

CO-OCCURRENCE OF FOUR ENDANGERED MAMMALS IN THE MEXICO–UNITED STATES BORDERLANDS: JAGUAR (PANTHERA ONCA), OCELOT (LEOPARDUS PARDALIS), BEAVER (CASTOR CANADENSIS) AND BLACK BEAR (URSUS AMERICANUS)

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NOTES

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ABSTRACT—The unique biogeography of the Madrean Archipelago facilitates the cohabitation of species that otherwise rarely overlap in their spatial distributions. As part of a long-term study at Cuenca Los Ojos, Sonora, we deployed 25 cameras along washes within the property from October 2018 to April 2019, adding to the camera-trap information collected at the site since 2016. Ocelot (*Leopardus pardalis*) was recorded once in 2018, twice in 2016 and 2020, but not during the 2018–2019 study period. Black bear (*Ursus americanus*) was recorded regularly throughout the season with several images including cubs. One picture and several signs of beaver (*Castor canadensis*) were discovered in 2018 and 2019. Lastly, the first record of jaguar (*Panthera onca*) in Cuenca Los Ojos was recorded in February and March 2019 at four different sites. All species are considered endangered in Mexico and species of conservation concern in the United States and were recorded within 5 km south of the USA–Mexico border wall. Our addition of the new ocelot sighting in this region marks the only known location with records of all four species overlapping in space and time despite historical distribution ranges of black bears, jaguars, and beavers overlapping. Given the current border wall construction and highway development, which both affect the natural connectivity of the region, it will be necessary to incorporate the presence of the four species in all future mitigation efforts.

RESUMEN—La biogeografía única del Archipiélago Madreano facilita la co-ocurrencia de especies que de otra manera raramente traslapan su distribución espacial. Como parte de un estudio a largo plazo en Cuenca Los Ojos, Sonora, colocamos 25 cámaras trampa en cañadas dentro de la propiedad de octubre de 2018 a abril de 2019, suplementando registros colectados con foto-trampeo en el sitio desde 2016. El ocelote (*Leopardus pardalis*) se registró una vez en 2018, dos veces en 2016 y 2020, pero no durante nuestro periodo de muestreo de 2018–2019. El oso negro (*Ursus americanus*) se registró con regularidad con varias imágenes incluyendo oseznos. Un registro fotográfico y varios signos de la presencia del castor (*Castor canadensis*) se encontraron en 2018 y 2019. Finalmente, se obtuvo el primer registro de jaguar (*Panthera onca*) en cuatro sitios diferentes en Cuenca Los Ojos en Febrero y Marzo de 2019. Todas las especies se consideran en peligro de extinción en México y de preocupación de conservación en los Estados Unidos y se registraron a menos de 5 km hacia el sur del muro fronterizo entre Estados Unidos y México. Aunque la distribución histórica del castor, el oso negro y el jaguar se sobrelapa, con los nuevos avistamientos del ocelote, éste es el único sitio conocido en que se han registrado las cuatro especies cohabitando espacial y temporalmente. Dada la expansión actual del muro fronterizo y el desarrollo carretero que impactan la conectividad natural en la región, será necesario incorporar la presencia de las cuatro especies en todos los esfuerzos futuros de mitigación.

The Madrean Archipelago is an expanse of forested mountain “islands” in a sea of grassland and desert,

spanning from the Sierra Madres in northern Mexico across the southwestern United States to the Colorado

Plateau. It is a recognized biodiversity hotspot (Myers, 2003) where five main ecological regions collide: the Chihuahuan and Sonoran deserts, the Great Plains grasslands, the Colorado Plateau, and the Sierra Madre Occidental mountain range (Van Devender et al., 2013). The intersection of these highly biodiverse regions facilitates the overlap of both Nearctic and Neotropical realms where many endangered species reach the limit of their distribution in North America (DeBano et al., 1995; McCormack et al., 2009; Peters et al. 2018). Low population numbers of beaver (*Castor canadensis*), American black bear (*Ursus americanus*), ocelot (*Leopardus pardalis*), and jaguar (*Panthera onca*) qualify them as endangered species in Mexico, and they are federally protected (Secretaría de Medio Ambiente y Recursos Naturales [SEMARNAT], 2010) despite their wide distribution elsewhere (Feldhamer et al., 2003). For instance, although jaguars range from Argentina to Arizona, their populations have become extremely fragmented and have severely declined everywhere outside of the Amazon Basin due to human activities, but especially in their northern distribution where they were already uncommon (Brown and Gonzalez, 2001; United States Fish and Wildlife Service, 2014).

