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CONSERVATION STATUS OF THE THREATENED, INSULAR SAN JOSE BRUSH RABBIT (*SYLVILAGUS MANSUETUS*)

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ABSTRACT.—The conservation status and distribution of the insular endemic San Jose brush rabbit (*Sylvilagus mansuetus*), as well as threats to its population viability, were determined through surveys undertaken since 1995 on San José Island in the Gulf of California, Mexico. *Sylvilagus mansuetus* is restricted to a specific desert habitat found in the southwestern coastal plains of the island. Vegetation in this habitat is composed primarily of 7 plant species. The extent of rabbit occurrence is only 20 km^2, and the population density estimate in the most optimal habitat is 25–35 individuals · km^{-2}. To our knowledge, the San Jose brush rabbit possesses the smallest distribution among all lagomorph species. *Sylvilagus mansuetus* is threatened by a population of feral cats and by human activities, including illegal hunting, development of a tourist area, and a salt mine. Human activities, even over a short time frame, could severely impact this restricted area and endanger the survival of this species. Recommended management includes removing cats and conducting additional research on the rabbit's life history and ecology.

RESUMEN.—Se determinó el estado de conservación y la distribución del conejo de San José (*Sylvilagus mansuetus*), una especie insular endémica, mediante muestreos que se han llevado a cabo desde 1995 en la isla de San José en el Mar de Cortés, México. *Sylvilagus mansuetus* quedó restringido a un tipo específico de hábitat desértico en la llanura costera suroccidental de la isla, donde predominan 7 especies de plantas. La extensión de la especie es de sólo 20 km^2, y la densidad de la población en el hábitat óptimo se estimó entre 25 y 35 individuos · km^{-2}. Hasta donde conocemos, el conejo de San José tiene el área de distribución más pequeña de todas las especies de lagomorfos. *Sylvilagus mansuetus* se ve amenazado por una población de gatos ferales y por actividades humanas tales como la caza ilegal, el turismo y la operación de una mina de sal. Las actividades humanas podrían tener un impacto severo en esta área restringida y podrían poner en peligro la supervivencia de esta especie dentro de poco tiempo. Algunas acciones recomendables para el manejo de la especie incluyen el eliminar los gatos y llevar a cabo estudios adicionales para obtener más detalles sobre la biología y ecología del conejo a fin de mejorar su conservación.

The San Jose brush rabbit (*Sylvilagus mansuetus*) is endemic to San José Island in the Gulf of California (Cervantes et al. 2005) near the east coast of the Baja California Peninsula (Fig. 1). It is one of the least studied lagomorph species in the world and is considered a high priority for conservation (Chapman and Ceballos 1990, Romero and Rangel 2008). Presently, *S. mansuetus* is listed as near threatened (Smith 2008, IUCN 2009) and is protected by the Mexican government (SEMARNAT 2002). Serious threats facing the species include predation by feral cats, competition from goats for edible vegetation, destruction of habitat, and illegal hunting (Gómez 2006). The species has high priority for a status survey (Chapman and Ceballos 1990).

According to several authors, the rabbit occupies all of San José Island (Chapman and Ceballos 1990, Thomas and Best 1994, Cervantes et al. 1999); however, there have been no assessments of the specific presence or density of *S. mansuetus* across the island's varied terrain, which includes mountains in the northeast, riverbeds, and flat areas with sandy soil and low vegetative cover in the northwest and southwest (Espinosa-Gayosso and Álvarez-Castañeda 2006). Survey results in recent years have not supported claims that this rabbit occupies the entire island, but instead found it restricted to a specific habitat covering a small area in the southwest.

Several animals prey on the San Jose brush rabbit, including feral cats (*Felis sylvestris*), ringtails (*Bassariscus astutus*), rattlesnakes (*Crotalus enyo enyo, Crotalus mitchelli mitchelli,* and *Crotalus ruber lucanensis*), and gopher snakes (*Pituophis melanoleucus bimaris* and *Pituophis vertebralis;* Espinosa-Gayosso and Álvarez-Castañeda 2006). Avian predators include Osprey (*Pandion haliaetus*), Red-tailed Hawk (*Buteo jamaicensis*), Peregrine Falcon (*Falco peregrinus*), and American Kestrel (*Falco sparverius;* Cody

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and Velarde 2002). Fecal analysis in a study by Espinosa-Gayosso and Álvarez-Castañeda (2006) showed that feral cats commonly prey on the San Jose brush rabbit.

