

# Distribution and abundance of Barbary sheep and other ungulates in Carlsbad Caverns National Park

## *Implications for native bighorn sheep restoration*

By Anthony Novack, Kelly Fuhrmann, Kristin Dorman-Johnson, and Scott Bartell

### **NATIVE DESERT BIGHORN SHEEP (*OVIS CANADENSIS*)**

roamed Carlsbad Caverns when it became a national monument in 1923 and seven years later when the Congress designated the area, a national park. However, in the 1940s a combination of excessive hunting, competition with other species, and diseases introduced by domestic livestock resulted in elimination of bighorn sheep from the park (New Mexico Department of Game and Fish 2003). At the same time, a private ranching operation in the Hondo Valley of New Mexico, northeast of the Guadalupe Mountains, introduced Barbary sheep (*Ammotragus lervia*), a native of arid environments in northern Africa. Animals from this ranch began escaping into the countryside in 1943. By 1950, the New Mexico Department of Game and Fish had introduced Barbary sheep into several areas of the state with the intent that this drought-resistant exotic might be a desirable substitute for New Mexico's beleaguered native bighorn sheep in areas that the desert bighorn did not inhabit or from which they had been extirpated (Ogren 1965). In 1959, Barbary sheep were first recorded in Carlsbad Caverns National Park (Laing 2003).

Resource managers at Carlsbad Caverns National Park suspect that the founders of the park's exotic herd were escaped sheep from the Hondo Valley ranch. In 2004, they conducted an inventory of the three species of ungulates that inhabit the park: two native—mule deer (*Odocoileus hemionus*) and collared peccary (*Pecari tajacu angulatus*), and one nonnative—Barbary sheep (figs. 1–3). A long-term goal of the National Park Service is to reestablish bighorn sheep in Carlsbad Caverns National Park and Guadalupe Mountains National Park (Texas), to the southwest of Carlsbad Caverns (fig. 4). Managers at both parks are investigating the possibility of eliminating Barbary sheep and restoring desert bighorn. Results of this survey provide a baseline from which to evaluate the removal of Barbary sheep from, and the restoration of desert bighorn sheep to, Carlsbad Caverns National Park (New Mexico Department of Game and Fish 2003).

## Site description

Located in the northeastern corner of the Chihuahuan Desert in southeastern New Mexico, Carlsbad Caverns National Park consists of 46,766 acres (18,926 ha) of rugged terrain along the south-east-facing Guadalupe Escarpment, which extends northeast with diminishing elevations from Guadalupe Moun-



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**Figure 1.** A nonnative ungulate from northern Africa, Barbary sheep first appeared in Carlsbad Caverns National Park in 1959. The founders of the Carlsbad herd probably escaped from a private ranch in the Hondo Valley of New Mexico.

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tains National Park. Elevations in Carlsbad Caverns National Park range from 3,596 feet (1,096 m) to 6,519 feet (1,987 m). The Guadalupe Mountains are an uplifted Permian (270–260 million years ago) limestone reef that rises from the desert lowlands. The escarpment consists of steep slopes and cliff faces that dominate the western two-thirds of the park. Canyons cut the escarpment and open onto desert flats along the escarpment face.

For this study, investigators divided the park into three landscape categories: canyon, escarpment, and ridge (fig. 5, page 95). Grasslands and shrublands occur on both ridges and the escarpment. Canyons contain a mix of habitat types. Vegetation in the canyon