Mountain ranges and riparian habitats between Sonora and Arizona have been recognized as wildlife corridors (Beier et al., 2006, 2008a, 2008b; Grigione et al., 2009; Coronel-Arellano et al., 2018). Located in northwestern Sonora, Cajon Bonito is one of few perennial streams remaining within the Madrean Archipelago and is among the last remaining habitats for many species that depend on surface water in northwestern Mexico (Hunt and Anderson, 2002). Furthermore, the riparian forest associated with the Cajon Bonito watershed and the forests in the Sierra de San Luis Mountains have both been suggested as corridors for jaguars, ocelots, black bears, and many other species that have historically moved freely through the unique Madrean Archipelago ecosystem that ranges across both sides of the border (Lomolino et al., 1989; López-González et al., 2003; Beier et al., 2006, 2008a, 2008b; Grigione et al., 2009).

Cuenca de los Ojos A.C. (CLO hereafter) is a Mexican nonprofit that owns and manages 53,000 ha of conservation land in the northeastern corner of Sonora, Mexico, bordering the state lines of New Mexico and Arizona. It is bounded by the Janos Biosphere Reserve to the east, private ranches to the south, and ejidos (communal owned land) to the west. CLO's land is one of few wilderness areas left in Mexico and is fundamental for the conservation of northern Mexico and southwestern United States biodiversity. The protected land supports a striking amount of ecological diversity ranging from the pine (*Pinus*) and oak (*Quercus*) forest ridgelines of the Sierra Madre Occidental mountain range and the Madrean chaparral, grasslands, and mesquite-dominated scrublands to the well-spread network of riparian corri-

dors leading to the Cajon Bonito stream. CLO is home to several globally threatened species, including the Vulnerable Chiricahua leopard frog (*Lithobates chiricahuensis*; Santos-Barrera et al., 2004), seven species of fish protected in the United States or Mexico, and several regionally threatened mammals and reptiles (SEMARNAT, 2010; Rorabaugh et al., 2018).

The compounding impacts of the recent expansion of Mexican Federal Highway 2, the growth of agriculture in northwestern Sonora and Chihuahua, and border wall construction has renewed the concern to ensure habitat connectivity of movement corridors for large mammals (e.g., American bison [*Bison bison*], pronghorn [*Antilocapra americana*], black bear, Mexican gray wolf [*Canis lupus baileyi*], etc.) and northernmost populations of Neotropical felids within the Madrean Archipelago (Sanderson et al., 2002; Grigione et al., 2007; Coronel-Arellano et al., 2018; Peters et al., 2018). To better understand mammal movement in the U.S.–Mexico borderland region, we deployed camera-traps (Bushnell HD, Overland Park, Kansas, and HCO Scoutguard, Norcross, Georgia) in washes throughout CLO in Sonora, Mexico. We set 25 camera-traps from October 2018 to April 2019 for 3,807 total camera-trap days (Ragan, 2020). Cameras were placed in four major washes and along Cajon Bonito, the largest perennial stream in the area. Adequate attachment points in washes were selected based on tree availability, finite backgrounds, and limiting problematic vegetation when possible. We sorted the photos by location, species, and number of individuals following the guidance of the Sanderson method (Sanderson and Harris, 2013). All records mentioned in this paper can be found at Ragan and Schipper (2021; doi:10.5063/1V5CB9). Here we present noteworthy records of four endangered mammals overlapping in time and space during our research.

