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Patagonian Weasel *Lyncodon patagonicus* (Photo: Darío Podesta).

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EDITORIAL

# Small carnivores in the Americas: reflections, future research and conservation priorities

The Small Carnivore Specialist Group includes among its mandate the gathering and dissemination of data and knowledge for a group of species seemingly unnoticed by many conservationists, researchers, government management authorities and funders. In fact, an emerging major source of data on small carnivores is the ancillary information from projects about larger and more charismatic species (e.g. Jaguar *Panthera onca*), which are much easier to raise funds for and consequently the focus of many researchers and non-government organisations. A common example is the use of data from camera-trap surveys of such animals (see González-Maya *et al.*).

There is great disparity in the amount of published information and hence our 'state of knowledge' between the small carnivore species. Most of the last 20 issues of *Small Carnivore Conservation* have a strong predominance of coverage towards Asia, especially Southeast Asia. This is strategic because this is where the greatest threats lie, but also it reflects: 1) limited evolving process to capture information in many other regions; 2) huge regional deficiencies in data generation due to both paucity of research, and political and social dimensions beyond our control; and 3) that only a few of the projects that do exist publish their data. The two glaring geographic gaps for small carnivore information are Latin America and Africa. Both contain species of small carnivores which are common but about which we know almost nothing. Thus, we felt it prudent to focus occasional special issues of *Small Carnivore Conservation* on little-known regions, to take stock and consolidate what we do know into an accessible form, and to highlight priorities for future research.

Following the IUCN Red List Assessment for 2008 we are identifying a network of experts in the various regions and for each species. With the International Mammalogical Congress to be held in Mendoza, Argentina, in August 2009, the American continents were the clear first choice to trial this approach. Indeed, this special issue is published ahead of its normally scheduled date to coincide with the Congress.

We started organising this issue with three questions: 1) what is the next step after defining threatened species and clarifying the status of several?; 2) can we fill critical data gaps?; and 3) how do we keep species off the IUCN Red List to begin with? First, we wanted to verify and update the conservation status for all threatened species. Second, we wanted a long hard look at each species considered Data Deficient. Finally, we wanted to use experience gained in species recovery to highlight the need to move from discussions of threats and declines to applied research and on-the-ground action.

In the regional context, this seemed not so daunting. In general, small carnivores of the Americas are not faring as badly as in Southeast Asia, for example. Of the 46 species of native small carnivores (Procyonidae, Mephitidae and Mustelidae, including for this purpose, otters) recognised here for the Americas, only eight (17%) are threatened and five (11%) are considered Data Deficient (Belant *et al.*). These figures do not include Eastern Mountain Coati *Nasuella meridensis* or Dwarf Coati *Nasua nelsoni*, not currently assessed on the IUCN Red List (but see Cuaron *et al.*, for preliminary assessment) or the two introduced species, Stone Marten *Martes foina* and Small Asian Mongoose *Herpestes javanicus*. In sum, four species of small carnivores are threatened and not recovering, and therefore need urgent conservation attention. Two (Pygmy Raccoon *Procyon pygmaeus* and Dwarf Coati) occur only on a single small island off the Caribbean coast of Mexico, another (Pygmy Spotted Skunk *Spilogale pygmaea*) along the Pacific Coast of Mexico, and the fourth (Colombian Weasel *Mustela felipei*), in the high Andes of Colombia and Ecuador, is known only from a handful of records.

Have we learned anything from the Black-footed Ferret *M. nigripes* recovery (Jachnowski & Lockhart) to help recover other threatened species? The answer is a resounding 'yes', but there is no secret or fixed formula to successful recovery. The longer we wait, the more resource-intensive recovery becomes. It takes political and social will as well as money, none of which is easy to come by in regions with larger issues at hand, and several hundred species requiring conservation attention and action (such as Mexico and Colombia).

However, one would think that the conservation community could pull together to save two charismatic small carnivores and a handful of other threatened endemic taxa on a small Caribbean tourist destination (Cozumel) in the Mexican 'Riviera'. The scientists and politicians have done so, but only after much of the remaining habitat was lost to development and land conversion. To add insult to injury, a series of hurricanes flattened almost all remaining habitat, making the situation even more urgent. These remaining populations are severely reduced, and mustering the required political and social forces is a daunting task, especially with so few individuals remaining in the wild.

The Colombian Weasel and mountain coatis, all of the Northern Andes, suffer both from extensive habitat alteration and lack of research and conservation. As the banner suggests in Bogota airport, 'Drugs, cartels and wars are so 1990s: this is the new Colombia' - threats to these species are not just the often assumed coca and guerilla warfare problems. The weasel is a high-elevation species perhaps threatened as much by misidentification as by deforestation through logging and for farmland, urbanisation and fragmentation (see Burneo *et al.* and Tirira *et al.*). Similar syndromes affect several other Andean species, and the scarcity of information forestalled assessing the then Mountain Coati for the 2008 Red List: it is now considered to be two species (see Balaguera-Reina *et al.*, Helgen *et al.*).

To clarify the necessary links between science and policy which affect recovery, we need to understand if the Black-footed Ferret is recovering as a result of listing on the US Endangered Species Act (ESA). Most Latin American countries also have national Red Lists and national species priority lists: the principal difference from the ESA is that the ESA has 'teeth': legal ramifications (e.g. penalties for harming Critical Habitat), financial support to research, recovery, habitat conservation and an enforcement body (the US Fish & Wildlife Service), not to mention numerous independent organisations which monitor recovery efforts (see Jachnowski & Lockhart). However the ESA, weakened in recent years, is not without its problems. We do, however, conclude that in bridging science and policy, we can use national lists to guide laws which are enforceable.

The Black-footed Ferret recovery reflects a combination of funding, will within national, local and tribal governments, public support, and a dedicated group of scientists who went out on a limb to save this species. Vital is the interagency, interdisciplinary, strategic conservation and recovery plan joining politics and science for a common good. Importantly, threats diminished following ongoing adaptive research, education and community outreach. However, it has taken nearly 20 years and millions of dollars, and is not over yet. We do not have resources on this scale for each threatened small carnivore, highlighting the need, strategic and financial, for proactive measure to keep species from becoming threatened and to invest in win–win situations for humans and carnivores. Adequate research to clarify the status of little-known species (Balaguera-Reina *et al*., Kasper *et al*., Prevosti *et al*.) and regions (Oliveira), and the effects of potentially threatening processes (Proulx) may allow action before a crisis situation is reached: this is more desirable than recovery plans and conservation fire-fighting.

That the Black-footed Ferret is still with us means that we can halt extinction, not just purely to save a small carnivore, but to benefit *Homo sapiens*. This species offers ecosystem services for human welfare and wellbeing, living in obligatory communion with prairie dog *Cynomys* spp. colonies, the proliferation of which enhance soil quality and native plant communities of the prairies. That prairie ecosystems and soil quality also benefit us should come as no surprise.

We learned several things in assembling this issue. We know a lot less about small carnivores of the Americas than we thought, especially in Latin America. We realised that as scientists and biologists we are not doing a very good job ‘selling’ our products to meet shifting global information demands. To show the importance of small carnivores in *many* ecosystem services (e.g. controlling pest rodents) will reach new audiences, resources and conservation tools. To focus some efforts on community-scale projects to reveal both the species-level data and the broader context of ecosystem services rendered – then maybe we can muster what we need to keep species off the threatened list. We cannot change the ebbs and flows of global funding but we can do a better job of tying our science and our species of interest into the context of humanity.

In sum, five research and conservation priorities seem especially relevant to Latin America (where lie most of the data gaps and threats), but can be applied elsewhere:

1. *Recovery*: to keep species off the various threat lists, we need examples of success and lessons learned from unsuccessful efforts. Documentation of what it takes to recover threatened small carnivore species, reverse population declines and keep species out of threat categories, is rare.
2. *Inventory and monitoring research*: at least five species are considered Data Deficient: they very well could be threatened, so clearly are research priorities. Interventions for species already threatened are urgent, with monitoring of populations to assess progress.
3. *Data sharing and accessibility*: some data available are not readily and widely accessible (grey literature, regional reports, etc.). Even more lamentable are the transitory potential data, generated but never captured for eternity, which we need to make available through data sharing and partnerships, e.g. collating by-catch data and then placing them in the public domain.
4. *Education*: we need to educate ourselves, decision-makers and the public on the importance of these species intrinsically, and as part of the ecosystem, and the vital underpinnings of healthy ecosystems to human health and even persistence.
5. *Interdisciplinary studies*: we need to continue to work collaboratively and extend our cross-boundary networks of government management agencies, scientists, conservationists and donors, to ensure the conservation of small carnivores. Linkage of ecological and social sciences to answer complex questions about human aspects, interactions and benefits from small carnivores is so far rare.

We only hope that herein we have encouraged the process by highlighting both species-specific and regional issues – and that more people in the region will see *Small Carnivore Conservation* as a place both to publish their research, observations, lessons learned and notes, and to which they will alert more generalist conservation practitioners.

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# The conservation status of small carnivores in the Americas

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## Abstract

Global conservation status of small carnivores with geographic range in the Americas was assessed using the 2008 IUCN Red List. Small carnivores as categorised by IUCN, including otters, in the Americas represent about 26% of the extant small carnivores worldwide. Familial diversity is low, with only three of the world's nine families (Mephitidae, Mustelidae and Procyonidae) represented. Greatest species richness occurred in Central America, the Andes Mountains, and the west coast of the United States of America. Of the small carnivore species currently evaluated on the global *2008 IUCN Red List of Threatened Species*, 46 are native to the Americas (43 endemic), one is Extinct (EX), six are Endangered (EN), two are Vulnerable (VU), one is Near Threatened (NT), 31 are Least Concern (LC), and five are Data Deficient (DD). Cozumel Coati *Nasua nelsoni* and Eastern Mountain Coati *Nasuella meridensis* are excluded from these analyses because their taxonomy was modified after the *2008 IUCN Red List of Threatened Species*. No small carnivore species of the Americas are currently listed as Critically Endangered (CR) or Extinct in the Wild (EW). Thus, for extant species with data adequate to assign a status, 20% were considered globally threatened (i.e. CR, EN or VU), primarily a result of four of the region's five otter species being categorised as Endangered. The exact threat level is unknown, but is between 18% (if no Data-Deficient species is threatened) and 29% (if all are). Global populations are estimated to be declining for 62% of carnivore species with adequate data and stable for 29%; only 9% of small carnivore species populations are estimated to be increasing. The five (11%) categorisations as DD are in part a consequence of recent taxonomic revision. Although overall conservation status of small carnivores in the Americas compares favourably with mammals worldwide, declining populations of many species and existing and new threats (e.g. climate change) suggest that additional small carnivore species may become threatened unless effective conservation strategies are implemented.

*Keywords*: conservation status, Data Deficient, Endangered, IUCN Red List, Least Concern, Mephitidae, Mustelidae, Procyonidae, species richness, Near Threatened, threatened, Vulnerable

## Estado de conservación de los pequeños carnívoros en las Américas

## Resumen

El estado de conservación global de las especies de pequeños carnívoros, cuyos ámbitos geográficos incluyen las Américas, fueron evaluados usando la Lista Roja de UICN de 2008. Los pequeños carnívoros de las Américas representan cerca del 28% de los pequeños carnívoros vivientes a nivel mundial. Sin embargo, la diversidad de familias es baja, representado por solo 3 de 9 familias (Mephitidae, Mustelidae y Procyonidae). Las mayores riquezas de especies ocurren en Centro América, los Andes, y la costa oeste de Estado Unidos. De las 46 especies de pequeños carnívoros nativos de las Américas (43 endémicas), una esta extinta (EX), seis están Amenazadas (EN), dos son Vulnerables (VU), una es Casi Amenazada (NT), 31 de Baja Preocupación (LC) y cinco fueron consideradas Deficientes de Datos (DD) en términos de las evaluaciones de Lista Roja. No incluimos el Coati de Cozumel *Nasua nelsoni* y el Coatí de Montaña del Este *Nasuella meridensis* ya que su taxonomía fue modificada posterior a la Lista Roja de UICN 2008. Ninguna especie fue listada como Críticamente Amenazada (CR) o Extinta en la Naturaleza (EW). Para las especies con datos adecuados para asignarles una categoría, 20% fueron considerados globalmente amenazados (ej. CR, EN o VU), principalmente como resultado de que cuatro de las cinco especies de nutrias de la región fueron consideradas Amenazadas. Las estimaciones globales de poblaciones fueron consideradas en declive para el 62% de las especies con datos adecuados, 29% fueron considerados estables y solo el 9% fueron considerados en aumento. Cinco especies (11%) fueron consideradas DD, en parte debido a su reciente revisión taxonómica. A pesar de que el estado de conservación general de los pequeños carnívoros de las Américas es favorable comparado con los mamíferos a nivel mundial, el estado general de poblaciones en declive y la presencia de nuevas amenazas (ej. cambio climático) y aquellas que previamente existían, sugieren que más especies de pequeños carnívoros pueden convertirse en amenazadas a menos que estrategias de conservación efectivas sean implementadas.

*Palabras clave*: amenaza, Amenazada, Baja Preocupación, Casi Amenazada, Deficiente de Datos, estado de conservación, Lista Roja de UICN, Mephitidae, Mustelidae, Procyonidae, riqueza de especies, Vulnerable

### Introduction

Small carnivores play important roles in ecosystem function (e.g. seed dispersal), predator–prey dynamics, and in relation to people (e.g. hunting, disease; Graham & Lambin 2002, LoGiudice & Ostfeld 2002, Sterner *et al.* 2008). Similarly, a wide variety of anthropogenic threats (e.g. climate change, harvest, habitat loss and fragmentation) demonstrably effect small carnivore species adversely (Carroll 2007, Koen *et al.* 2007, Medina-Vogel *et al.* 2007a). Numerous studies have assessed the effects of these threats on mammalian species, including small carnivores (Hargis *et al.* 1999, Carroll *et al.* 2003, Whiteman *et al.* 2007). The global conservation status of all mammals worldwide was assessed for the *2008 IUCN Red List of Threatened Species* (Schipper *et al.* 2008b) and results were summarised for small carnivores worldwide by Schipper *et al.* (2008a). We report on the conservation status of all small carnivores (Mephitidae, Mustelidae and Procyonidae) in the Americas.

The Americas cover about 8.3% of the Earth's total surface and 28.4% of the Earth's total land area. North America and Central America are about 24,709,000 km² in size and South America about 17,840,000 km². The Americas are bounded with coastal mountains on the Pacific and Atlantic Coasts. The western portion is dominated by the American Cordillera, a near-continuous series of mountain ranges extending from the Brooks Range in Alaska to the southern extent of the Andes Mountains in Chile and Argentina. The eastern coast includes the Arctic Cordillera along the east coast of Canada; the Appalachian Mountains which extend about 2,400 km from Newfoundland, Canada to central Alabama in the United States; and the Brazilian Highlands including much of eastern, southern and central Brazil. Dominant rivers include the Amazon in South America with the largest drainage basin in the world (~6,915,000 km²) and the Mississippi–Missouri System in North America which is the fourth longest in the world (~6,300 km). About 13.6% (930 million) of the estimated total human population (6,829 million in 2009) occurs in the Americas with 582 million in Latin America and the Caribbean and 348 million in Northern America (United States, Canada, Greenland, Bermuda, Saint Pierre and Miquelon; United Nations Population Division 2009).

## Materials and methods

Methods to assess the conservation status of the world's mammals for the *2008 IUCN Red List of Threatened Species* were reported by Schipper *et al.* (2008a, 2008b). In contrast to previous mammal conservation assessments, this one was supported by peer-reviewed documentation. Basic information was collected on distribution, population size and trends, habitat use, ecology, threats, and conservation actions for each species. In addition, full documentation was supplied to support the decision criteria for the categories and criteria used in each assessment. A digital map of the geographic range of each species was developed in a Geographic Information System. Small carnivore species occurring in the Americas were assessed using expert consultation during 2006–2008, and were then evaluated by regional and taxonomic experts during a workshop held at the Regional Institute of Biodiversity (IRBio), Zamorano, Honduras, on 30 January 2008.

We report on the results of the 2008 IUCN Red List for all species of small carnivores, defined for the present purposes as species in the order Carnivora within the remits of the IUCN/Species Survival Commission (SCC) Small Carnivore Specialist Group (SCSG) and the IUCN/SSC Otter Specialist Group (OSG), with native geographic distributions in the Americas; we excluded small carnivores introduced to the Americas (Small Asian Mongoose *Herpestes javanicus* and Beech Marten *Martes foina*). Status for each species refers to their global status, not their status specific to the Americas. Data used in this paper are freely available online (IUCN 2008)

## Results

Three families of small carnivores occur partly or entirely in the Americas, representing 20 genera and 46 species under the classification followed by IUCN (Appendix), which is broadly based on Wozencraft (2005); there are many points of taxonomic uncertainty and the species count is evolving with further research. For example, neither Cozumel Coati *Nasua nelsoni* nor Eastern Mountain Coati *Nasuella meridensis* were treated as species in the 2008 IUCN Red List assessment, but strong arguments exist for ranking them as such (Cuaron *et al*. 2009, Helgen *et al.* 2009). The most speciose extant family in the Americas is Mustelidae (22 species), followed by Procyonidae (14 species) and Mephitidae (10 species). Areas of greatest species richness of small carnivores occur throughout Central America, with areas of moderate species richness across the Andes Mountains in South America and along the west coast of the United States (Fig. 1).

Of the 46 small carnivore species native to the Americas, of which 43 are endemic, the *2008 IUCN Red List of Threatened Species* indicates that about 2% are Extinct (EX), 13% are Endangered (EN), 4% are Vulnerable (VU), 2% are Near Threatened (NT), 67% are of Least Concern (LC), and 11% are Data Defi-

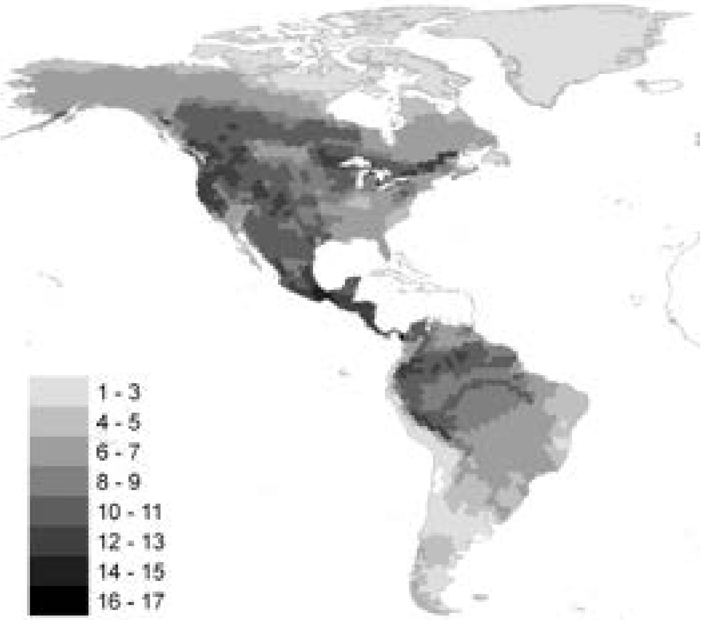

*Fig. 1. Species richness of small carnivores in the Americas based on the 2008 IUCN Red List.*

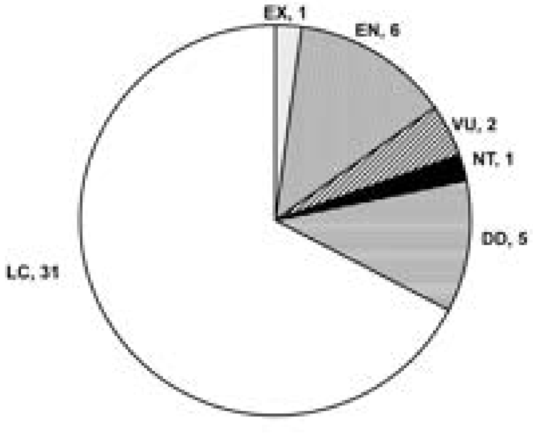

*Fig. 2. 2008 IUCN Red List global conservation status by category for small carnivores in the Americas. EN = Endangered, EX = Extinct, VU = Vulnerable, NT = Near Threatened, LC = Least Concern, DD = Data Deficient. Numbers refer to the number of species in each category.*

cient (DD) (Fig. 2). No carnivore species were listed as Critically Endangered (CR) or Extinct in the Wild (EW). For those extant carnivore species with adequate data to assign a status ($n = 40$), 20% were considered globally threatened (i.e. CR, EN or VU). The exact threat level for small carnivore species lies between 18% (assuming no Data-Deficient species threatened) and 29% (assuming all Data-Deficient species threatened).

Of the eight species considered globally threatened, five (Sea Otter *Enhydra lutra*, Marine Otter *Lontra felina*, Southern River Otter *Lontra provocax*, Giant Otter *Pteronura brasiliensis* and Pygmy Spotted Skunk *Spilogale pygmaea*) were listed using the A Criterion (population decline), two (Colombian Weasel *Mustela felipei* and Cozumel Raccoon *Procyon pygmaeus*) using the B Criterion (geographic range size), none using the C Criterion (population size and decline), one (Black-footed Ferret *Mustela nigripes*) using the D Criterion (very small or restricted population), and none using the E Criterion (quantitative analyses). Four of the threatened small carnivore species (Black-footed Ferret, Cozumel Raccoon, Pygmy Spotted Skunk, and Sea Otter), occur in North America; all are endemic with the exception of the Sea Otter which also occurs in the Northwest (Asian) Pacific Ocean (Fig. 3).