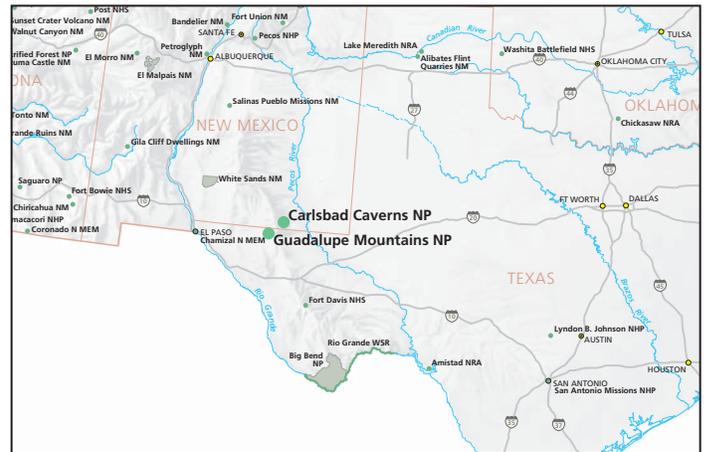


**Figures 2 and 3.** Mule deer (left) are one of two native ungulates in Carlsbad Caverns National Park. Also known as javelina or peccari, collared peccary (right) inhabit the southwestern parts of North America and live throughout South America. It is one of two native ungulate species in Carlsbad Caverns National Park.

bottoms and escarpments consists of various grasses, as well as sotol (*Dasylyrion leiophyllum*), lechuguilla (*Agave lecheguilla*), pinchot juniper (*Juniperus pinchotii*), prickly pear cactus (*Opuntia* spp.), catclaw mimosa (*Mimosa aculeaticarpa* var. *biuncifera*), ocotillo (*Fouquieria splendens*), and yucca (*Yucca* spp.). Common plant species along ridges are alligator juniper (*Juniperus deppeana*), ponderosa pine (*Pinus ponderosa*), two needle pinyon (*Pinus edulis*), mountain mahogany (*Cercocarpus ledifolius*), and sandpaper oak (*Quercus pungens*). Most rainfall (14.8 inches [376.1 mm] annually) accumulates during the monsoon season between late May and early September. Temperatures range from 109°F (43°C) in summer to 1.4°F (-17°C) in winter. Water sources are rare and limited to ephemeral desert springs and seeps.

## Surveys

Based on a method by Buckland et al. (2001), investigators used line transects to index densities of Barbary sheep, mule deer, and collared peccary. This type of survey is used effectively to monitor ungulates worldwide (Peres 2000; Devcharan et al. 2003; Novack et al. 2005). In Carlsbad Caverns National Park, investigators established 11 transects, ranging from 1.5 miles (2.5 km) to 1.9 miles (3.0 km) in length (fig. 6, page 96). Transects were typically located along the existing trail network. Transects were widely distributed throughout the study area to ensure adequate sampling and coverage of the three landscape categories. With sighting distances typically in excess of 0.6 mile (1 km), this sampling method is appropriate for the desert landscape of Carlsbad Caverns National Park, which is mostly devoid of large trees and dense stands of brush. Investigators surveyed each transect on average once every 6 to 10 days between 26 March 2004 and 21 September 2005. Surveys began immediately after daybreak, when one or two observers walked the transect line at 0.6–1.2 miles per hour



**Figure 4.** Carlsbad Caverns (New Mexico) and Guadalupe Mountains (Texas) national parks were once home to native bighorn sheep. The National Park Service is studying the potential for restoring this species, which has been displaced by introduced Barbary sheep.

(1–2 kph). When surveyors observed an ungulate or group of ungulates, they recorded the distance of each animal or group from the transect line; they also recorded group size and the sex and age class of individual animals (when possible). Encounter rates, measured as the number of individuals and number of groups per 100 km, were compared for each species in each landscape category (table 1, page 97). Investigators analyzed transect data using Program R (version 2.4.0) (R Development Core Team 2006) and made comparisons running separate Poisson regressions (using log transect distance as the offset) and deviance tests for each subquestion with an alpha value of 0.05 and no adjustment for multiple comparisons. These regression models treat each ungulate count as a Poisson distribution, a common assumption for non-negative integer counts that are not normally distributed. These regression models compare the encounter rate across species or across habitat type, in order to determine whether the differences are strong enough to conclude statistical significance (i.e., unlikely to have been caused by chance alone).

In addition, on 24 April 2004, four observers completed a helicopter survey to locate ungulates. The helicopter followed a predetermined area census grid that covered all landscape categories and passed over 90% of the park, excluding the visitor center and northwestern corner. The helicopter survey provided an estimate or snapshot for one species, Barbary sheep. Observers detected only groups of sheep; single individuals or pairs of animals are likely to have been missed during the helicopter survey.



