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FOOD HABITS OF OCELOTS AND POTENTIAL FOR COMPETITION WITH BOBCATS IN SOUTHERN TEXAS

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Abstract—Recovery efforts for the endangered ocelot (*Leopardus pardalis*) would be aided by knowledge of its feeding ecology in the affected region. We analyzed scat of ocelots and bobcats (*Lynx rufus*) from southern Texas. As has been found for most other populations of ocelots, rodents were the primary prey, but the principal species of rodent, the Mexican spiny pocket mouse (*Liomys irroratus*), is smaller than the principal prey reported for other populations of ocelots. Lagomorphs were more common prey than has been reported in other studies of ocelots, and birds more common prey than in all but one previous study. The diet of bobcats appeared similar overall to the diet of ocelots, but lagomorphs occurred in a significantly higher proportion of scats from bobcats. The data suggest that bobcats also preyed more heavily on the largest rodents and less on the medium-sized rodents than ocelots did. There was no clear division by type of habitat; both felids preyed approximately equally on species that are found primarily in grassland and those that are found in thornscrub. Near the United States-Mexico border, where the ranges of these felids overlap, there is the potential for substantial competition for resources between the two species. An important component of efforts to restore the population of ocelots in this region, therefore, will be a thorough investigation of this possibility. Studies of the dietary differences when both or only one of the felid species is present in an area, use of foraging habitat by both species, and the relationship between densities of prey and felids would allow the likelihood of negative impacts of competition to be fully evaluated.

Resumen—Información sobre la ecología alimentaria del ocelote (*Leopardus pardalis*) en peligro de extinción ayudaría los esfuerzos de su recuperación. Analizamos excretas de ocelote y de gato montés (*Lynx rufus*) colectadas en el sur de Texas. Como se ha encontrado en la mayoría de poblaciones de ocelote, los roedores fueron la presa principal, pero la especie de presa principal, *Liomys irroratus*, es más pequeña que las especies de presa principal de las otras poblaciones de ocelote. Los lagomorfos fueron presas más frecuentes que reportan otros estudios de ocelotes, y aves fueron presas más frecuentes que en todos los estudios anteriores menos uno. La dieta del gato montés se pareció a la del ocelote, pero se encontraron lagomorfos en una proporción significativamente mayor en las excretas del gato montés. Los datos sugieren también que los gatos montés depredaron más a los roedores grandes y menos a los roedores medianos que los ocelotes. No hubo división clara por hábitat; ambos felinos depredaron casi igualmente a las especies que se encuentran principalmente en las praderas como las que se encuentran en el matorral espinoso. Cerca de la frontera USA-México, donde traslapan las distribuciones de estos felinos, hay potencial para competencia sustantiva por recursos entre las dos especies. Un componente importante de los esfuerzos de recuperación del ocelote en esta región será una investigación completa de esta posibilidad. Los estudios sobre las diferencias de dieta cuando ambos o uno de los felinos ocupa un área, el uso de hábitat por cada especie durante el forrajeo, y la conexión entre la densidad de presas y la de los felinos permitirían una evaluación completa de la probabilidad de efectos negativos de la competencia.

Ocelots (*Leopardus pardalis*) are critically endangered in the United States, with <50 individuals thought to remain in two isolated populations in the southern tip of Texas (United States Fish and Wildlife Service, in litt.).

The current United States Fish and Wildlife Service draft revised Recovery Plan (http://www.fws.gov/southwest/es/documents/r2es/draft_ocelot_recovery_plan-first_revision.pdf) calls for restoring viable populations in Texas by increasing the amount of land occupied by the existing populations and reintroducing ocelots into parts of their former range to create new populations. In both cases, evaluations of the suitability of habitat will need to be conducted to determine whether the selected sites are capable of supporting ocelots in sufficient numbers to meet the goals of recovery. An important component of suitability of habitat is abundance of prey, but information on feeding ecology of ocelots in this region is lacking. Although numerous studies have been published on food habits of ocelots throughout the tropics (e.g., Emmons, 1987; Ludlow and Sunquist, 1987; Konecny, 1989; Chinchilla, 1997; de Villa Meza et al., 2002; Moreno et al., 2006; Bianchi et al., 2010; Silva-Pereira et al., 2011), there are none from the northern temperate portion of the range of the ocelot.

