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Conservation of the endemic dwarf carnivores of Cozumel Island, Mexico

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Abstract

Cozumel Island, Mexico, harbours two endemic species of dwarf procyonids: the Pygmy Raccoon *Procyon pygmaeus* and the Dwarf Coati *Nasua nelsoni*. Both species are Critically Endangered, and are among the world's most threatened Carnivora. Here we summarise the research we have been conducting on their ecology, evolution, genetics, and conservation. We also summarise the conservation initiatives we have been undertaking and promoting in order to advance the conservation of these unique species and their habitats. This effort illustrates the importance of an interdisciplinary approach in conservation science and action in maximising effectiveness. Nevertheless, the precarious status of the species make it imperative to continue and expand the work we have carried out in Cozumel to prevent two imminent global extinctions.

Keywords: Critically Endangered, Dwarf Coati, interdisciplinary collaboration, island, *Nasua nelsoni*, *Procyon pygmaeus*, Procyonidae, Pygmy Raccoon

Conservación de los carnívoros enanos endémicos de la Isla Cozumel, México

Resumen

La Isla Cozumel, México, cuenta con dos especies de prociónidos enanos endémicos a ella: el Mapache Enano *Procyon pygmaeus* y el Pizote Enano *Nasua nelsoni*. Ambas especies están *En Peligro Crítico*, y se encuentran entre los carnívoros más amenazados de todo el planeta. Resumimos aquí parte de los estudios que hemos estado realizando sobre su ecología, evolución, genética y conservación. También presentamos un resumen de las iniciativas que hemos venido desarrollando y promoviendo para lograr la conservación de estas especies únicas y de sus hábitat. Este esfuerzo ilustra la importancia de adoptar un enfoque interdisciplinario en la ciencia y en la acción para la conservación con el fin de maximizar su eficiencia. No obstante, dado el precario estado de conservación de las especies, es imperativo continuar y ampliar el trabajo que hemos desarrollado en Cozumel para prevenir dos inminentes extinciones globales.

Palabras clave: colaboración interdisciplinaria, En Peligro Crítico, Isla, Mapache Enano, *Nasua nelsoni*, pizote enano, *Procyon pygmaeus*, Procyonidae

Introduction

Cozumel is the largest island in the Mexican Caribbean. It harbours a unique and impressive biological diversity, including at least 31 endemic animal taxa (Cuarón 2009). Three native carnivore species inhabit the island: two endemic procyonids (Pygmy Raccoon *Procyon pygmaeus* and Dwarf Coati *Nasua nelsoni*), and a dwarf grey fox with undetermined taxonomic position (probably an undescribed form of *Urocyon*) (Cuarón *et al.* 2004, Gompper *et al.* 2006). As is the tendency for insular fauna, these carnivores are smaller than their mainland counterparts (Goldman 1950, Jones & Lawlor 1965, Gompper *et al.* 2006). These species are Critically Endangered (Cuarón *et al.* 2004, McFadden *et al.* in press) and are two of the three top priorities in terms of Carnivora conservation in Mexico (Valenzuela & Vázquez 2007).

We constituted an interdisciplinary multi-institutional team in order to obtain high quality scientific information to propose objective solutions to the social and environmental problems of Cozumel Island, determining and working on priority management actions. We have developed numerous activities on Cozumel

since 1994-1995, and continuously since 2000. Here we summarise current knowledge of Cozumel endemic procyonids, and the work developed as part of an ongoing study on the ecology, evolution, genetics and conservation of the Cozumel biota, highlighting some of the initiatives we have been developing to promote the conservation of native biota of the island. A summary of the geography, history, archaeology, socioeconomic and biological characteristics of Cozumel Island has been published elsewhere (Cuarón 2009). Also, an extensive compilation of available information on *P. pygmaeus* is presented elsewhere (de Villa-Meza *et al.* in press).