## Results

Observers completed surveys on a total of 297 miles (478 km) of transect lines. They observed Barbary sheep on 7 transects (table 1, page 97) with the highest encounter rates in canyons (57.14 animals/100 km [35.48/100 mi]) and escarpments (47.84 animals/100 km [29.71/100 mi]). Only 11.85 Barbary sheep per kilometer (7.36/mi) were encountered on ridges. Group size ranged from 1 to 34 individuals along these transects, with a mean group size of 7.75 animals. Based on both transect observations and the helicopter survey, observers estimated that a minimum of 40 to 50 Barbary sheep inhabit the park. Observers did not record estimates of the other ungulate species during the helicopter survey.

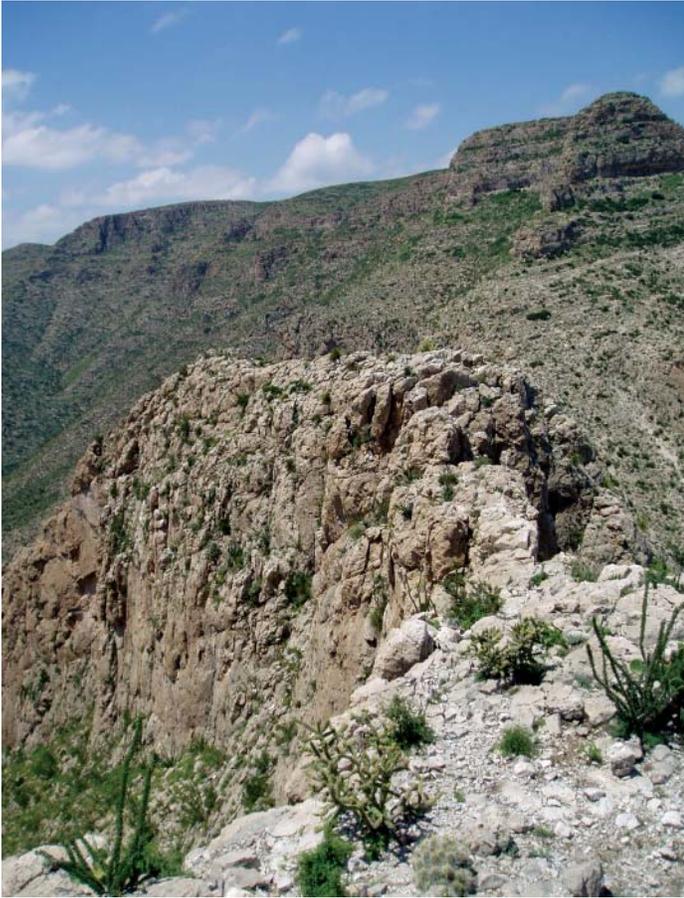
Mule deer occurred on 7 of 11 transects, with the highest encounter rates occurring on the escarpment transects (55.81 animals/100 km [34.66/100 mi]), and much lower encounter rates in canyons (7.79 animals/100 km [4.84/mi]) and along ridges (14.81 animals/100 km [9.20/mi]). Groups of deer ranged in size from 1 to 14 animals (mean number of animals 3.67).

Surveyors observed collared peccary on four transects; group size ranged from 1 to 22 individuals (mean group size 8.45). The largest

number of peccary observations occurred on the escarpment transects (48.50 animals/100 km [30.12/mi]), especially a single transect that followed a dirt road and was open to limited traffic (Sewage Road transect; see table 1 and fig. 4).

Investigators found significant differences in the total number of Barbary sheep (deviance = 53.06, degrees of freedom [df] = 2, probability [p] < 0.001), mule deer (deviance = 80.02, df = 2, p < 0.001), and collared peccary (deviance = 127.03, df = 2, p < 0.001) observed among landscape categories. These differences were constant when comparing the total observations of individuals for all species within a single habitat type (canyons: deviance = 231.2, df = 3, p < 0.001; escarpments: deviance = 109.61, df = 3, p < 0.001; ridges: deviance = 29.890, df = 3, p < 0.001).