As one of the most fundamental elements of the biology of all animals, diet must be considered in planning recovery of any endangered species. For a predator, availability of adequate prey is a critical determinant of viability of populations through its effects on reproductive and survival rates (Fernández et al., 2003; Karanth et al., 2004; Laundrė et al., 2007; Owen et al., 2010). Furthermore, the relationship between abundance of prey and density of populations of a given species of predator may be modified by the density of competitors. Interspecific competition has the potential to reduce the carrying capacity of an area for an endangered species, thereby decreasing the likelihood that actions for recovery will be successful (Roth et al., 2008). Populations of prey, therefore, must be evaluated in the context of the suite of predators that relies on them.

Most of the studies of food habits of ocelots in tropical systems have included consideration of competitive relationships (e.g., Emmons, 1987; Konecny, 1989; Sunquist et al., 1989; Chinchilla, 1997; Moreno et al., 2006; Silva-Pereira et al., 2011). They have found little dietary overlap between ocelots and similar-sized nonfelids, and apparent partitioning of prey based on body size between ocelots and other felid species. There is some evidence that this partitioning may result from competitive interactions (Moreno et al., 2006). In Texas, ocelots are most likely to experience significant competition from bobcats (*Lynx rufus*; United States Fish and Wildlife Service, in litt.). They are similar in size, there is substantial overlap of home range between individuals of the two species (Tewes, 1986), and both species select thornscrub over most other available types of habitat (Shindle, 1995; Fischer, 1998), although they seem to prefer different densities of canopy cover (Horne et al., 2009). Studies of food habits of bobcats in southern Texas have revealed that, when hispid cotton rats (*Sigmodon hispidus*) are abundant, they are the principal prey, with eastern cottontails (*Sylvilagus floridanus*) second in importance (Beasom and Moore, 1977; Blankenship, 2000). When these species are less abundant, bobcats prey more on other rodents, larger mammals, and birds. The current study was conducted to provide information on food habits of ocelots in Texas and explore the potential for interspecific competition with bobcats based on the similarities in the diets of the two species.

Materials and Methods—Scat from ocelots and bobcats was collected opportunistically from individuals that were captured in box traps for monitoring of the population of ocelots on Laguna Atascosa National Wildlife Refuge (Laguna Atascosa NWR) in Cameron County, Texas, by the United States Fish and Wildlife Service. Laguna Atascosa NWR is 392 km^2 and is located at 26°13′N, 97°20′W. The upland areas of the refuge are 63% grassland and 37% thornscrub (United States Fish and Wildlife Service, in litt.). Trapping was conducted in all parts of the refuge believed to be habitable by ocelots. Scats that were deposited in the traps by the cats were collected, labeled, and stored frozen in zip-top plastic bags. Sixty-one scats from ocelots and 20 scats from bobcats were collected between 1992 and 2007.

To avoid damage to fragile structures, samples (which were mostly dehydrated from having been frozen for many years) were not washed initially but were simply thawed and dissected under magnification, using teasing needles and forceps to remove mammalian and avian remains. Mammalian jaws and teeth found in the samples were identified to species where possible, following characteristics outlined in Jones and Manning (1992), Glass and Thies (1997), and Schmidly (2004). These and other mammalian skeletal remains were then cataloged and deposited into the Natural Science Research Laboratory, Museum of Texas Tech University, Lubbock. Feathers, beaks, and avian skeletal remains were used to identify avian prey where possible, using specimens in the Texas Cooperative Wildlife Collection (Texas A&M University, College Station) for reference.

The hair in each sample was placed in a plastic container and soaked in soapy (antimicrobial detergent) water for 12–24 h. Samples were then washed through three sieves of decreasing size of mesh (8.0, 4.2, and 3.7 mm) and dried in plastic bowls for 12–24 h under 100-W lights. Macroscopic and microscopic (cuticular scales and medulla pattern) characteristics of hair were used to identify mammalian prey to order and large-bodied mammals to species, using specimens in a collection at New Mexico State University (Las Cruces) for reference (Rosas-Rosas et al., 2003).