The percentage of species considered globally threatened varied across families, with more than a quarter (29%) of Mustelidae currently threatened (Fig. 4). This is a consequence of four of the region's five globally threatened species being otters. Excluding the otters, the threatened percentage within the Mustelidae is about 13%; and for the otters endemic to the Americas, the proportion of threatened species is 75%. In contrast, only 7% of the Procyonidae and 10% of the Mephitidae were considered globally threatened. Treating only extant species with adequate data to assess whether or not they are globally threatened (i.e., non Data Deficient), the percentage of threatened species increases slightly to 32% for Mustelidae, 10% for Mephitidae and 9% for Procyonidae. Within Mustelidae, the percentage of globally threatened species excluding otters is 14%; the percentage of otters is 80%.

*Fig. 3. Distribution of small carnivores in the Americas classified as globally threatened based on the 2008 IUCN Red List (black indicates a single species; note that island species such as* Procyon pygmaeus *and* Nasua nelsoni *are not visible at this scale).*

Overall, only five (11%) small carnivore species in the Americas are considered Data Deficient. This category (DD) is used for species that could not safely be categorised as Least Concern because insufficient information is available to evaluate ongoing threats. Therefore a status of DD does not mean a species is not threatened: it means we need more information to assess its threats. There are no Data Deficient species in Mephitidae, in contrast to about 10% of Mustelidae and 21% of Procyonidae being classified as Data Deficient (Fig. 4). Geographic distribution of Data Deficient species includes Mexico and extends southward through Central and South America (Fig. 5).

Globally averaged population trends are increasing for only three of the Americas' small carnivore species (Black-footed Ferret *Mustela nigripes*, Northern Raccoon *Procyon lotor* and Hooded Skunk *Mephitis macroura*). Of those species with known population trends, 9% are increasing, 29% are stable, and 62% are decreasing (Fig. 6). Overall, population trends for 26% of small carnivore species in the Americas are unknown globally. The population trends for almost half (43%) of Procyonidae species remain unknown.

## Discussion

Small carnivores in the Americas represent about 28% of the extant small carnivores worldwide. Familial diversity is low, with only three of the world's currently recognised nine families represented. Greatest species richness of small carnivores in the Americas follows the general pattern of overall terrestrial mammal species richness, with the greatest diversity occurring in the tropics and in areas of high topographic and ecological complexity (Schipper *et al.* 2008b). Small carnivore species richness generally declines with increasing latitude.

Human threats resulting in the current threatened status of small carnivores vary among species. For example, Sea Otters were hunted to near extinction during the nineteenth and early twentieth centuries for their valuable pelts until the International Fur Seal Treaty protected surviving remnant colonies beginning in 1911 (Lensink 1962, Kenyon 1969). Also, Black-footed Ferrets are an obligate associate of prairie dogs *Cynomys*, which they use as prey in addition to their inhabiting their burrows as shelter (Forrest *et al.* 1985). Large-scale conversion of lands from prairie to agriculture, eradication of prairie dogs because of perceived com-

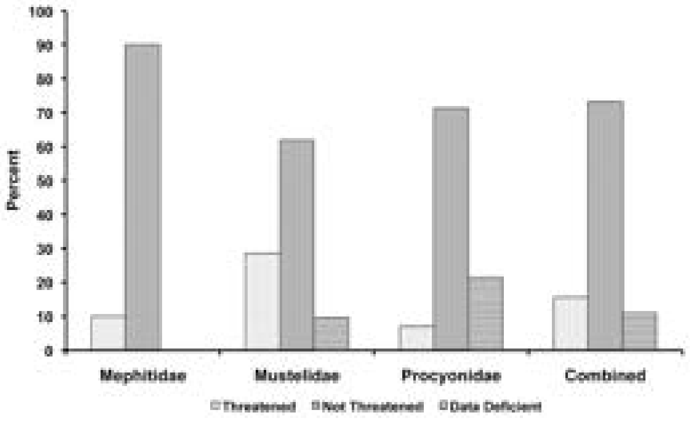

*Fig. 4. Percentage of species in small carnivore families in the Americas by global 2008 IUCN Red List category.*

*Fig. 5. Distribution of small carnivores in the Americas classified globally as Data Deficient based on the 2008 IUCN Red List (grey indicates a single species and black represents where two species overlap; note that island species such as* Procyon pygmaeus *and* Nasua nelsoni *are not visible at this scale).*

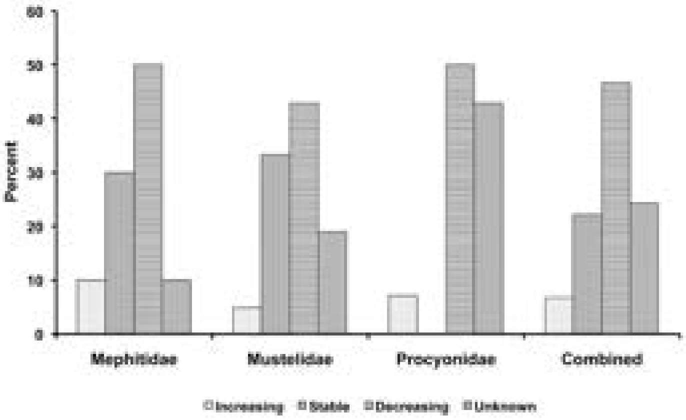

*Fig. 6. Global population trends of small carnivore species by family in the Americas based on the 2008 IUCN Red List.*

petition with livestock, and plague all contributed to the decline of Black-footed Ferrets (Miller *et al.* 1990). Habitat destruction, pollution and overharvest have presumably led to the decline of Marine Otters (Estes 1986, Chehebar 1990). Although on a local scale, Marine Otters can benefit from some human activities such as food waste from fishing activities (Medina-Vogel *et al.* 2007b), recent human-caused fragmentation of coastline habitats is suggested as a major factor causing local extirpations of this species (Medina-Vogel *et al.* 2007a).

The percentage of small carnivores in the Americas with inadequate data to assess conservation status (i.e. Data Deficient; 11%) is slightly lower than the percentage of such terrestrial mammals overall (14.7%; Schipper *et al.* 2008b) and higher than small carnivores worldwide (~9%; Schipper *et al.* 2008a). These Data Deficient species occur primarily in Central and South America and are in large part a consequence of gaps in our current knowledge and recent and ongoing taxonomic revisions, especially within Mephitidae and Procyonidae (e.g. Helgen & Wilson 2003, Helgen *et al.* 2008, 2009).

Although most of the Americas' species of small carnivores appear to be undergoing some form of global decline, a few species such as Northern Raccoon are increasing in abundance (Timm *et al.* 2008), evidently with this species a result of its adaptability to human-altered landscapes, particularly urban areas (Riley 1988, Prange *et al.* 2003). Effective management strategies can also have positive effects on small carnivore species recovery. For example, the Black-footed Ferret was Extinct in the Wild from 1987 (when the last remaining individuals were captured) to 1991, the first release of captive-born Ferrets into the wild. As a consequence of intense management efforts including multiple site restorations, this species is now categorised as Endangered (Belant *et al.* 2008). Although several factors still threaten recovery, reduction of threats and scientifically-based management strategies have ensured survival of this species to date (Jachowski & Lockhart 2009).

Small carnivore species in the Americas appear more secure than small carnivores globally or mammals overall. In the Americas, only 18% of extant small carnivore species are currently considered threatened. In contrast, 22% of all small carnivores and 25% of all mammals worldwide are considered threatened (Schipper *et al.* 2008a, 2008b). The majority of threatened species of small carnivores in the Americas (four of eight) are otters; this reflects a global pattern of anthropogenic threats including pollution and trade that adversely affect this group of small carnivores (Schipper *et al.* 2008a, 2008b). Overexploitation was similarly responsible for the extinction of Sea Mink (Campbell 1988, Black *et al.* 1998), one of only two species of small carnivores to become extinct globally since the year 1500 CE and the only species to have done so in the Americas (Schipper *et al.* 2008b).

Two additional small carnivore species, *Nasua nelsoni* and *Nasualla meridensis*, have recently been recognised in the Americas, (Cuaron *et al*. 2009, Helgen *et al.* 2009). Proposals for both species are under preparation for submission to IUCN for inclusion in the forthcoming *2009 IUCN Red List of Threatened Species*. *Nasua nelsoni* is tentatively listed as Critically Endangered (Cuaron *et al*. 2009).

Although small carnivores in the Americas are faring slightly better than mammals worldwide, most are presently declining, and several are in urgent need of both research and conservation efforts. Consequently, if population trends continue, we would expect additional species to become threatened unless effective conservation efforts are implemented to ensure long-term species survival.

## Acknowledgments

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## References

Belant, J., Gober, P. & Biggins, D. 2008. *Mustela nigripes*. In *2008 IUCN Red List of Threatened Species*. <www.iucnredlist.org>. Downloaded on 14 May 2009.

Black, D. W., Reading, J. E. & Savage, H. G. 1998. Archaeological records of the extinct Sea Mink, *Mustela macrodon* (Carnivora: Mustelidae) from Canada. *Canadian Field-Naturalist* 112: 45–49.

Campbell, R. R. 1988. Status of the Sea Mink, *Mustela macrodon*, in Canada. *Canadian Field-Naturalist* 102: 304–306.

Carroll, C. 2007. Interacting effects of climate change, landscape conversion, and harvest on carnivore populations at the range margin: Marten and Lynx in the Northern Appalachians. *Conservation Biology* 21: 1092–1104.

Carroll, C., Noss, R. F., Paquet, P. C. & Schumaker, N. H. 2003. Use of population viability analysis and reserve selection algorithms in regional conservation plans. *Ecological Applications* 13: 1773–1789.

Chehebar, C. 1990. Action plan for Latin American otters. Pp. 64–140 in Foster-Turley, P., MacDonald, S. & Mason, C. (eds). *Otters: an action plan for their conservation.* IUCN/SSC, Gland, Switzerland.

Cuarón A. C., Valenzuela-Galván, D., García-Vasco, D. & others. 2009. Conservation of the endemic dwarf carnivores of Cozumel Island, Mexico. *Small Carnivore Conservation* 41: 15–21.

Estes, J. A. 1986. Marine Otters and their environment. *Ambio* 15: 181–183.

Forrest, S. C., Clark, T. W., Richardson, L. & Campbell, T. M. III 1985. Black-footed Ferret habitat: some management and reintroduction considerations. *Wyoming Bureau of Land Management Wildlife Technical Bulletin* 2: 1–49.

Graham, I. M. & Lambin, X. 2002. The impact of Weasel predation on cyclic Field Vole survival: the specialist predator hypothesis contradicted. *Journal of Animal Ecology* 71: 946–956.

Hargis, C. D., Bissonette, J. A. & Turner, D. L. 1999. The influence of forest fragmentation and landscape pattern on American Martens. *Journal of Applied Ecology* 36: 157–172.

Helgen, K. M., Kays, R., Helgen, L. E. & others. 2009. Taxonomic boundaries and geographic distributions revealed by an integrative systematic overview of the mountain coatis, *Nasuella* (Carnivora:Procyonidae). *Small Carnivore Conservation* 41:65–74.

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

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

IUCN 2008. *2008 IUCN Red List of Threatened Species*. <http://www.iucnredlist.org>. Downloaded on 19 April 2009.

Jachowski, D. S. & Lockhart, J. M. 2009. Reintroducing the Black-footed Ferret *Mustela nigripes* to the Great Plains of North America. *Small Carnivore Conservation* 41: 58–64.

Kenyon, K. W. 1969. The Sea Otter in the eastern Pacific Ocean. *North American Fauna* 68: 1–352.

Koen, E. L., Bowman, J. & Findlay, C. S. 2007. Fisher survival in eastern Ontario. *Journal of Wildlife Management* 71: 1214–1219.

Lenskink, C. J. 1962. *The history and status of Sea Otters in Alaska*. Purdue University (Ph.D. thesis), West Lafayette, Indiana, U.S.A.

LoGiudice, K. & Ostfeld, R. S. 2002. Interactions between mammals and trees: predation on mammal-dispersed seeds and the effect of ambient food. *Oecologia* 130: 420–425.

Medina-Vogel, G., Merino, L. O., Alarcón, R. M. & Vianna J. de A. 2007a. Coastal–marine discontinuities, critical patch size and isolation: implications for Marine Otter conservation. *Animal Conservation* 11: 57–64.

Medina-Vogel, G., Boher, F., Flores, G. Santibañez, A. & Soto-Azat, C. 2007b. Spacing behavior of Marine Otters (*Lontra felina*) in relation to land refuges and fishery wastes in central Chile. *Journal of Mammalogy* 88: 487–494.

Medina-Vogel, G., Merino, L. O., Alarcón, R. M & Vianna, J. de A. 2008. Coastal–marine discontinuities, critical patch size and isolation: implications for Marine Otter conservation. *Animal Conservation* 11: 57–64.

Miller, B. J., Wemmer, C., Biggins, D. E. & Reading, R. P. 1990. A proposal to conserve Black-footed Ferrets and the prairie dog ecosystem. *Environmental Management* 14: 763–769.

Prange, S., Gehrt, S. D. & Wiggers, E. P. 2003. Demographic factors contributing to high Raccoon densities in urban landscapes. *Journal of Wildlife Management* 67: 324–333.

Riley, S. 1988. Population density, survival, and rabies in Raccoons in an urban national park. *Canadian Journal of Zoology* 76: 1153–1164.

Schipper, J., Hoffmann, M., Duckworth, J. W. & Conroy, J. 2008a. The 2008 IUCN red listings of the world's small carnivores. *Small Carnivore Conservation* 39: 29–34.

Schipper, J. *et al*. [132 authors] 2008b. The status of the world's land and marine mammals: diversity, threat, and knowledge. *Science* 322: 225–230.

Sterner, R. T., Sun, B., Bourassa, J. B., Hale, R. L., Shwiff, S. A., Jay, M. T. & Slate, D. 2008. Skunk rabies in California (1992–2003) – implications for oral rabies vaccination. *Journal of Wildlife Diseases* 44: 1008–1013.

Timm, R., Cuarón, A. D., Reid, F. & Helgen, K. 2008. *Procyon lotor*. In *2008 IUCN Red List of Threatened Species*. <http://www.iucnredlist.org>. Downloaded on 14 May 2009.

United Nations Population Division 2009. *World population prospects: the 2008 revision population database*. <http://esa.un.org/unpp/>. Downloaded on 29 April 2009.

Whiteman, C. W., Matushima, E. R., Confalonieri, U. E. C., Palha, M. D. C., da-Silva, A. S. L. & Monteiro, V. C. 2007. Human and domestic animal populations as a potential threat to wild carnivore conservation in a fragmented landscape from the Eastern Brazilian Amazon. *Biological Conservation* 138: 290–296.

Wozencraft, W. C. 2005. Order Carnivora. Pp. 532–628 in Wilson, D. E. & Reeder, D. M. (eds) *Mammalian species of the world: a taxonomic and geographic reference*, 3rd edn. John Hopkins University Press, Baltimore, Maryland, U.S.A.

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*Appendix. Conservation status of small carnivores in the Americas (from 2008 IUCN Red List).*

| Taxon[1] | English name | Category[2] | Criteria |
|---|---|---|---|
| Family Mephitidae | | | |
| *Conepatus chinga* | Molina's Hog-nosed Skunk | LC | |
| *Conepatus humboldtii* | Humboldt's Hog-nosed Skunk | LC | |
| *Conepatus leuconotus* | American Hog-nosed Skunk | LC | |
| *Conepatus semistriatus* | Striped Hog-nosed Skunk | LC | |
| *Mephitis macroura* | Hooded Skunk | LC | |
| *Mephitis mephitis* | Striped Skunk | LC | |
| *Spilogale angustifrons* | Southern Spotted Skunk | LC | |
| *Spilogale gracilis* | Western Spotted Skunk | LC | |
| *Spilogale putorius* | Eastern Spotted Skunk | LC | |
| *Spilogale pygmaea* | Pygmy Spotted Skunk | VU | A2c |
| Family Mustelidae | | | |
| *Eira barbara* | Tayra | LC | |
| *Enhydra lutris* | Sea Otter | EN | A1a |
| *Galictis cuja* | Lesser Grison | LC | |
| *Galictis vittata* | Greater Grison | LC | |
| *Gulo gulo* | Wolverine | NT | |
| *Lontra canadensis* | North American Otter | LC | |
| *Lontra felina* | Marine Otter | EN | A3cd |
| *Lontra longicaudis* | Neotropical Otter | DD | |
| *Lontra provocax* | Southern River Otter | EN | A3cd |
| *Lyncodon patagonicus* | Patagonian Weasel | DD | |
| *Martes americana* | American Marten | LC | |
| *Martes pennanti* | Fisher | LC | |
| *Mustela africana* | Amazon Weasel | LC | |
| *Mustela erminea* | Ermine | LC | |
| *Mustela felipei* | Colombian Weasel | VU | B1ab(ii,iii) |
| *Mustela frenata* | Long-tailed Weasel | LC | |
| *Mustela nigripes* | Black-footed Ferret | EN | D1 |
| *Mustela nivalis* | Least Weasel | LC | |
| *Neovison macrodon* | Sea Mink | EX | |
| *Neovison vison* | American Mink | LC | |
| *Pteronura brasiliensis* | Giant Otter | EN | A3cd |
| *Taxidea taxus* | American Badger | LC | |
| Family Procyonidae | | | |
| *Bassaricyon alleni* | Allen's Olingo | LC | |
| *Bassaricyon beddardi* | Beddard's Olingo | LC | |
| *Bassaricyon gabbii* | Gabbi's Olingo | LC | |
| *Bassaricyon lasius* | Harris's Olingo | DD | |
| *Bassaricyon pauli* | Chirique Olingo | DD | |
| *Bassariscus astutus* | Ringtail | LC | |
| *Bassariscus sumichrasti* | Cacomistle | LC | |
| *Nasua narica* | White-nosed Coati | LC | |
| *Nasua nasua* | South American Coati | LC | |
| *Nasuella olivacea* | Mountain Coati | DD | |
| *Potos flavus* | Kinkajou | LC | |
| *Procyon cancrivorus* | Crab-eating Raccoon | LC | |
| *Procyon lotor* | Northern Raccoon | LC | |
| *Procyon pygmaeus* | Cozumel Raccoon | EN | B1ab(ii,iii) + 2ab(ii,iii) |

[1] Genus and species limits and spellings mostly follow Wozencraft (2005).
[2] DD = Data Deficient, EN = Endangered, EX = Extinct, LC = Least Concern, NT = Near Threatened, VU = Vulnerable.

# Activity patterns and community ecology of small carnivores in the Talamanca region, Costa Rica

José F. GONZÁLEZ-MAYA[1,2], Jan SCHIPPER[1,3] and Angelica BENÍTEZ[1,2]

## Abstract

Activity patterns among small carnivores are seldom studied, especially at multi-species and community levels. Herein we report them for five Neotropical small carnivores (Procyonidae, Mephitidae and Mustelidae) captured during 2005–2007 at photographic sampling stations from sea level to 3,600 m elevation in the Talamanca region of southern Costa Rica. We measured frequencies of capture for each species and estimated daily activity patterns by averaging site captures. Strong overlap was determined for Striped Hog-nosed Skunk *Conepatus semistriatus* and Northern Raccoon *Procyon lotor*, with the lowest similarity for White-nosed Coati *Nasua narica* and Kinkajou *Potos flavus*. All species combined, the animals were predominantly active during night but with two activity peaks—one in the afternoon (14h00–15h00) and one before dawn (03h00–04h00). This defined separation among the small carnivore assemblage for the Talamanca forests suggests a probable relationship with resource distribution at the ecosystem level (prey and foraging competition). The basic knowledge thus gained shows the importance of recording and analysing data on tropical forest small carnivore community ecology from camera-trap studies.

*Keywords*: cathemeral, Chao-Jaccard similarity index, *Conepatus semistriatus*, diurnal, *Eira barbara*, natural history, *Nasua narica*, small carnivores, nocturnal, *Potos flavus*, *Procyon lotor*

## Patrones de actividad y ecología de la comunidad de pequeños carnívoros de la región de Talamanca, Costa Rica

## Resumen

Los patrones de actividad han sido pobremente estudiados para pequeños carnívoros, especialmente a nivel de ensamblajes. Estimamos los patrones de actividad usando datos de cámaras-trampa capturados en Talamanca, Costa Rica. Estimamos las frecuencias de ocurrencia de cada especie en periodos de 24 h y determinamos los patrones a lo largo del ciclo. Se determinaron fuertes relaciones y sobre posiciones significativas entre el Zorrillo *Conepatus semistriatus* y el Mapache Común *Procyon lotor* y las similitudes más bajas entre el Pizote *Nasua narica* y la Martilla *Potos flavus*. Para el grupo total se determinó una actividad predominantemente nocturna pero con dos picos de actividad principales durante el día, uno a la tarde (14h00–15h00) y uno al amanecer (03h00–04h00). Los resultados indican una separación definitiva dentro del ensamblaje para los Bosques Montanos de Talamanca y probablemente está relacionado con la distribución del uso de los recursos al nivel del ecosistema (competencia por forrajeo y presas). Esta información es de gran importancia para el conocimiento básico de todas las especies, y sienta la ruta para análisis más profundos de la organización de pequeños carnívoros en bosques tropicales.

*Palabras clave*: catameral, Chao-Jaccard, *Conepatus semistriatus*, *Eira barbara*, Historia Natural, *Nasua narica*, Pequeños carnívoros, nocturno, *Potos flavus*, *Procyon lotor*

## Introduction

Ecological roles of tropical small carnivores remain poorly studied but it is presumed they are crucial predators, prey and seed dispersers (Mudappa *et al.* 2007). Some species (e.g. White-nosed Coati *Nasua narica*) have benefited from human disturbances (Elmhagen & Rushton 2007) due to population release following top/large predator absence, a hyper-abundance of prey following disturbance, or changes in habitat suitability (Terborgh *et al.* 1999, Larivière 2004, Elmhagen & Rushton 2007). Any change in small carnivore communities, be it population growth or decline, impacts ecosystem dynamics directly (Terborgh 1988, Dirzo & Miranda 1990, Redford 1992, Crooks & Soulé 1999). Herein we use three years of camera-trap 'by-catch' data, from an ongoing Jaguar *Panthera onca* and prey research project (ProCAT-Talamanca), to assess activity patterns and ecology of small carnivores in and surrounding the Cordillera Talamanca region of southern Costa Rica.

