veracruz, Mexico.

Arizona Game and Fish Department. 2006. Hunt Arizona 2006: survey, harvest and hunt data for big and small game. Arizona Game and Fish Department, Information and Education Division, Information Branch, Public Division, Phoenix.

Bernstein, R. 2006. Louisiana loses population, Arizona edges Nevada as fastest growing state. 24 June 2007.

Boydston, E. E., and C. A. López González. 2005. Sexual differentiation in the distribution potential of northern jaguars (*Panthera onca*). United States Department of Agriculture Forest Service Proceedings RMRS-P-36:51–56.

Bridges, A. S., M. R. Vaughan, and S. Klenzendorf. 2004. Seasonal variation in American black bear *Ursus americanus* activity patterns: quantifications via remote photography. Wildlife Biology 10:277–284.

Brook, A., M. Zint, and R. De Young. 2003. Landowners' response to an Endangered Species Act listing and implications for encouraging conservation. Conservation Biology 17:1638–1649.

Brown, D. E. 1983. On the status of the jaguar in the Southwest. Southwestern Naturalist 28:459–460.

Brown, D. E. 1994. Biotic communities: southwestern United States and northwestern Mexico. University of Utah Press, Salt Lake City.

Brown, D. E., and C. A. López González. 2001. Borderland jaguars—tigres de la frontera. University of Utah Press, Salt Lake City.

Channell, R., and M. V. Lomolino. 2000. Dynamic biogeography and conservation of endangered species. Nature 403:26–29.

Childs, J. L. 1998. Tracking the felids of the borderlands. Printing Corner Press, El Paso, Texas.

Curtin, C. G. 2002. Integration of science and community-based conservation in the Mexico–U.S. borderlands. Conservation Biology 16:880–886.

Gannon, W. L., R. S. Sikes, and the Animal Care and Use Committee of the American Society of Mammalogists. 2007.

Guidelines of the American Society of Mammalogists for the use of wild mammals in research. Journal of Mammalogy 88:809–823.

Glenn, W. 1996. Eyes of fire: encounter with a borderlands jaguar. Printing Corner Press, El Paso, Texas.

Gunzel, S. L. 2006a. Decision memorandum; Black Pearl Minerals: Four Metals Mine Area. Sierra Vista Ranger District, United States Department of Agriculture Forest Service, Sierra Vista, Arizona.

Gunzel, S. L. 2006b. Decision memorandum; Patagonia Gem Mine trenching. Sierra Vista Ranger District, United States Department of Agriculture Forest Service, Sierra Vista, Arizona.

Haines, A. M., J. E. Janecka, M. E. Tewes, L. I. Grassman, and P. Morton. 2006. The importance of private lands for ocelot (*Leopardus pardalis*) conservation in the United States. Oryx 40:1–5.

Hansen, K. 1994. Cougar—the American lion. Northland Publishing, Flagstaff, Arizona.

Hansen, K. 2006. Bobcat: master of survival. Oxford University Press, New York.

Hardy, D. 2007a. Decision memorandum; proposed exploratory drilling in Provodencia Canyon. Sierra Vista Ranger District, United States Department of Agriculture Forest Service, Sierra Vista, Arizona.

Hardy, D. 2007b. Decision memorandum; proposed road maintenance and repair to access Hardshell Mine. Sierra Vista Ranger District, United States Department of Agriculture Forest Service, Sierra Vista, Arizona.

Hass, C. C. 2002. Home range dynamics of white-nosed coatis in southeastern Arizona. Journal of Mammalogy 83:934–946.

Hatten, J. R., A. Averill-Murray, and W. E. Van Pelt. 2005. A spatial model of potential jaguar habitat in Arizona. Journal of Wildlife Management 69:1024–1033.

Hibben, F. C. 1948. Hunting American lions. University of New Mexico Press, Albuquerque.

Hoffmeister, D. F. 1986. Mammals of Arizona. University of Arizona Press, Tucson.