The rodents of Laguna Atascosa NWR were surveyed by live-trapping to obtain indices of abundance. Four 6-day trapping sessions were conducted in October 2006 and January, March, and June 2007. One hundred Sherman traps (H. B. Sherman Traps, Tallahassee, Florida), 76 × 89 x 228 mm and baited with a mixture of peanut butter and horse feed (Country Acres Horse Sweet Feed 10%, Purina Mills, St. Louis, Missouri), were set in five transects of 90 m each, with 10 trap-stations spaced 10 m apart along each transect. The transects were scattered throughout the part of the refuge (ca. 45 km^2) that has been most consistently occupied by ocelots. Transects were along dirt

roads, with the trap-stations located 5 m into the habitat from the road. There were two traps placed 1–2 m apart at each trap-station. Four transects were located in thornscrub (because of its apparent importance as habitat for ocelots) and one in grassland, and the same trap-stations were used throughout the study. Traps were checked shortly after sunrise each morning. Captured individuals were identified to species and sex, weighed, measured, marked, and released at the site of capture.

Because the sample size of scats from bobcats was small and identification of small mammalian prey to species was possible in only 54% of all samples (52% for ocelots, 60% for bobcats), analyses of the data on diet were qualitative as well as quantitative. Dietary contribution of broad taxonomic categories of prey was compared for the two felids using a separate chi-square test for each category of prey (Reynolds and Aebischer, 1991; Wright, 2010). Yates' correction for continuity was used to reduce the risk of committing a Type I error. For analysis of differences with respect to body size of prey, rodents and shrews were divided into three size classes: >75 g (*Geomys personatus*, *Neotoma micropus*, and *Sigmodon hispidus*); 30–40 g (*Chaetodipus hispidus*, *Liomys irroratus*, and *Onychomys leucogaster*); <20 g (*Cryptotis parva*, *Notiosorex crawfordi*, *Perognathus merriami*, *Peromyscus leucopus*, and *Reithrodontomys fulvescens*). Levels of predation by the two felids were then compared using Fisher's exact tests.

To facilitate comparison of indices of abundance of rodents in different types of habitat, the total numbers of individuals (treating each initial capture in a given trapping session as a new individual) of each species captured on each thornscrub transect were averaged over the four transects. All species of which more than five individuals were captured in thornscrub (*L. irroratus*, *N. micropus*, *O. leucogaster*, and *P. leucopus*) were captured on all four transects, indicating that the four sites had similar communities of rodents. For comparison of the amounts of prey obtained in different types of habitat, species of rodents and shrews identified in scat were classified as species of open (*C. parva*, *G. personatus*, *P. merriami*, *R. fulvescens*, and *S. hispidus*) or closed (*C. hispidus*, *L. irroratus*, *N. micropus*, *O. leucogaster*, and *P. leucopus*) habitat, based on where they were primarily trapped or, if they were not trapped, on the literature (Best and Skupski, 1994; Davis and Schmidly, 1994). It was not possible to classify *N. crawfordi* according to type of habitat (Armstrong and Jones, 1972; Davis and Schmidly, 1994).

Statistical tests were conducted with SYSTAT 13 (Systat Software, Inc., Chicago, Illinois) and SPSS 8.0 (SPSS, Inc., Chicago, Illinois). All tests were two-tailed.

Table 1—Prey of ocelots (*Leopardus pardalis*) and bobcats (*Lynx rufus*) identified in scat collected on Laguna Atascosa National Wildlife Refuge, Texas, 1992–2007.

Prey	Ocelot ($n = 61$)	Bobcat ($n = 20$)
Mammals		
Insectivora		
Cryptotis parva	X	
Notiosorex crawfordi	X	X
Lagomorpha		
Lepus californicus	X	X
Sylvilagus floridanus	X	X
Rodentia		
Chaetodipus hispidus	X	
Geomys personatus	X	
Liomys irroratus	X	X
Neotoma micropus	X	X
Onychomys leucogaster	X	
Perognathus merriami	X	
Peromyscus leucopus	X	X
Reithrodontomys fulvescens	X	
Sigmodon hispidus	X	X
Artiodactyla		
Odocoileus virginianus	X	X
Birds		
Cuculiformes		
Geococcyx californianus		X
Passeriformes		
Cyanocorax yncas	X	
Icteria virens	X	
Mimus polyglottos	X	
Passer	X	
Sialia currucoides	X	
Reptiles		
Squamata		
Sceloporus	X	

