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Procyon pygmaeus (Carnivora: Procyonidae)

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Abstract: *Procyon pygmaeus* Merriam, 1901, commonly called the Cozumel raccoon, is a procyonid that is endemic to Cozumel Island, Mexico. It is the smallest member of the genus (about 45% lighter and 15–37% smaller in linear measurements than the mainland *P. lotor*). *P. pygmaeus* prefers mangrove stands and sandy areas, but it also can be found in semievergreen and subdeciduous tropical forests and agricultural areas. Diet is primarily composed of crabs followed by fruits, insects, crayfish, and small vertebrates. *P. pygmaeus* is listed as ''Critically Endangered'' by the International Union for Conservation of Nature and Natural Resources. Introduced congeners and predators, parasite and disease spillover from exotic animals, habitat fragmentation as a result of the expansion and widening of the road system and rapid development of other infrastructure for tourism, and hurricanes are the primary threats to this species.

Key words: endangered species, endemic species, Mexico, procyonid, pygmy raccoon

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Procyon pygmaeus Merriam, 1901
Cozumel Raccoon

Procyon pygmaeus Merriam, 1901:101. Type locality ''Cozumel Island, Yucatan,'' Quintana Roo, Mexico.

CONTEXT AND CONTENT. Order Carnivora, suborder Caniformia, family Procyonidae, genus *Procyon*, subgenus *Procyon*. *P. pygmaeus* is monotypic (Goldman 1950).

NOMENCLATURAL NOTES. Although the many similarities between *Procyon lotor shufeldti* and *P. pygmaeus* indicate a clear relationship, some specific characteristics suggest a long isolation of the latter (Goldman 1950). Body size and cranial characters have been sufficient to consider *P. pygmaeus* a separate species (Goldman 1950; Jones and Lawlor 1965; McFadden 2004; Merriam 1901). Examination of morphometric data from García-Vasco (2005) and McFadden (2004) supports that *P. pygmaeus* is a true dwarf and a separate species. Although genetic data by itself are not conclusive about the species status of *P. pygmaeus*, a holistic perspective, considering not only the allele diversity but also data on genetic differentiation, estimated divergence times of sequences, and morphometric data clearly support continuing

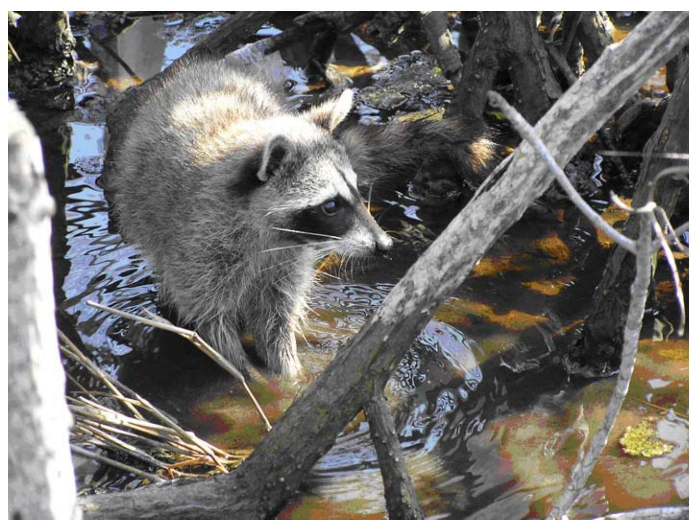

Fig. 1.—An adult female *Procyon pygmeus*. Photo by D. Valenzuela.

species-level recognition and strongly urge management of the population of *P. pygmaeus* independently from populations of *P. lotor* from the mainland (McFadden et al. 2008). *Procyon pygmaeus* is considered the only valid taxon among the insular raccoons from the Caribbean (Helgen and Wilson 2003, 2005; Helgen et al. 2008).

DIAGNOSIS

Procyon pygmaeus is the smallest species of the genus. *P. pygmaeus* can be easily distinguished from *P. lotor* by its much smaller size (total length < 710 mm, hind foot ≤ 90 mm; Fig. 1). Compared to *P. lotor*, *P. pygmaeus* has a reduction of nearly 45% in weight, 18% in total length, 28% in length of hind foot, and 28–37% in tail length (García-Vasco 2005). On average, *P. pygmaeus* is about 15% smaller than *P. lotor shufeldti*, the raccoon subspecies on the adjacent mainland (McFadden 2004). Compared to *P. lotor shufeldti*, *P. pygmaeus* has shorter and posteriorly more-rounded nasals, much smaller teeth (less than half the size of those of the former), relatively shorter and narrower rostrum, 2nd and 3rd upper premolars more spaced, and last upper molar with a narrower internal lobe (Goldman 1950; Hall 1981; Merriam 1901). Chin and throat are separated by a distinctive broad black band, and the tail is golden yellowish (Merriam 1901).