Taxonomic status and genetics

Procyon pygmaeus, described by Merriam (1901), is the only valid taxon among the insular raccoons of the Caribbean (Helgen & Wilson 2003, 2005, Helgen *et al.* 2008). Evidence suggests that *P. pygmaeus* has been isolated from continental populations of *P. lotor* at least several thousand years (McFadden *et al.* 2008). Morphometric data for *P. pygmaeus* (McFadden 2004, García-Vasco

2005) confirm that it is a true dwarf, nearly 20% smaller than continental *P. lotor* in linear dimensions). Morphometrics and molecular data (mtDNA) together indicate that *P. pygmaeus* can be considered a species and should be managed independently of populations of mainland raccoons (McFadden *et al.* 2008).

The Dwarf Coati *N. nelsoni* was historically considered a distinct species, being strikingly smaller in both body and cranium size than continental White-nosed Coati *N. narica* (Merriam 1901, Thomas 1901, Jones & Lawlor 1965). Cozumel Dwarf Coatis measure 62–72% in total length (nose to tail) of *N. narica* from Arizona, western Mexico and Panama (Cuarón *et al.* 2004), as shown in Fig. 1. A craniometric study by Decker (1991), based on a small sample size ($n=6$), argued that the Cozumel coati deserved only subspecific status (*N. narica nelsoni*), but molecular data (McFadden *et al.* 2008) combined with morphological findings (Cuarón *et al.* 2004) strongly suggest species-level uniqueness. Although molecular data are limited reflecting the extreme scarcity of this species, both pairwise distances and coalescent divergence models suggest 1) levels of genetic differentiation similar to the genetic differentiation of *P. pygmaeus*, 2) colonisation of



Fig. 1. From left to right, crania of adult male *Nasua nelsoni*, adult female *N. narica*, and adult male *N. narica*, showing the conspicuous difference in size between the two species. The scale on the left is in centimeters (Photograph by David Valenzuela-Galván).

Cozumel Island well before Mayans arrived ~3,000 years before present, and 3) significant genetic differentiation from *N. narica* haplotypes from the Yucatan peninsula. Best evidence therefore suggests that, pending more robust data, the Cozumel coati be considered a distinct species (Cuarón *et al.* 2004). New morphometric and genetic studies of Dwarf Coatis are in process.

The available body of evidence supports species-level recognition for *Nasua nelsoni* and *Procyon pygmaeus* (McFadden *et al.* 2008). Both species are geographically and reproductively isolated, and genetically and morphologically distinct, from their mainland congeners (Figs 2 and 3). They should be treated as discrete taxonomic entities and, crucially, as separate management units (McFadden *et al.* 2008).

Ecology

Recent studies of *P. pygmaeus* population ecology, using intensive trapping, estimated that the total population is between 323 and 955 individuals, with a minimum number of 105 individuals (based on individuals that actually were captured) (McFadden



Fig. 2. Adult Pygmy Raccoons *Procyon pygmaeus* (Photo: Alfredo D. Cuarón)



Fig. 3. Adult Dwarf Coati *Nasua nelsoni* (Photo: K. McFadden).

2004, García-Vasco 2005, Copa-Alvaro 2007). Considering that 59.4% of captured individuals were adults (McFadden *et al.* in press), then the estimated number of mature individuals ranges from 192 to 567 (62, when one considers the minimum number of known individuals). Populations are heterogeneously distributed and tend to cluster near coasts; Pygmy Raccoons were captured only in three of 19 trapping locations. Average population estimates (\pm SE) for the three main known Pygmy Raccoon populations was 27.8 ± 5.5 individuals, ranging from 16 to 48 individuals (McFadden *et al.* in press). The estimated average density is 22 ± 5.1 Pygmy Raccoons/km² (McFadden *et al.* in press).

The Dwarf Coati is considerably scarcer than the Pygmy Raccoon. During 1994–1995 we used diurnal line transect sampling (386 km) to assess the population of large bird and mammal species on Cozumel (Martínez-Morales 1996, Martínez-Morales & Cuarón 1999, unpublished data). We estimated a Coati encounter rate of 0.05 ± 0.03 (mean \pm SE) individuals/10 km, equivalent to 0.43 ± 0.27 Dwarf Coatis/km² (Cuarón *et al.* 2004). Assuming Coatis were present throughout Cozumel tropical forests estimated a population of 150 ± 95 individuals (Cuarón *et al.* 2004).