Talamanca is considered an important ecoregion for biodiversity conservation due to its unique biogeographical, evolutionary, and historical characteristics, and because of its declining state of conservation (Powell *et al.* 2001). As a predominantly montane ecosystem it holds high endemism across numerous taxa and supports several species at their northern or southern range limits. Talamanca is also very important for its connectivity across the Mesoamerican Isthmus and as one of the last well-preserved forest patches in southern Mesoamerica. It encompasses a vast number of ecosystems and habitats due in part to its spatial and elevational complexity; and new species are continuing to be discovered. The region includes all mammals endemic to Costa Rica and represents the last refuge for more than 74% of the endangered mammals of the country (Rodríguez-Herrera *et al.* in press). However, the Cordillera Talamanca also represents the least studied region in the country, with the lowest number of collection localities and research for mammals (Rodríguez-Herrera *et al.* 2002).

The species discussed are small carnivores photographed by camera-traps: Tayra *Eira barbara*, Northern Raccoon *Procyon lotor*, White-nosed Coati *Nasua narica*, Kinkajou *Potos flavus* and Striped Hog-nosed Skunk *Conepatus semistriatus*. The Kinkajou is predominantly arboreal but was present in enough photographs on the forest floor for statistical analysis. Another arboreal species present, an olingo *Bassaricyon*, was not photographed. Greater Grison *Galictis vittata* was photographed only once, so data could not be used in the analysis. The families included in this study, Mustelidae, Mephitidae and Procyonidae, hold some of the least studied carnivores and receive very little conservation attention (Ginsberg 2001). Results for Felidae and Canidae are reported elsewhere (González-Maya *et al.* 2008).

Three of the species are adaptable to human-dominated landscapes (Tayra, White-nosed Coati, Northern Raccoon) but two (Kinkajou and Striped Hog-nosed Skunk) are predominantly restricted to forested areas (de la Rosa & Nocke 2000). All five co-occur across the study area and share similar diets, although probably with different foraging strategies: thus our primary interest herein is to enhance understanding of how they temporally partition resources in the same space.

Resource partitioning by sympatric species may explain their coexistence and therefore is fundamental to their ecology. Ecological aspects, such as activity patterns, represent important variables in the dynamics of carnivore communities (Gittleman 1989, Brown & Peinke 2007), key factors that affect life histories (Enright 1970), may provide important information for conservation if they vary in response to threats and other disturbances (Laundré *et al*. 2001), and are important considerations for conservation planning (Griffiths & van Schaik 1993, Hwang & Garshelis 2007).

## Methods

### *Study site*

The Cordillera Talamanca is located in south-eastern Costa Rica and western Panama, over 8°37′ – 9°38′N, 82°24′ – 83°25′W. The mountain range protrudes abruptly from the surrounding lowlands and is characterised by steep slopes and various montane habitats. It represents the most important natural forest block in Costa Rica, one of the most important corridors in Central America, and has the highest level of endemism in Costa Rica (González-Maya *et al.* 2008). The greater Talamanca region consists of a mosaic of land uses and protected areas, with 55% under national parks, 31% indigenous territories, 2% in national wildlife refuges and 12% not protected (González-Maya & Mata-Lorenzen 2008). The area ranges from sea-level to 3,828 m, rising from both the Caribbean and Pacific coasts to one of the highest massifs in Central America (Chirripó), and includes numerous ecosystems from lowland tropical and montane forests to high-elevation grasslands and páramo. In 1982, the region was declared a UNESCO–MAB Biosphere Reserve (La Amistad) and in 1983 (1990 extension), the Talamanca Range - La Amistad Reserves/La Amistad National Park was declared a UNESCO World Heritage Site (Kapelle 1996; Fig. 1). In addition, the region is considered an Endemic Bird Area (Harcourt *et al.* 1996), is included in the Global 200 most important ecoregions list (Olson & Dinerstein 2002), and is an important component of the Mesoamerican Hot Spot (Myers *et al.* 2000, Mittermeier *et al.* 2005). Data were collected on both the Caribbean and Pacific sides of the Cordillera in a wide variety of habitats from coastal sand forests to páramo grasslands.

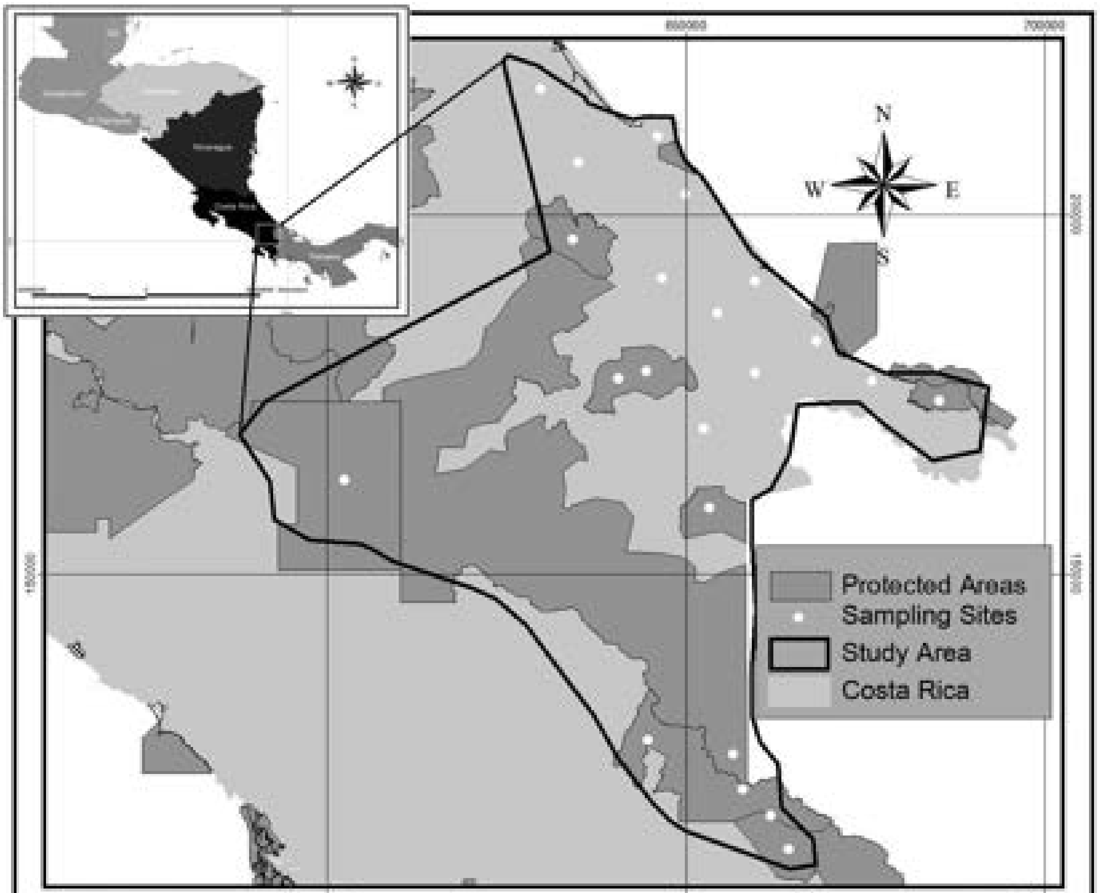

*Fig. 1. The study site and surveyed area.*

*Camera trapping*

Sampling was carried out using 'heat-in-motion' sensor 35 mm film and digital camera-traps (Photoscout, PTC technologies, and Woodland Technologies) for approximately three years (January 2005 – December 2007). Camera-traps were modified to be waterproof and theft-resistant, and outfitted with desiccant packets (Zorbit). The data presented here are 'by-catch' from a three-year project with a primary objective to estimate Jaguar densities and prey abundance to establish their conservation status in the region. Multiple camera arrays were deployed across the region and along elevational gradients (sea level to 3,600 m) to cover variation in habitat and estimate distribution and activity patterns across the entire region. Cameras were set to be active continuously for 30–60 days (to account for bad weather and other factors limiting field access). The delay (time between pictures) was set at 1 minute. Some cameras were set as pairs to acquire images of both sides of the animal; such capture events were considered as one observation. All cameras recorded date and time directly on the image and were synchronised exactly for time. The location of cameras was selected to maximise probability of photographic capture; each camera was placed about 30–60 cm above ground. Lures or other attractants were used only exceptionally, as part of an experiment on lure effect (unpublished data).

*Data analysis*

Each picture was scored for species, date, time and site. Every picture was considered an independent occasion, excepting those evidently representing the same individual on the same pass. For the entire assemblage we standardised the data using relative frequencies for species (to minimise effects of species abundances). The analysis between the absolute frequencies distributed across the hours used a Kruskal-Wallis test (since the homogeneity of variances was tested negatively) with the Chao-Jaccard index (Chao *et al*. 2005) for activity frequency comparisons among species. This analysis was selected because it has been showed to reduce the negative bias of traditional similarity indices, and calculates confidence intervals for comparison purposes (Chao *et al*. 2005). Data were analysed using InfoStat (Infostat 2007) and EstimateS (Colwell 2005).

## Results

The unique Greater Grison picture was taken in a primary forest remnant along the Caribbean coast at an elevation of 70 m on a private farm approximately 15 km NW of Cahuita, Costa Rica. After excluding this picture, we evaluated activity patterns of five species in 546 images (Table 1). When activity patterns of all five species together are normalised as relative frequencies (Fig. 2), two main activity peaks are apparent, one in the afternoon (14h00–15h00) and one before dawn (03h00–04h00). There was no strong statistical difference between the frequencies among hours ($H = 8.05$, $p = 0.9971$).

*Table 1. Species analysed and frequency of capture.*

| Species | Common name | Pictures | Relative frequency |
|---|---|---|---|
| *Nasua narica* | White-nosed Coati | 312 | 0.57 |
| *Potos flavus* | Kinkajou | 4 | 0.01 |
| *Conepatus semistriatus* | Striped Hog-nosed Skunk | 53 | 0.10 |
| *Eira barbara* | Tayra | 70 | 0.13 |
| *Procyon lotor* | Northern Raccoon | 107 | 0.20 |
| TOTAL | | 546 | 1 |

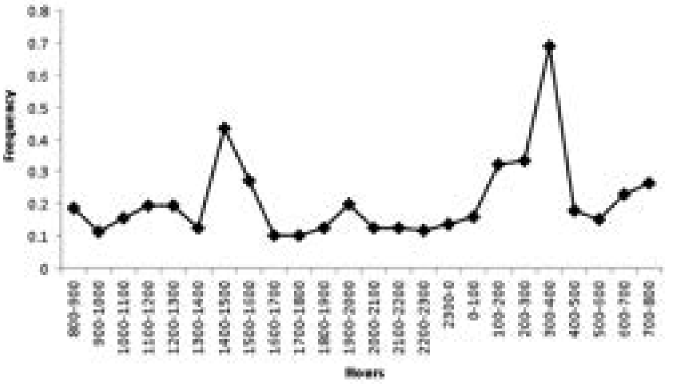

*Fig. 2. Daily activity patterns for the small carnivore community (all species combined). Capture frequency is expressed as the relative frequency of photographs per species per hour periods, summed for each hour period. This is to eliminate the distorting effects of commonly photographed species dominating the all-species-combined index.*

Daily activity patterns for each species (Fig. 3) demonstrate that Tayra and White-nosed Coati are predominantly diurnal, Kinkajou and Hog-nosed Skunk predominantly nocturnal, while Northern Raccoon, with no predominant period of activity, is cathemeral (defined in van Schaik & Griffiths 1996). The Chao-Jaccard index showed the highest similarity pattern of activity patterns between the Hog-nosed Skunk and Northern Raccoon and the lowest similarity between the White-nosed Coati and Kinkajou (Fig. 4). According to these analyses, two major 'groups' of relationships were identified: one group comprised dyads with a higher degree of overlapping activity periods (over 0.6) and the other dyads with low overlap (below 0.3). These latter represent time partitioning within the small carnivore community.

## Discussion

The distribution of activities among the species assessed displays a recognisable pattern with the separation of the assemblage in two main groups. Previous research across mammal communities has shown a clear separation among nocturnal, diurnal and crepuscular species, and generally nocturnal activities are reported to be more common in tropical forests (e.g. van Schaik & Griffiths 1996).

Small carnivores in Talamanca were divided primarily among diurnal–nocturnal rhythms, with one species being cathemeral (showing activity in both periods). This separation may reflect resource partitioning and competitive avoidance as shown for other groups, such as some primates competing with some birds (Charles-Dominique 1975). Other factors probably influencing these patterns are related to predation pressure, competition for food, food supply and dietary category (Monteiro-Vieira & Baumgarten 1995). For Northern Raccoon, the cathemeral activity pattern reflects its size (the largest of the five species, at mean body mass 6 kg, up to 10 kg; Dewey & Fox 2001), related previously to increased foraging time (van Schaik & Griffiths 1996). In addi-

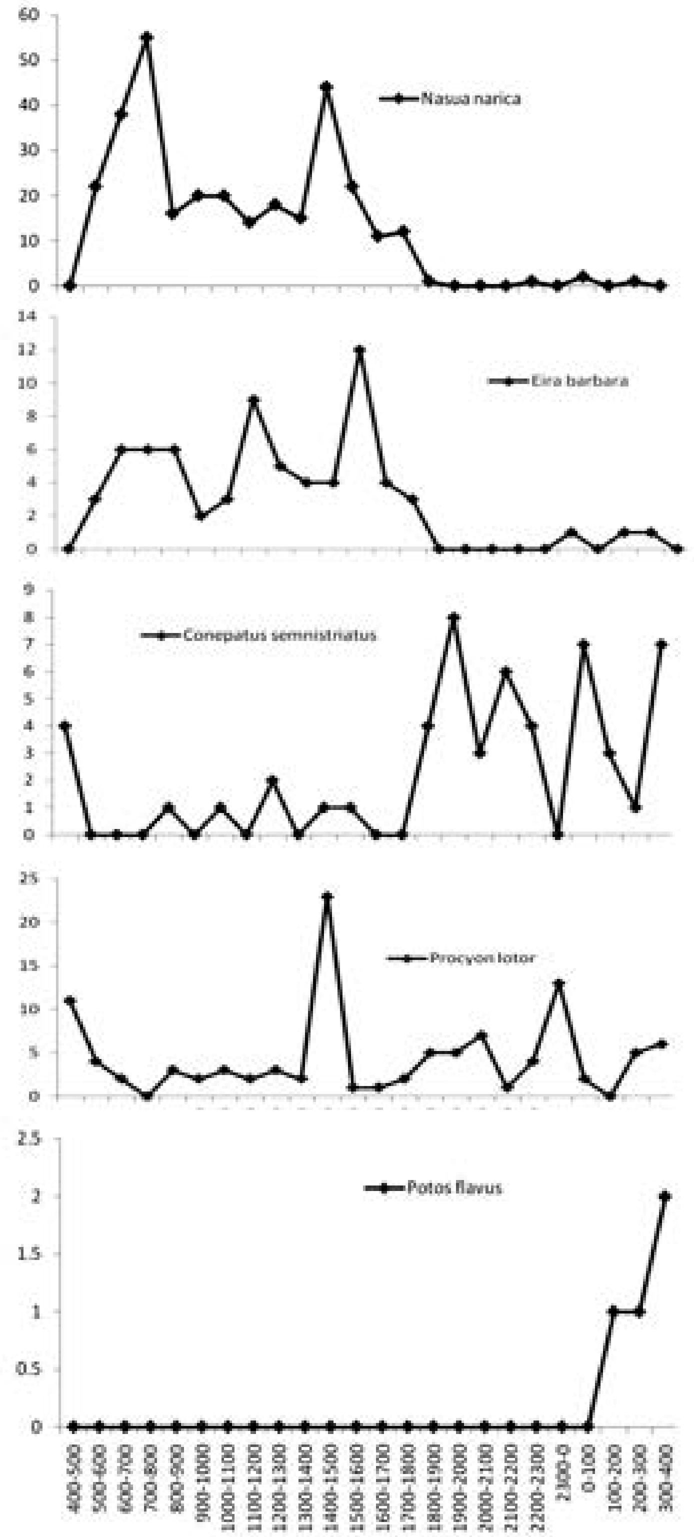

*Fig. 3. Daily activity patterns for (A)* Nasua narica*, (B)* Eira barbara*, (C)* Conepatus semistriatus*, (D)* Procyon lotor *and (E)* Potos flavus*. Capture frequency, the total number of photographs at each hourly period, is plotted on the y-axis.*

tion the Northern Raccoon may take advantage of specialised diurnal and nocturnal food sources. Even the two primarily diurnal species somewhat partitioned time, presumably for competitive avoidance, with only a 10% overlap according to Chao-Jaccard index.

There is a potential confusion with the high similarity index calculated between Hog-nosed Skunk and Northern Raccoon: based on absolute captures the former is evidently nocturnal, but the latter was categorised as cathemeral. This is because the estimators used by this index incorporate the contribution to the real value of the probability made by the time period in which each species was actually present, but not detected in one nor five of the species (Chao *et al*. 2005).

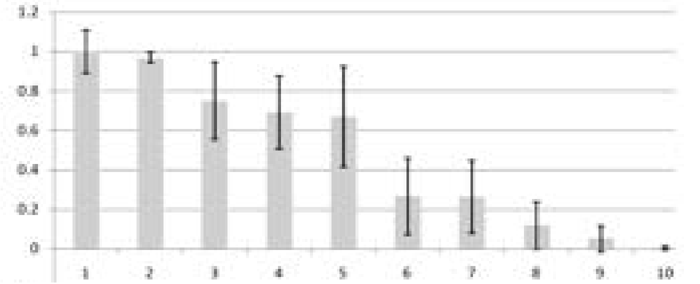

*Fig. 4. Chao-Jaccard similarity index for activity patterns of every pair of species with confidence intervals (expressed as proportions). 1:* C. semistriatus - P. lotor*; 2:* N. narica - E. barbara*; 3:* E. barbara - P. lotor*; 4:* N. narica - P. lotor*; 5:* N. narica - C. semistriatus*; 6:* P. flavus - C. semistriatus*; 7:* C. semistriatus - E. barbara*; 8:* P. flavus - P. lotor*; 9:* P. flavus - E. barbara*; 10:* N. narica - P. flavus.

The New World contains a number of small carnivores about which relatively little is known, even though some are more common than better known larger mammals. For example, there is almost no information on the behaviour, ecology, population or threats in wild populations of Tayra even though it has a large geographic range, is locally common (Emmons & Feer 1990), and is adaptable to human modified landscapes (Emmons & Feer 1990, Cuarón *et al.* 2008). This study highlights the information available on these elusive and little-known common species using camera-trap data.

Designing a camera-trap protocol for multiple species is very challenging at both the design and analysis phase; therefore we believe that the analysis of 'by-catch' data from a Jaguar density protocol is more useful in this case as the methodology was consistently applied across a large area and over a long time period. More photographs from the project were of small carnivores (N = 546) than of the target species, Jaguar (N = 111). 'By-catch' data are increasingly used to advance understanding of non-target species, and often require little additional effort for the data collectors. Their use in obtaining even the most basic information about poorly known species is highly desirable since it is often very difficult to fund studies of small carnivores versus, for example, cats. We encourage researchers to publish their data and perhaps as collaborations and partnerships among projects.

Natural history information previously reported was similar to that from the present study for White-nosed Coati (Sunquist *et al.* 1989, Emmons & Feer 1990, Reid 1997), Hog-nosed Skunk (Sunquist *et al.* 1989, Emmons & Feer 1990, Reid 1997) and Kinkajou (Emmons & Feer 1990, Reid 1997, Kays & Gittleman 2001). However, Tayra (Konekny 1989, Emmons & Feer 1990, Reid 1997) and Northern Raccoon (Emmons & Feer 1990, Reid 1997) patterns are inconsistent with previous reports. The Tayra is reported to be crepuscular in some areas (Aranda & March 1987, Konekny 1989) and diurnal in others (Emmons & Feer 1990, Reid 1997). The Northern Raccoon is considered mainly nocturnal (e.g. Nowak 1991), which does not match with our results. Furthermore, this species represents one of the 'significantly different' variables when comparing the similarity indexes of all the species; this can be explained by its cathemeral nature and the resulting marked differences caused by two nocturnal species.

### *Conservation*

Conservation planning in regions like Talamanca should take into account many variables including species diversity, abundance, natural history and ecology. Current conservation efforts are restricted to the protection and control of hunting and deforestation, but are not necessarily protecting those species in need of conservation. Currently, protection and control efforts by government and private environmental agencies and authorities are more active by day, due to logistical issues; but hunting occurs predominantly by night for species of commercial interest (e.g. Paca *Agouti paca*) during which other species are by-catch. Furthermore, the lack of accurate information about the species that require active conservation and management also restricts the adequate control and protection and the timing and design of these programmes. Our results suggest that active nocturnal protection efforts are also needed until new conservation strategies are applied.

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## References

Aranda, M. & March, I. 1987. *Guia de los mamíferos silvestres de Chiapas*. Instituto Nacional de Investigaciones sobre Recursos Bióticos, Xalapa, Veracruz, México.

Brown, C. & Peinke, D. 2007. Activity patterns of Springhares from the Eastern Cape Province, South Africa. *Journal of Zoology* 272: 148–155.

Chao, A., Chazdon, R., Colwell, R. & Shen, T. 2005 A new statistical approach for assessing similarity of species composition with incidence and abundance data. *Ecology Letters* 8: 148–159.

Charles-Dominique, P. 1975. Nocturnality and diurnality; an ecological interpretation of these two modes of life by an analysis of the higher vertebrate fauna in tropical forest ecosystems. Pp. 69–88 in Luckett, W. & Szalay, F. (eds) *Phylogeny of the primates: a multidisciplinary approach*. Plenum Press, New York, U.S.A.