The transect data reveal that Barbary sheep, mule deer, and collared peccary are unevenly distributed throughout the park. Mule deer were concentrated on one transect of the escarpment where no Barbary sheep were observed (Sewage Road transect; see table 1 and fig. 4). Surveyors recorded fairly high numbers of Barbary sheep on the two escarpment transects where mule deer were absent (Nuevo and Midnight transects; see table 1 and fig. 4). The absence of Barbary sheep from one escarpment transect (Sewage



Road) may indicate an inability to adapt to human disturbance; this single transect was the only one located on a road that had occasional vehicular traffic (<3 vehicles per day). By contrast, the greatest encounter rate of mule deer occurred along the Sewage Road transect. Because mule deer readily adapt to human disturbance in central Arizona, they commonly occur near roads and housing developments (Tull and Krausman 2007). Surveyors also observed collared peccary most frequently on this transect. This road is located in the only segment of the park that is dominated by desert shrubland vegetation types, including creosote bush (*Larrea tridentata*), viscid acacia (*Acacia neovernicosa*), tarbush (*Flourensia cernua*), and littleleaf sumac (*Rhus microphylla*). The shrubland provides cover and forage for animals that use the habitat.

## Discussion

Resource managers at Carlsbad Caverns National Park need to analyze many factors in the planning process for removing Barbary sheep and restoring desert bighorn sheep. Barbary sheep are socially aggressive toward desert bighorn sheep, have higher reproductive rates, and can transmit diseases to bighorn sheep



**Figure 5.** In Carlsbad Caverns National Park, investigators conducted ungulate surveys along transects in three landscape types: canyon (facing page), ridge (left), and escarpment (above). The escarpment is an uplifted Permian-age reef. A segment of Rattlesnake Canyon served as a survey transect in the canyon landscape category. Slaughter Cave Ridge exemplifies the ridge landscape type.