Results—Twenty species or genera of prey were identified in scat from ocelots (Table 1). With the exception of the greater roadrunner (*Geococcyx californianus*), every species that was found in scat from bobcats also was found in scat from ocelots. Rodents were the most common type of prey for both felids and were found in almost every scat (Fig. 1a). Lagomorphs appeared significantly more in scat from bobcats than in scat from ocelots ($\chi^2 = 9.894$, $df = 1$, $P = 0.002$). Each species of cat had one species of rodent that appeared in over 40% of the scats in which any small mammals were identified to species (Fig. 1b). The top three rodents preyed on by the two felids overlapped by one species, *S. hispidus*. The largest size-class of rodents tended to appear with greater frequency in scat from bobcats (Fisher's exact $P = 0.124$), whereas medium-sized rodents tended to be more common in scat from ocelots (Fisher's exact $P = 0.061$) than in scat from bobcats (Fig. 1c).

Only three of nine species of rodents were captured in thornscrub and grassland (Fig. 2). *Peromyscus leucopus* was the most commonly trapped species in thornscrub (Fig. 2) and was among the top three prey for bobcats, based on remains identified in scat, but not for ocelots (Fig. 1b). *Sigmodon hispidus*, which was a principal prey for both felids, was the most commonly trapped species in grassland (Fig. 2). *Liomys irroratus*, which was identified in more scats from ocelots than were any other species (Fig. 1b), was the second most commonly trapped species in thornscrub (Fig. 2). Overall, the composition of the diet of the two felids was virtually identical with respect to the primary associations with habitat of rodents and shrews identified in scat (Fig. 3).