Colwell, R. K. 2005. *EstimateS: Statistical estimation of species richness and shared species from samples*. Version 7.5. User's Guide and application published at <http://purl.oclc.org/estimates>.

Crooks, K. R. & Soulé, M. E. 1999. Meso-predator release and avifaunal extinctions in a fragmented system. *Nature* 400: 563–566.

Cuarón, A. D., Reid, F. & Helgen, K. 2008. *Eira barbara*. In *2008 IUCN Red List of Threatened Species*. <www.iucnredlist.org>. Downloaded on 12 January 2009.

de la Rosa, C. & Nocke, C. 2000. A guide to the carnivores of Central America: natural history, ecology, and conservation. University of Texas Press, Austin, Texas, U.S.A.

Dewey, T. & Fox, R. 2001. *Procyon lotor*. *Animal Diversity Web*. University of Michigan. <http://animaldiversity.ummz.umich.edu/site/accounts/information/Procyon_lotor.html>. Downloaded on 7 January 2008.

Dirzo, R. & Miranda, A. 1990. Contemporary Neotropical defaunation and forest structure, function, and diversity—a sequel to John Terborgh. *Conservation Biology* 4: 444–447.

Elmhagen, B. & Rushton, S. 2007. Trophic control of mesopredators in terrestrial ecosystems: top-down or bottom-up? *Ecology Letters* 10: 197–206.

Emmons, L. H. & Feer, F. 1990. *Neotropical rainforest mammals: a field guide*. University of Chicago Press, Illinois, U.S.A.

Enright, J. 1970. Ecological aspects of endogenous rhythmicity. *Annual Review of Ecology and Systematics* 1: 221–238.

Ginsberg, J. 2001. Setting priorities for carnivore conservation: what makes carnivores different? Pp. 498–523 in Gittleman, J., Funk, S., Macdonald, D. & Wayne, R. (eds) *Carnivore Conservation*. Cambridge University Press. Cambridge, U.K.

Gittleman, J. 1989. Carnivore group living: comparative trends. Pp. 183–207 in Gittleman, J. (ed.) *Carnivore behavior, ecology and evolution*. Cornell University Press, Ithaca, U.S.A.

González-Maya, J. F. & Mata-Lorenzen, J. 2008. Dung-beetles (Coleoptera: Scarabeidae) from the Zona Protectora Las Tablas, Talamanca, Costa Rica. *Checklist, Brazil* 4(4): 458–463.

González-Maya, J. F., Finegan, B. G., Schipper, J. & Casanoves, F. 2008. *Densidad absoluta y conservación del Jaguar y sus presas en la región Talamanca, Pacífico, Costa Rica*. The Nature Conservancy, San José, Costa Rica.

Griffiths, M. & van Schaik, C.1993. The impact of human traffic on the abundance and activity periods of Sumatran rain forest wildlife. *Conservation Biology* 7: 623–626.

Harcourt, C. S., Sayer, J. & Billington, C. (eds) 1996. *The conservation atlas of tropical forests: the Americas*. IUCN – CIFOR – WCMC – BP and Simon & Schuster, New York, U.S.A.

Hwang, M. & Garshelis, D. 2007. Activity patterns of Asiatic Black Bears (*Ursus thibetanus*) in the Central Mountains of Taiwan. *Journal of Zoology* 271: 203–209.

InfoStat (2007). *InfoStat versión 2007*. Grupo InfoStat, FCA, Universidad Nacional de Córdoba, Argentina.

Kappelle, M. 1996. *Los bosques de Roble (*Quercus*) de la Cordillera de Talamanca, Costa Rica*. University of Amsterdam and Instituto Nacional de Biodiversidad, Santo Domingo de Heredia, Costa Rica.

Kays, R. & Gittleman, J. 2001. The social organization of the Kinkajou *Potos flavus* (Procyonidae). *Journal of Zoology, London* 253: 491–504.

Konekny, M. 1989. Movement patterns and food habits of four sympatric carnivore species in Belize, Central America. Pp. 243–264 in Redford, K. & Eisenberg, J. (eds) *Advances in Neotropical mammalogy*. Sandhill Crane Press, Gainesville, U.S.A.

Larivière, S. 2004. Range expansion of Raccoons in the Canadian prairies: review of hypotheses. *Wildlife Society Bulletin* 32: 955–963.

Laundré, J. W., Hernandez, L. & Altendorf, K. B. 2001. Wolves, Elk, and Bison: reestablishing the "landscape of fear" in Yellowstone National Park, U.S.A. *Canadian Journal of Zoology* 79: 1401–1409.

Mittermeier, R., Schipper, J., Davidse, G., Koleff, P., Soberon, M., Ramirez, M., Goettsch, M. & Mittermeier, C. 2005. Mesoamerica. Pp. 103–112 in Mittermeier, R., Robles-Gil, P., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C., Lamoreux, J. & da Fonseca, G. A. (eds) *Hotspots revisited*. CEMEX, Mexico City, Mexico.

Monteiro-Vieira, E. & Baumgarten, L. 1995. Daily activity patterns of small mammals in a cerrado area from Central Brazil. *Journal of*

*Tropical Ecology* 11: 255–262.

Mudappa, D., Noon, B., Kumar, A. & Chellam, R. 2007. Responses of small carnivores to rainforest fragmentation in the southern Western Ghats, India. *Small Carnivore Conservation* 36: 18–26.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., da Fonseca, G. A. & Kent, J. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858.

Nowak, R. 1991. *Walker's Mammals of the World*. Johns Hopkins University Press, Baltimore, U.S.A.

Olson, D. M. & Dinerstein, E. 2002. The Global 200: priority ecoregions for global conservation. *Annals of the Missouri Botanical Garden* 89: 199–224.

Powell, G., Palminteri, S. & Schipper, J. 2001. *Talamancan montane forests* (NT0167). <http://www.worldwildlife.org/wildworld/profiles/terrestrial/nt/nt0167_full.html>. Downloaded on 30 March 2009.

Redford, K. H. 1992. The empty forest. *BioScience* 42: 412–422.

Reid, F. 1997. *A field guide to the mammals of Central America and Southeastern Mexico*. Oxford University Press, New York, U.S.A.

Rodríguez-Herrera, B., Chinchilla, F. & May-Collado, L. M. 2002. Lista de especies, endemismo y conservación de los mamíferos de Costa Rica. *Revista Mexicana de Mastozoología* 6: 19–41.

Rodriguez-Herrera, B., Sanchez, R. & González-Maya, J. F. in press. Mamíferos terrestres en las IBAs: un enfoque de especies de importancia para conservación. in *Áreas Importantes para Aves de Costa Rica*. Editorial INBio, Santo Domingo de Heredia, Costa Rica.

Sunquist, M., Sunquist, F. & Daneke, D. 1989. Ecological separation in a Venezuelan llanos carnivore community. Pp. 197–232 in Redford, K. & Eisenberg, J. (eds) *Advances in Neotropical mammalogy*. Sandhill Crane Press, Gainesville, U.S.A.

Terborgh, J. 1988. The big things that run the world – a sequel to E. O. Wilson. *Conservation Biology* 2: 402–403.

Terborgh, J., Estes, J. A., Paquet, P., Ralls, K., Boyd-Heger, D. & Miller, B. J. 1999. The role of top carnivores in regulating terrestrial ecosystems. Pp. 39–64 in Soulé, M. & Terborgh, J. (eds) *Continental conservation: design and management principles for long-term, regional conservation networks*. Island Press, Washington D.C., U.S.A.

van Schaik, C. & Griffiths, M. 1996. Activity periods of Indonesian rain forest mammals. *Biotropica* 28: 105–112.

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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 (Cuaron *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 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.


*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).*

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 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 (±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).


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


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

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 ± 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, Rómero-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, estimated, inferred or suspected population size reduction of ≥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 safeguard 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 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.

*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).*

## 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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## References

Arista, I. 2009. *¿Qué saben y cómo aprenden los niños sobre el valor de la selva en la Isla Cozumel?: un análisis desde el hogar, la escuela y la comunidad.* Universidad Nacional Autónoma de México (MSc thesis), Mexico City, Mexico.

Barillas-Gómez, A. L. 2007. *Influencia de la exposición al borde sobre la estructura de la vegetación de la selva mediana en la Isla Cozumel.* Universidad Nacional Autónoma de México (MSc thesis), Mexico City, Mexico.

Barraza, L. 2000. Educar para el futuro: En busca de un nuevo enfoque de investigación en Educación ambiental. Pp. 253–260 in *Memorias del Foro Nacional de Educación Ambiental*. UAA, SEP and SEMARNAP, Mexico City, Mexico.

Bautista, S. M. 2006. *Distribución, abundancia y dieta de perros y gatos ferales en la Isla Cozumel*. Instituto de Ecología A.C., (MSc thesis), Xalapa, Veracruz, Mexico.

Copa-Álvaro, M. E. 2007. *Efectos de los huracanes Emily y Wilma en los mamíferos medianos de Cozumel*. Universidad Nacional Autónoma de México (MSc thesis), Mexico City, Mexico.

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

Cuarón, A. D. & de Grammont, P. C. 2007. Shortcomings of threatened species categorization systems: Reply to Soberón and Medellín. *Conservation Biology* 21: 1368–1370.

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

Cuarón, A. D., de Grammont, P. C., Vázquez-Domínguez, E., Valenzuela-Galván, D., García-Vasco, D., Reid, F. & Helgen, K. 2008. *Procyon pygmaeus*. In *2008 IUCN Red List of Threatened Species*. <www.iucnredlist.org>. Downloaded on 19 November 2008.

de Grammont, P. C. & Cuarón, A. D. 2006. An evaluation of threatened species categorization systems used on the American continent. *Conservation Biology* 20: 14–27.

de Villa-Meza, A., Avila-Flores, R., Cuarón, A. D. & Valenzuela-Galván, D. (in press). *Procyon pygmaeus*. *Mammalian Species*.

Decker, D. M. 1991. Systematics of the coatis, genus *Nasua* (Mammalia: Procyonidae). *Proceedings of the Biological Society of Washington* 104: 370–386.

Forman, R. T. T. & Alexander, L. E. 1998. Roads and their major ecological effects. *Annual Review of Ecology and Systematics* 29: 207–231.

Fuentes-Montemayor, E., Cuarón, A. D., Vázquez-Domínguez, E., Benítez-Malvido, J., Valenzuela, D. & Andresen, E. 2009. Living on the edge: roads and edge effects on small animal populations. *Journal of Animal Ecology* 78: 857–865.

García-Vasco, D. 2005. *Distribución, abundancia y aspectos poblacionales del Mapache Enano (*Procyon pygmaeus*), un carnívoro insular endémico*. Universidad Veracruzana (Licenciatura, Advanced BSc thesis), Xalapa, Veracruz, México.

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

Gompper, M. E., Petrites, A. E. & Lyman, R. L. 2006. Cozumel Island Fox (*Urocyon* sp.) dwarfism and possible divergent history base on subfossil bones. *Journal of Zoology, London* 270: 72–77.

González-Baca, C. 2006. *Ecología de forrajeo de la boa (*Boa constrictor*), un depredador introducido a la Isla Cozumel*. Universidad Nacional Autónoma de México (MSc thesis), Mexico City, Mexico.

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

Helgen, K. M. & Wilson, D. E. 2005. A systematic and zoogeographic overview of the raccoons of Mexico and Central America. Pp. 221–236 in Sanchez-Cordero, V. & Medellin, R. A. (eds) *Contribuciones mastozoológicas: en homenaje a Bernardo Villa*. Instituto de Biologia e Instituto de Ecologia, UNAM, Mexico City, Mexico.

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

[IPCC] Intergovenmental Panel on Climate Change 2007. *Climate change synthesis report 2007*. Geneva, Switzerland.

Jones, J K. & Lawlor, T. E. 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. 1996. *The Cozumel Curassow: abundance, habitat preference and conservation*. University of Cambridge (MPhil thesis), Cambridge, U.K.

Martínez-Morales, M. A. & Cuarón, A. D. 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.* Columbia University (PhD thesis), New York, U.S.A.

McFadden, K. W., Wade, S. W., Dubovi, E. J. & Gompper, M. E. 2005. A serological and fecal parasitologic survey of the critically endangered Pygmy Raccoon (*Procyon pygmaeus*). *Journal of Wildlife Disease* 41: 615–617.

McFadden, K. W., Sambrotto, R. N., Medellín, R. A. & Gompper, M. E. 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., Gompper, M. E., Valenzuela, D. G. & Morales, J. C. 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., García-Vasco, D., Cuarón, A. D., Valenzuela, D., Medellín, R. A. & Gompper, M. E. in press. Vulnerable island carnivores: the endangered endemic dwarf procyonids from Cozumel Island. *Biodiversity and Conservation*

Mena, H. 2007. *Presencia de* Leptospira *spp. y moquillo canino en poblaciones de perros y carnívoros silvestres en la Isla Cozumel*. Universidad Nacional Autónoma de México (MSc thesis), Mexico City, Mexico.

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

Multicriteria SC 2007. *Caracterización y Diagnóstico*. Programa de Ordenamiento Ecológico Local del Municipio de Cozumel. Informe Técnico.

Navarro, D. & Suárez, M. 1989. A survey of the Pygmy Raccoon (*Procyon pygmaeus*). *Mammalia* 53: 458–461.

Navarro-Ramírez, M. G. 2005. *Conocimientos y percepciones sobre la fauna por los habitantes de la Isla Cozumel*. Universidad de Guadalajara (Licenciatura, Advanced BSc thesis), Guadalajara, Mexico.

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*. Universidad Nacional Autónoma de México (MSc thesis), Mexico City, Mexico.

Rojas-Pérez, J. D. 2007. *Efectos sinergéticos de la apertura de caminos y el huracán Emily sobre la vegetación arbórea, en una selva tropical de Cozumel, Quintana Roo*. Universidad Michoacana de San Nicolás de Hidalgo (Licenciatura, Advanced BSc) thesis, Morelia, Michoacán, México.

Romero-Nájera, I. 2004. *Distribución, abundancia y uso de hábitat de* Boa constrictor *introducida a la Isla Cozumel*. Universidad Nacional Autónoma de México (MSc thesis), Mexico City, Mexico.

Romero-Nájera, I., Cuarón, A. D. & González-Baca, C. 2007. Distribution, abundance, and habitat use of introduced *Boa constrictor* threatening the native biota of Cozumel Island, Mexico. *Biodiversity and Conservation* 16: 1183–1195.

Samudio, R., Kays, R., Cuarón, A. D., Pino, J. L. & Helgen, K. 2008. *Nasua narica*. In *2008 IUCN Red List of Threatened Species*. <www.iucnredlist.org>. Downloaded on 19 November 2008.

Schipper, J., Hoffmann, M., Duckworth, J. W. & Conroy, J. 2008. The 2008 IUCN red listings of the world's small carnivores. *Small Carnivore Conservation* 39: 29–34.

[SEDUMA] Secretaria de Desarrollo Urbano y Medio Ambiente 2008. *Programa de Ordenamiento Ecológico Local del Municipio de Cozumel*.<http://seduma.qroo.gob.mx/bitacora/index.php?option=com_docman&task=cat view&gid=108&Itemid=33> Downloaded on 19 November 2008.

[SEMARNAT] Secretaría de Medio Ambiente y Recursos Naturales 2002. Norma Oficial Mexicana NOM-059-ECOL-2001. Protección ambiental – Especies nativas de México de flora y fauna silvestres – Categoría de riesgo y especificaciones para su inclusión, exclusión o cambio – Lista de especies en riesgo. Diario Oficial de la Federación, Mexico City, Mexico.

Sotomayor, J. J. 2009. *Asociación de* Leptospira *y los ratones endémicos y exóticos en la Isla Cozumel, México*. Universidad Nacional Autónoma de México (Licenciatura, Advanced BSc thesis), Mexico City, Mexico.

Thomas, O. 1901. New insular forms of *Nasua* and *Dasyprocta*. *Annals and Magazine of Natural History* (7)7: 271–273.

Torres-Villegas, C. P. 2006. *Distribución, abundancia y comportamiento de perros y gatos en la Isla de Cozumel*. Universidad Nacional Autónoma de México (MSc thesis), Mexico City, Mexico.

Valenzuela, D. & Vázquez L. B. 2007. Consideraciones para priorizar la conservación de los carnívoros mexicanos. Pp. 197–214. in Sánchez-Rojas G. & Rojas-Martínez A. E. (eds) *Tópicos en sistemática, biogeografía, ecología y conservación de mamíferos*. Universidad Autónoma del Estado de Hidalgo, Pachuca, Hidalgo, México.

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# Notes on the distribution, status, and research priorities of little-known small carnivores in Brazil

Tadeu G. de OLIVEIRA

## Abstract

Ten species of small carnivores occur in Brazil, including four procyonids, four mustelids (excluding otters), and two mephitids. On the *IUCN Red List of Threatened Species* eight are assessed as Least Concern and two as Data Deficient. The state of knowledge of small carnivores is low compared to other carnivores: they are among the least known of all mammals in Brazil. The current delineation of *Bassaricyon* and *Galictis* congeners appears suspect and not based on credible information. Research needs include understanding distributions, ecology and significant evolutionary units, with emphasis on the Amazon Weasel *Mustela africana*.

*Keywords:* Amazon weasel, Data Deficient, Olingo, Crab-eating Raccoon, Hog-nosed Skunk

## Notas sobre la distribución, estado y prioridades de investigación de los pequeños carnívoros de Brasil

## Resumen

En Brasil ocurren diez especies de pequeños carnívoros, incluyendo cuatro prociónidos, cuatro mustélidos (excluyendo nutrias) y dos mephitidos. De acuerdo a la Lista Roja de Especies Amenazadas de la UICN, ocho especies son evaluadas como de Baja Preocupación (LC) y dos son consideradas Deficientes de Datos (DD). El estado de conocimiento de los pequeños carnívoros es bajo comparado con otros carnívoros y se encuentran entre los mamíferos menos conocidos de Brasil. La delineación congenérica actual de *Bassaricyon* y *Galictis* parece sospechosa y no basada en información confiable. Las necesidades de investigación incluyen el entendimiento de las distribuciones, ecología y unidades evolutivas significativas, con énfasis en la Comadreja Amazónica *Mustela africana*.

*Palabras clave:* Comadreja Amazónica, Deficiente de Datos, Mapache Cangrejero, Olingo, Zorrillo

## Introduction

The first records of natural history of Brazilian carnivores came from explorers of the late 18th to mid 19th centuries, discussing almost exclusively on morphology and taxonomy, with a few anecdotal records of biology (Oliveira 2006). This remained the sole source of knowledge until the 1970s, when field research began in Brazil and neighbouring countries, although mostly focused on larger canids, felids, and otters (e.g. Brady 1979, Schaller & Crawshaw 1980). Brazil supports 26 species of land Carnivora and, with a land area of 8.5 million km², should play a pivotal role in carnivore conservation in South America. Oliveira (2006) listed 10 small carnivores, with four in the Family Procyonidae (Crab-eating Raccoon *Procyon cancrivorus*, South American Coati *Nasua nasua*, Kinkajou *Potos flavus* and Beddard's Olingo *Bassaricyon beddardi*), four in Mustelidae (Amazon Weasel *Mustela africana*, Greater Grison *Galictis vittata*, Lesser Grison *G. cuja* and Tayra *Eira barbara*) and two in Mephitidae (Molina's Hog-nosed Skunk *Conepatus chinga* and Striped Hog-nosed Skunk *C. semistriatus*). Here I describe the distribution, status, and research priorities for Procyonidae, Mustelidae (excluding otters) and Mephitidae in Brazil.

## Distribution

The geographic ranges of Crab-eating Raccoon, South American Coati and Tayra are well understood compared with the remaining species. The Kinkajou's occurrence in the Atlantic rainforest region has been historically known but largely ignored (e.g. Vieira 1952, Emmons & Feer 1990, Nowak 1991, Eisenberg & Redford 1999), but recently has been recognised (e.g. Ford & Hoffmann 1988, Emmons & Feer 1997) and adequately assessed (Gonzaga & Rajão 2002).

The olingos *Bassaricyon* have often been considered conspecific and were considered a single species, *B. gabbii*, in Brazil by Cheida *et al.* (2006). However, considering the species acknowledged by Wozencraft (2005), *B. beddardi* would occur in northern Brazil, *B. alleni* might inhabit the western Amazon basin (see Emmons & Feer 1997), and *B. gabbii* would not occur at all. Using this taxonomy, the occurrence of what would seem to be *B. beddardi* has only recently been documented in Brazil, with a single specimen collected in 1998 in the northwest of the state of Amazonas, in Santa Isabel do Rio Negro (0°22′N, 64°02′W; Vaz 2004). An earlier record of *B. beddardi* (Mendez Pontes *et al.* 2002) from the country was presented by the authors as provisional because it was based solely on field observations of morphology.

The first published report of olingos in Brazil was from the Maracá Ecological Station (3°15′N, 61°22′W) in the state of Roraima (Mendes Pontes & Chivers 2002, Mendez Pontes *et al.* 2002). As yet *B. alleni* has not been reported for Brazil. However, Vaz (2004) reported a specimen collected in 1991 or 1992 at the Juruá River (8°40′S, 72°47′W), state of Acre, and deposited in the collection of Instituto Nacional de Pesquisas da Amazônia. Following Wozencraft (2005), this specimen would be assigned to *B. alleni*, but was regarded as *B. gabbi* (under a taxonomy considering these two conspecific) by Cheida *et al.* (2006). Consequently, two species of *Bassaricyon* seem to occur in Brazil, increasing to 27 the number of land carnivores. Their distributions, however, remain largely unknown.