GENERAL CHARACTERS

External pelage of *Procyon pygmaeus* is similar in most respects to that of mainland *P. lotor* (McFadden 2004). Pelage at upper parts is light buffy gray uniformly mixed with black hairs, and with a pale buffy or yellowish tinge along the median dorsal area; some individuals have a narrow ochraceous buffy patch at the nuchal area; top of head is clearer, grizzled gray and black, and lacks the light buffy tone extending back; the typical black bar enclosing the eyes as a mask becomes brownish and usually more or less mixed with gray on middle of face; the black mask, sides of muzzle, lips, and chin are surrounded by white lines; the clearly defined patch crossing the throat is dark brownish to black; underparts and legs are thinly overlaid with light buffy hairs; tail is golden yellowish or ochraceous buffy with 6 or 7 dark rings; the brownish or blackish rings of tail are faint on underside (Goldman 1950; Merriam 1901). Males have a pronounced orange coloration on their neck scruff region and dorsal tail pelage compared to females (McFadden 2004).

External measurements (mm) of type (male) and topotype (female) specimens are, respectively: total length, 667, 665; length of tail, 230, 250; and length of hind foot, 90, 97 (Merriam 1901). Average (± *SD*) morphometrics (mm) of 32 adult *P. pygmaeus* from the northwestern section of Cozumel Island were: total length, 755.4 (± 73.7); length of tail, 243.2 (± 14.4); length of hind foot, 95.6 (± 4.4); width of hind foot, 25.2 (± 2.3); axillary girth, 318.7 (± 25.1); and neck circumference, 218.7 (± 16.7); mean body mass of the same individuals was 3,530 g (± 470—McFadden 2004).

In another study, the following average (± *SE*) morphometrics (g and mm) were reported, respectively, for 9 male and 14 female adult individuals (García-Vasco 2005): total length, 790.3 (± 15.9), 740.6 (± 6.1); length of tail, 256.2 (± 5.7), 243.1 (± 6.1); length of hind foot, 99.1 (± 1.9), 92.0 (± 0.6); length of ear, 45.9 (± 1.1), 43.5 (± 0.6); body mass, 3,812.8 (± 137.4), 3,146.0 (± 80). There is sexual dimorphism in *P. pygmaeus* with males being larger than females (García-Vasco 2005; McFadden 2004). Means and ranges of total length (mm) of 6 males and 7 females from Punta Chunchacab and Isla de la Pasión were, respectively (Navarro and Suárez 1989): 687 (675–708), 656.7 (580.0–680.0). Data from 2 separate samples (one of 20 males and 12 females and the other of 9 males and 14 females) from northwestern Cozumel showed independently that, on average, males are 11.2–19.6% heavier and 6.5% larger, have a thicker neck circumference, larger hind feet, and have canines 1 or 2 mm longer than females (García-Vasco 2005; McFadden 2004).

Skull of *P. pygmaeus* is small, short, and flattened, with a relatively broad braincase, broad frontal region, and a short, narrow rostrum; postorbital processes of frontals are well developed, the upper orbital border is concave, and the braincase is slightly depressed near the frontoparietal suture (Fig. 2; Goldman 1950). Skull measurements (mm) of type and topotype specimens were, respectively: greatest length, 100.0, 96.7; condylobasal length, 93.7, 91.9; zygomatic breadth, 58.8, 60.8; interorbital breadth, 19.5, 19.8; least width of palatal shelf, 12.5, 12.3; length of maxillary toothrow, 35.3, 35.5; length of crown of upper carnassial, 6.8, 7.0; and width of crown of upper carnassial, 7.8, 8.0 (Goldman 1950).

Skull measurements (mm) of the specimen (an adult male) deposited at the Colección Nacional de Mamíferos, Instituto de Biología—Universidad Nacional Autónoma de México, Mexico (CNMA 44027) are: greatest length, 108.5; skull height, 51.8; length of rostrum, 30.6; orbitonasal length, 26.6; interorbital constriction, 21.4; postorbital constriction, 23.0; zygomatic breadth, 67.5; mastoidal breadth, 54.0; basal length, 96.2; basilar length, 93.2; palatilar length, 63.6; palatal length, 66.1; postglenoid length, 25.8; length of maxillary toothrow, 39.8; length of mandibular toothrow, 46.0; mandible length, 76.4; nasal length, 26.3; nasal width, 12.2; interorbital width, 18.8; biorbital width, 51.9; braincase height, 30.8; and braincase width, 46.3 (D. Valenzuela-Galván and A. D. Cuarón, in litt.; Fig. 2). Interparietal bone measurements (mm) from an adult male are: length, 13 mm; and width, 8 mm (Jones and Lawlor 1965).