Because of the ongoing threats to *S. mansuetus* and competition from exotics, this study was designed to survey the rabbit population; present updated information on distribution, density, and habitat selection; and discuss the conservation status of the species.

METHODS

Study Area

San José Island is located immediately north of La Paz Bay and is separated from the Baja California Peninsula by a channel 5–8 km wide (Thomas and Best 1994). The island is approximately 28 km long by 7.5 km wide (Álvarez-Castañeda and Patton 1999), and its endemic fauna has been isolated for no more than 10,000 years (Best and Thomas 1991).

The vegetation of San José Island is mainly desert scrubland (Rzedowski 1978). Common plants are chollas (*Opuntia* sp.), elephant tree (*Bursera microphylla*), saltbush (*Atriplex* sp.), mesquites (*Prosopis* sp.), cardon cactus (*Pachycereus pringlei*), and palo verde (*Cercidium microphyllum*). There is also a small region of mangroves at the southern end of the island (Maya and Guzmán 1998).

The climate is arid and dry. Average summer temperature is 21–23 °C, and total rainfall is typically 100–150 mm, largely concentrated in late summer (Cody et al. 1983). The island has been a protected natural area since 1978 (SEMARNAT 2002) but is now home to many exotic free-ranging mammals (cats, goats, and donkeys; Wood et al. 2002, Álvarez-Castañeda and Ortega-Rubio 2003). Additionally, dogs, goats, sheep, and cattle are found at the Palma Sola settlement on the northern end of the island. Here, 70 inhabitants engage in line fishing and ranching (Espinosa-Gayosso and Álvarez-Castañeda 2006).

Faunal surveys

We made several general faunal surveys across the island in 1995, 1996, and 2008. During these surveys, we did not detect *S. mansuetus* in the mountainous parts of the island (Fig. 1). As a result, in 2008 we designed surveys specifically to determine the habitat occupancy of the rabbit in nonmountainous parts of the island. Additionally, den site data were collected, reproductive data were obtained from specimens collected on 16–21 November, and museum specimens were deposited in the mammal collection of the Centro de Investigaciones Biológicas del Noroeste (CIB) in La Paz, Baja California Sur. Possible predators were recorded in the study area by direct observation or by sign, and some local people (fishermen) were interviewed about their perception of the current conservation status of the San Jose brush rabbit.

The 2008 survey, which specifically focused on *S. mansuetus*, included 24 transects, each covering 2 km, made by 2 persons from 6:00 to 12:00 and 19:00 to 23:00 in a desert area in the southwest part of the island and east of the salt mine from 16 to 21 November (Fig. 1).

Location and elevation of each rabbit sighted was determined with a GPS unit. The potential distributional range occupied by the San Jose brush rabbit was estimated from known preferred habitat (similar vegetation) where the rabbits were actually observed. The locations of each individual were overlaid on a satellite image of the island divided into 1-km^2 units to quantify the distributional range occupied by this species.

Habitat Analysis

Along each transect where rabbits were observed, all plant species were identified. When a plant species could not be identified in the field, we collected leaves, stems, and fruit and identified them later with help from botanists.

Vegetation cover of each plant species was calculated in areas where the San Jose brush rabbit was observed. This was done by first dividing the area into 12 squares of 1 ha. Then in 6 of the 1-ha plots, twelve 5 × 5-m squares were randomly selected. Perennial vegetation in those squares was identified and measured (longest axis length and perpendicular axis length) and categorized as taller or shorter than 2.5 m. Cover was estimated using the formula

$$c = \pi \times 0.25 \times \mathrm{D1} \times \mathrm{D2},$$

where D1 = longest axis length and D2 = perpendicular axis length. Only in the case of the cardon cactus were measurements taken at the base of the plant. Importance values of plant species were calculated by the addition of the relative cover (cover of a specific species / total cover of all the species) and the relative frequency