Intensive trapping (>6,600 trap-days) in 2001–2003 in 19 separate locations throughout the island, including all main vegetation types, captured only a single coati (McFadden *et al.* in press). Undoubtedly, the Dwarf Coati is now exceedingly rare.

Main subpopulations of the Pygmy Raccoon are restricted to coastal areas of Cozumel (mainly in its northern half), and vast areas of the central part are uninhabited or have only very sparse subpopulations. Mangroves and other coastal vegetation are the preferred habitat, but the species is recorded also in areas of semi-evergreen and subdeciduous tropical forests and in agricultural areas (e.g. the vicinity of San Gervasio Archaeological Site, areas near El Cedral), and can be found close to human settlements or roads (Navarro & Suárez 1989, Cuarón *et al.* 2004, McFadden 2004, García-Vasco 2005, Copa-Alvaro 2007, McFadden *et al.* in press). Limited radio-telemetry data provide an initial home range estimate of nearly 70 ha (García-Vasco *et al.* unpublished data). Dwarf Coati sightings have occurred mainly in the tropical semi-evergreen forest of the island's interior, but we also have had sightings in coastal and mangrove areas.

Recent studies (McFadden *et al.* 2006, Martínez-Godínez *et al.* unpublished data), based on faecal analysis, and on stable isotope analysis of different tissues, showed that the diet of *P. pygmaeus* consists mainly on crabs, fruits and insects, and that it can change importantly between seasons and sites or after major changes in habitat quality (e.g. after hurricanes). We still have little information on the feeding ecology of the Dwarf Coati, but its habits seem similar to *N. narica*.

We have studied some of the ecological interactions of Cozumel carnivores. For instance, they are both predators and prey. Pygmy Raccoons are among the main predators of sea turtle eggs in Cozumel, but their populations are too small to pose significant threat to the conservation of these threatened reptiles (García-Vasco *et al.* unpublished data). On the eastern coast of Cozumel, the abundance of Pygmy Raccoons is linked to variations in chelonian nesting; sea turtle eggs and nestlings supplement the diet of Pygmy Raccoons during that part of the year in that region of the island. Meanwhile, although we know of no natural (native) enemies of the endemic carnivores, they are killed by feral dogs (McFadden 2004, García-Vasco 2005, Bautista 2006).

Conservation threats

We have previously described the main conservation threats faced by Cozumel carnivores (Cuarón *et al.* 2004). In sum, they are affected by introduced congeners (genetic introgression), introduced predators, parasite and disease spill-over from exotic animals, habitat fragmentation, hunting and collection of carnivores as pets, and hurricanes. Also, they can potentially be affected by overexploitation of underground freshwater, disturbance associated with an expanding human population and increasing development for tourists.

Below we elaborate on the threats faced by these species and their habitats. We have made evaluations of the effects of the different types of natural and anthropogenic disturbance, which are real or potential threats to the endemic carnivores of Cozumel or to the biota and society of the island. We have done this in order to understand what has brought the endemic carnivores and other threatened biota to the critical conservation status in which we currently find them, and to identify the necessary management actions.

Although hunting has been mentioned as a concern (Navarro & Suárez 1989), we have found that there is currently no significant hunting pressure in Cozumel, in general, and of the endemic carnivores, in particular (Navarro-Ramírez 2005). The introduction of continental *Nasua narica* and *Procyon lotor* onto the island (usually as pets), however, is indeed an important threat that needs to be addressed. The risk and potential for genetic introgression and pathogen and disease spill-over are high (McFadden *et al.* 2005, Mena 2007).

We have made assessments of land-cover (vegetation and land-use) changes in Cozumel using remote sensing techniques and Geographical Information Systems. Approximately 90% of the island remains covered with natural vegetation, and net land-cover change in the last few decades has been negligible (Romero-Nájera 2004, Multicriteria 2007, Romero-Nájera *et al.* 2007, Cuarón 2009). Thus, habitat loss *per se* is currently not a major threat for the endemic carnivores of Cozumel. There are several important caveats, however. A concern is that new major touristic developments (which will trigger land-cover changes) are likely to occur along the coast, overlapping with prime habitat for *P. pygmaeus* and, to a lesser degree, for *N. nelsoni*, resulting in habitat loss for these species, and creating potential wildlife-human conflicts. Although these carnivores (particularly, raccoons) may be able to persist near human settlements, it will be necessary that people learn to tolerate them, and that management actions to minimize conflict are implemented. All types of touristic developments, low or high density, will require attention to these considerations.