Other puzzling distribution ranges are those of the grisons

*Fig. 1. Greater Grison* Galictis vittata *(left) and Lesser Grison* G. cuja *(right) from the Amazon region of Maranhão state (northern Brazil). Similar in appearance, they differ is several characters, particularly size and colour pattern.*

*Galictis*. Typically, the genus's range is divided in two, with the larger *G. vittata* in the mid-central and northern parts and the smaller *G. cuja* in mid-central and southern Brazil (Emmons & Feer 1997, Eisenberg & Redford 1999). There are no barriers or other obvious reasons to explain this pattern. All specimens I observed in museums and zoos from outside the Amazon basin were *G. cuja*, whereas all specimens from the Amazon basin were *G. vittata*. Although the two species are similar in appearance, there are several differences, of which colour and size are most easily seen in live specimens (Fig. 1). Typically, *G. vittata* is larger with silver-white dorsal hair, whereas *G. cuja* is smaller with yellowish dorsal hair. In the northern part of its range *G. cuja* is smaller than in the south, with some individuals that could be similar in size to *G. vittata*; and from this, some misidentifications have been made.

If this distribution pattern is correct, I infer that *G. vittata* would be restricted to the Amazon basin, whereas *G. cuja* would occur elsewhere in Brazil. What seems to limit their distribution is the Amazon rainforest – Cerrado borderline, even though *G. cuja* occupies rainforest areas outside the basin. Interestingly, two live captures from two different localities, besides several specimens collected at highways in the Amazonian part of the state of Maranhão were also of the latter species. *Galictis cuja* specimens have been collected in the Cerrado (savanna) biome of this state, but their presence in Amazonian localities is rather intriguing. One explanation is that, with loss of rainforest on its eastern border, this species could be expanding its range into highly degraded and open (anthropogenic) vegetation of former rainforests of the Amazon region, where *G. vittata* is typically found. Alternatively, but less likely to be so, *G. cuja* could have always been there but was not detected.

The Amazon Weasel is the least known carnivore in Brazil. Its distribution appears widespread but patchy throughout the Amazon basin. Most records were of specimens collected in the first half of the 20th century, with few additional recent observations, including those of live specimens (Izor & Peterson 1985, Ferrari & Lopes 1992, W. Cevidanes pers. comm.)

## Research knowledge and priorities

A recent analysis for Brazilian carnivores of the state of knowledge of ecology and conservation issues, and research priorities (Oliveira 2006) found that the least-known carnivore species are mostly the smallest. Of the 26 species evaluated (of which the small carnivores are described below in order of highest to lowest priority for research), the Amazon Weasel was the least known, lacking every sort of data. It was followed by the Lesser Grison, with a little information on diet, whereas the Greater Grison had limited information on diet and home range. Of the mustelids, the Tayra had only slightly more information on diet and home range, but lacks other basic ecological data. Molina's and Striped Hog-nosed Skunks had only limited data on distribution, diet and home range. The procyonids ranked as slightly better known, but were also poorly understood. For the olingos a similar pattern of the preceding species followed, with very limited records on diet and home range. The Crab-eating Raccoon and South American Coati had information almost restricted to diet, whereas the Kinkajou (rank 11), the best-studied, but still overall little-known, species, had a few studies related to home range/spatial ecology and social organisation. Of special interest should be clarification on species' distribution, especially for *Galictis*, *Bassaricyon* and *Conepatus*.

Therefore the research priorities for small carnivores in Brazil are: 1) basic natural history information for all species, including diet, home range, population dynamics and social organisation; 2) geographic ranges of *Bassaricyon, Galictis* and *Conepatus* species; 3) detection of significant evolutionary units of wide-ranging species; and 4) a nation-wide effort to collect any information on the Amazon Weasel. The paucity of scientific information synthesised by Oliveira (2006), which included some unpublished reports, has improved little in the past three years for most species. Nevertheless, some efforts are currently underway, especially related to species' distribution and molecular ecology (e.g. Kasper *et al*. 2009). There are also ongoing efforts to enhance knowledge of species' ecology, notably for skunks and coatis.

## Conservation status

None of the small carnivore species was considered threatened by the current Red List of the Brazilian government or by the *IUCN Red List of Threatened Species* (IUCN 2008). All were listed as Least Concern, except for the Amazon Weasel and olingos, which were listed as Data Deficient (Machado *et al*. 2005). The Amazon Weasel is probably rare with a patchy distribution, but given the enormousness of the Amazon basin does not seem to be in imminent danger. In contrast, olingos could be common, especially if the density reported by Mendes Pontes & Chivers (2002; 20 individuals/$km^2$) is typical. Although no formal evaluation has been made, field biologists tend to find skunks, coatis, raccoons and Kinkajou quite common where they occur, whereas grisons and Tayra tend to range from rare to common. None is in immediate danger or under any serious threat nationwide. However, some are threatened locally. For example, Tayra and South American Coati were considered Vulnerable in the Red List of the state of Rio Grande do Sul (Fontana *et al*. 2003), and Molina's Hog-nosed Skunk was considered Data Deficient in the red list of the state of Paraná (Mikich & Bérnils 2004), both in southern Brazil.

Brazilian species of small carnivores are poorly known, ranking among the least known mammals in the country. These species lack even the most basic information, especially on their ecology and distribution patterns. Detection of significant evolutionary units of wide-ranging species and a better understanding of their evolutionary patterns and relationships are also of interest. Although most of these species are listed as Least Concern on the *IUCN Red List of Threatened Species*, all remain research priorities through their importance in ecological communities and for the advancement of scientific information in the country.

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### References

Brady, C. A. 1979. Observations on the behavior and ecology of Crab-eating Fox (*Cerdocyon thous*). Pp. 161–171 in Eisenberg, J. F. (ed.) *Vertebrate ecology in the northern Neotropics*. Smithsonian Institution Press, Washington, D.C., U.S.A.

Cheida, C. C., Nakano-Oliveira, E., Fusco-Costa, R., Rocha-Mendes, F. & Quadros, J. 2006. Ordem Carnivora. Pp. 231–276 in dos Reis, N. R., Peracchi, A. L., Pedro, W. A. & Lima, I. P. (eds) *Mamíferos do Brasil*, Londrina, Brazil.

Eisenberg, J. F. & Tedford, K. H. 1999. *Mammals of the Neotropics: the central Neotropics (Ecuador, Peru, Bolivia, Brazil)*. University of Chicago Press, Chicago, U.S.A.

Emmons, L. H. & Feer, F. 1990. *Neotropical rainforest mammals: a field guide*, 1st edn. University of Chicago Press, Chicago, U.S.A.

Emmons, L. H. & Feer, F. 1997. *Neotropical rainforest mammals: a field guide*, 2nd edn. University of Chicago Press, Chicago, U.S.A.

Ferrari, S. F. & Lopes, M. A. 1992. A note on the behaviour of the weasel *Mustela* cf. *africana* (Carnivora, Mustelidae), from Amazonas, Brazil. *Mammalia* 56: 482–483.

Fontana, C. S., Bencke, G. A. & Reis, R. E. (eds) 2003. *Livro vermelho da fauna ameaçada de extinção no Rio Grande do Sul*. Edipucrs, Porto Alegre, Brazil.

Ford, L. S. & Hoffmann, R. S. 1988. *Potos flavus*. *Mammalian Species* 321: 1–9.

Gonzaga, L. P. & Rajão, H. 2002. Distribution of the Kinkajou *Potos flavus* (Procyonidae, Carnivora) in the Atlantic forest region of eastern Brazil. *Mammalia* 66: 123–127.

IUCN 2008. *2008 IUCN Red List of Threatened Species*. <http://www.iucnredlist.org>. Downloaded on 30 March 2009.

Izor, R. J. & Peterson, N. E. 1985. Notes on South American weasels. *Journal of Mammalogy* 66: 788–790.

Kasper, C. B., da Fontoura-Rodrigues, M. L., Cavalcanti, G. N., de Freitas, T. R. O., Rodrigues, F. H. G., Oliveira, T G. de & Eizirik, E. 2009. Recent advances in the knowledge of Molina's Hog-nosed Skunk *Conepatus chinga* and Striped Hog-nosed Skunk *C. semistriatus* (Carnivora, Mephitidae) in South America. *Small Carnivore Conservation* 41: 25–28.

Machado, A. B. M., Martins, C. S. & Drummond, G. M. (eds) 2005. *Lista da fauna brasileira ameaçada de extinção*. Fundação Biodiversitas, Belo Horizonte, MG, Brazil.

Mendes Pontes, A. R. & Chivers, D. J. 2002. Abundance, habitat use and conservation of the olingo *Bassaricyon* sp. in Maracá Ecological Station, Roraima, Brazilian Amazonia. *Studies on Neotropical Fauna and Environment* 37: 105–109.

Mendes Pontes, A. R., Rosas Ribeiro, P. F.& Mndonça, T. M. 2002. Olingos, *Bassaricyon beddardi* Pocock, 1921 in Brazilian Amazonia: status and recommendations. *Small Carnivore Conservation* 26: 7–8.

Mikich, S. B. & Bérnils, R. S. (eds) 2004. *Livro vermelho da fauna ameaçada no Estado do Paraná*. Instituto Ambiental do Paraná, Curitiba, Brazil.

Nowak, R. M. 1991. *Walker's mammals of the world*. Johns Hopkins University Press, Baltimore, U.S.A.

Oliveira, T. G. de 2006. Research in terrestrial Carnivora from Brazil: current knowledge and priorities for the new millennium. Pp. 39–45 in Morato, R. G., Rodrigues, F. H. G., Eizirik, E., Mangini, P. R., de Azevedo, F. C. C. & Marinho-Filho, J. (eds) *Manejo e conservação de carnívoros neotropicais*. Edições IBAMA, São Paulo, Brazil.

Schaller, G. B. & Crawshaw, P. G. 1980. Movement patterns of Jaguar. *Biotropica* 12: 161–168.

Vaz, S. M. 2004. Sobre a ocorrência de *Bassaricyon gabbii* Allen, 1876 no Brasil (Carnivora, Procyonidae). *Boletim do Museu Nacional, série zoologia*.

Vieira, C. C. 1952. Sobre o jupará do nordeste do Brasil (*Potos flavus nocturnus* (Wied)). *Papéis Avulsos do Museu de Zoologia* 11: 33–36.

Wozencraft, W. C. 2005. Order Carnivora. Pp. 532–628 in Wilson, D. E. & Reeder, D. M. (eds) *Mammal species of the world: a taxonomic and geographic reference*, 3rd edn. Johns Hopkins University Press, Baltimore, Maryland, U.S.A.

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# Recent advances in the knowledge of Molina's Hog-nosed Skunk *Conepatus chinga* and Striped Hog-nosed Skunk *C. semistriatus* in South America

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## Abstract

Biological knowledge of South American hog-nosed skunks *Conepatus* remains scarce. Although common in several regions, even basic life-history aspects are poorly known, and important issues of taxonomy and biogeography are yet to be resolved. A better understanding of these species' evolutionary history, biology and ecology would provide a solid basis for conservation planning. Here we provide an overview of current research efforts targeting these issues in Molina's Hog-nosed Skunk *Conepatus chinga* and Striped Hog-nosed Skunk *C. semistriatus*. Preliminary data corroborating these species' evolutionary distinctiveness, and concerning distribution, habitat use, food habits, spatial ecology, life history, and reproductive biology are provided. We hope that these will serve as a basis for in-depth studies targeting these species and the role they play in Neotropical carnivore communities.

*Keywords:* conservation planning, distribution, ecology, life history, morphology, reproductive biology, taxonomy

## Avances recientes en el conocimiento sobre *Conepatus chinga* y *C. semistriatus* en Suramérica

## Resumen

El conocimiento biológico sobre las mofetas de Suramérica aún permanece escaso. A pesar de ser comunes en muchas regiones, aún se conoce muy poco, incluso de aspectos básicos de su historia natural, y asuntos importantes todavía necesitan ser resueltos con respecto a su taxonomía y biogeografía. Por esta razón existe una necesidad urgente de llenar estos vacios y de tener un mejor entendimiento de la historia evolutiva, biología y ecología de estas especies, con el fin de proveer una base sólida para la planificación de su conservación. Aquí proveemos un vistazo a los esfuerzos de investigación actuales enfocados a estos aspectos relacionados con *Conepatus chinga* y *C. semistriatus*. Reportamos datos preliminares corroborando la distinción evolutiva entre estas dos especies y proveemos algunos datos sobre su distribución, uso de hábitat, hábitos alimenticios, ecología espacial y biología reproductiva. Esperamos que estos esfuerzos puedan servir como base para estudios más profundos enfocados en estas especies y en el rol que juegan en las comunidades de carnívoros neotropicales.

*Palabras clave*: biología reproductiva, distribución, ecología, historia de vida, morfología, planificación para conservación, taxonomía

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## Introduction

The family Mephitidae (skunks) comprises four genera, of which three occur exclusively in America: *Mephitis*, *Spilogale* and *Conepatus*. *Conepatus* (the hog-nosed skunks) is the only genus with species in both North (American Hog-nosed Skunk *C. leuconotus* and Striped Hog-nosed Skunk *C. semistriatus*) and South America (Molina's Hog-nosed Skunk *C. chinga*, *C. semistriatus* and Humboldt's Hog-nosed Skunk C. *humboldtii*); *Mephitis* and *Spilogale* occur exclusively in North America (Nowak 1999, Wozencraft 2005). In contrast to these two latter genera, *Conepatus* has received little attention from researchers, especially for the three South American species. In the last few years, our research group initiated studies concerning basic behaviour, distribution and ecology of *C. chinga* (Fig. 1) and *C. semistriatus* in Brazil. Molecular approaches are being employed to clarify taxonomy, biogeography and evolutionary history of the genus. Here we report first results of these ongoing efforts and project the future steps.

## Distribution, habitat use and taxonomy

One basic aspect is the geographic range of the two species. According to Redford & Eisenberg (1992) and Eisenberg & Redford (1999), *C. chinga* occurs from the northern region of Argentina to Uruguay, southern Bolivia, western Paraguay and central Chile. Recently, Cheida *et al.* (2006) and Cáceres (2004) reported it from the southern limits of Brazil to the Paraná (PR) and São Paulo (SP) states. However, records in the latter two states are rare, despite the fact that this region is one of the most studied in Brazil. Conspicuous, confirmed occurrence of *C. chinga* in Brazil is restricted to its southernmost states, Rio Grande do Sul (RS) and Santa Catarina (SC). The species's distribution in this region seems discontinuous, associated with two grassland regions historically separated by a broad patch of Atlantic Forest: the Brazilian Pampa in the southern part of RS and the Campos de Altitude region in Southern SC and northern RS. In sum, the species's occurrence seems strongly associated with Pampa and Chaco biomes, both characterised by open vegetation, cold temperatures and well-defined climatic seasons.

Use of forest areas by *C. chinga* is reported by Cáceres (2004) and Cheida *et al.* (2006) but is controversial. Cáceres (2004) suggested that its range is continuous along the mountains of the Serra do Mar, covered by dense Atlantic Forest. However, the record reported by Cáceres (2004), and many of our own records, suggest restriction to forest borders and to the *Araucaria* Forest, habitats

*Fig. 1. Hog-nosed Skunks; on the left:* Conepatus chinga *(Photo: Benhur Kasper), on the right:* C. semistriatus *(Photo: Jan Schipper).*

associated with grassland environments. In addition, it is possible that current fragmentation within forested regions is allowing the species's range to expand, a process also observed in species such as the Maned Wolf *Chrysocyon brachyurus* (R. de Paula verbally 2009). Thus, our view is that *C. chinga* is a grassland-dweller, not adapted to forested areas that may even bar its dispersal.

Regarding *C. semistriatus*, Eisenberg (1989) and Eisenberg & Redford (1999) suggested a geographic range from Mexico to northern Colombia, northern Venezuela, Peru and northeastern Brazil. Regarding this latter country, Cheida *et al.* (2006) extended the species's distribution to SP and also reported occurrence in the Cerrado (central Brazil) and Caatinga (northeastern Brazil) biomes. In agreement, our own records include the states of Maranhão, Goiás, Minas Gerais, São Paulo, Piauí, Bahia and Distrito Federal, all of which encompass a large portion of the Cerrado and/or Caatinga biomes, where the species seems relatively abundant. As reported by Cheida *et al.* (2006), the species does not seem to use forested areas, although some individuals could use densely covered sites as refuges, mainly in the dry season (Ferreira 2008). Some records point to use of Cerrado patches inside the Amazonian Forest and to transitional regions between the Cerrado and the Atlantic Forest, where open vegetation areas can be found.

Therefore, extensive forests probably constitute a barrier for *C. semistriatus* as well, raising the hypothesis that *C. semistriatus* and *C. chinga* populations could have been historically isolated by the broad extension of Atlantic Forest that covers most of the land between the Cerrado and the grassland environments of RS and SC states. This may also be so for other open-environment carnivores, such as Pampas Fox *Lycalopex gymnocercus* (RS and SC grasslands) and Hoary Fox *L. vetulus* (Cerrado).

However, uncertainties concerning the total geographic and reproductive isolation between *C. chinga* and *C. semistriatus* still persist. It is still uncertain which species has been recorded in SP state. Furthermore, the distribution limits of *C. semistriatus* in Brazil are also unclear. As *C. chinga* is thought to occur in the southern region of Bolivia and Paraguay, the possibility of additional contact zones cannot be discarded. Consequently, there may be some sympatry and gene flow between these two recognised species. Indeed, taxonomic delimitation within this genus has few systematic studies to confirm the traditionally described species (Cabrera 1958, Kipp 1965, Wozencraft 2005). A recent phylogenetic overview showed that two North American *Conepatus* species previously recognised through morphology (*C. leuconotus* and *C. mesoleucus*) actually comprise a single species (Dragoo *et al.* 2003). Similar taxonomic confusion could be involved with other species in the genus and should be investigated.

To elucidate these issues, we are initiating phylogenetic and phylogeographic studies based on molecular data. Our preliminary results, employing nucleotide sequences spanning about 550 base pairs (bp) of the mitochondrial DNA *NADH dehydrogenase 5* (*ND5*) gene from *Conepatus* individuals sampled in the grassland environments of RS and SC states, and also from three different points in the Cerrado, corroborate the recognition of two taxonomic entities. One clade, corresponding to *C. chinga*, seems to be restricted to the RS and SC grassland domains, while another, corresponding to *C. semistriatus*, was sampled only in the Cerrado field sites. The genetic distance between these two groups indicates that they diverged at least one million years ago. Additional genetic markers and more individuals have to be added to this survey to confirm the two clades and date their evolutionary divergence more precisely. Also, we aim to identify the limits of occurrence of both species and to investigate the possibility of any degree of gene flow, which is most likely in potential zones of sympatry. Furthermore, a broader taxonomic investigation of all *Conepatus* species, aiming to identify the number of valid taxa and to shed light on their evolution and phylogenetic relationships, is also of great interest for the design of adequate conservation strategies for this group, and may soon be feasible. For example, the validity of *C. humboldtii* demands investigation: there are no apparent ecological barriers between its range (Patagonian grasslands) and that of *C. chinga*.

## Ecology

There is currently very little information on the ecology of South American skunks. *Conepatus* is a specialised feeder of arthropods, mainly insects on the vegetation and within the soil (Redford & Eisenberg 1992). It is also an opportunistic predator, of small vertebrates and at carcasses of larger animals (Travaini *et al.* 1998, Donadio *et al.* 2004). Our field observations show that the foraging strategies of *C. chinga* and *C. semistriatus* mainly involve an active search for large insects such as beetles and larvae that live underground, digging the soil throughout almost their entire activity period. In some areas the consumption of vertebrates can be very important, as we observed for *C. chinga* in southeastern Brazil, where we have records of individuals feeding on fish (these being the first records of this item in their diets), amphibians, and eggs of both freshwater turtles and ground birds. Ingestion of eggs seems very frequent, with many turtle nests presenting characteristic signs of Molina's Hog-Nosed Skunk predation. In agreement, Gonçalves *et al.* (2007) noted that *C. chinga* is an important predator of nests of the turtle *Trachemys dorbigni* in southern Brazil. Regarding *C. semistriatus*, in addition to the high consumption of invertebrates (mainly beetles), some vertebrates have been recorded as being part of its diet as well. One individual was reported to feed on a dead bird, after attacking an owl nest. Silveira (1999) also reported the consumption of rodents and toads *Bufo* in the same region of the Cerrado.

Behavioural studies of both species are scarce. Rodrigues & Auricchio (1994) described *C. semistriatus* as solitary and non-territorial, with many individuals living in the same area, and males and females appearing together only in the breeding season. Data from a capture effort in Bahia state (Brazil) support these observations, with many individuals caught in a small area, where they seemed to have resting dens. Also, two individuals were caught at one time, in one trap. Behavioural observations of *C. chinga* are also very few, but nest sharing seems to be rare.

Concerning abundance estimates of *C. chinga*, there are two distinct patterns in the two different environments occupied in Brazil. In the Pampas it is among the most common carnivores, preliminary data showing 1.5 individuals/km². Conversely, *C. chinga* in the Campos de Altitude region seems to be very sparse: 280 km of line transects yielded only one sighting, and a 450 trap-night effort only one capture. It is not clear which factors cause this extreme variation in abundance, but they may relate to food availability and/or climate. Although *C. semistriatus* seems relatively abundant in Cerrado and Caatinga, there are no precise abundance estimates.

Other issues being studied are the spatial structure of home ranges and the activity patterns of *C. chinga*. The first survey found a home range of 1.9 km², shared by a male and a female, in Argentina (Donadio *et al.* 2001). Similarly, our preliminary observations indicate a mean home range of 1.9 km² (0.8 to 2.45 km²) for four males, with females showing much smaller home ranges (mean 0.8 km², range 0.3 to 1.2 km²), as measured for three individuals. The home ranges observed for *C. chinga* are much larger than those estimated for *C. humboldtii* (0.074–0.16 km²; Fuller *et al.* 1987) and *C. semistriatus* (0.18–0.53 km²; Sunquist *et al.* 1989), although caution should be taken in comparisons due to the limited number of sample individuals so far. More detailed survey might drastically change these preliminary results, especially for *C. semistriatus*, because it is larger than *C. chinga* and could plausibly use a larger home range.