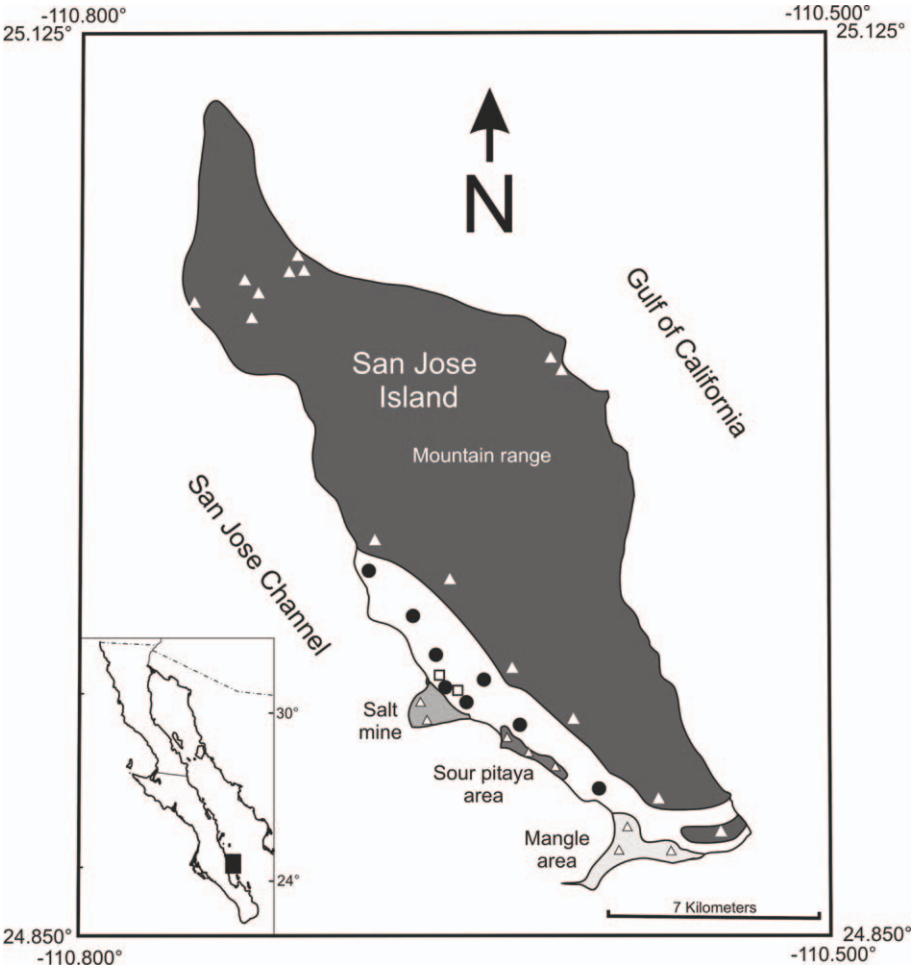

Fig. 1. Map of San José Island, Baja California Sur, Mexico. The white area is the range of *Sylvilagus mansuetus,* which is restricted to a desert habitat. Circles show sites where *S. mansuetus* was recorded. Squares are den locations. Triangles show sites surveyed without any sightings or sign of *S. mansuetus* during 1995–2008. The light-gray area depicts mangle (mangroves); medium gray, the salt mine; dark gray, the area with a great concentration of sour pitaya (*Stenocerus gummosus*); and black, the island's steeply sloped mountain range.

(frequency of a specific species / total of frequencies of all species) for each species (Krebs 2001).

RESULTS

Having crossed San José Island in several places during our general faunal censuses, we found the San Jose brush rabbit only in specific areas. No rabbits were found on gently or steeply sloping areas of the island or in the region with mangroves. This rabbit was found only on the southwestern coastal plain at 10 m above sea level. Here the extent of occurrence was only 20 km^2 (Fig. 1). During the survey in 2008, we observed 23 rabbits, and their density was estimated at 25–35 individuals · km^2 in an area of optimal habitat approximately 4 km^2. Optimal habitat conditions for *S. mansuetus* were based on vegetation cover and slope; optimal sites also contained the highest frequency of observed resting sites. The reproductive data of San Jose brush rabbit specimens indicates that rabbits were reproductively active in November 2008. Two pregnant specimens (CIB 15168 and 15171) had 2 embryos each (40 × 30 mm), and 2 females were lactating (CIB 15170 and 15172).

TABLE 1. Perennial vegetation cover and importance value of plant species at the sites where *Sylvilagus mansuetus* was observed. The values were estimated for the species <2.5 m tall and those >2.5 m tall. The species in bold show the highest importance values. The table includes species with an importance value ≥0.1.