Another habitat conservation concern is that of roads. Roads cause major habitat loss and disturbance (Forman & Alexander 1998). The road system in Cozumel has expanded recently. New roads have been built, and part of the road system has been widened, with no infrastructure to facilitate the movement of organisms or attempt to maintain proper hydrological (and hence habitat) dynamics. There are plans to continue this expansion of the road system on the island. We have documented some of the pervasive negative effects of roads on the biota of the island (Perdomo 2006, Barillas-Gómez 2007, Fuentes-Montemayor *et al.* 2009). In the case of the endemic carnivores, particular concerns relate to road-induced mortality (road-kills and other), habitat loss and fragmentation, and the dispersal of exotic species (especially, feral dogs and cats). In fact, the main road in Cozumel has fragmented the forest of the island in three separate sections (Cuarón *et al.* 2004).

Exotic species are a significant problem on Cozumel Island and likely represent the greatest threat to the native biota on the island. Of particular importance are *Boa constrictor*, house mice and rats, and feral dogs and cats (Martínez-Morales & Cuarón 1999, Bautista 2006, González-Baca 2006, Torres-Villegas 2006, Mena 2007, Romero-Nájera *et al.* 2007, Sotomayor 2009). These species are a problem for the endemic carnivores of Cozumel because they are both predators and competitors, facilitate disease spill-over, and (in the case of their continental counterparts, *N. narica* and *P. lotor*) also genetic introgression. Exotic species also cause other environmental, public health and socioeconomic problems on the island.

Disease is another concern threatening the populations of the endemic carnivores of Cozumel and other wildlife. We have evaluated the presence of some diseases that could have implications for conservation, public and animal health (McFadden *et al.*

2005, Mena 2007, Sotomayor 2009). We have also explored possible connections between pathogens and diseases of endemic and exotic species on Cozumel. Our serological and parasitological surveys of Cozumel endemic carnivores show evidence of exposure to infectious canine hepatitis, canine distemper, feline panleukopenia virus, *Toxoplasma gondii*, and several serovarieties of *Leptospira* spp (McFadden *et al.* 2005, Mena 2007). Although no epizootic event has been found, the endemic carnivores of Cozumel are at risk of exposure to pathogens and parasites from feral, domestic and other exotic animals on the island (McFadden *et al.* 2005, Mena 2007).

Hurricanes are the most important type of natural disturbance affecting Cozumel (Cuarón *et al.* 2004, Perdomo 2006, Copa-Alvaro 2007, Rojas-Pérez 2007, Barraza *et al.* unpublished data). Cozumel is located in the main hurricane belt in the Caribbean, and at least one hurricane hits the island every decade (Martínez-Morales 1996). Major hurricanes in the Caribbean are predicted to become more frequent and more intense in the coming years (IPCC 2007). Major hurricanes may reduce *P. pygmaeus* numbers by as much as 60%, and may cause significant changes in age composition of subpopulations (Copa-Alvaro 2007). Additionally, after intense hurricanes an important proportion of *P. pygmaeus* subpopulations show signs of physical damage or stress (e.g., fractured teeth or overall poor body condition; Mena 2007). Paradoxically, sightings and capture success rate of *N. nelsoni* increased after the major hurricanes of 2005, perhaps as a consequence of food scarcity on the island which may have forced the animals to be more conspicuous because of defoliation— and which may have resulted also in greater trappability.

Conservation status

Both the Pygmy Raccoon and Dwarf Coati are included in the official Mexican list of threatened species (SEMARNAT 2002). The Pygmy Raccoon is considered “*En Peligro de Extinción*” (‘endangered’), and the Dwarf Coati is considered “*Amenazada*” (‘threatened’). It should be noted, however, that the species were assessed in 1994 based only on the opinion of experts, and did not use an objective method or explicit criteria (de Grammont & Cuarón 2006, Cuarón & de Grammont 2007). Although a new Mexican listing is currently under review, these species have not been re-assessed. Still, this standing provides official protection to the species in Mexico, which is vital for the conservation of the species and their habitats.