Jaguar (*Panthera onca*)—On 17 February 2019, we identified a jaguar at two sites along the same wash (Fig. 1). The site locations were 1.8 and 2.4 km from the Mexican Federal Highway 2, and 2.8 and 3.2 km from the international border, respectively. The individual was following the wash from Mexican Federal Highway 2 southwest to the perennial stream, Cajon Bonito. This individual was an adult; however, the low quality of the photo made it impossible to determine gender or any unique spot patterns that would identify it as a jaguar previously recorded (Fig. 2a). On 22 February 2019, what we presume to be the same individual was captured on an additional camera in our perennial network at 3.8 km south from the highway and 5.8 km south from the border. Finally, on 27 March 2019 we recorded a fourth photo of a jaguar in the southern wash approximately 6 km south of the highway and 8 km south of the border. All photos were low in quality and in all instances, the jaguar was moving south, heading away from Federal

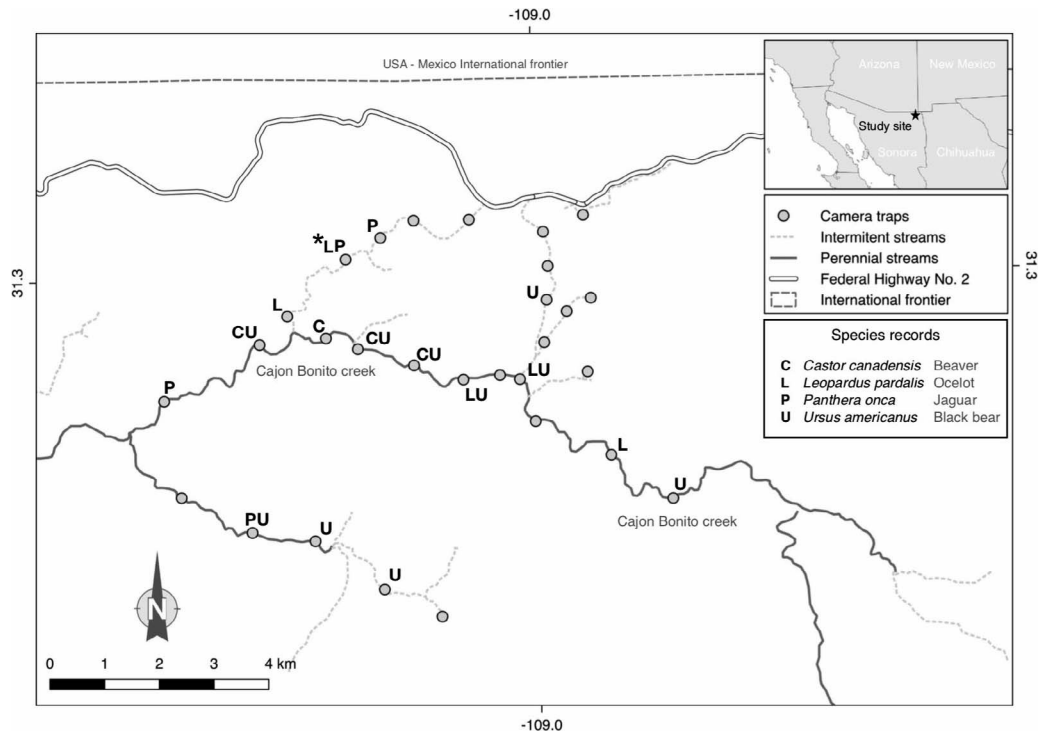


FIG. 1—Records of jaguar (*Panthera onca*), ocelot (*Leopardus pardalis*), black bear (*Ursus americanus*), and beaver (*Castor canadensis*) in the borderlands of northeastern Sonora, Mexico. The two major features in the landscape are the Cajon Bonito stream and the Federal Highway 2. The asterisk marks the 2020 site where we recorded the same ocelot individual on video in April and June 2020.

Highway 2. This is the first sighting of a jaguar in this region in the past 25 years.