DISTRIBUTION

Procyon pygmaeus is endemic to Cozumel Island, Quintana Roo, Mexico, located 17.5 km off the northeastern

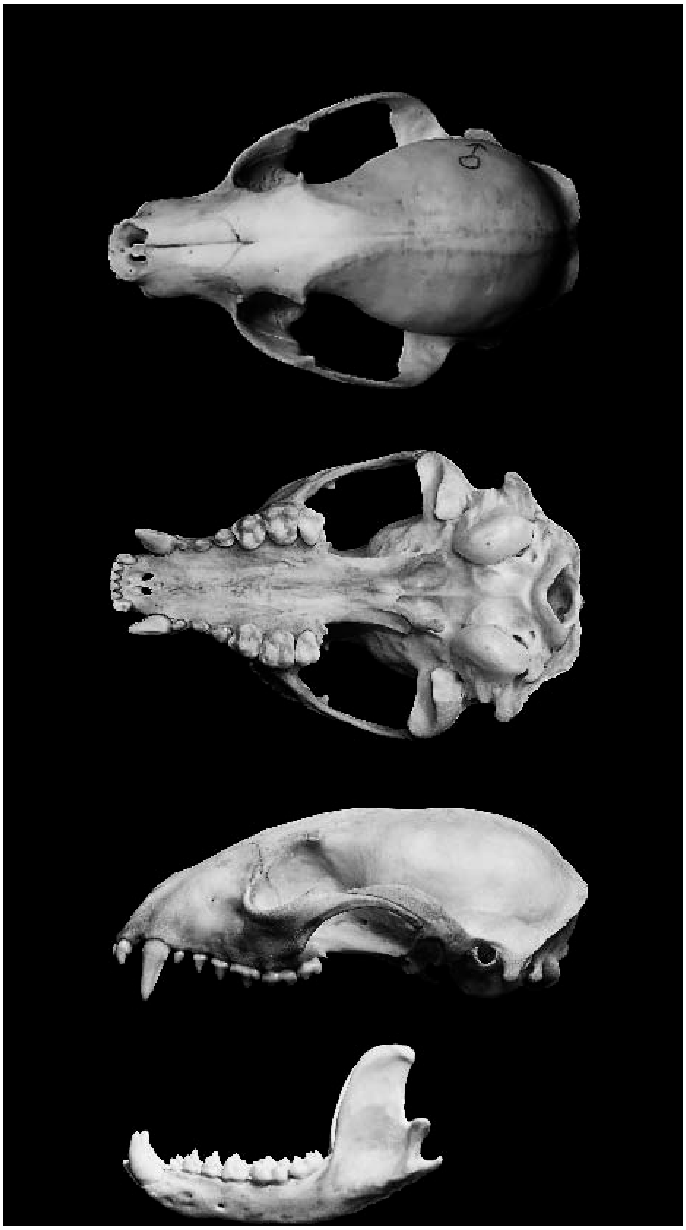

Fig. 2.—Dorsal, ventral, and lateral views of skull and lateral view of mandible of an adult male of *Procyon pygmaeus* deposited at Colección Nacional de Mamíferos, Instituto de Biología—Universidad Nacional Autónoma de México, México (CNMA 44027). Greatest length of skull is 108.45 mm. Photo by D. Valenzuela.

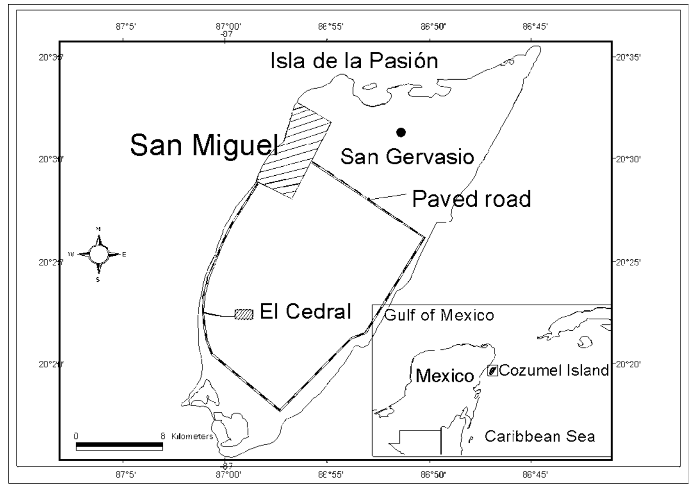

Fig. 3.—Geographic distribution of *Procyon pygmaeus*. Map redrawn from Cuarón et al. (2004).