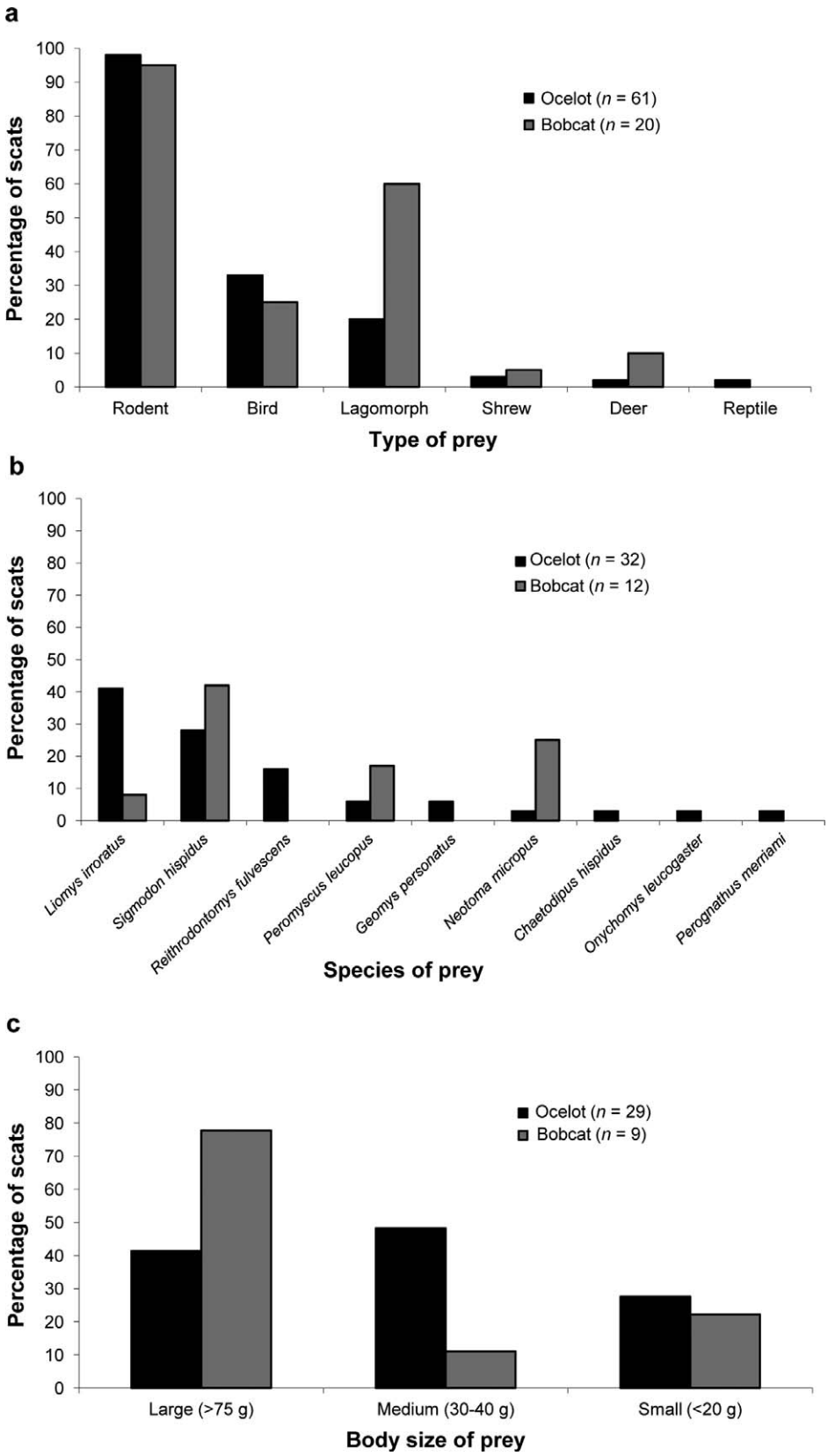

FIG. 1—Frequency of occurrence a) of types of prey, b) of rodents (sample sizes = samples in which any small mammal was identified to species), and c) of size classes of rodents and shrews (sample sizes = samples in which any rodent or shrew was identified to species) in scat from ocelots (*Leopardus pardalis*) and bobcats (*Lynx rufus*) at Laguna Atascosa National Wildlife Refuge, Texas, 1992–2007.