Historically the northernmost range of the jaguar extended across the southwestern United States, including Arizona, New Mexico, and Texas (Brown, 1983; Brown and Gonzalez, 2000, 2001). Jaguars were listed as endangered in the United States through the Endangered Species Conservation Act in 1997 (United States Fish and Wildlife Service, 1997, 2014). During the late 1800 early 1900s, more than 60 individual jaguars were captured or killed within the United States. Several of the individuals in Arizona sighted in the early 1900s were females, one of which was recorded as far north as the Grand Canyon (Brown and Gonzalez, 2000). A 50% reduction in jaguar capture frequency in the United States has occurred progressively every 25 years between 1900 and 2000, making jaguar sightings now extremely rare (Brown, 1983; Brown and Gonzalez, 2001). In recent years, all jaguars recorded in the United States have been males, presumably dispersing from established populations to the south; the last recorded female in Arizona was killed in 1963 in the White Mountains (Brown and Gonzalez, 2001). Several factors are hypothesized to have led to the decline of jaguar in the United States and Northern Mexico, including degradation of riparian areas, reduction in prey populations, and both government and private predator control programs (Grigione et al., 2007).

Since early 2000, the combination of increased jaguar

research and the advancement of camera-trap technology has led to several male jaguars being recorded as far north as the Santa Rita mountains of Tucson, Arizona (Culver, 2016) and the Dos Cabezas mountains near Wilcox, Arizona (J. Schipper, pers. comm.). Overall, around 10 males have been reported in Arizona (Brown and Gonzalez, 2000; Culver, 2016). Currently only one identifiable individual (nicknamed “sombra”) is occasionally spotted in camera-traps in the Chiricahua and Dos Cabezas Mountain ranges. Individuals are often covering long distances, exploring new territories, and not staying in a specific area for an extended period, instead returning south to find a mate (Rosas-Rosas and Bender, 2012).

Our CLO records of jaguar are the farthest north record of a jaguar in Mexico at less than 5 km south of the U.S.–Mexico border. Although there have been a handful of jaguar sightings in the United States and northern Sonora in recent years (Culver, 2016), specifically recording jaguars along the border is a less studied area of research. Understanding how jaguars and other wildlife navigate this unique region, especially with the added contexts of new border wall construction, is essential for better mitigating wildlife movement within the biodiversity hotspot known as the Madrean Archipelago (Cohn, 2007).

Black Bear (*Ursus americanus*)—Black bears are classified as endangered in Mexico; however, in a few conserved forests of northern Mexico they are locally