Concerning activity patterns, as reported by Donadio *et al.* (2001), *C. chinga* in southern Brazil is almost exclusively nocturnal. Our first data indicate that it leaves its resting site about 30 minutes before sunset, remaining active until approximately 30 minutes before sunrise. At night, the activity is almost continuous, with few resting moments. Daytime activity is negligible, generally involving sleeping all day in resting or den sites. In the same study, Donadio *et al.* (2001) cited use of burrows as cover, each generally reused a few times. Our observations identified 14 types of resting sites, divided into four larger groups: burrows in the soil; under trunks and branches; within vegetation; and inside human-made structures. It seems to use several types of cover present in its home range, with different degrees of reuse. Further, each individual seems to use a central area, with several resting sites around it. The reuse of some resting sites may be intense, especially in the breeding season, when we recorded use of the same den for more than a month. Observations on the activity patterns on *C. semistriatus* in Mesoamerica are reported by González-Maya *et al.* (2009).

The proximity of hog-nosed skunks to houses or other human-made structures, along with high tolerance of people and domestic animals, seems strongly to affect their mortality rate. In our telemetry study focusing on *C. chinga*, of seven monitored individuals with home ranges near human dwellings, six died through human activity within six months of capture. Although usually not directly hunted or persecuted by farmers or other local people, the species is often killed by vehicles on roads and also by hunting dogs. In some roads of southernmost RS, *C. chinga* is one of the most frequent road-killed carnivores (F. Mazim verbally 2009). A similar situation may occur with *C. semistriatus*, which also seems to occupy human-modified landscapes and tolerates areas near town centres. The major observed threat is the high number of individuals killed on roads throughout the species's distribution. These data suggest that the species are very abundant in these areas; the impact of such mortality on populations is unknown.

Our observations indicate that *C. chinga* does not avoid the proximity of domestic dogs, nor of native wild canids such as Crab-eating Fox *Cerdocyon thous* and Pampas Fox. There is mortality from domestic dog attacks, but this overall proximity suggests no history of strong intraguild predation between these skunks and canids. This observation seems also to fit *C. semistriatus*, which may live near Crab-eating Fox and Maned Wolf, occasionally even chasing them off.

## Biology

Our *C. chinga* studies are also shedding some light on aspects of its biology and natural history. During capture for placement of radio-collars, we recorded morphometric data including body mass. In one studied population in southern Brazil there were significant differences between males and females in mean total length (58.8 cm for males and 55.3 cm for females) and mean body mass (2.26 kg and 1.58 kg), giving a remarkable sexual difference of 43%. Van Gerdal's (1968, *apud* Redford & Eisenberg 1992) assertion of sexual size dimorphism in Molina's Hog-nosed Skunk in Uruguay is therefore corroborated by our data.

Regarding reproduction of *C. chinga*, we recorded six litters, ranging from two to three pups (mean, 2.5). The reproductive period of *C. chinga* seems related to climatic seasons. Several matings were recorded in late winter and early spring (July–October), when we also found road-killed individuals carrying foetuses. In our telemetry survey, two females were observed with pups in the spring and early summer (October–January); one seemed to have given birth in September, being always seen with its pups until February, when the pups were no longer observed. In the summer (January and February), there were many observations of young individuals, apparently dispersing or searching for territories. Thus, we believe that birthing coincides with the beginning of the spring, and that the juveniles disperse in summer, after living 4–5 months with their mothers. There are still no such data for *C. semi-*

*striatus*, but our ongoing field efforts are also designed to address issues of this species's biology.

## Conclusions

Considering information from literature and our first surveys, we can recognise that *C. chinga* and *C. semistriatus* are: (i) two separate species—genetically and morphologically distinct and apparently occurring in two different (and perhaps isolated) habitats: Cerrado (*C. semistriatus*) and Pampa/Chaco (*C. chinga*); (ii) closely associated with grassland habitats; (iii) feeders mainly on insects, but also opportunistically on small vertebrates, larger carcasses and vertebrate eggs; (iv) nocturnal, solitary, with an apparently defined breeding season associated with warmer weather (early spring), and showing some degree of parental care (pups spend 4–5 months with their mothers) prior to juvenile dispersal; and (v) tolerant of human disturbance, although this is a major cause of mortality.

All these studies and field observations are in a very initial phase, and some current impressions may need to be re-evaluated as we gather more data. Moreover, it is also clear that these are very poorly known species, still requiring many studies to refine current understanding of ecology, behaviour, evolution and taxonomy. We hope that our ongoing efforts will enhance understanding of the biology of *Conepatus*, allowing design and implementation of effective conservation strategies.

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### References

Cabrera, A. 1958 (for 1957). Catálogo de los mamíferos de América del Sur. *Revista del Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", Ciencias Zoológicas* 4(1): i–iv, 1–308.

Cáceres, N. C. 2004. Occurrence of *Conepatus chinga* (Molina) (Mammalia, Carnivora, Mustelidae) and other terrestrial mammals in the Serra do Mar, Paraná, Brazil. *Revista Brasileira de Zoologia* 21: 577–579.

Cheida, C. C., Nakano-Oliveira, E., Fusco-Costa, R., Rocha-Mendes, F. & Quadros, J. 2006. Ordem Carnivora. Pp. 231–276 in dos Reis, N. R., Peracchi, A. L., Pedro, W. A. & Lima, I. P. (eds) *Mamíferos do Brasil*. Londrina, Brazil.

Donadio, E., Di Martino, S., Aubone, M. & Novaro, A. J. 2001. Activity patterns, home-range, and habitat selection of the Common Hog-nosed Skunk, *Conepatus chinga* (Mammalia, Mustelidae), in north-western Patagonia. *Mammalia* 65: 49–54.

Donadio, E., Di Martino, S., Aubone, M. & Novaro, A. J. 2004. Feeding ecology of the Andean Hog-nosed Skunk (*Conepatus chinga*) in areas under different land use in north-western Patagonia. *Journal of Arid Environments* 56: 709–718.

Dragoo, J. W., Honeycutt, R. L. & Schmidly, D. J. 2003. Taxonomic status of white-backed hog-nosed skunks, genus *Conepatus* (Carnivora: Mephitidae). *Journal of Mammalogy* 84: 159–176.

Eisenberg, J. F. 1989. *Mammals of the Neotropics: the northern Neotropics*. University of Chicago Press, Chicago, U.S.A.

Eisenberg, J. F. & Redford, K. H. 1999. *Mammals of the Neotropics: the central Neotropics (Ecuador, Peru, Bolivia, Brazil)*. University of Chicago Press, Chicago, U.S.A.

Ferreira, G. B. 2008. *O mosaico de habitats e a comunidade de mamíferos de médio e grande porte do Parque Nacional Cavernas do Peruaçu, norte de Minas Gerais*. Universidade Federal de Minas Gerais (Msc. dissertation), Minas Gerais, Brazil.

Fuller, T. K., Johnson, W. E., Franklin, W. L. & Johnson, K. A. 1987. Notes on the Patagonian Hog-nosed Skunk (*Conepatus humboldtii*) in southern Chile. *Journal of Mammalogy* 68: 864–867.

Gonçalves, F. A., Cechin, S. Z. & Bager, A. 2007. Predação de ninhos de *Trachemys dorbigni* (Duméril & Bibron) (Testudines, Emydidae) no extremo sul do Brasil. *Revista Brasileira de Zoologia* 24: 1063–1070.

González-Maya, J. F., Schipper, J. & Benítez, A. 2009. Activity patterns and community ecology of small carnivores in the Talamanca region, Costa Rica. *Small Carnivore Conservation* 41: 9–14.

Kipp, H. 1965. Beitrag zur Kenntnis der Gattung *Conepatus* Molina, 1782. *Zeitschrift für Säugetierkunde* 30: 193–232.

Nowak, R. M. 1999. *Walker's mammals of the world*. Johns Hopkins University Press, Baltimore, U.S.A.

Redford, K. H. & Eisenberg, J. F. 1992. *Mammals of the Neotropics: the southern cone*. University of Chicago Press, Chicago, U.S.A.

Rodrigues, A. S. M. & Auricchio, P. 1994. *Mustelídeos do Brasil*. Coleção Terra Brasilis, Série Zoologia – Zoo III, Mamíferos do Brasil, São Paulo-SP, Brazil.

Silveira, L. 1999. *Ecologia e conservação dos mamíferos carnívoros do Parque Nacional das Emas, Goiás*. Universidade Federal do Goiás (Msc. dissertation), Goiânia, Goiás, Brazil.

Sunquist, M. E., Sunquist, F. & Daneke, D. E. 1989. Ecological separation in a Venezuelan llanos carnivore community. Pp. 197–232 in Redford, K. H. & Eisenberg, J. F. (eds) *Advances in Neotropical mammalogy*. Sandhill Crane Press, Gainesville, Florida, U.S.A.

Travaini, A., Delibes, M. & Ceballos, O. 1998. Summer foods of the Andean Hog-nosed Skunk (*Conepatus chinga*) in Patagonia. *Journal of Zoology, London* 246: 457–460.

Wozencraft, W. C. 2005. Order Carnivora. Pp. 532–628 in Wilson, D. E. & Reeder, D. M. (eds) *Mammal species of the world: a taxonomic and geographic reference*, 3rd edn. Johns Hopkins University Press, Baltimore, Maryland, U.S.A.

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# Distribution, natural history, and conservation of the Patagonian Weasel *Lyncodon patagonicus*

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## Abstract

The Patagonian Weasel *Lyncodon patagonicus* is a small mustelid that lives in the Southern Cone of South America (Argentina and Chile). The species is known from relatively few direct observations and collected specimens. In this paper we review available data about *L. patagonicus* to assess its conservation status. Information about its natural history is largely anecdotal, and suggests that it feeds on fossorial rodents. Known record localities are based on specimens observed or collected during the nineteenth and twentieth centuries. Its distribution encompasses herbaceous and shrub steppes and xerophytic woodlands, and presumably includes protected areas. However, the presence of *L. patagonicus* in these areas must be reconfirmed, because most records of occurrence are more than 10 years old. The perceived scarcity of this species in the wild could be real, but its relatively widespread distribution might protect it from the effects of environmental alteration and other human impacts. We conclude that field studies are urgently needed to confirm the current distribution and ecological requirements of the Patagonian Weasel.

*Keywords*: Argentina, Chile, Mustelidae, recommendations for study, research needs, South America

### Distribución, historia natural y conservación del Huroncito Patagónico *Lyncodon patagonicus*

## Resumen

El Huroncito Patagónico *Lyncodon patagonicus* es un pequeño mustélido que habita el extremo sur de América del Sur (Argentina y Chile). Esta especie es conocida a través de escasas observaciones directas y unos pocos ejemplares depositados en museos. En este trabajo recopilamos la información existente sobre este mustélido para diagnosticar su estado de conservación. La información sobre historia natural es básicamente anecdótica y sugiere que depreda principalmente sobre roedores fosoriales. La mayoría de las referencias sobre su distribución fueron hechas durante los siglos XIX y XX. La amplia distribución de esta especie abarca ambientes de estepas graminosas y arbustivas y bosque xerófilo, incluyendo presuntivamente algunas áreas protegidas. Sin embargo, la presencia de *Lyncodon patagonicus* en las mismas debe ser confirmada, dado que las citas para dichas áreas fueron realizadas en general hace más de 10 años. La escasa abundancia de esta especie podría ser natural y por su amplia distribución podría verse moderadamente amparada ante las modificaciones ambientales y el impacto antrópico. Sin embargo, hacen faltan urgentes trabajos de campo y ecológicos para corroborar la distribución de esta especie y obtener información precisa sobre su historia natural.

*Palabras clave*: Argentina, Chile, Mustelidae, necesidad de estudios, necesidades de investigación, Sur America

## Introduction

Twelve mustelid species live today in South America: four are otters (Lutrinae) and the remaining seven native species are currently classified in the subfamily Mustelinae (Wilson & Reeder 2005, Koepfli *et al.* 2008). Another species, the non-native American Mink *Neovison vison,* was introduced from North America for fur farming in some ranches of southern Argentina and in recent decades has invaded Patagonia and Tierra del Fuego (Fasola *et al.* 2009). The habits of most species are relatively well studied, excepting the three smaller species (*Mustela africana*, *M. felipei*, *Lyncodon patagonicus*): these are only known from a few collected specimens and anecdotal information (Izor & de la Torre 1978, Schreiber *et al.* 1989, Larivière 1998, 1999a, 1999b, Presley 2000, Prevosti & Pardiñas 2001, Nowak 2005, Kruuk 2006, Yensen & Tarifa 2003a, 2003b).

The Patagonian Weasel *Lyncodon patagonicus* (de Blainville, 1842) (Fig. 1) is one of the most poorly known carnivores of southern South America (Redford & Eisenberg 1992; Prevosti & Pardiñas 2001). Most available information about this small mustelid (head and body length ~25 cm; tail ~10 cm) comes from the very few specimens housed in museum collections, which are useful primarily for morphological, phylogenetic, and distributional studies (Prevosti & Pardiñas 2001). Data regarding its natural history remains entirely anecdotal (e.g. Pocock 1926, Cabrera & Yepes 1940, Redford & Eisenberg 1992, Prevosti & Pardiñas 2001).

In this paper we review the available information about systematics, distribution, and natural history of *Lyncodon patagonicus* to assess its conservation status.

## Systematics

*Lyncodon* was traditionally included with *Galictis* in the family Mustelidae, subfamily Galictinae, tribe Galictini (Reig 1956, Baskin 1998). However, other authors do not recognise Galictinae and Galictini, simply allocating these species to the subfamily Mustelinae (e.g. Wozencraft 2005). Morphology-based phylogenetic study suggested that *Lyncodon* might be the sister taxon of the African weasel genus *Poecilogale* (Bryant *et al.* 1993). Unfortunately, *Lyncodon* has not been included in published molecular phylogenies (e.g. Fulton & Strobeck 2006, Koepfli *et al.* 2008), but in these phylogenies *Galictis* is allied with *Poecilogale* and another African genus, *Ictonyx* (along with the Marbled Polecat

*Fig. 1. Female Patagonian Weasel* Lyncodon patagonicus *from Puerto Madryn surroundings, Chubut, Argentina (Photograph by Darío Podesta). See front cover for the photograph of a male.*

*Vormela peregusna* of Eurasia), suggesting that *Lyncodon* could be part of this clade of largely Neotropical and African species.

The genus *Lyncodon* comprises only two species: the living *L. patagonicus*, known from Late Pleistocene to Recent contexts (Prevosti & Pardiñas 2001), and the extinct *L. bosei*, known from the Middle-Lower Pleistocene (Pascual 1958).

Two subspecies have sometimes been recognised under the living species, *L. p. patagonicus* (de Blainville, 1842), in Patagonia, southern Buenos Aires and Mendoza provinces, and *L. p. thomasi* Cabrera, 1929, from north-western Argentina (Cabrera 1929, Cabrera 1958). However, the validity and the distribution of these nominal taxa is far from clear and ideally requires testing with modern approaches.

## Distribution

*Lyncodon patagonicus* is found in herbaceous and shrub steppes and xerophytic woodlands of north-western, central, and southern Argentina and southern Chile, from sea level up to 2,000 m, and within arid–semi-arid climates (Osgood 1943, Tamayo & Frassineti 1980, Prevosti & Pardiñas 2001). In Table 1 we provide a revised list of recorded occurrences, both contemporary and fossil (see also Fig. 2). *Lyncodon* is almost entirely restricted to Argentina and indications from Chile are limited to two references (Wolffsohn 1923, Peña 1966). Most historical records were made in the nineteenth and early twentieth centuries. The last confirmed record from Buenos Aires was made in the first part of the 20th century, in Pocock (1926). In fact, the species is probably extirpated from most of the territory of this province (Prevosti & Pardiñas 2001), potentially surviving only south Bahía Blanca and in the boundary with the La Pampa province. An increase of precipitation of more than 300 mm per year in recent decades and the expansion of agriculture are considered the main factors that triggered the retraction of the Patagonian Weasel in Buenos Aires province (Prevosti & Pardiñas 2001). Only about 10 site occurrences for *Lyncodon* have been recorded in the past decade. These recent records originate from Santa Cruz, Chubut, Río Negro, and San Juan provinces in Argentina. During Late Pleistocene and Holocene, *L. patagonicus* occurred in eastern portions of Buenos Aires province where it is now absent (Prevosti & Pardiñas 2001). This geographic occurrence was related to the existence of more arid climates in these areas compared to present times (Tonni *et al.* 1999, Prevosti & Pardiñas 2001). In the Late Holocene the species was also present in Chilean side of the Isla Grande de Tierra del Fuego (Latorre 1998), an island that was part of the South American continent until late Pleistocene (Clapperton 1993), and is the

*Table 1. Modern and fossil record localities for* Lyncodon patagonicus.

| # | Specific locality | Province/Region | Country | Lat. ºS | Long. ºW | Age | Date | Primary source |
|---|---|---|---|---|---|---|---|---|
| 1 | Alemanía | Salta | Argentina | 25º 38′ | 65º 37′ | Recent | 1976 | Olrog 1976 |
| 2 | Cafayate | Salta | Argentina | 26º 06′ | 65º 57′ | Recent | 1976 | Olrog 1976 |
| 3 | El Timbó | Tucumán | Argentina | 26º 14′ | 65º 23′ | Recent | 1958 | Olrog 1958 |
| 4 | Colalao del Valle | Tucumán | Argentina | 26º 22′ | 65º 56′ | Recent | 1976 | Olrog 1976 |
| 5 | Amaicha del Valle | Tucumán | Argentina | 26º 23′ | 65º 55′ | Recent | 1976 | Olrog 1976 |
| 6 | Santa María | Catamarca | Argentina | 26º 42′ | 66º 02′ | Recent | 1976 | Olrog 1976 |
| 7 | Banda del río Salí | Tucumán | Argentina | 26º 51′ | 65º 10′ | Recent | 1976 | Olrog 1976 |
| 8 | Andalgalá | Catamarca | Argentina | 27º 36′ | 66º 20′ | Recent | 1946 | Olrog 1958 |
| 9 | Guampacha | Santiago del Estero | Argentina | 28º 03′ | 64º 48′ | Recent | 1986 | Massoia & Latorraca 1992 |
| 10 | La Rioja | La Rioja | Argentina | 29º 25′ | 66º 51′ | Recent | 1929 | Cabrera 1929 |
| 11 | Sol de Julio | Santiago del Estero | Argentina | 29º 33′ | 63º 27′ | Recent | 1976 | Olrog 1976 |
| 12 | Patquía | La Rioja | Argentina | 30º 03′ | 66º 53′ | Recent | 1931 | Yepes 1935 |
| 13 | Pampa de Gualilan | San Juan | Argentina | 30º 80′ | 68º 90′ | Recent | 2003 | Sanabria & Quiroga 2003 |
| 14 | Uspallata | Mendoza | Argentina | 32º 41′ | 69º 22′ | Recent | 1986 | Castro & Cicchino 1986 |
| 15 | Tupungato | Mendoza | Argentina | 33º 21′ 55″ | 69º 08′ 3″ | Recent | <1965 | Roig 1965 |
| 16 | Tunuyán | Mendoza | Argentina | 33º 34′ 24″ | 69º 01′ 19″ | Recent | <1965 | Roig 1965 |
| 17 | San Carlos | Mendoza | Argentina | 33º 45′ 57″ | 69º 02′ 4″ | Recent | <1965 | Roig 1965 |
| 18 | San Rafael | Mendoza | Argentina | 34º 36′ 35″ | 68º 21′ 12″ | Recent | <1935 | Yepes 1935 |
| 19 | Cueva del Tigre | Mendoza | Argentina | 35º 45′ 49″ | 69º 13′ | Recent | 1991 | Trajano 1991 |
| 20 | Azul | Buenos Aires | Argentina | 36º 47′ | 59º 51′ | Recent | 1879 | Burmeister 1879 |
| 21 | Bonifacio | Buenos Aires | Argentina | 36º 49′ | 62º 15′ | Recent | 1926 | Pocock 1926 |
| 22 | Macachín | La Pampa | Argentina | 37º 09′ | 63º 40′ | Recent | 1992 | Prevosti & Pardiñas 2001 |
| 23 | Marimenuco | Araucanía | Chile | 38º 42′ | 71º 06′ | Recent | 1966 | Peña 1966 |
| 24 | Rincón Grande | Buenos Aires | Argentina | 39º 42′ | 63º 13′ | Recent | 1881 | Doering 1881 |