We have previously recommended that the Pygmy Raccoon and Dwarf Coati be categorised as Critically Endangered by IUCN (Cuarón *et al.* 2004, McFadden *et al.* in press). In the 2008 IUCN Red List of Threatened Species, the Pygmy Raccoon was indeed categorised as Critically Endangered (CR2a(i)b; Cuarón *et al.* 2008 [contra Schipper *et al.* 2008]), but the Dwarf Coati was considered a subspecies of *N. narica* (following Decker 1991), so was not assessed.

We hereby submit, based on new and emerging evidence, that *N. nelsoni* be elevated to species level for the IUCN Red List of Threatened Species. Categorisation of *N. narica* as Least Concern (Samudio *et al.* 2008) does not reflect the conservation situation of the Dwarf Coati. Based on our population assessments, as well as the rationale in Cuarón *et al.* (2004) and McFadden *et al.* (in press), we recommend that *N. nelsoni* be categorised as Critically Endangered (CR A2c + C2a(i)b), through an observed, es-

timated, inferred or suspected population size reduction of $\geq 80\%$ over the last 10 years and a decline in area of occupancy, extent of occurrence and/or quality of habitat (A2c). Like Pygmy Raccoon, there are estimated to be fewer than 250 mature individuals with no subpopulation holding more than 50, while there are extreme fluctuations in numbers of mature individuals due to periodic hurricanes (C2a(i)b) The conservation status of the Dwarf Coati is even worse than that of the Pygmy Raccoon, due to both its extreme scarcity and the large declines in population and extent of occurrence in the last half century (criteria A2c).

Conservation actions

Together with other non-governmental and governmental organisations, we used ‘lessons learned’ from our research programme in Cozumel to implement management actions towards solution of social and environmental problems on the island. The following are some actions important for conservation of Cozumel endemic carnivores.

As part of the development of habitat protection schemes, we coordinated the technical work in the development of the new (2008) Ecological Ordinance Program (*Programa de Ordenamiento Ecológico Local* – POEL) for Cozumel (SEDUMA 2008). A POEL seeks to determine the pattern of land occupation, minimising conflict and maximising consensus among stakeholders (e.g. tourism, agriculture, mining, conservation). This programme defines the areas important for conservation and development, and in which ways they can be used (through zoning), and setting the basis for habitat conservation and other activities on the island. As required in Mexico, the POEL was prepared through rigorous, systematic, transparent, democratic, and explicit procedures. The POEL, which has been decreed and published (SEDUMA 2008), reflects public participation from the different social sectors and stakeholders of Cozumel.

There are important gaps in terms of a strategic conservation plans for biodiversity and cultural heritage. There are currently one federal (marine) and two small state (land) protected areas on Cozumel. None provides significant habitat protection for the island’s endemic carnivores. The establishment of a substantial land protected area, covering representative portions of the island’s ecosystems while maximising extent and connectivity, has been proposed in the POEL. A protected area network designed and managed for the conservation of endemic flora and fauna is paramount for the long-term persistence of the endemic carnivores, as for other native biota of Cozumel.

Our proposals of new protected areas have gone through several stages. Initially, a proposal was presented for a Biosphere Reserve including marine areas complementing the existing (marine) Parque Nacional Arrecifes de Cozumel, but also considerable areas of the central and coastal portions of the island. This proposal was supported by the then municipal government and by the federal government, but lacked the complete approval of the state government. To overcome this situation, a strategy of two protected areas was discussed. Following the POEL, a state protected area would include a selection of land portions of the island (ideally with major habitat areas for the endemic carnivores), while a federal protected area would include the coastal lagoons in northern Cozumel and marine areas surrounding the island (which are all federal areas) complementing the existing national park. This federal protected area, however, would safe-