coast of the Yucatán Peninsula, with an estimated area of 478 km^2 (Fig. 3; Cuarón 2009; Cuarón et al. 2004). In 1987 and 1988, *P. pygmaeus* was recorded at 5 localities: Isla de la Pasión, a site near San Miguel Cozumel, San Gervasio, El Cedral, and Punta Chunchacab (Navarro and Suárez 1989). After Hurricane Gilbert in 1988, *P. pygmaeus* at Isla de la Pasión seemed to have diminished in numbers or even disappeared (Navarro and Suárez 1989), but more recently one of use (A. D. Cuarón) has registered a significant population there. Between 1995 and 1999, *P. pygmaeus* was recorded in the southeastern section of the island, near Laguna Colombia (currently Punta Sur Park), and between 1999 and 2001 individuals were observed in the northeastern section near San Miguel (Cuarón et al. 2004). During surveys conducted across Cozumel Island between 2001 and 2003, *P. pygmaeus* was only captured at the most northwestern section of the island (García-Vasco 2005; McFadden 2004). However, during surveys conducted in 2005 and 2006 using olfactory stations, numerous tracks of *P. pygmaeus* were recorded in semievergreen forests in the central portion of the island (Bautista 2006; Copa-Alvaro 2007). In addition, in an intensive trapping study during 2006, *P. pygmaeus* also was captured and observed in that area of central Cozumel and to the northeast of San Gervasio archeological site, as well as in the northwestern section of Cozumel (Copa-Alvaro 2007).

FOSSIL RECORD

Geological evidence suggests that Cozumel Island emerged permanently by the late Pleistocene (Spaw 1978); thus, raccoons could in theory have colonized the island between 122,000 and 11,000 years ago (McFadden 2004). Examination of molecular clock data suggests that *Procyon pygmaeus* diverged from the mainland raccoon 47,570 $\pm$ 21,510 years ago (McFadden et al. 2008) but no fossil record supports this hypothesis. However, there is evidence that the ancient Maya from Cozumel used *P. pygmaeus* during Classic and Postclassic Mayan periods (1,900–500 years ago—Hamblin 1984). Subfossil remains of *P. pygmaeus* (19 bones including skull elements, mandibles, major limb bones, and vertebrae) have been found at various archeological sites on Cozumel Island (Hamblin 1984). These remains represent at least 13 individuals, mostly young adults and juveniles (Hamblin 1984).

FORM AND FUNCTION

The dental formula is i 3/3, c 1/1, p 4/4, m 2/2, total 40 (Fig. 2). Males possess a well-developed baculum. Length of baculum of the adult male deposited at the CNMA was 83.7 mm (D. Valenzuela-Galván and A. D. Cuarón, in litt.).

Locomotion in *Procyon pygmaeus* can be semiplantigrade or plantigrade. Tree climbing is documented in the literature (Jones and Lawlor 1965) and at our field sites we also observed that they easily climbed trees. Based on the molting patterns of other tropical procyonids it is suggested that *P. pygmaeus* molts in summer (McFadden 2004).

ONTOGENY AND REPRODUCTION

Inferences from body mass, dentition, and evidence of lactation in captured females suggest that the majority of births must occur between November and January (García-Vasco 2005; McFadden 2004). However, the capture of females with prominent teats in July and August suggests that another peak of births occurs in summer (García-Vasco 2005; Navarro and Suárez 1989).

ECOLOGY

Population characteristics.—Intensive trapping efforts have been done at 19 sites in Cozumel during 2002–2003 and 2006, but captures were obtained mostly at 3 sites in the northwestern tip of the island. Resulting estimates of subpopulation sizes varied between sites, ranging from 11 to 48 individuals (Copa-Alvaro 2007; McFadden 2004; McFadden et al. 2010). Density estimates also varied between sites and year of study, and ranged from 12.4 to 112 individuals/km^2 (Copa-Alvaro 2007; McFadden 2004). The overall ratio of females to males for all individuals at all sites was equal (1:1), of which adults made up the majority of captures (59%), followed by juveniles (22%), and subadults (19%; Copa-Alvaro 2007; Cuarón et al. 2009; García-Vasco 2005; McFadden 2004; McFadden et al. 2010). At Isla de la Pasión, the population size was estimated at no more than 20 individuals before Hurricane Gilbert in 1988 (Navarro and Suárez 1989).