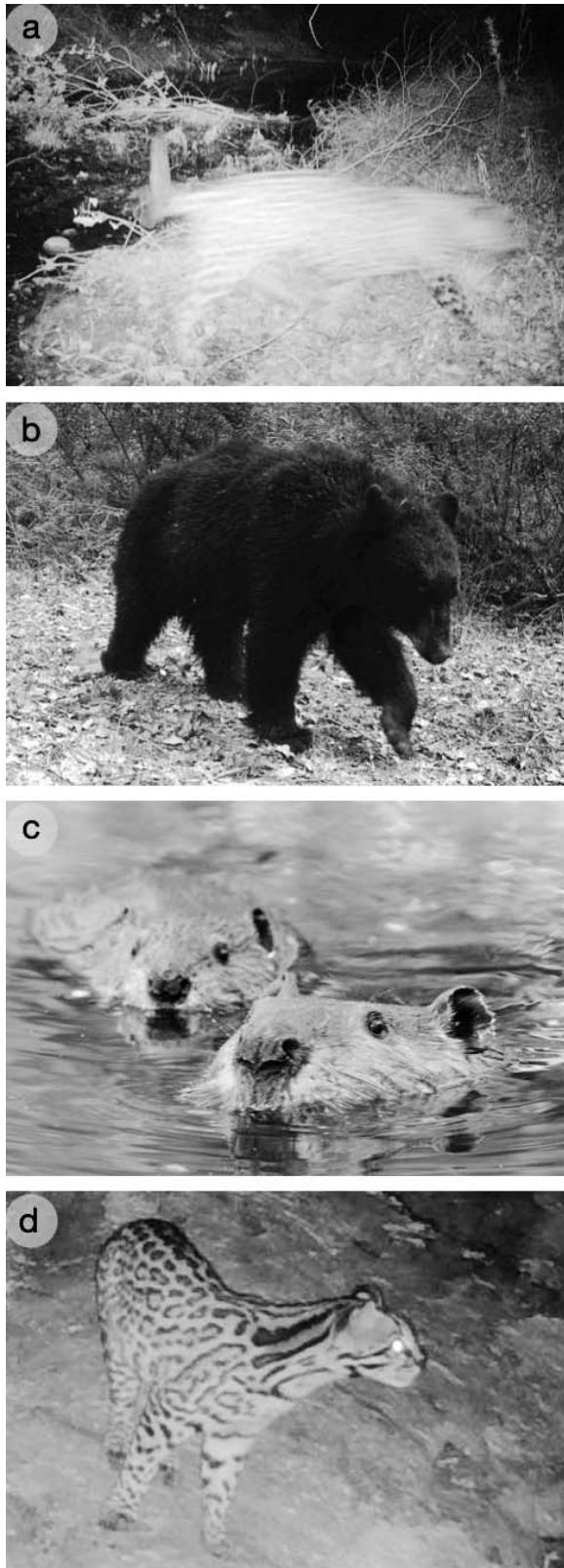


FIG. 2—Photographs of the four endangered species we recorded in Cajon Bonito watershed in the borderlands of northeastern Sonora, Mexico. (a) Individual jaguar (*Panthera onca*) was spotted at four sites during the camera-trap survey. (b) American black bear (*Ursus americanus*) roaming. (c) Adult beaver (*Castor canadensis*) with her cub in the Cajon Bonito stream. (d) Ocelot (*Leopardus pardalis*) captured in April 2020.

abundant (Doan-Crider and Hellgren, 1996; Onorato et al., 2003; Espinosa-Flores et al., 2012; Lara-Díaz et al., 2012). During our study period, we recorded black bears at 10 of the 25 camera-trap sites (Fig. 2b) and most of these sites were along the Cajon Bonito stream (Fig. 1). Other carnivore species such as puma (*Puma concolor*), bobcat (*Lynx rufus*), striped skunk (*Mephitis mephitis*), hog-nosed skunk (*Conepatus leuconotus*), and white-nosed coati (*Nasua narica*) were detected more frequently than black bear at our sites. This is likely due to hibernation occurring during our study period of October 2018 to April 2019. Our data contrasted the relative abundance of black bears reported in a previous study in Cajon Bonito in which black bears were the most abundant carnivore and the fourth most detected species only after prey such as white-tailed deer (*Odocoileus virginianus*), collared peccary (*Pecari tajacu*), and small carnivores such as the white-nosed coati and raccoon (*Procyon lotor*; Coronel-Arellano et al., 2018). Other studies in the region showed that black bears use more habitats dominated by oak-pine forests and secondary growth forests (Sierra Corona et al., 2005; Delfín-Alfonso et al., 2012; Marín, 2018), instead of riparian vegetation and open grasslands ecosystems that dominate in our study site.

Beaver (*Castor canadensis*)—Historically beavers were abundant in rivers near the U.S.–Mexico border, such as the Rio Grande, Colorado, San Pedro, and Bavispe (Baird, 1859; Mearns, 1907; Leopold, 1959; Gallo-Reynoso et al., 2002; Pollock et al., 2003). In northeastern Sonora, beavers have been reported only in association with the Cajon Bonito stream. The first record of beaver in the CLO region was in 1859 in the Guadalupe Canyon upstream of Cajon Bonito at an elevation of 1,524 m (Baird, 1859). Later Mearns mentioned the presence of beaver cuttings downstream in Cajon Bonito (Mearns, 1907). Unfortunately, beavers were extirpated in many southwestern rivers in the early 1900s due to overhunting and population control (Pelz-Serrano, 2011). In 2003, an 18-km survey along Cajon Bonito found five dens of beavers at El Diablo ranch in the lower part of the stream (Pelz-Serrano et al., 2005). Additionally, during 2015 to 2016, three beavers were relocated to Cajon Bonito from the San Pedro River (130 km east of CLO; Carreón, 2016; López-Pérez et al., 2017).