Hornocker, M. G. 1970. Winter territoriality in mountain lions. Journal of Wildlife Management 33:457–464.

Johnson, T. B., and W. E. Van Pelt. 1997. Conservation assessment and strategy for the jaguar in Arizona and New Mexico. Arizona Game and Fish Department, Phoenix.

Johnson, T. B., W. E. Van Pelt, and J. N. Stuart. 2007. Draft jaguar conservation assessment for Arizona, New Mexico, and northern Mexico. Arizona Game and Fish Department, Phoenix, and New Mexico Department of Game and Fish, Albuquerque.

Karanth, U. K. 1995. Estimating tiger *Panthera tigris* populations from camera-trap data using capture–recapture models. Biological Conservation 71:333–338.

Karanth, U. K., and J. D. Nichols. 1998. Estimating tiger densities in India using photographic capture and recapture techniques. Ecology 79:2852–2862.

Karanth, U. K., J. D. Nichols, and S. N. Kumar. 2004. Photographic sampling of elusive mammals in tropical forests. Pp. 229–247 in Sampling rare or elusive species; concepts, designs, and techniques for estimating population parameters (W. L. Thompson, ed.). Island Press, Washington, D.C.

Karl, T. R., R. W. Knight, D. R. Easterling, and R. G. Quayle. 1996. Indices of climate change for the United States. Bulletin of the American Meteorological Society 77:279–292.

López González, C. A., and D. E. Brown. 2002. Status and distribution of the jaguar in Sonora, Mexico. Pp. 379–392 in El jaguar en el nuevo milenio (R. A. Medellín, et al., comps.). Universidad Nacional Autónoma de México, Wildlife Conservation Society, Fondo de Cultura Económica, Distrito Federal México, México.

Main, M. B., and L. W. Richardson. 2002. Response of wildlife to prescribed fires in southwest Florida pine flatwoods. Wildlife Society Bulletin 30:213–221.

Martínez-Mendoza, A. 2000. Jaguar occurrence in northeastern Sonora, Mexico. M.S. thesis, New Mexico State University, Las Cruces.

McCain, E. B., et al. 2006. Research recommendations for the Arizona–New Mexico Jaguar Conservation Team. Research Committee—Arizona–New Mexico Jaguar Conservation Team, Lordsburg, New Mexico.

Menke, K. A., and C. L. Hayes. 2003. Evaluation of the relative suitability of potential jaguar habitat in New Mexico. New Mexico Department of Game and Fish, Albuquerque.

Nielsen, J. L., J. M. Scott, and J. L. Aycrigg. 2001. Endangered species and peripheral populations: cause for conservation. Endangered Species Update 18:194–197.

Nowak, R. M. 2005. Walker's carnivores of the world. Johns Hopkins University Press, Baltimore, Maryland.

O'Neill, D. M., and W. E. Van Pelt. 2004. Review of Jaguar Conservation Agreement activities March 1997 through December 2003. Arizona Game and Fish Department, Phoenix.

Pierce, B. M., V. C. Bleich, and R. T. Bowyer. 2000. Social organization of mountain lions: does a land-tenure system regulate population size? Ecology 81:1533–1543.

Quigley, H. B., and P. G. Crawshaw. 1992. A conservation plan for the jaguar *Panthera onca* in the Pantanal region of Brazil. Conservation Biology 8:501–507.

Rabinowitz, A. R. 1986. Jaguar: one man's struggle to establish the world's first jaguar preserve. Arbor House, New York.

Rabinowitz, A. R. 1999. The present status of jaguars (*Panthera onca*) in the southwestern United States. Southwestern Naturalist 44:96–100.

Rosas-Rosas, O. C. 2006. Ecological status and conservation of jaguars in northeastern Sonora, Mexico. Ph.D. dissertation, New Mexico State University, Las Cruces.

Sanderson, E. W., et al. 2002. Planning to save a species: the jaguar as a model. Conservation Biology 16:58–72.