Based on these data, and considering different methods to estimate habitat availability, total population estimates for *P. pygmaeus*, including juveniles, ranged from 323 (McFadden 2004) to a maximum of 955 individuals (Copa-Alvaro 2007), a population size that surely compromises its viability in the long term (Reed et al. 2003). During 2006, a total of 105 different individuals were caught indicating that the total population of *P. pygmaeus* is composed of at least this number (Copa-Alvaro 2007).

Fig. 4.—Several adult individuals from a mangrove site near the wharf to Isla de la Pasión. Note the ochraceous buffy coloration of the tail. These temporary aggregations of individuals are related to the exploitation of food supplemented by humans. Photo by A. D. Cuarón.

Contrary to the pattern of carnivore abundance hypothesized to occur in pre-Hispanic times (Hamblin 1984), recent surveys suggest that at present *P. pygmaeus* is more abundant and widespread than other carnivores at Cozumel Island (Copa-Alvaro 2007; Cuarón et al. 2004, 2009; McFadden 2004). In the semi-evergreen tropical forest of central Cozumel, the activity index, based on tracks recorded at olfactory stations, was higher for *P. pygmaeus* than for any other recorded mammal (Copa-Alvaro 2007).

Space use.—*Procyon pygmaeus* occupies a variety of habitats (Bautista 2006; Copa-Alvaro 2007; García-Vasco 2005; McFadden 2004). It is frequently found in mangrove stands and sandy coastal areas, which seem to be preferred habitats (Copa-Alvaro 2007; García-Vasco 2005; McFadden 2004; Navarro and Suárez 1989). *P. pygmaeus* also can be found in semievergreen and subdeciduous tropical forests and agricultural areas (Copa-Alvaro 2007; Cuarón et al. 2004; García-Vasco 2005; Goldman 1905; Jones and Lawlor 1965; McFadden 2004; Navarro and Suárez 1989). *P. pygmaeus* may inhabit areas that are in proximity to human settlements, as well as to paved and unpaved roads (Copa-Alvaro 2007; Cuarón et al. 2004; García-Vasco 2005; McFadden 2004). Limited information suggests that *P. pygmaeus* is mainly nocturnal, although it is not uncommon to see it during daylight. Generally it is a solitary mammal that sometimes forms family groups (Cuarón et al. 2004, 2009; Jones and Lawlor 1965) or temporary aggregations to exploit human-related food sources (see Fig. 4). Based on preliminary data from 8 radiocollared individuals a conservative estimation of average home range, considering 85% minimum convex polygons, was 67 ha (Cuarón et al. 2009; D. García-Vasco et al., in litt).

Diet.—Fecal samples from Isla de la Pasión showed that the diet of *Procyon pygmaeus* was primarily based on crabs and ants (Navarro and Suárez 1989). Crayfish, frogs, and occasionally other vertebrates, also were consumed (Hamblin 1984; McFadden et al. 2006; Navarro and Suárez 1989).

In addition, seeds of *Manilkara achras* and *Pithecellobium* and leaves of grass *Panicum* have been found in feces (Navarro and Suárez 1989).

Stable isotopes analyses of tissue samples from individuals collected in the northwestern area of Cozumel Island showed that crabs represent more than 50% of the diet of *P. pygmaeus*, followed by fruits and insects, with low variation between seasons, locations, sex, and age classes (McFadden et al. 2006). However, analysis of fecal samples, although in general confirming this, also showed that the relevance of the different food items varied between seasons and sites (McFadden et al. 2006).

Diet may change significantly following major changes in habitat quality. Comparison of nearly 300 fecal samples collected in 2006–2007, after 2 major hurricanes (Emily and Wilma) impacted Cozumel, revealed a lower relative importance of crabs and plant material in the diet and an increase in the importance of vertebrates than prior to the hurricanes in 2005 (Cuarón et al. 2009; Martínez-Godínez, in litt.).