*Table 1 contd.*

| # | Specific locality | Province/Region | Country | Lat. ºS | Long. ºW | Age | Date | Primary source |
|---|---|---|---|---|---|---|---|---|
| 25 | Estancia Cerro de los Pinos | Neuquén | Argentina | 39º 57′ | 71º 05′ | Recent | 1993 | Prevosti & Pardiñas 2001 |
| 26 | Carmen de Patagones | Buenos Aires | Argentina | 40º 48′ | 63º | Recent | 1881 | Doering 1881 |
| 27 | 9 km SE Los Menucos | Río Negro | Argentina | 40º 53′ 24″ | 68º 02′ 59″ | Recent | 1987 | Prevosti & Pardiñas 2001 |
| 28 | Estancia San Pedro | Río Negro | Argentina | 40º 54′ | 70º 42′ | Recent | 2000-2002 | Teta *et al.* 2008 |
| 29 | San Carlos de Bariloche | Río Negro | Argentina | 41º 08′ | 71º 17′ | Recent | 1973 | Massoia 1992 |
| 30 | Estancia El Desafío | Río Negro | Argentina | 41º 18′ | 71º 06′ | Recent | 2000-2002 | Teta *et al.* 2008 |
| 31 | Puesto Horno, Estancia Maquinchao | Río Negro | Argentina | 41º 42′ | 68º 39′ | Recent | 2000-2002 | Teta *et al.* 2008 |
| 32 | Estancia Calcatreo | Río Negro | Argentina | 41º 42′ | 69º 24′ | Recent | 2006 | This paper |
| 33 | Cañadón Angostura de Cides, Estancia Calcatreo | Río Negro | Argentina | 41º 43′ | 69º 22′ | Recent | 2000-2002 | Teta *et al.* 2008 |
| 34 | Puerto Pirámide | Chubut | Argentina | 42º 34′ | 64º 18′ | Recent | 1991 | Prevosti & Pardiñas 2001 |
| 35 | Piedra Parada | Chubut | Argentina | 42º 39′ | 70º 06′ | Recent | 2004 | This paper |
| 36 | Puerto Madryn | Chubut | Argentina | 42º 45′ | 65º 02′ | Recent | 2005 | This paper |
| 37 | Arroyo Quichaure | Chubut | Argentina | 43º 50′ | 70º 50′ | Recent | 1887 | Burmeister 1888 |
| 38 | Cabo Dos Bahías | Chubut | Argentina | 44º 54′ | 65º 39′ | Recent | 1979 | Harris 2008 |
| 39 | Puesto El Chango, Ea. Santa María | Chubut | Argentina | 45º 27′ 51″ | 69º 25′ 54″ | Recent | 2007 | This paper |
| 40 | Lago Blanco | Chubut | Argentina | 45º 56′ | 71º 16′ | Recent | 1904 | Koslowsky 1904 |
| 41 | 10 km S Perito Moreno on RN 40 | Santa Cruz | Argentina | 46º 41′ | 70º 52′ | Recent | 2005 | This paper |
| 42 | Río Guenguel | Chubut | Argentina | 46º | 71º | Recent | 1896 | Koslowsky 1904 |
| 43 | Aguada Grande | Santa Cruz | Argentina | 47º 20′ | 67º 35′ | Recent | 1923 | Yepes 1935 |
| 44 | Extremo NE Lago Cardiel and RN 40 | Santa Cruz | Argentina | 48º 54′ | 71º 01′ | Recent | 2005 | This paper |
| 45 | Near Puerto Santa Cruz | Santa Cruz | Argentina | 50º 01′ | 68º 32′ | Recent | 1899 | Allen 1905 |
| 46 | Puerto Prat | Magallanes | Chile | 51º 37′ | 72º 38′ | Recent | 1921 | Wolffsohn 1923 |
| 47 | “Las Represas de las Indias” | Santiago del Estero | Argentina | 28º 10′ | 63º | Holocene | - | Kraglievich & Rusconi 1931 |
| 48 | Córdoba | Córdoba | Argentina | 31º 25′ | 64º 12′ | Pleistocene | - | Ameghino 1889 |
| 49 | Las Lagunitas | San Luis | Argentina | 33º 41′ | 65º 28′ | Pleistocene | - | Prevosti & Pardiñas 2001 |
| 50 | Estancia el Centenario | San Luis | Argentina | 34º 12′ 27″ | 65º 51′ 59″ | Holocene | - | This paper |
| 51 | Luján | Buenos Aires | Argentina | 34º 34′ | 59º 06′ | Pleistocene | - | Ameghino 1888 |
| 52 | Estación Manuel J. García | Buenos Aires | Argentina | 34º 40′ | 59º 26′ | Holocene | - | Prevosti & Pardiñas 2001 |
| 53 | Cortaderas | Buenos Aires | Argentina | 38º 21′ | 61º 06′ | Holocene | - | Politis *et al.* 1983 |
| 54 | Chenque Haichol | Neuquén | Argentina | 38º 35′ | 70º 40′ | Holocene | - | Massoia 1992 |
| 55 | Camet Norte | Buenos Aires | Argentina | 38º | 57º 33′ | Pleistocene | - | Prevosti & Pardiñas 2001 |
| 56 | Cueva y Paredón Loncomán | Río Negro | Argentina | 40º 47′ | 70º 10′ | Holocene | - | Andrade *et al.* 2005 |
| 57 | Alero Santo Rosario | Río Negro | Argentina | 41º 43′ | 68º 40′ | Holocene | - | Andrade *et al.* 2007 |
| 58 | Punta Buenos Aires | Chubut | Argentina | 42º 12′ | 64º 11′ | Holocene | - | This paper |
| 59 | El Riacho | Chubut | Argentina | 42º 25′ | 64º 36′ | Holocene | - | This paper |
| 60 | Playa Pardelas | Chubut | Argentina | 42º 38′ | 64º 12′ | Holocene | - | This paper |
| 61 | Establecimiento San Pablo | Chubut | Argentina | 42º 39′ 55″ | 64º 12′ 54″ | Holocene | - | This paper |
| 62 | Punta Este | Chubut | Argentina | 42º 47′ | 64º 57′ | Holocene | - | This paper |
| 63 | Cerro Avanzado | Chubut | Argentina | 42º 50′ | 64º 52′ | Holocene | - | This paper |
| 64 | El Pedral | Chubut | Argentina | 42º 57′ | 64º 22′ | Holocene | - | This paper |
| 65 | Cueva de los Chingues, Parque Nacional Pali-Aike | Magallanes | Chile | 52º 05′ 37″ | 69º 44′ 31″ | Pleistocene | - | This paper |
| 66 | Tres Arroyos 1 | Magallanes | Chile | 53º 23′ | 68º 47′ | Holocene | - | Latorre 1998 |

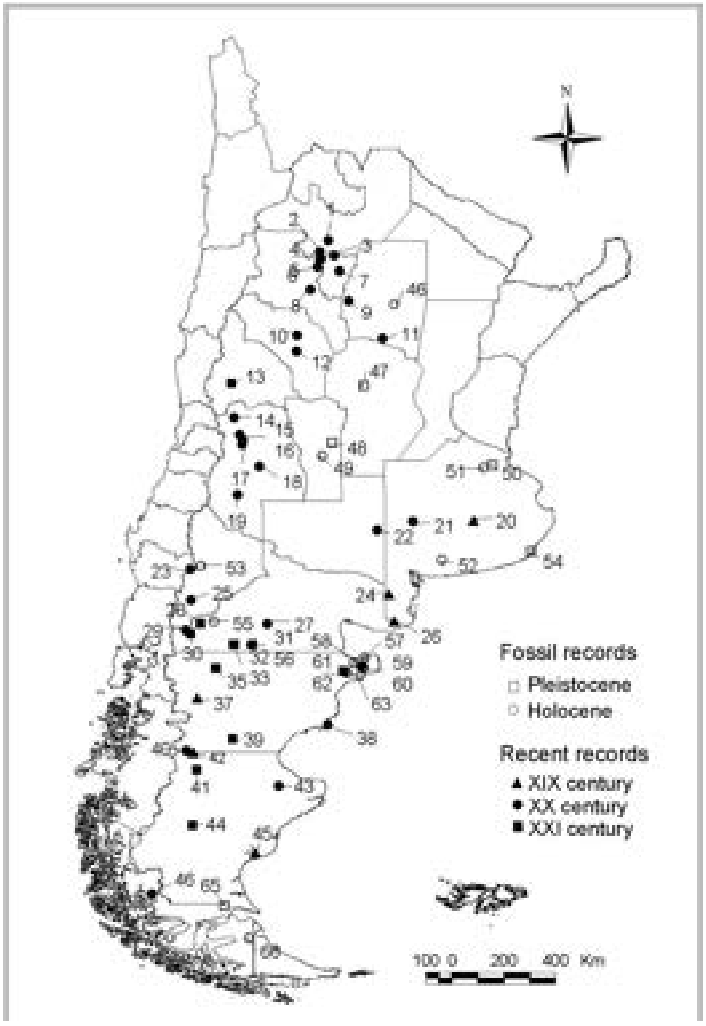

*Fig. 2. Modern and fossil recorded localities for the Patagonian Weasel* Lyncodon patagonicus*, endemic to southern South America. Numbers refer to localities listed in Table 1.*

only known mustelid that reached this island. However, as with many other aspects of this species, its extirpation from the Tierra del Fuego region remains to be studied in detail.

## Natural history

The habits of *L. patagonicus* are little known. Information about its natural history is based on scattered and occasional field observations (e.g. Cabrera & Yepes 1940, Redford & Eisenberg 1992). Available information indicates that *L. patagonicus* is nocturnal–crepuscular and preys on fossorial rodents (e.g. *Ctenomys* and *Microcavia*) and birds (Koslowsky 1904, Cabrera & Yepes 1940, Redford & Eisenberg 1992). Its predation of subterranean micromammals is supported by several incidental lines of evidence. First, it has a small, long and tubular body (e.g. Pocock 1926, Cabrera 1929) perfectly matching the small diameter (8–10 cm) of *Ctenomys* burrows. Second, several specimens of *L. patagonicus* were recovered from Holocene sand-dune deposits in Chubut and San Luis provinces, in which cranial and mandible remains of *Ctenomys* were the most common fossil specimens present. In addition, Castro & Cicchino (1986) found ectoparasites of *Ctenomys* in a study-skin of *L. patagonicus*. A complete picture of *L. patagonicus* habits requires direct ecological studies; the same is true regarding its potential trophic overlap with the more widespread, larger, and aggressive sympatric Lesser Grison *Galictis cuja*. It is eaten by the Black-chested Buzzard Eagle *Geranoaetus melanoleucus*, at least in Patagonia (Teta *et al*. 2008). Ecological interactions with other small mustelids, such as *G. cuja* and the introduced invasive *Neovison vison,* merit further study.

## Conservation

*Lyncodon patagonicus* was categorised as "Near Threatened" in the Argentinean Red Book (Díaz & Ojeda 2000), primarily based on the scarcity of knowledge. In Chile it was listed as "rare" by the Corporación Nacional Forestal (1993). More recently, IUCN assessed the species globally as Data Deficient (Kelt & Pardiñas 2008): there is no published information on current population status, ecology or major threats. According to Kelt & Pardiñas (2008), the scarcity of this species appears natural. Thus, there are no reasonable justifications for considering it to be globally threatened; which would seem over-precautionary. In addition, its large distribution range and its occurrence in some protected areas seem to ensure its immediate conservation. In addition, there is no likely major threat to this species, although habitat degradation (mainly due to sheep grazing) and occasional killing by ranchers are local threats. It is possible that it occurs in several protected areas of southern Patagonia (e. g. Nahuel Huapi, Lanin, Lago Puelo, Los Alerces, Perito Moreno, and Los Glaciares National Parks), although most of these reserves are dominated by forested habitats rather than open arid-lands. Better documentation is needed to confirm occurrence in all protected areas For example, a skin exhibited as *L. patagonicus* in the visitor centre of the Natural Monument Bosques Petrificados (Santa Cruz, Argentina) is actually *Galictis cuja* (see Prevosti & Travaini 2005). Occurrence of *Lyncodon* in the Reserva Provincial Península Valdés, Chubut, as stated by Daciuk (1974) and Prevosti & Pardiñas (2001) is open to doubt and recent voucher specimens are much needed.

## Conclusions

The main message from this review is the scarcity of reliable information on *L. patagonicus*, a surprise considering its wide distribution and potentially important trophic role as a predator, especially in Patagonia. Several factors may explain this lack of knowledge. First, and perhaps the main factor, is its apparent natural scarcity. Even local farmers and settlers, in general with good knowledge of mammal fauna, are not aware of the existence of this mustelid (pers. obs.). Another factor is confusion between *L. patagonicus* and *G. cuja*, the latter being more visible and abundant. We also highlight the lack of any specific programmes of research focused on the ecology or other biological aspects of *L. patagonicus*. Several groups of researchers are working with Patagonian or Central Argentinean mammals, including research aimed at a better understanding of carnivore dynamics and diets (e.g. Novaro *et al.* 2000, Zapata *et al.* 2008), but we are not aware of any study efforts regarding the Patagonian Weasel.

Clearly, field and ecological studies are urgently needed to confirm the current distribution, natural history, and ecological requirements of this species. This information will be necessary for developing effective conservation strategies for this little-known species.

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## References

Allen, J. A. 1905. The Mammalia of southern Patagonia. *Reports of the Princeton University Expedition to Patagonia 1896–1899*, vol. 3 (Zoology): 1–210.

Ameghino, F. 1888. *Rápidas diagnósis de algunos mamíferos fósiles nuevos de la República Argentina*. P. E. Coni, Buenos Aires, Argentina.

Ameghino, F. 1889. Contribución al conocimiento de los mamíferos fósiles de la República Argentina. *Actas de la Academia Nacional de Ciencias en Córdoba* 6: 1–1027.

Andrade, A., Carignano, L., Panti, C. & Teta, P. 2005. Bioestratigrafía del sitio arqueológico Cueva y Paredón Loncomán, área Pilcaniyeu, SO. Río Negro. *Actas del XIII Congreso Nacional de Arqueología* 4: 303–308.

Andrade, A., Teta, P. & Panti, C. 2007. Tafonomía de mamíferos en el sitio arqueológico Alero Santo Rosario (Área Maquinchao, provincia de Río Negro, Argentina). *Publicación del XIV Congreso Nacional de Arqueología Argentina* 1: 503–511.

Baskin, J. A. 1998. Mustelidae. Pp. 152–173 in Janis, C. M., Scott, K. M. & Jacobs, L. L. (eds) *Evolution of Tertiary mammals of North America, Volume 1: terrestrial carnivores, ungulates, and ungulate-like mammals*. Cambridge University Press, Cambridge, U.K.

Bryant, H. N., Russell, A. P. & Fitch, W. D. 1993. Phylogenetic relationships within the extant Mustelidae (Carnivora): appraisal of the cladistic status of the Simpsonian subfamilies. *Zoological Journal of the Linnean Society* 108: 301–334.

Burmeister, C. V. 1888. *Ultimas exploraciones en Patagonia*. J. A. Alsina, Buenos Aires, Argentina.

Burmeister, G. 1879. *Description physique de la République Argentine d'après des observations personelles et étrangères. 3 (Animaux vertébrés, 1: mammifères vivants et éteints)*. P. E. Coni, Buenos Aires, Argentina.

Cabrera, A. 1929. Sobre *Lyncodon patagonicus* con descripción de una nueva sub-especie. *Revista Chilena de Historia Natural* 32: 259–263.

Cabrera, A. 1958 (for 1957). Catálogo de los mamíferos de América del Sur. Parte I. *Revista del Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", Zoología*, 4(1): i–iv, 1–307.

Cabrera, A. & Yepes, J. 1940. *Mamíferos Sud-Americanos*. Historia Natural Ediar, Companía Argentina de Editores, Buenos Aires, Argentina.

Castro, D. del C. & Cicchino, A. C. 1986. Colonización de *Lyncodon patagonicus* (Mammalia, Carnivora, Mustelidae) por *Phtheiropoios forticulatus* (Neumann) (Insecta, Phthiraptera, Gyropidae) en proximidades de Uspallata, provincia de Mendoza, Argentina. *II Jornadas Argentinas de Mastozoología* (*Buenos Aires*), *Resúmenes* 1: 397.

Clapperton, C. M. 1993. La última glaciación y deglaciación en el Estrecho de Magallanes: implicaciones para el poblamiento de Tierra del Fuego. *Anales del Instituto de la Patagonia, Serie Ciencias Humanas* 21: 113–128.

Corporación Nacional Forestal 1993. *Libro rojo de los vertebrados de Chile.* Impresora Creces Ltda, Santiago, Chile.

de Blainville, H. M. D. 1842. *Ostéographie ou description iconographique comparée du squelette et du système dentaire des mammifères récents et fossiles des cinq classes d'animaux vertébrés récents et fossiles pour sevir de base à la zoologie et à la géologie*. A. Bertrand, Paris, France.

Daciuk, J. 1974. Notas faunisticas y bioecologicas de Peninsula Valdes y Patagonia. XII. Mamíferos colectados y observados en la Peninsula Valdes y zona litoral de los Golfos San Jose y Nuevo (Provincia de Chubut, Republica Argentina). *Physis Seccion C* 33: 23–39.

Díaz, G. B. & Ojeda, R. A. 2000. *Libro rojo de los mamíferos amenazados de la Argentina.* Sociedad Argentina para el Estudio de los Mamíferos, Méndoza, Argentina.

Doering, A. O. 1881. *Enumeración sistemática de las especies observadas durante la expedición. Vertebrados. Informe Oficial de la Comisión Científica Agregada a la Expedición al Río Negro de 1879. Entrega I, Zoología*. Buenos Aires, Argentina.

Fasola, L., Chehébar, C., Macdonald, D. W., Porro, G. & Cassini, M. H. 2009. Do alien North American Mink compete for resources with native South American River Otter in Argentinean Patagonia? *Journal of Zoology, London* 277: 187–195.

Fulton, T. L. & Strobeck, C. 2006. Molecular phylogeny of the Arctoidea (Carnivora): effect of missing data on supertree and supermatrix analyses of multiple gene data sets. *Molecular Phylogenetics and Evolution* 41: 165–181.

Harris, G. 2008. *Guía de aves y mamíferos de la costa patagónica*. Editorial El Ateneo, Buenos Aires, Argentina.

Izor, R. J. & de la Torre, L. 1978. A new species of weasel (*Mustela*) from the highlands of Colombia, with comments on the evolution and distribution of South American weasels. *Journal of Mammalogy* 59: 92–102.

Kelt, D. & Pardiñas, U. F. J. 2008. *Lyncodon patagonicus*. In *2008 IUCN Red List of Threatened Species.* <www.iucnredlist.org>. Downloaded on 7 April 2009.

Koepfli, K. P., Deere, K. E., Slater, G. J., Begg, C., Begg, K., Grassman, L., Lucherini, M., Veron, G. & Wayne, R. K. 2008. Multigene phylogeny of the Mustelidae: Resolving relationships, tempo and biogeographic history of a mammalian adaptive radiation. *BMC Biology* 6: '10' [article number; volume not paginated].

Koslowsky, J. 1904. Dos mamíferos de Patagonia cazados en el valle del lago Blanco (Territorio del Chubut). *Revista del Museo de La Plata* 11(13): 129–132.

Kraglievich, L. & Rusconi, C. 1931. Restos de vertebrados vivientes y extinguidos hallados por los señores E. R. Wagner y hermano en túmulos precolombianos de Santiago del Estero. *Physis* 10: 229–241.

Kruuk, H. 2006. *Otters: ecology, behaviour and conservation*. Oxford University Press, New York, U.S.A.

Larivière, S. 1998. *Lontra felina*. *Mammalian Species* 575: 1–5.

Larivière, S. 1999a. *Lontra longicaudis*. *Mammalian Species* 609: 1–5.

Larivière, S. 1999b. *Lontra provocax*. *Mammalian Species* 610: 1–4.

Latorre, C. 1998. Paleontología de mamíferos del Alero Tres Arroyos I, Tierra del Fuego, XII Region, Chile. *Anales Instituto Patagonia, Serie Ciencas Naturales* (*Chile*) 26: 77–90.

Massoia, E. 1992. Zooarqueología, I. Mammalia. Pp. 447–505 in Fernández, J. (ed.) *La Cueva de Haichol. Arqueología de los Pinares Cordilleranos del Neuqué. Anales de Arqueología y Etnología* 1: 43–45.

Massoia, E. & Latorraca, J. A. 1992. Contribución al conocimiento de la Mastofauna reciente de la Provincia de Santiago del Estero - 1.

*Boletín Científico Asociación para la Protección de la Naturaleza* 23: 49–57.

Novaro, A. J., Funes, M. C. & Walter, R. S. 2000. Ecological extinction of native prey of a carnivore assemblage in Argentine Patagonia. *Biological Conservation* 92: 25–33.

Nowak, R. M. 2005. *Walker's carnivores of the world*. Johns Hopkins University Press, Baltimore, U.S.A.

Olrog, C. C. 1958. Notas mastozoológicas sobre la colección del Instituto Miguel Lillo (Tucumán). *Acta Zoológica Lilloana*, 16: 91–95.

Olrog, C. C. 1976. Sobre mamíferos del noroeste argentino. *Acta Zoológica Lilloana* 32(1): 5–14.

Osgood, W. H. 1943. The mammals of Chile. *Publications of the Field Museum of Natural History, Zoological Series* 30: 1–268.

Pascual, R. 1958. "*Lyncodon bosei*" nueva especie del Ensenadense. Un antecesor del Huroncito Patagónico. *Revista del Museo de La Plata, Serie Paleontología* 4: 1–34.

Peña, L. 1966. Dos especies raras de mamíferos. *Noticiario Mensual, Museo Nacional de Historia Natural* 11(123): 7–8.

Pocock, R. I. 1926. The external characters of the Patagonian Weasel (*Lyncodon patagonicus*). *Proceedings of the Zoological Society of London* '1926': 1085–1094.

Politis, G. G., Tonni, E. P. & Fidalgo, F. 1983. Cambios corológicos de algunos mamíferos en el Area Interserrana de la provincia de Buenos Aires durante el Holoceno. *Ameghiniana* 20(1–2): 72–80.

Presley, S. J. 2000. *Era barbara*. *Mammalian Species* 636: 1–6.

Prevosti, F. J. & Pardiñas, U. F. J. 2001. Variaciones corológicas de *Lyncodon patagonicus* (Carnivora, Mustelidae) durante el Cuaternario. *Mastozoología Neotropical* 8: 21–39.

Prevosti, F. J. & Travaini, A. 2005. Concrete evidence of the presence of *Galictis cuja* (Molina, 1782) (Mammalia, Carnivora, Mustelidae) in southern Patagonia: new records from Santa Cruz province, Argentina. *Mammalian Biology* 70: 317–320.

Redford, K. H. & Eisenberg, J. F. 1992. *Mammals of the Neotropics. Vol. 2. The Southern Cone. Chile, Argentina, Uruguay, Paraguay*. University of Chicago Press, Chicago, U.S.A.