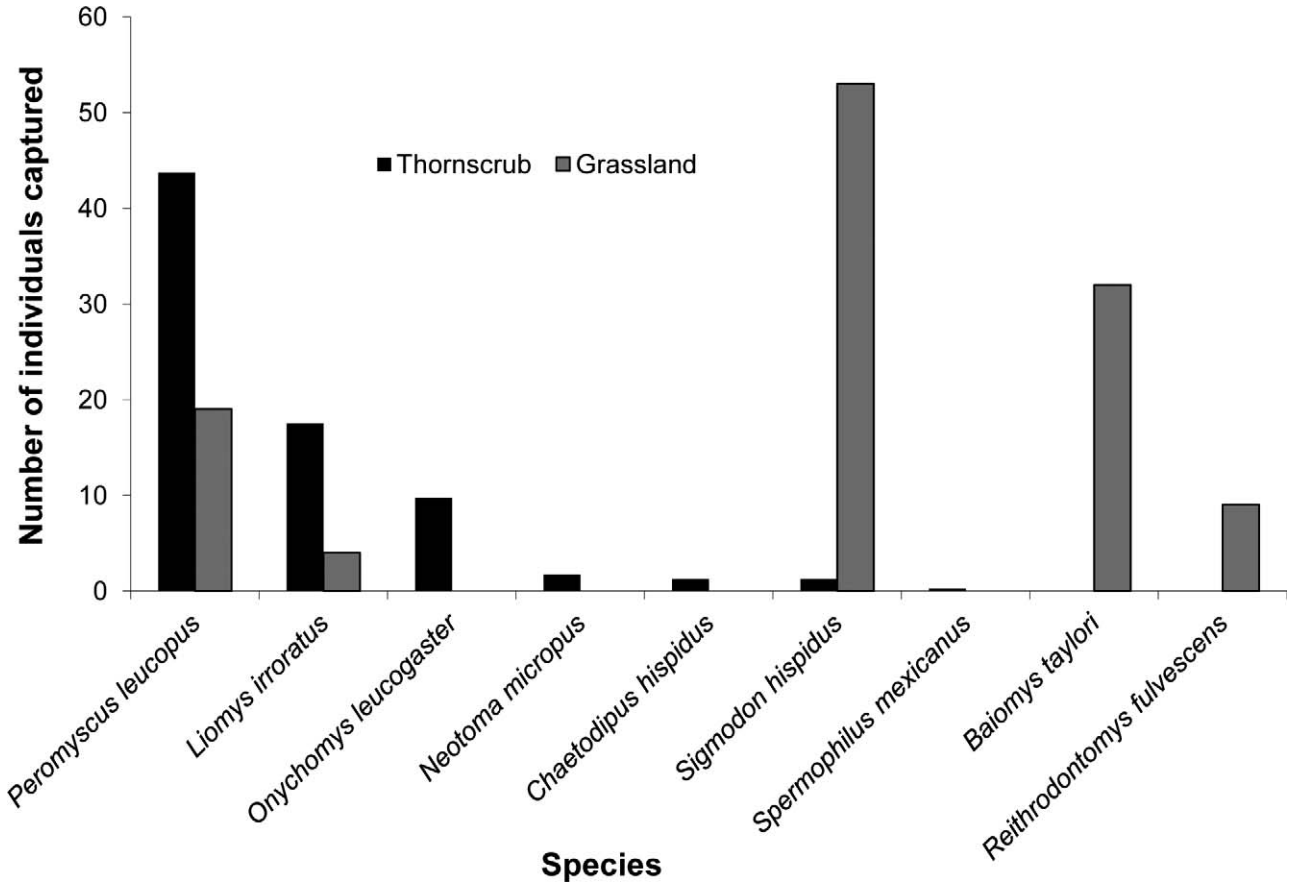

Fig. 2—Number of individuals captured as an index of relative abundance of rodents in thornscrub and grassland on Laguna Atascosa National Wildlife Refuge, Texas. Numbers are means of trapping results from four thornscrub transects and totals from one grassland transect, all of which were surveyed simultaneously during four trapping sessions in different seasons, 2006–2007.

Discussion—Ocelots at Laguna Atascosa NWR eat primarily rodents, with birds and lagomorphs also making a substantial contribution to the diet. The majority of studies of ocelots in other locations (Emmons, 1987; Sunquist et al., 1989; Chinchilla, 1997; de Villa Meza et al., 2002; Moreno and Giacalone, 2006; Bianchi and Mendes, 2007; Abreu et al., 2008; Bianchi et al., 2010) also have found rodents to be the most frequently consumed type of prey, but there are exceptions. In the Cockscomb Basin of Belize, opossums appeared more frequently in scat than any other type of prey (Konecny, 1989), and in Soberanía National Park, Panama, xenarthrans were the most common prey (Moreno et al., 2006). Lagomorphs seem to be more important to ocelots in Texas (20% frequency of occurrence) than to those elsewhere; they appeared second most frequently in scats (10%) from Soberanía National Park, Panama (Moreno et al., 2006), and were absent or minimally present in the other studies. Birds have been documented in the diet of ocelots at virtually all locations studied, but generally at low frequencies. Only in the pine forest of southern Brazil (Abreu et al., 2008), the only other temperate location where the feeding ecology of ocelots has been studied, were they more common prey items (38% of scats) than in Texas (33%).

Although rodents are generally the most common type of prey in the diet of ocelots, larger species that also are preyed upon frequently may contribute more overall

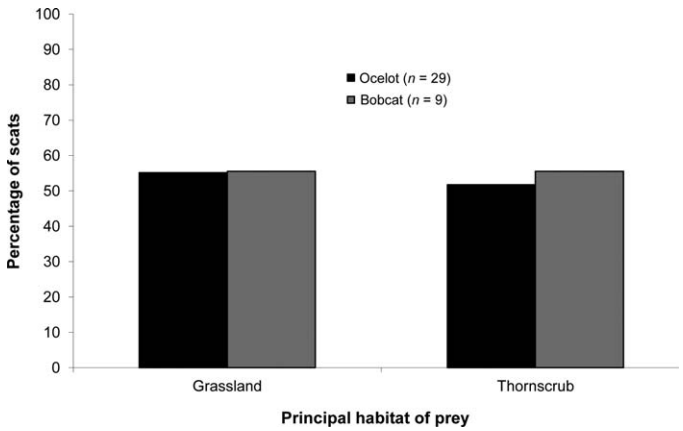

Fig. 3—Frequency of occurrence of rodents and shrews as prey, grouped by type of habitat, in scat from ocelots (*Leopardus pardalis*) and bobcats (*Lynx rufus*) at Laguna Atascosa National Wildlife Refuge, Texas, 1992–2007. Sample sizes represent samples in which any rodent or shrew was identified to species.