Diseases and parasites.—As many other island species, *Procyon pygmaeus* is particularly vulnerable to introduced pathogens and diseases such as mange, rabies, and canine distemper from exotic animals (Cuarón et al. 2004, 2009; McFadden 2004; Mena 2007). In 1999 and 2001, a feral dog population infected with mange was observed close to population sites of *P. pygmaeus* (Cuarón et al. 2004), and although no infection incidence was measured in raccoons, it is known that *Procyon* can be infected with mange (Fitzgerald et al. 2004; Ninomiya and Ogata 2002). The parasites *Eimeria nutalli*, *Placoconus lotoris*, *Capillaria procyonis*, *Physaloptera*, a mite in the family Listrophoridae, and a trematode in the family Heterophyidae have been collected from individual *P. pygmaeus* (McFadden et al. 2005). The identification of *Toxoplasma gondii* in some *P. pygmaeus* suggests a recent spillover from domestic cats (McFadden et al. 2005).

Procyon pygmaeus has been exposed to infectious canine hepatitis, canine distemper, and feline panleukopenia viruses (McFadden et al. 2005; Mena 2007). During 2002–2003, 3.6% of *P. pygmaeus* ($n = 28$) were found to be positive for canine distemper (McFadden et al. 2005), whereas during 2006, 2.6% of raccoons ($n = 39$) were positive according to the immunofluorescence assay test (Mena 2007). In a preliminary study using the reverse transcriptase–polymerase chain reaction test, 30% of *P. pygmaeus* ($n = 10$) were found to be positive to morbillivirus, suggestive of canine distemper (Mena 2007).

Mena (2007) reported that 51% of *P. pygmaeus* ($n = 39$) presented antibodies against *Leptospira*, as detected by the microscopic agglutination test. The most common serovarieties were *calledoni*, *australis*, *bratislava*, *autumnalis*, and *canicola*. No difference was found between the percentage of animals with *Leptospira* antibodies in mangrove, semievergreen tropical forest, and the transition between both vegetation types. Most of these animals had low concentrations of antibodies against *Leptospira*, and only 3% were regarded as positive because they had concentrations greater than 1:100. In addition, 18% of *P. pygmaeus* were positive for the presence of *Leptospira* in blood or urine samples as detected by polymerase chain reaction testing. Nevertheless, none of the positive animals presented symptoms compatible with leptospirosis (Cuarón 2009; Mena 2007).

GENETICS

Limited information based on the analysis of 893 base pairs of mitochondrial DNA from 43 specimens indicates that individual *Procyon pygmaeus* share the same mitochondrial DNA haplotypes, which in turn suggests a recent population bottleneck that might be related to the founder effect (McFadden et al. 2008). Analysis of mitochondrial DNA also indicates that this species is genetically distinct from the Yucatan Peninsula *P. lotor* (i.e., the closest congeneric populations—McFadden et al. 2008). Although available genetic data are not conclusive in defining species status for *P. pygmaeus*, it has been strongly suggested to use a precautionary approach and consider this species at least as a distinct management unit (Cuarón et al. 2009; McFadden et al. 2008).

CONSERVATION

Although no natural enemies have been identified, *Procyon pygmaeus* is facing several human-induced threats (e.g., introduced congeners and predators, parasite and disease spillover from exotic animals, or habitat fragmentation—Cuarón et al. 2004, 2009).

Mainland individuals of *P. lotor* kept as pets on Cozumel Island represent a potential risk of genetic introgression that must be controlled more strictly (Cuarón et al. 2004, 2009; McFadden et al. 2008). Introduced predators such as domestic and feral dogs, and *Boa constrictor* (considered to be introduced to Cozumel in 1971—Martínez-Morales and Cuarón 1999), may have important impacts on the *P. pygmaeus* population. There is evidence that feral dogs predate on *P. pygmaeus* (Bautista 2006; García-Vasco 2005; McFadden 2004). Additionally, introduced carnivores could easily become a source of parasites and pathogens that could potentially negatively affect populations of *P. pygmaeus* (Cuarón et al. 2004; McFadden et al. 2005; Mena 2007).

Habitat fragmentation caused by the rapid development of infrastructure for tourism or other purposes is also an issue of concern. Although approximately 90% of the island remains covered by natural vegetation (Cuarón et al. 2009; Romero-Nájera 2004; Romero-Nájera et al. 2007), it has been divided into a northeastern, a central, and a southwestern region by a highway, which favors the economic development of human population and promotes the expansion of infrastructure and human settlements (Cuarón et al. 2004, 2009; McFadden 2004). This road was widened in 2006 to 4 lanes (about 25 m wide), potentially increasing its barrier effect and exacerbating its negative impact on the conservation of pygmy raccoons and other native species. Most cases of *P. pygmaeus* mortality documented since 2001 have been the result of animals being run over by cars on the island's highways (García-Vasco 2005).