guard only a small fraction of Pygmy Raccoon habitat, and almost none for the Dwarf Coati and other terrestrial endemic taxa. The proposal for the federal area has gone through a successful public consultation (which started on 19 February 2008, and a second period was announced on 14 May 2009), and other legal requirements for establishment of federal protected areas. At this stage it is not clear if or when the terrestrial state protected area (which actually could protect significant areas of habitat for the endemic terrestrial biota of Cozumel, including the carnivores) will be established. The technical and social justification for new protected areas in Cozumel has been presented and the situation is now in the hands of the government. Delaying this process further will result in continuing declines of endemic species. Consistent with the POEL, private protected areas are being encouraged. This is particularly important in and adjacent to tourism developments, as buffer areas, so that no undesirable unplanned or unregulated urban settlements are created, disturbing or destroying wildlife habitats.

Additionally, we developed an exotic species control programme in Cozumel. Together with the municipal government, the Sociedad Humanitaria de Cozumel, and other concerned parties, we negotiated and promoted a coalition of institutions and individuals to work on the subject. Since 2005 significant progress has been made in the stray (urban) dog control, having developed a permanent animal control campaign in the urban area (over 3,000 stray dogs have been despatched in a three-year period), sterilisation and adoption programmes, population monitoring, an assessment of the effectiveness of the programme, and an education programme. In addition to continuing this work, it is necessary to expand to urban stray cats, feral cats, feral dogs, house rats and mice, and the introduced snake *Boa constrictor*.

In collaboration with leading Mexican zoos, we are in the process of developing a collaborative captive breeding programme for some Cozumel endemic species. The first candidate is the Pygmy Raccoon (obtaining a founding population of Dwarf Coatis is extremely difficult at this point). Critical consideration will be given to health issues, as insular carnivores may have not been exposed to pathogens found on the mainland. Discussions have been underway so that proper facilities and resources are allocated for the species, with particular concern to the animal welfare and sanitary conditions, before obtaining the founding captive population. This work is still in its early stages and, given the critical status of these species, it is necessary to accelerate it. Education and public awareness work will be integral.

Capacity-building is a priority of our team. Numerous graduate and undergraduate students have participated, with their thesis and research carried out on the biota or society of Cozumel. We also provided training on environmental education and evaluation techniques for teachers and professionals of governmental and non-governmental organisations on the island and elsewhere. Some former students now collaborate with local, regional, national, or international governmental, non-governmental or academic institutions.

As a part of our research programme we evaluated environmental perceptions, attitudes and knowledge of Cozumel's resident population and visitors (Navarro-Ramírez 2005, Arista 2009, Barraza *et al.* unpublished data). This captures valuable local knowledge about the island and its biota, and reveals aspirations and goals in the lives of Cozumel's inhabitants, essential information for design and development of educational and management



Fig. 4. People wearing Pygmy Raccoon t-shirts and disguises at the 2009 Cozumel Carnival. The t-shirts say "I ♥ the Pygmy Raccoon of Cozumel" (Photo by Petrus).

programmes consistent with the needs and ambitions of the local people (Barraza 2000). We developed educational activities with children, teachers, and parents at schools and other places. We also work very actively, including through local media, to disseminate lessons learned in our research programme and inform the general population about the management actions undertaken or necessary to promote biological diversity conservation in Cozumel. Fostering pride in the unique natural and cultural heritage of the island, such as using costumes in local parades (Fig. 4), is an important aspect. We seek to encourage and enhance a positive environmental culture in the local and visiting population.

Final remarks

We have made considerable progress in learning about the ecology, evolution, genetics and conservation of Cozumel endemic carnivores, and important steps in establishing bases for essential conservation management actions. Conservation requires long-term commitment, reliable information, dedication and action. Contrary to most research and conservation initiatives in the terrestrial part of Cozumel Island, our programme is not a short, intermittent or isolated effort, but a long-standing coordinated one, with a broad vision, for the conservation of biodiversity, humanity, and their interactions. This illustrates the importance of interdisciplinary approaches to maximise effectiveness of conservation science and action. Nevertheless, the conservation status of Cozumel endemic carnivores is precarious. The Pygmy Raccoon and the Dwarf Coati verge on extinction: they are among the world's most threatened carnivores and it is imperative to continue and expand work on Cozumel Island to prevent two imminent global extinctions.

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