biomass (de Villa Meza et al., 2002; Abreu et al., 2008; Bianchi et al., 2010). In some locations, ocelots prey heavily on mammals weighing >4 kg, such as howler monkeys (*Alouatta*; Abreu et al., 2008; Bianchi and Mendes, 2007), sloths (*Bradypus variegatus* and *Choloepus hoffmanni*; Moreno et al., 2006), and pacas (*Cuniculus paca*; Bianchi et al., 2010). They even consume ungulates as large as white-tailed deer (*Odocoileus virginianus*; de Villa Meza et al., 2002; present study), although that may represent scavenging rather than predation. Not all studies make it clear which single species was the most frequently preyed upon in their study, but, from those that do (Konecny, 1989; Sunquist et al., 1989; Chinchilla, 1997; de Villa Meza et al., 2002; Moreno et al., 2006), the body mass of the principal prey ranged from 70–3,900 g for six populations of ocelots, with a mean of 1,655 g. De Oliveira et al. (2010) reviewed the literature on the feeding ecology of ocelots and calculated the mean body mass of all mammalian prey taken by ocelots across 11 studies, obtaining a similar value of 1,500 g. In contrast, *L. irroratus*, the principal prey of ocelots in the present study, averages 38 g at Laguna Atascosa NWR, based on 74 captured individuals.

Ocelots at Laguna Atascosa NWR, thus, seem to be relying on smaller prey than are most populations of ocelots. Furthermore, they are preying most heavily on a medium-sized rodent rather than the much larger and more abundant *S. hispidus*. In contrast, bobcats at Laguna Atascosa NWR are preying principally on the largest rodents and the even larger lagomorphs, as they also have been found to do at other sites in Texas (Beasom and Moore, 1977; Blankenship, 2000). Although the sample size of scats from bobcats in the present study is small, the close concordance of the results with those from other studies in southern Texas indicates that the primary components of the diet of bobcats are accurately represented. Those earlier studies also documented consumption by bobcats of all but one of the mammals recorded as prey of ocelots in the present study as well as dozens of avian species and some reptiles (Beasom and Moore, 1977; Blankenship, 2000), suggesting that any apparent difference in dietary diversity between the two felids in this study is simply an artifact of the difference in sample size.

It appears, then, that the diets of ocelots and bobcats in southern Texas are qualitatively very similar in composition, but that the two felids focus on different taxa. One possible explanation for this difference in focus might relate to preferred habitat. At Laguna Atascosa NWR, ocelots spend most of their time in areas with >75% canopy coverage (i.e. thornscrub), whereas bobcats at Laguna Atascosa NWR spend most of their time in areas with <25% canopy cover such as grassland (Horne et al., 2009). The principal prey of ocelots in our study, *L. irroratus*, is found primarily in thornscrub, and *S. hispidus*, the principal rodent preyed on by bobcats, is found primarily in grassland. However, among rodents, the second and third most common prey of ocelots are species found in grassland, and the second and third most common prey of bobcats are species found in thornscrub. Overall, both felids apparently obtain equal proportions of rodents and shrews in each type of habitat, suggesting that associations with habitat are insufficient to explain their dietary differences at Laguna Atascosa NWR.

Another possibility is that interspecific differences in diet may be at least partially due to competition. Throughout most of the range of the ocelot, all sympatric felids are either several times larger, such as the jaguar (*Panthera onca*) and the puma *(Puma concolor*), or distinctly smaller, such as the margay (*Leopardus wiedii*), jaguarundi (*Puma yagouaroundi*), and oncilla (*Leopardus tigrinus*). Ocelots typically weigh 8.0–14.5 kg, whereas the three smaller species are 3.0–9.0 kg, 4.5–9.0 kg, and 1.5–3.0 kg, respectively (Emmons, 1990). There is substantial dietary overlap among these four species, although ocelots tend to eat larger prey than the others do (de Oliveira et al., 2010). The ocelot is generally considered the dominant species in the Neotropical small-cat guild. Ocelots seem to prey on rodents proportionally to their availability more than the smaller felids do (Silva-Pereira et al., 2011), and some evidence suggests that competition or predation by ocelots may limit the abundance of the smaller species (de Oliveira et al., 2010; Di Bitetti et al., 2010). In the northern portions of the range of the ocelot, however, where they are sympatric with bobcats, the situation is quite different (López González et al., 2003). Bobcats in southern Texas weigh 7.1–12.3 kg (Blankenship, 2000), and ocelots at Laguna Atascosa NWR weigh 6.6–10.3 kg (Laack, 1991). Bobcats are more abundant than ocelots and use a wider variety of habitats, including the dense thornscrub favored by ocelots (Fischer, 1998; Horne et al., 2009), which would give them the edge in a scenario of exploitative competition.