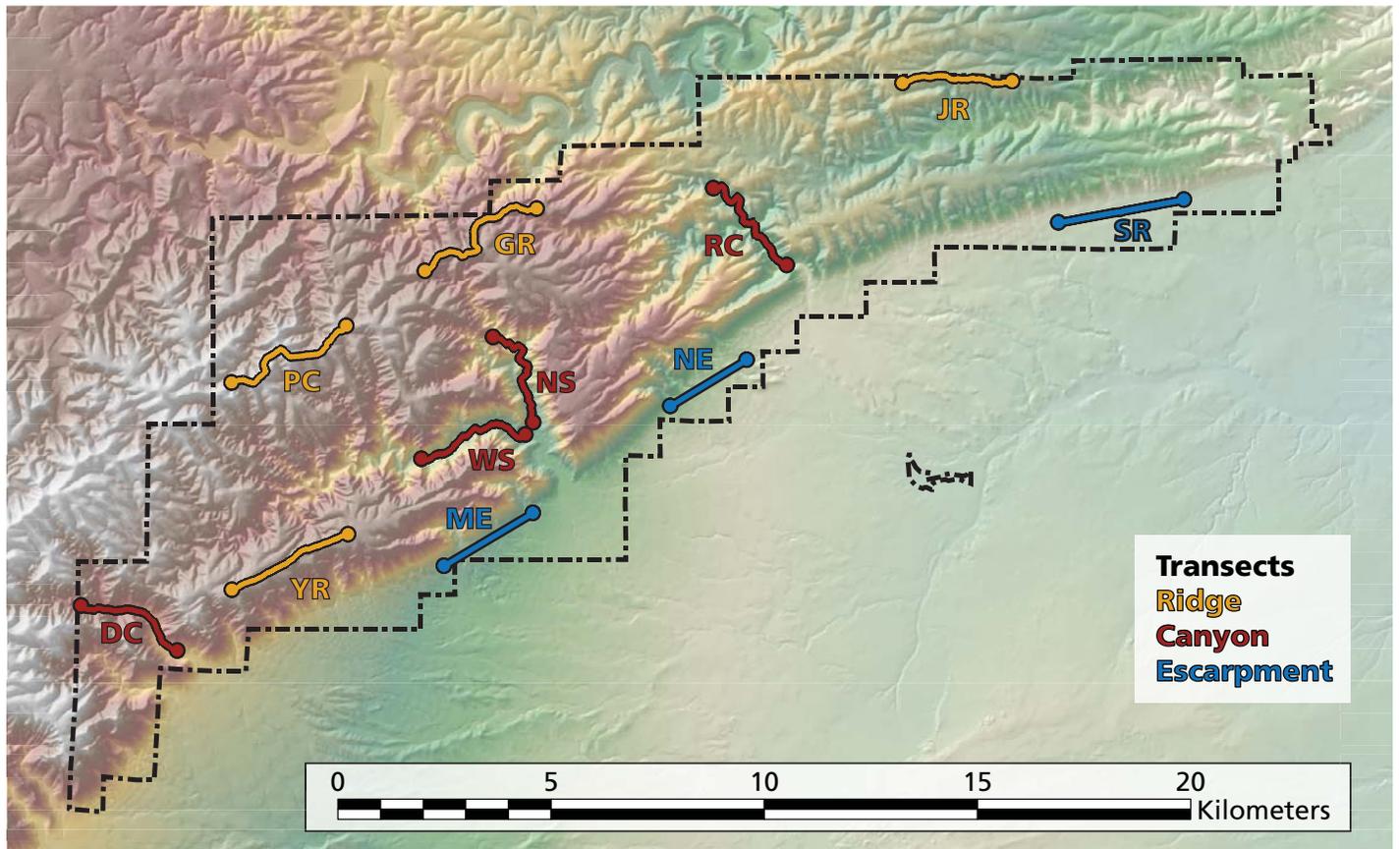
and mule deer (Ogren 1965, Johnston 1979, Pence 1979, Seegmiller and Simpson 1979, Simpson et al. 1979, McCarty and Bailey 1994). Although Barbary sheep survive on lower-quality forage than bighorn sheep, their diet overlaps with both desert bighorn sheep and mule deer (Krysl et al. 1979), resulting in direct competition (Simpson et al. 1978). Furthermore, given the size of Carlsbad Caverns National Park and the population estimate of a minimum of 40 Barbary sheep, the maximum potential for desert bighorn is probably lower than the threshold of  $100 \pm 20$  animals needed to ensure a viable population (Berger 1990). Because Barbary sheep are larger than bighorns and deer, they possibly impact native vegetation more negatively; for example, Barbary sheep can stand on their hind legs to feed on the flowers of tall yuccas and rare plants that grow on vertical cliff faces.

Successful bighorn restoration would likely require connectivity with another population in the Guadalupe Mountains or periodic translocations of individuals from other populations into the Carlsbad population to maintain genetic diversity. Should a

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**Figure 6.** Investigators surveyed 11 transects for ungulates within Carlsbad Caverns National Park: Juniper Ridge = JR, Guadalupe Ridge = GR, Putnam Cabin = PC, Yucca Ridge = YR, Rattlesnake Canyon = RC, Double Canyon = DC, West Slaughter = WS, North Slaughter = NS, Nuevo Escarpment = NE, Midnight Escarpment = ME, and Sewage Road = SR.

bighorn population become established in Guadalupe Mountains National Park, that source of genetic diversity would help ensure the long-term viability of the Carlsbad Caverns National Park population.

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tions exist in close proximity, and these sheep are able to disperse long distances (Cassinello 1998). In addition to the Barbary sheep population residing in the Guadalupe Mountains (an estimated 400–700 animals), more than 1,000 animals live within 300 miles of this area (482 km) in Presidio, Brewster, and Jeff Davis counties of western Texas (Mungall and Sheffield 1994). Preventing reinvasion by Barbary sheep would require collaboration with the New Mexico Department of Game and Fish to increase hunter harvest or extend the hunting season in the area surrounding Carlsbad Caverns National Park and the Guadalupe Mountains. Making the area a trophy hunt location may promote a reduction in numbers. Recreational hunting does not reduce Barbary sheep numbers within Carlsbad Caverns National Park because laws prohibit public hunting inside park boundaries. Furthermore, Barbary sheep may be drawn to the area during the hunting season because of the refuge it provides.