Recreational and subsistence hunting does not appear to be currently impacting populations of *P. pygmaeus*, but in the past it has been reported that some individuals have been shot or poisoned at El Cedral and Isla de la Pasión to avoid damage to agricultural crops (Cuarón et al. 2004; Navarro and Suárez 1989).

Hurricanes are the main natural threat recognized for the Cozumel biota (Barillas 2007; Copa-Alvaro 2007; Cuarón et al. 2004, 2009; Perdomo 2006). After major hurricanes in 2005, a significant reduction in the density of *P. pygmaeus* and in the proportion of juveniles was recorded at some sites (Copa-Alvaro 2007). Although the 2005 hurricanes caused, in general, a tremendous negative impact on Cozumel's vegetation, *P. pygmaeus* survival probability was much lower at a mangrove site that was very intensely affected than at a semievergreen tropical forest site that was less disturbed by the hurricanes (Copa-Alvaro 2007).

During 2006, after 2 major hurricanes, in more than half of 39 *P. pygmaeus* subject to external physical medical examination, some sign of pathological change, including glaucoma, ectoparasites, external wounds, fractured teeth, and overall poor body condition, was apparent (Mena 2007). This was particularly acute in raccoons from mangrove areas.

The *P. pygmaeus* is included in the official Mexican list of threatened species as "En Peligro de Extinción" (Secretaría de Medio Ambiente y Recursos Naturales [SEMARNAT] 2010). Considering current threats and recent population data, *P. pygmaeus* has been categorized as "Critically Endangered" by the International Union for the Conservation of Nature and Natural Resources threatened species categorization system (Cuarón et al. 2008).

Important actions that have been proposed, and are at different degrees of implementation, to promote the conservation of *P. pygmaeus* and the native biota of Cozumel include an Ecological Ordinances Program (Programa de Ordenamiento Ecológico Local), the establishment of protected areas, an exotic species control program, a captive breeding program, a technical, undergraduate, and graduate capacity building program, and an environmental education and awareness program (Cuarón et al. 2004, 2009).

LITERATURE CITED

Barillas, A. L. 2007. Influencia de la exposición de borde sobre la estructura de la vegetación de la selva mediana en la Isla Cozumel. M.S. thesis, Universidad Nacional Autónoma de México, Ciudad de México, México.

Bautista, S. M. 2006. Distribución, abundancia y dieta de perros y gatos ferales en la Isla Cozumel. M.S. thesis, Instituto de Ecología A.C., Xalapa, México.

Copa-Alvaro, M. E. 2007. Efectos de los huracanes Emily y Wilma en la abundancia de mamíferos medianos en la Isla Cozumel, México. M.S. thesis, Universidad Nacional Autónoma de México, Ciudad de México, México.

Cuarón, A. D. 2009. Cozumel. Pp. 203–206 in Encyclopedia of islands (R. Gillespie and D. A. Clague, eds.). University of California Press, Berkeley.

Cuarón, A. D., M. A. Martínez-Morales, K. W. McFadden, D. Valenzuela, and M. E. Gompper. 2004. The status of dwarf carnivores on Cozumel Island, Mexico. Biodiversity and Conservation 13:317–331.

Cuarón, A. D., et al. 2008. *Procyon pygmaeus.* In IUCN 2008. 2008 IUCN Red list of threatened species. www.redlist.org, accessed 27 April 2011.

Cuarón, A. D., et al. 2009. Conservation of the endemic dwarf carnivores of Cozumel Island, Mexico. Small Carnivore Conservation 41:15–21.

Fitzgerald, S. D., T. M. Cooley, A. Murphy, M. K. Cosgrove, and B. A. King. 2004. Sarcoptic mange in raccoons in Michigan. Journal of Wildlife Diseases 40:347–350.

García-Vasco, D. 2005. Distribución, abundancia y aspectos poblacionales del mapache enano (*Procyon pygmaeus*), un carnívoro insular endémico. B.S. thesis, Universidad Veracruzana, Xalapa, México.

Goldman, E. A. 1950. Raccoons of North and Middle America. North American Fauna 60:1–153.

Hall, E. R. 1981. The mammals of North America. 2nd ed. John Wiley & Sons, Inc., New York.

Hamblin, N. L. 1984. Animal use by the Cozumel Maya. The University of Arizona Press, Tucson.

Helgen, K. M., and D. E. Wilson. 2003. Taxonomic status and conservation relevance of the raccoons of the West Indies. Journal of Zoology (London) 259:69–76.