Interspecific competition may have important ramifications for the future of ocelots in the United States. Although they once ranged throughout much of the southern half of Texas, occupying habitats as diverse as the bottomland forests near the Louisiana border and the rocky cedar brakes of the Hill Country (Bailey, 1905), ocelots are now found only in the southern tip of the state, and their populations have been reduced to crisis levels (United States Fish and Wildlife Service, in litt.). The population on Laguna Atascosa NWR apparently continues to decrease despite protection, leaving suitable habitat unoccupied (M. A. Sternberg and J. L. Mays, in litt.). Potential reasons for this decline include mortality caused by vehicles, reduced fitness due to genetic impoverishment, and competitive suppression. The effect of mortality on roads on populations of ocelots has been measured (Haines et al., 2005*a*), and the implications for recovery have been modeled (Haines et al., 2005*b*). The

other potential threats need to be similarly evaluated for informed decisions about management.

Competition could reduce carrying capacity of habitat for ocelots, reduce potential rate of growth of populations, or both (Roth et al., 2008), all of which would limit the effectiveness of actions such as restoration of habitat and reintroduction. There are several types of data that would be helpful in assessing the likelihood of competitive impacts. Comparing food habits of ocelots and bobcats at sites where both species are present to sites where only one of them is present would clarify whether competition is occurring and, if so, which species might be dominant. Measuring densities of small mammals at sites with differing densities of ocelots and bobcats would help identify the necessary levels of populations of prey to sustain populations of both felids. Conducting fine-scale monitoring of syntopic ocelots and bobcats during the active part of their daily cycle could document direct interaction or avoidance between individuals of the two species. It also would show where they do most of their hunting, providing critical data on use of habitat during foraging and possibly indicating the value of types of habitat that were previously thought to be unimportant or marginal, as has happened for several other felid species (Fernández et al., 2003; Balme et al., 2007; Bissett and Bernard, 2007).

As for the possible effects of the severely reduced genetic variability in ocelots in Texas (Walker, 1997; Janečka et al., 2008), decreased fitness is commonly expressed as reduced fertility and reduced survival of juveniles. Documenting current litter sizes, birth intervals, and rates of neonatal mortality and evaluating parameters of male fertility via analyses of semen would indicate whether compromised fitness is contributing substantially to the decrease in size of populations. It also would show the potential for population growth, which is a key piece of information for planning recovery. Most existing data on female fecundity and neonatal mortality at Laguna Atascosa NWR were obtained 17–29 years ago (Laack et al., 2005), and inbreeding depression, if it is occurring, could have altered vital rates significantly in that time.

Knowing what species of prey are important to ocelots in Texas will aid recovery planning and evaluations of the suitability of habitat, but, as previously indicated, much important information is still lacking. In addition, the dataset for ocelots in the present study has one distinct shortcoming; it does not provide comprehensive seasonal coverage. Eighty-nine percent of the samples are from the cooler half of the year (November-April), and there are no samples at all from the three hottest months. This is because live-trapping of ocelots is not conducted at Laguna Atascosa NWR during hot weather, due to concerns about possible heat stress on captured cats. The consequence is that the diet of ocelots in Texas during summer remains unknown. It may well be that the composition of the diet is similar throughout the year. However, at least one study of ocelots found significant seasonal variation in the diet (Ludlow and Sunquist, 1987), and the often-brutal summer weather in southern Texas dictates caution in making such an assumption. Severe heat and frequent drought can create difficult conditions for survival and reproduction, and it would be prudent to know what source of energy is sustaining ocelots during such times. Finally, with respect to the impacts of interspecific competition on populations of ocelots, bobcats are not the only other medium-sized mammalian carnivores that are common at Laguna Atascosa NWR; the role of coyotes as potential competitors of ocelots should be explored as well.

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