Species	Vegetation cover		Importance value	
	<2.5 m	>2.5 m	<2.5 m	>2.5 m
Simmondsia chinensis	26.2	0.0	0.54	0.00
Cercidium peninsulare	3.3	222.8	0.00	0.48
Maytenus phyllantoides	62.6	0.0	0.38	0.00
Fouqueria digueti	11.9	159.9	0.12	0.37
Stenocerus thurbei	0.1	43.1	0.35	0.33
Stenocerus gummosus	33.9	8.5	0.32	0.00
Jatropha cinerea	11.4	120.2	0.21	0.29
Hyptis laniflora	6.6	132.5	0.00	0.26
Antigonon leptopus	37.0	0.0	0.25	0.00
Cyrtocarpa edulis	45.5	101.5	0.21	0.23
Atamisquea marginata	7.0	11.3	0.23	0.00
Jolneya tesota	3.5	72.9	0.00	0.22
Ruellia californica	14.6	0.0	0.22	0.00
Lycium sp.	10.8	9.9	0.21	0.00
Pachicerus pringley	0.1	19.1	0.00	0.16
Esenbeckia flava	4.7	6.6	0.14	0.00
Condalia globosa	11.4	13.9	0.10	0.00
Opuntia cholla	23.9	21.8	0.10	0.10

Two nests of *S. mansuetus* were found in the 2008 survey (Fig. 1). The first den was found in the base of a cardon cactus and near a desert thorn (*Lycium* sp.). The den had entrance dimensions of 11 × 12 cm, was 15 cm deep, and had a total length of 8.5 cm. The bed of the den was lined with fur, dry leaves of blue palo verde (*Cercidium peninsulare*), and small branches of desert thorn. In the den, we found 2 dead young, which were being eaten by ants. The second den was found at the base of a cholla (*Opuntia cholla*). The entrance dimensions were 8.5 × 10.5 cm, and the den was 12 cm deep. The bed was lined with fur, dry leaves of blue palo verde, small branches of ashy limberbush (*Jatropha cinerea*), and desert thorn. No young were found in the den.

Common plants found in the area of highest abundance of *S. mansuetus* were Adam's trees (*Fouquieria diguetii*), ashy limberbush, cardon cactus, cholla, copal (*Bursera hindsiana*), elephant tree, goatnut (*Simmondsia chinensis*), blue palo verde, sour pitaya (*Stenocerus gummosus*), and wild plum (*Cyrtocarpa edulis*) (Espinosa-Gayosso and Álvarez-Castañeda 2006). We also found a local rue (*Esenbeckia flava*), desert thorn, and ironwood (*Olneya tesota*) in this area. The area of highest density of rabbits had very few sour pitaya; however, this plant was common in other parts of the coastal plain where the rabbit was less common.

The perennial vegetation at the 6 sites where San Jose brush rabbits were observed was composed of 23 species, mainly 7 plant species with importance values >0.25 (*Simmondsia chinensis, Cercidium peninsulare, Maytenus phyllantoides, Stenocerus thurbei, Stenocercus gummosus, F. digueti,* and *J. cinerea*). Of these species, *Simmondsia chinensis* had the greatest importance value (0.54 in specimens <2.5 m tall), followed by *Cercidium peninsulare* (0.48 in specimens >2.5 m tall) and *M. phyllantoides* (0.38 in specimens <2.5 m tall; Table 1).

Analysis of the importance values of the plant species did not show any relationship with the distribution area of *S. mansuetus.* At the 6 sites, *S. mansuetus* was primarily associated with certain plants with a growth form >2.5 m tall: *Cercidium peninsulare, F. digueti, Hyptis laniflora,* and *J. cinerea;* and some plants with a shorter growth form (<2.5 m): *M. phyllantoides, Cyrtocarpa edulis, Stenocercus gummosus,* and *Simmondsia chinensis* (Table 1). We observed at least 5 rabbits resting in the shade of palo verde trees.

The San Jose brush rabbit is preyed on by the native ringtail and the introduced cat. The ringtail was found mainly in the rocky hills, and only one ringtail carcass was found in the area where the rabbit is common; therefore, the ringtail is probably only an opportunistic predator and not a real threat to the rabbit population. In the same way, we found skeletons of cats in areas with high rabbit density. Since the average weight of brush rabbits is

0.8 kg (8 adults) and cats generally weigh approximately 2.5–7 kg and feed on small animals (birds, mice, rats, lizards) up to 0.6 kg, it is likely that cats prey on young and occasionally on mature rabbits. In surveys and interviews of local fishermen, some persons admit to hunting rabbits occasionally.