During our camera-trap survey we recorded the presence of one individual near a dam created in the lower portion of Cajon Bonito (Fig. 1). During the dry season in June 2019, the Cajon Bonito stream did not reach the beaver dam. While hiking in the area, 500 m upstream of the beaver dam, we photographed one of the reintroduced individuals with her cub in a small den along the stream bank (Fig. 2c), indicating that a reproductive couple inhabits that section of the stream. Additionally, we have older photos from 2017 of beaver along Cajon Bonito. In the same Yaqui-Bavispe watershed, the closer reports to our records are downstream in the

Bavispe River 90 km south (Gallo-Reynoso et al., 2002). Further research could determine whether both populations are connected and how many individuals are still inhabiting the watershed.

Ocelot (*Leopardus pardalis*)—Ocelots were infrequently sighted in Arizona from 1887 up until 2008 with 11 total official records (Culver, 2016). In 2009 an ocelot was recorded on a camera-trap in Cochise County, Arizona (Grigione et al., 2007; United States Fish and Wildlife Service, 2016). In 2011, an ocelot was treed by a hunter and his dogs leading to media coverage on the return of ocelots (United States Fish and Wildlife Service, 2016). These sightings in the 21st century reignited the discussion about Neotropical species exploring northern territories and an additional five records of ocelot were recorded between 2009 and 2018 (Culver, 2016). Recently records of ocelot have occurred as far north as in Sonora, Mexico, and Arizona, USA (Culver, 2016; United States Fish and Wildlife Service, 2016; Rorabaugh et al., 2020). Ocelot and jaguar are known to occupy similar habitats, especially riparian regions in arid systems (Brown and Gonzalez, 2001; Culver, 2016; Paolino et al., 2018). We did not detect ocelots in CLO during our study period from October 2018 to April 2019. However, six individual photos of ocelots in CLO occurred from 9 October 2016 to 27 December 2016 and two photos were recorded in March 2018 (Fig. 2d). Additionally, we captured two videos of an ocelot in April and June 2020, using a camera-trap we left working at one site (Fig. 1). Based on the spot pattern we determined that both records in 2020 corresponded to the same individual; however, we were not able to determine the identity of the individuals previously recorded due to the insufficient quality of the photographs.

Current road expansion and redesign of Mexican Federal Highway 2 has an increasing impact on the CLO region and Cajon Bonito stream. Vehicle traffic and the associated noise are demonstrated factors negatively affecting wildlife diversity, habitat use, and further contributing to the landscape of fear (Wilmers et al., 2013; Tucker et al., 2018). Habitat fragmentation, as a result of road expansion, is a known primary threat to wildlife, specifically in the case of large carnivores such as jaguar and black bear (Colchero et al., 2011). Other threats associated with roads are wildlife collisions, which have negative consequences for mammal populations and represent a deadly risk for drivers. It is estimated that over 2,000 vertebrates are killed along Mexican Federal Highway 2 every year, including seven large carnivores and five protected species (Wildlands Network, 2017). Recently, a female black bear was killed along Mexican Federal Highway 2 in Sonora, leading to a plea by the state congress to incorporate mitigation actions to reduce roadkill (Bravo, 2019). For large species with low reproductive rates, such as the carnivores we documented, car collisions are especially detrimental and can reduce local populations (Gilhooly et al., 2019). However,

the impacts of federal highway development on populations of more abundant carnivores (e.g., black bear) have not yet been assessed (Coronel-Arellano et al., 2018). Additionally, current infrastructure and human activities restrict free movement and further complicate the survival of these species of conservation concern.

Although historical distribution ranges of black bears, jaguars, and beavers overlap in CLO, and ocelots were hypothesized to use this area as a corridor (Grigione et al., 2009), this is the only known location with records of all four species overlapping in space and time. Our specific sighting illuminates an area of critical importance for wildlife connectivity within the borderlands of the Southwest. As many scientists have cautioned (Peters et al. 2018; Tucker et al., 2018), we think that future development in the region and the construction of additional border wall infrastructure are threats that will dramatically reduce landscape connectivity unless proper mitigation against the negative impacts of human activities is considered. Future research should address (1) whether there is a population of ocelots occupying the Cajon Bonito area, (2) what habitat is most used by jaguars in this corridor, and (3) further identify the specific sites that all four species of conservation concern use to cross both the highway and U.S.–Mexico border.

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