One strategy identified in New Mexico's long-range plan for desert bighorn sheep management is to eradicate nonnative species, including Barbary sheep, from suitable bighorn sheep range of Carlsbad Caverns and the Guadalupe Mountains (New Mexico

**Table 1. Ungulate encounter rates per 100 kilometers in Carlsbad Caverns National Park**

Transect	Kilometers surveyed	Encounter rate					
		Barbary sheep		Mule deer		Collared peccary	
		Individuals	Groups	Individuals	Groups	Individuals	Groups
Juniper Ridge	50.0	0	0	26.00	6.00	4.00	2.00
Guadalupe Ridge	26.5	60.40	7.55	26.41	7.55	0	0
Putnam Cabin	29.0	0	0	0	0	0	0
Yucca Ridge	29.5	0	0	0	0	0	0
<b>Total (ridge)</b>	<b>135.0</b>	<b>11.85</b>	<b>1.48</b>	<b>14.81</b>	<b>3.70</b>	<b>1.48</b>	<b>0.74</b>
Nuevo Escarpment	40.0	45.00	2.50	0	0	10.00	2.50
Midnight Escarpment	41.5	132.53	7.23	0	0	0	0
Sewage Road	69.0	0	0	121.70	31.88	100.00	8.70
<b>Total (escarpment)</b>	<b>150.5</b>	<b>47.84</b>	<b>2.66</b>	<b>55.81</b>	<b>14.62</b>	<b>48.50</b>	<b>4.65</b>
Rattlesnake Canyon	57.5	17.39	6.96	10.43	1.74	8.70	3.48
Double Canyon	30.0	53.33	10.00	6.67	3.33	0	0
West Slaughter	57.5	113.04	17.39	10.43	5.21	0	0
North Slaughter	47.5	44.21	6.32	2.11	2.11	0	0
<b>Total (canyon)</b>	<b>192.5</b>	<b>57.14</b>	<b>9.87</b>	<b>7.79</b>	<b>3.12</b>	<b>2.56</b>	<b>1.03</b>
Group size range			1–34		1–14		1–22
Mean			7.75		3.67		8.45

Department of Game and Fish 2003). Removal of nonnative Barbary sheep from Carlsbad Caverns and Guadalupe Mountains national parks is in accordance with National Park Service policy and would need to be successfully accomplished before attempting any translocation of desert bighorn. Past removal efforts of Barbary sheep from the park were limited to a few animals shot between 1979 and 1993. A successful program for the removal of Barbary sheep could incorporate the “Judas” technique, which managers have used effectively to control social ungulates, such as goats, in areas of difficult topography, dense vegetation, or low density of animals (Keegan et al. 1994). Investigators capture and affix radio collars to a sample of target animals. The radio collar allows managers to quickly locate the animal when it has rejoined with conspecifics. Once a radio-collared animal is relocated, the other members of the herd can be lethally removed via aerial or ground shooting.

## Conclusion

Recent anecdotal evidence from park personnel and visitors indicates that Barbary sheep numbers may be increasing. Reports of Barbary sheep from Guadalupe Mountains National Park are more frequent at the southern end of the Guadalupe Mountains.

A drier climate trend over the past two years has resulted in more sightings at springs and seeps in the park. Barring some major disturbance such as wildfire, extensive hunting, or introduction of another exotic ungulate species, no major changes are expected in the status of Barbary sheep or other ungulate populations within Carlsbad Caverns National Park.

Managers at Carlsbad Caverns and Guadalupe Mountains national parks are expecting to receive funding in 2010 to begin work on planning and compliance activities for addressing the Barbary sheep issue. Removal of Barbary sheep from the Guadalupe Mountains must be a joint effort between the New Mexico Department of Game and Fish and the National Park Service. Although the feasibility of total removal is remote, reduction in numbers will improve the chances of successful bighorn sheep restoration.

Managers could reapply the census method used for this survey, if action is taken to remove Barbary sheep, to assess program effectiveness, and determine if native ungulate distribution is influenced by removal of this nonnative species.

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