Sayre, N. F. 2005. Working wilderness: the Malpai Borderlands Group and the future of the western range. Rio Nuevo, Tucson, Arizona.

Schaller, G. B. 1967. The Serengeti lion. University of Chicago Press, Chicago, Illinois.

Secure Fence Act. 2006. Public Law 109-367. October 26, 2006, Secure Fence Act, 8 U.S.C. 1103. http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_bills&docid=f:h6061enr.txt.pdf. Accessed 4 June 2007.

Segee, B. P., and J. L. Neeley. 2006. On the line: the impacts of immigration policy on wildlife and habitat in the Arizona borderlands. Defenders of Wildlife, Washington, D.C.

Seidensticker, J., M. G. Hornocker, V. W. Wiles, and J. P. Messick. 1973. Mountain lion social organization in the Idaho Primitive Area. Wildlife Monographs 60:1–60.

Seymour, K. L. 1989. *Panthera onca*. Mammalian Species 340:1–9.

Silver, S. C., et al. 2004. The use of camera traps for estimating jaguar *Panthera onca* abundance and density using capture/recapture analysis. Oryx 38:148–154.

Smith, J. L., C. McDougal, and D. Miquelle. 1989. Scent marking in free-ranging tigers, *Panthera tigris*. Animal Behaviour 37:1–10.

Soisalo, M. K., and S. M. Cavalcanti. 2006. Estimating the density of a jaguar population in the Brazilian Pantanal using camera-traps and capture–recapture sampling in combination with GPS radio-telemetry. Biological Conservation 129:487–496.

Spangle, S. L. 2007. Biological opinion 22410-2007-F-0416: pedestrian fence projects at Sasabe, Nogales and Naco-Douglas, Arizona. United States Fish and Wildlife Service, Phoenix, Arizona.

Spector, S. 2002. Biogeographic crossroads as priority for biodiversity conservation. Conservation Biology 16:1480–1487.

Sunquist, M., and F. Sunquist. 2002. Wildcats of the world. University of Chicago Press, Chicago, Illinois.

Swank, W. G., and J. G. Teer. 1989. Status of the jaguar—1987. Oryx 23:14–21.

Tewes, M. E., and D. D. Everett. 1986. Status and distribution of the endangered ocelot and jaguarundi in Texas. Pp. 147–158 in Cats of the world: biology, conservation, and management (S. D. Miller and D. D. Everett, eds.). Ceasar Kleberg Wildlife Research Institute Press, Kingsville, Texas, and National Wildlife Federation, Washington, D.C.

Toolin, L. J., T. R. Van Devender, and J. M. Kaiser. 1979. The flora of Sycamore Canyon, Pajarito Mountains, Santa Cruz County, Arizona. Journal of the Arizona–Nevada Academy of Science 14:66–67.

Treves, A., and U. K. Karanth. 2003. Human–carnivore conflict and perspectives on carnivore management worldwide. Conservation Biology 17:1491–1499.

United States Fish and Wildlife Service. 1997. Final rule to extend endangered status for the jaguar in the United States. Federal Register 62:39147–39157.

United States Fish and Wildlife Service. 2006. Determination that designation of critical habitat is not prudent for the jaguar. Federal Register 71:39335–39337.

Valdez, R. 1999. Jaguar. Pp. 378–388 in Ecology and management of large mammals in North America (S. Demarais and P. R. Krausman, eds.). Prentice Hall, Upper Saddle River, New Jersey.

Wallace, R. B., H. Gomez, G. Ayala, and F. Espinoza. 2003. Camera trapping for jaguar (*Panthera onca*) in the Tuichi Valley, Bolivia. Journal of Neotropical Mammalogy 10:133–139.

Walther, G. R., et al. 2002. Ecological responses to current climate change. Nature 416:389–396.

Weber, W., and A. R. Rabinowitz. 1996. A global perspective on large carnivore conservation. Conservation Biology 10:1946–1054.

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