Helgen, K. M., and D. E. Wilson. 2005. A systematic and zoogeographic overview of the raccoons of Mexico and Central America. Pp. 221–C236 in Contribuciones mastozoológicas: en homenaje a Bernardo Villa (V. Sanchez-Cordero and R. A. Medellin, eds.). Instituto de Biologia e Instituto de Ecologia, UNAM, Ciudad de México, México.

Helgen, K. M., J. E. Maldonado, D. E. Wilson, and S. D. Buckner. 2008. Molecular confirmation of the origin and invasive status of West Indian raccoons. *Journal of Mammalogy* 89:282–291.

Jones, J. K., Jr., and T. E. Lawlor. 1965. Mammals from Isla Cozumel, Mexico, with description of a new species of harvest mouse. University of Kansas Publications, Museum of Natural History 16:409–419.

Martínez-Morales, M. A., and A. D. Cuarón. 1999. *Boa constrictor*, an introduced predator threatening the endemic fauna on Cozumel Island, Mexico. Biodiversity and Conservation 8: 957–963.

McFadden, K. W. 2004. The ecology, evolution and natural history of the endangered carnivores of Cozumel Island, Mexico. Ph.D. dissertation, Columbia University, New York.

McFadden, K. W., M. E. Gompper, D. G. Valenzuela, and J. C. Morales. 2008. Evolutionary history of the critically endangered Cozumel dwarf carnivores inferred from mitochondrial DNA analyses. Journal of Zoology (London) 276:176–186.

McFadden, K. W., R. N. Sambrotto, R. A. Medellín, and M. E. Gompper. 2006. Feeding habits of endangered pygmy raccoons (*Procyon pygmaeus*) based on stable isotope and fecal analyses. Journal of Mammalogy 87:501–509.

McFadden, K. W., S. E. Wade, E. J. Dubovi, and M. E. Gompper. 2005. A serology and fecal parasitology survey of the critically endangered pygmy raccoon (*Procyon pygameus*). Journal of Wildlife Disease 41:615–617.

McFadden, K. W., D. García-Vasco, A. D. Cuarón, D. Valenzuela-Galván, R. A. Medellín, and M. E. Gompper. 2010. Vulnerable island carnivores: the endangered endemic dwarf procyonids from Cozumel Island. Biodiversity and Conservation 19:491–502.

Mena, H. 2007. Presencia de *Leptospira* spp. y moquillo canino en poblaciones de perros y carnívoros silvestres en la Isla Cozumel. M.S. thesis, Universidad Nacional Autónoma de México, Ciudad de México, México.

Merriam, C. H. 1901. Six new mammals from Cozumel Island, Yucatan. Proceedings of the Biological Society of Washington 14: 99–104.

NAVARRO, D., AND M. SUÁREZ. 1989. A survey of the pygmy raccoon (*Procyon pygmaeus*) of Cozumel, Mexico. Mammalia 53:458–461.

NINOMIYA, H., AND M. OGATA. 2002. Notoedric mange in two free-ranging North American raccoons (*Procyon lotor*) in Japan. Veterinary Dermatology 13:119–121.

PERDOMO, H. 2006. Caminos como barreras para el movimiento de aves y efectos del huracán Wilma, en una comunidad de aves de sotobosque de la selva mediana subcaducifolia de la Isla Cozumel. M.S. thesis, Universidad Nacional Autónoma de México, Ciudad de México, México.

REED, D. H., J. J. O'GRADY, B. W. BROOK, J. D. BALLOU, AND R. FRANKHAM. 2003. Estimates of minimum viable population sizes for vertebrates and factors influencing those estimates. Biological Conservation 113:23–34.

ROMERO-NÁJERA, I. 2004. Distribución, abundancia y uso de hábitat de *Boa constrictor* introducida a la Isla Cozumel. M.S. thesis, Universidad Nacional Autónoma de México, Ciudad de México, México.

ROMERO-NÁJERA, I., A. D. CUARÓN, AND C. GONZÁLEZ-BACA. 2007. Distribution, abundance, and habitat use of introduced *Boa constrictor* threatening the native biota of Cozumel Island, Mexico. Biodiversity and Conservation 16:1183–1195.

SECRETARÍA DE MEDIO AMBIENTE Y RECURSOS NATURALES (SEMARNAT). 2010. Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio-Lista de especies en riesgo. Jueves 30 de diciembre de Diario Oficial de la Federación, Ciudad de México.

SPAW, R. 1978. Late Pleistocene carbonate bank deposition: Cozumel Island, Quintana Roo, México. Transactions Gulf Coast Association of Geological Societies 28:601–619.

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