DISCUSSION

Our surveys show that the San Jose brush rabbit is restricted to a 20-km^2 area on San José Island. Previously *S. mansuetus* has been considered to occupy most areas or the entire island (approximately 170 km^2; Romero and Rangel 2008). The highest rabbit density observed was approximately 35 individuals · km^{-2}. The area of highest density was densely vegetated and difficult to traverse. The most common plants were Adam's tree, cardon cacti, cholla, copal trees, and goatnut. Common shrubs included blue palo verde and ashy limberbush. The species richness and density of annuals, including grasses, were very low.

The area where we observed the San Jose brush rabbit is characterized by a high richness of brush and tree species that offer the rabbits sufficient food, areas where adults and young can hide, and cover from possible predators.

The most imminent threat to the San Jose brush rabbit is likely related to hunting activities, despite protections under Mexican law for all wildlife on San José Island. The island has a high density of mule deer and goats. Local fishermen legally hunt goats, which are not protected; however, while on these hunts, they illegally kill protected mule deer and brush rabbits for fresh meat.

Another potential threat to the San Jose brush rabbit is the possible development of a resort with an accompanying golf course, private airport, and small marina. The owners of the island have planned this project for several years, though development plans stopped when the island was afforded protected status. However, the national courts are now considering allowing approximately 10% of the island as a tourist development, leaving the rest of the island for conservation purposes. Unfortunately, the best habitat for the San Jose brush rabbit and the San José Island kangaroo rat (*Dipodomys insularis,* a critically endangered [CR] mammal; IUCN 2009) is the area scheduled for development, because it is the most attractive level area and is close to the best location for the proposed marina and airport.

The least imminent threat is the salt mine, which was intensively exploited until recently. The salt mine is close to the area of highest rabbit density and could be used for housing workers and equipment storage. Free-ranging dogs and cats belonging to the workers would then contribute to further predation on the rabbit.

The current conservation status of the San Jose brush rabbit should be based on the 20-km^2 area that the species occupies. Because the population density in optimum habitat is 25–35 individuals · km^{-2}, the maximum total population on the island could be between 500 and 700 individuals; in fact, the total population could be significantly lower. Following the IUCN Red List criteria, *S. mansuetus* could be considered critically endangered (CR) by criteria B1 (extent of occurrence estimated to be $<$100 km^2: subcriterion *a*, existing at only a single location, and subcriterion *b*, experiencing a continuing decline due to many threats; IUCN 2001). This analysis contrasts with the current consideration of *S. mansuetus* as near threatened (NT) by IUCN (2009).

The population density of *S. mansuetus* may be within the normal range for a cottontail in a desert habitat. For example, the density of Mexican cottontail (*Sylvilagus cunicularius*) in central Tlaxcala, México, is 27 ± 5.4 individuals · km^{-2} (González et al. 2007). Other cottontail rabbits found outside of warm-desert environments have variable densities that often exceed that of *S. mansuetus:* desert cottontail (*Sylvilagus audubonii;* 1630 individuals · km^{-2}) in northeastern Colorado (Flinders and Hansen 1973), eastern cottontail (*Sylvilagus floridanus;* 300–2000 individuals · km^{-2}) in the United States, mountain cottontail (*Sylvilagus nuttallii;* 6–250 individuals · km^{-2}) in Oregon, and swamp rabbit (*Sylvilagus aquaticus;* 40 individuals · km^{-2}) in Indiana (Chapman et al. 1982).

Sylvilagus mansuetus is part of the *bachmani* species group. A recent study of the endemic *Sylvlagus bachmani cerrosensis* from Cedros Island, off the west coast of Baja California Sur (density = 9.5 individuals · km^{-2}), demonstrated that this species is under predation pressure from feral dogs. The higher density of rabbits on San José Island may be related to a habitat that provides more favorable food and cover conditions (Bronson and Tiemeier 1959, Daniel et al. 1993), contrary to the conditions on Cedros Island. The cautionary lesson from Cedros Island

is that feral cats could severely impact the San Jose brush rabbit population on San José Island. Extirpation of cats on the island would certainly be a beneficial management strategy.

The current conservation status of *S. mansuetus* may become more critical with small changes in activities on San José Island. Environmental and anthropogenic factors that affect the San Jose brush rabbit population require urgent mitigation to conserve the species in the near future. Hence, we need to continue studies of this endemic rabbit to assess basic population ecology and determine if anthropogenically caused changes in abundance and density will affect its survival.

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