Reig, O. A. 1956. Note préliminaire sur un nouveau genre de mustelidés fossiles du Pléistocéne de la République Argentine. *Mammalia* 20: 223–230.

Roig, V. 1965. Elenco sistemático de los mamíferos y aves de la provincia de Mendoza y notas sobre su distribución geográfica. *Boletín de Estudios Geográficos* 12(49): 175–222.

Sanabria, E. A. & Quiroga, L. B. 2003. *Lyncodon patagonicus* Blainville, 1842 (Mustelidae: Carnivora). Primer registro para la provincia de San Juan, Argentina. *Nótulas Faunísticas* 13: 1–2.

Schreiber, A., Wirth, R., Riffel, M. & Van Rompaey, H. 1989. *Weasels, civets, mongooses, and their relatives: an action plan for the conservation of mustelids and viverrids*. IUCN, Gland, Switzerland.

Tamayo, M. H. & Frassinetti, D. C. 1980. Catálogo de los mamíferos fósiles y vivientes de Chile. *Boletín del Museo Nacional de Historia Natural de Chile* 37: 323–399.

Teta, P., Prevosti F. J. & Trejo, A. 2008. Raptor predation and new locality records for the poorly known Patagonian Weasel (*Lyncodon patagonicus*) (Carnivora: Mustelidae). *Mammalian Biology* 73: 238–240.

Tonni, E. P., Cione, A. L. & Figini, A. 1999. Predominance of arid climates indicated by mammals in the pampas of Argentina during the Late Pleistocene and Holocene. *Palaeogeography, Palaeoclimatology, Palaeoecology* 147: 257–281.

Trajano, E. 1991. Notas biológicas sobre cavernas argentinas (resultados de la primera expedición espeleológica argentino–brasileña, Neuquén-Mendoza). *Spelaion* 2(2): 3–8.

Wilson D. E. & Reeder, D. M. 2005. *Mammal species of the world. A taxonomic and geographic reference*, 3rd edn. Johns Hopkins University Press, Baltimore, U.S.A.

Wolffsohn, J. A. 1923. Medidas máximas y mínimas de algunos mamíferos chilenos colectados entre los años 1896 y 1917. *Revista Chilena de Historia Natural* 27: 159–165.

Yensen, E & Tarifa, T. 2003a. *Galictis vittata*. *Mammalian Species* 727: 1–8.

Yensen, E & Tarifa, T. 2003b. *Galictis cuja*. *Mammalian Species* 728: 1–8.

Yepes, J. 1935. Los mamíferos de Mendoza y sus relaciones con las faunas limítrofes. *Novena Reunión de la Sociedad Argentina de Patología Regional* 1: 689–725.

Zapata, S. C.; Travaini, A., Delibes, M. & Matínez-Peck, R. 2008. Identificación de morfogremios como aproximación al estudio de reparto de recursos en ensambles de carnívoros terrestres. *Mastozoología Neotropical* 15: 85–101.

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# The state of knowledge of Western Mountain Coati *Nasuella olivacea* in Colombia, and extent of occurrence in the Northern Andes

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## Abstract

A complete bibliographic review of Western Mountain Coati *Nasuella olivacea* was made to improve and disseminate the state of knowledge about the species in the Colombian portion of its range. Reports are distributed across the three ranges of the Northern Andes in Colombia (West, Central, and East), but little is known about the biology, ecology or natural history of the species. In total, 53 georeferenced records were compiled for Colombia plus some confirmed records for Ecuador. All the records ranged from 1,300 to 4,000 m in the high Andean forests and páramo biomes; these elevations represent some of the most disturbed habitats in the country. There is little information about the species's conservation status but it is probably threatened by habitat loss, hunting and human–wildlife conflict. It is potentially present in 10.11% of the protected areas within the Colombian portion of the Tropical Andes hotspot. With this first published review of the state of knowledge of the species, and the first explicit extent of occurrence estimation, we propose that it be considered Near Threatened on the *IUCN Red List of Threatened Species*.

*Keywords*: distribution, elevational range, extent of occurrence, Procyonidae, Near Threatened, Red List

## Estado del conocimiento del Coatí de Montaña del Oeste *Nasuella olivacea* en Colombia, y determinación de su extensión de ocurrencia en los Andes del Norte

## Resumen

Se realizó una revisión bibliográfica completa referente al Coatí de Montaña del Oeste, *Nasuella olivacea*, con el fin de mejorar y hacer fácilmente disponible el estado de conocimiento acerca de esta especie en Colombia. Los reportes de la especies están distribuidos a lo largo de las tres cordilleras de los Andes en Colombia (Oriental, Central y Occidental), pero muy poca información acerca de su biología, ecología e historia natural está disponible. Un total de 53 registros georeferenciados fueron recopilados para Colombia y algunos registros confirmados para Ecuador. Todos los registros estuvieron dentro del rango de 1.300 a 4.000 msnm en los biomas de bosques Alto-Andinos y paramos, donde esta franja de elevación representa algunos de los hábitats más alterados en el país. Existe escaza información acerca del estado de conservación de la especie, pero está probablemente amenazada por pérdida de hábitat, cacería y conflicto social, sin embargo, está potencialmente presente en cerca de 10,11% de las áreas protegidas dentro del *hotspot* Andes del país. Aquí presentamos la primera Extensión de Ocurrencia de la especie como herramienta valiosa para su evaluación en la Lista de Especies Amenazadas de UICN y proponemos la categoría de Casi Amenazada para la especie.

*Palabras clave*: casi amenazada, distribución, rango altitudinal, extensión de ocurrencia, Procyonidae, Lista Roja

## Introduction

Colombia has reported 471 species of mammals (Alberico *et al.* 2000), of which Procyonidae contributes five genera and seven species. These numbers represent 38.9 and 83.3% of the world's procyonid species and genera, a significant number for a relatively small region considering the broad distribution of the group (Alberico *et al.* 2000, Guzmán-Lenis 2004, Wilson & Reeder 2005).

The Colombian Andes support two coati species, the Western Mountain Coati *Nasuella olivacea* and the South American Coati *Nasua nasua*. With the Eastern Mountain Coati *Nasuella meridensis* these are the only procyonids living above 2,000 m elevation (Rodríguez-Bolaños *et al.* 2000, Sánchez & Alvear 2003, Helgen *et al.* 2009). The Western Mountain Coati is a small carnivore of the Andean forests and páramos of Colombia and Ecuador. Currently, there is little reliable information about distribution, ecology, and biology, reflecting its elusive and cryptic behaviour, and relatively sparse survey in its range. Thus, *Nasuella olivacea* was considered Data Deficient (DD) on the *2008 IUCN Red List of Threatened Species* (there including *N. meridensis;* Reid & Helgen 2008).

Natural forest cover in Latin America has decreased fast mainly through logging, cropping and cattle production (FAO 2009), and, specifically, the Andes are considered among the highest historically impacted areas, and with among the highest rates of biodiversity loss and dramatic landscape transformation in the world (Mittermeier *et al.* 1999). In Colombia, 45% of the territory has suffered significant disturbances and degradation of the landscapes structure, mainly related with the growth of human populations (and resulting expansion of urban areas and infrastructure) and the continued expansion of the agricultural frontier (Andrade 1993, Otálora 2003). The páramo and Andean forests are among the country's most affected biomes, and natural ecosystems cover only 27% of their original extent at the national level (Etter 1993). The resulting habitat fragmentation has numerous indirect impacts such as the increase in human–wildlife conflict, where mammals and specially carnivores are among the most affected groups (Andrade 1993). The specific impacts on *N. olivacea* are still unknown.

The aim of the present study is to determine the current state of knowledge for Western Mountain Coati in Colombia, to provide a solid basis for applying IUCN Red List Categories and Criteria, to clarify conservation status of its remaining habitat and to add basic information for conservation planning efforts in Colombia.

## Data compilation

A meta-analysis of existing data compiled information on ecology, threats, taxonomy and natural history of Western Mountain Coati in Colombia. An important emphasis was to collect every confirmed report, sighting or museum record (voucher) in the literature or other media to define its distribution in Colombia.

In total, 41 documents were examined from several databases, libraries and the internet. Of the total, four are specific studies of the species, six are related to Procyonidae in general (mentioning the species), 19 are mammal community general studies (e.g. ecological evaluation of mammal community in protected areas) and 12 are faunal inventories or checklists (Table 1). Higher publication rates were found during 1912–1916 and 1982–2008, with only one study in the intervening period (Cabrera 1958). This mirrors variation in studies in the region during these periods.

## General information

*Common names*

English: Mountain Coati (Glatston 1994, MMA 1973), Little Coati (Donegan *et al.* 2004, Glatston 1994), Mountain Cusumbo (Rodríguez-Bolaños & Cadena 1994) and Western Mountain Coati (Helgen *et al.* 2009). Only the last is for *N. olivacea* s.s. (as used here); the others are for *N. olivacea* s.l., including what is here regarded as *N. meridensis*.

Spanish: Coati de Montaña (MMA 1973), Cusumbo Guache (Rodríguez 2005), Guache (MMA 1973, Defler & Rodríguez-Mahecha 1998, Ramírez-Chávez *et al.* 2008), Cusumbo de Montaña (Morales *et al*. 2007), Guache de Montaña (Donegan *et al.* 2004), Coati (Lizcano & Cavelier 2004), Runcho Guache (Rodríguez-Mahecha *et al.* 1995), Cusumbo (MMA 1973, Franco & Bravo 2005, Ramírez-Chávez *et al.* 2008), Cusumbe (Ramírez-Chávez *et al.* 2008), Cusumbo mocoso (Ramírez-Chávez *et al.* 2008), Cusumbo de páramo (MMA 1973), Guache de páramo (MMA 1973), Guache de tierra fría (MMA 1973), Zorro guache (MMA 1973), Cuchuche Andino (Reid & Helgen 2008). All these names are for *N. olivacea* s.l., including what is here regarded as *N. meridensis*, and we suggest Coatí de Montaña Sureño as the Spanish name for *N. olivacea* s.s. (as used here).

*Taxonomy*

The name *Nasua olivacea* was first used by Gray (1843: 195), but this is a *nomen nudum* and so is not available. The first available name for a mountain coati is *Nasua olivacea* Gray, 1865, with the type locality of "Santa Fé de Bogota" [Colombia], restricted by Cabrera (1958: 249) to "Bogotá, lo que debe interpretarse como las montañas próximas a esta capital" ["Bogotá, what should be interpreted as the mountains near the capital"]. Hollister (1915) proposed the genus *Nasuella* for the mountain coatis, a treatment retained by Goodwin (1953) and most subsequent authors. Three other species-group names have been proposed in the genus, all usually regarded as within *N. olivacea*: *N. o. lagunetae* (Allen, 1913), also with type locality of Bogotá, is usually taken as a synonym of *N. o. olivacea*; *N. o. quitensis* (Lönnberg, 1913) is found in the Ecuadorian Andes in the southern slope of the Pichincha volcano between 2,700 m and 3,000 m (Cabrera 1958); and *N. o. meridensis* (Thomas, 1901) inhabits the western mountains of Venezuela with the type locality in Montes de la Culata, Estado de Merida (Cabrera 1958). Helgen *et al.* (2009) proposes a taxonomic revision of this genus, treating *N. meridensis* as a monotypic species.

*Habitat*

The Western Mountain Coati inhabits forests above 2,000 m a.s.l., being more abundant above 3,000 m in Andean forests and high páramos; it is sympatric in several areas with *Nasua nasua* (Rodríguez-Bolaños *et al.* 2000). The species is reported as fairly common in a variety of ecosystems, from Andean forests to *Alnus acuminata* reforestation stands, pastures and crops (Sánchez & Alvear 2003). The climate within the elevational range where the species is found is characterised by temperatures of 9–24 °C and an annual precipitation range of 1,600–2,400 mm (Sánchez 2000, Sánchez & Alvear 2003, Sánchez *et al.* 2004a, 2008, Delgado 2009).

Sánchez *et al.* (2008) used indirect methods to estimate abundance (e.g. track stations) showing that coatis (both *Nasuella olivacea* and *Nasua nasua*), are more abundant in the *Alnus acuminata* reforested stands than in natural Andean forests relicts, probably due to increase in soil invertebrates in such plantations during the rainy season. Otálora (2003) found that in Charalá, Santander department, even when the forest is highly fragmented, connectivity is still high between oak patches with healthy populations of *N. olivacea*. Furthermore, páramo fragments contribute to connectivity between oak / habitat patches.

*Table 1. Classification of documents that include* Nasuella olivacea *information.*

| Subject | Count | Reference |
|---|---|---|
| Specific studies | 4 | Rodríguez-Bolaños & Cadena 1994, Rodríguez-Bolaños *et al.* 2000, 2003, Reid & Helgen 2008. |
| General Procyonidae or mammal studies | 6 | Decker & Wozencraft 1991, Glatson 1994, Rodriguez-Mahecha et al. 1995, Guzmán-Lenis 2004, Fultron & Strobeck 2007, Koepfli *et al.* 2007 |
| Mammal community general studies | 19 | Allen 1912, 1913, 1916, Cabrera 1957, López-Arévalo & Montenegro-Díaz 1993, Alberico *et al.* 2000, Sánchez 2000, Castaño et al. 2003, Cuartas-Calle & Muñoz-Arango 2003, Otálora 2003, Sanchez & Alvear 2003, Sánchez *et al.* 2004a, Meiri *et al.* 2005, Rodríguez 2005, Wilson & Reeder 2005, Ramírez-Cháves *et al.* 2008, Sánchez *et al.* 2008, Schipper *et al.* 2008, Delgado 2009 |
| Fauna and flora regional and local inventories | 12 | Defler & Rodríguez-Mahecha 1998, Mosquera *et al.* 2001, Cifuentes 2003, Donegan *et al.* 2004, Lizcano & Cavelier 2004, Sánchez *et al.* 2004b, Vélez-Sosa 2004, Franco & Bravo 2005, Morales *et al.* 2007, Cámara Colombiana de Turismo 2009, CAR 2009, PNNC 2009 |

*Diet*

Its diet may be similar to that of *Nasua nasua* (see Gompper & Decker 1998), because it is suspected to forage opportunistically on several items, predominantly invertebrates and fruits, but consuming vertebrates and carrion when available. Limited studies found that it feeds mostly on invertebrates, such as arthropods, with a preference for some orders like Coleoptera, Orthoptera, Miriapoda and Hymenoptera; Chelicerae (spiders); small vertebrates such as amphibians, and fruits such as Blackberry *Rubus*, Higueron *Ficus gigantosisae* and Higuito *Axinea* (Rodríguez-Bolaños *et al.* 2000, Sánchez & Alvear 2003). The diet changes in items and quantity with age of the animal; juveniles eat invertebrates and fruit, while adults gradually increase the quantity of vertebrates in their diets (Rodríguez-Bolaños *et al*. 2000, Sánchez & Alvear 2003).

*Behaviour*

Coatis *Nasua* and *Nasuella* are uniquely gregarious within Procyonidae, with complex social organisation (Russell 1982). Social groups generally comprise adult females and juveniles of both sexes (López-Arévalo & Montenegro-Díaz 1993). Several authors reported groups of 50–80 individuals (López-Arévalo & Montenegro-Díaz 1993, Rodríguez-Bolaños *et al*. 2003, Sánchez & Alver 2003), but groups most commonly hold 6–8 (Rodríguez-Bolaños *et al*. 2003) or 4–20 animals (Sánchez & Alvear 2003). Adult males are usually solitary, being accepted into groups only during mating seasons, and then exiled by females because of potential cannibalism of new-borns and juveniles, a normal strategy to increase the survival of the progeny (Janzen 1970, Newcomer & De Farcy 1985). Also, this strategy allows adult males to increase foraging efficiency and decrease the resource competition, which is presumably higher within groups (Rodríguez-Bolaños *et al.* 2000). *N. olivacea* lives more frequently in small groups of 6 to 8 individuals (Rodríguez-Bolaños *et al.* 2003, Sánchez & Alver 2003) but groups up to 50, 60 and 80 individuals have been reported (Lopez-Arevalo & Montenegro-Díaz 1993, Rodríguez-Bolaños *et al.* 2003, Sánchez & Alver 2003).

*Population estimates*

Few studies deal with abundance, density or any other population parameter for the species. Sánchez *et al*. (2008) estimated an abundance through direct sightings of 0.0035 individuals/km in Andean forests, with a higher indirect abundance in *Alnus acuminata* stands than in natural oak forests relicts in the Río Blanco Natural Reserve, Manizales, Caldas department. The species is considered as widely common in higher parts of some areas of its distribution (Ramírez-Chávez *et al.* 2008) and numerous groups have been reported (Rodríguez-Bolaños *et al.* 2003).

*Threats and conservation*

Western Mountain Coati is currently listed as Data Deficient by the *IUCN Red List of Threatened Species* (Reid & Helgen 2008), reflecting earlier applications: Insufficiently Known in 1994 (Groombridge 1993), Data Deficient in 1996 (Baillie & Groombridge 1996). It is not protected in either Ecuador or Colombia (Glatston 1994).

Several threats have been reported, related to general Andean biodiversity loss. The species is widely considered as a pest and harmful species (Vélez-Sosa 2004), because of potential predation of small domestic animals (mainly poultry; Sánchez 2000) and frequent damage to potato crops, reflecting the low availability of areas for agriculture and *N. olivacea* to coexist peacefully (Sánchez 2000, Sánchez & Alvear 2003, Sánchez *et al.* 2008). It is also harvested as food (subsistence and commercial; Sánchez 2000, Ramírez-Chávez *et al.* 2008), for skin (Sánchez 2000) and as a pet and for a soil-rooter in small gardens in urban areas of its range (Ramírez-Chávez *et al.* 2008).

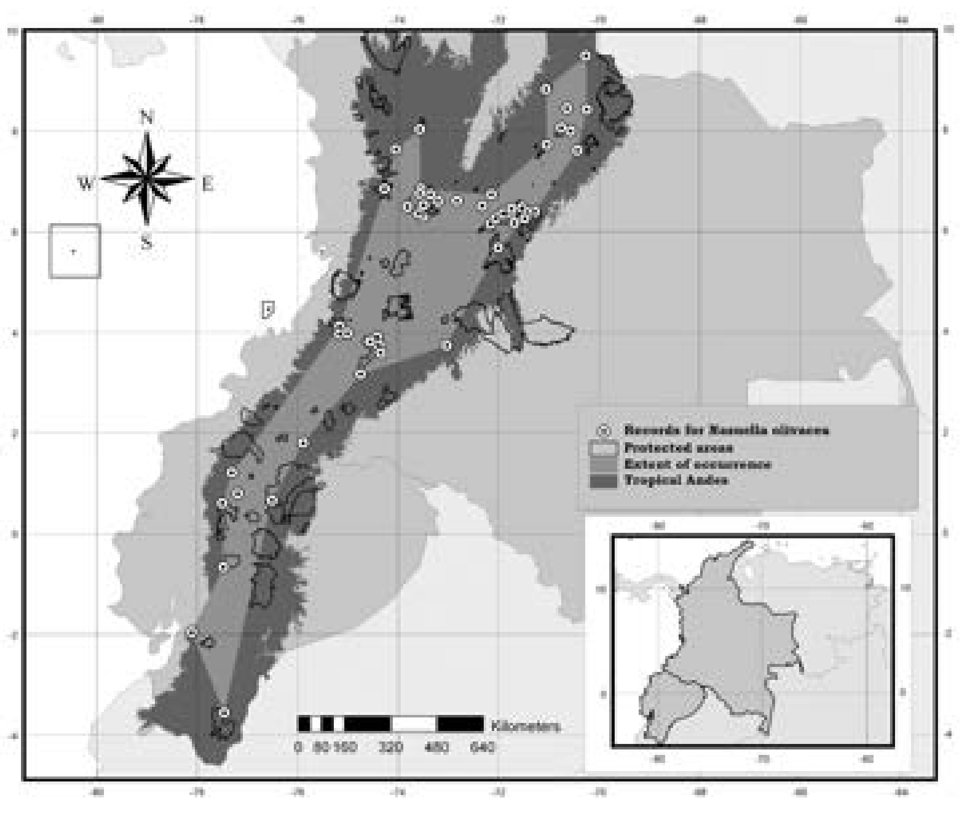

*Fig. 1. Confirmed records of* Nasuella olivacea *in the Tropical Andes Hotspot of Colombia and Ecuador with estimated extent of occurrence and protected areas within its range.*

*Fig. 2. Juvenile* Nasuella olivacea *in captivity, Colombia (Photograph by Abelardo Rodriguez Bolaños).*

*Distribution data*

We selected only confirmed and reliable records of the species across its range, from 14 documents in total. Museum records from Colombia (18) and Ecuador (eight), and collections from the American Museum of Natural History (AMNH), the United States National Museum (USNM) and the Natural History Museum, U.K. (NHM), were included in the analysis (K. Helgen *in litt*. 2009).

Records came from 1912 to 2009, from primary and secondary Andean forests and páramos and intervening encroached habitats such as potato crops, reforestation stands and pastures (Fig. 1). All records were located in the Andes range and derivations (West, East and Central mountain range in Colombia), at 1,300 to 4,000 m. All (including those from Ecuador) fell inside the Tropical Andes Hotspot (Rodríguez-Mahecha *et al.* 2004), consistent with its high biodiversity importance on the global scale. Furthermore, based on these records, the species is present in at least nine (10.1%) of the 89 protected areas and indigenous territories of the Tropical Andes Hotspot in Colombia, and 21.4% of the protected areas within the Ecuadorian part of the hotspot. Administratively, *Nasuella olivacea* is reported in 12 of 32 departments of Colombia and six of 24 provinces in Ecuador.

Based on the entire dataset, Minimum Convex Polygons were constructed in order to estimate the first data-generated extent of occurrence following IUCN (2001) guidelines and definitions. An approximate total extent of 164,000 km² was calculated from the records, all included in the Andes Hotspot and eco-region, and over the Andes mountain range including Colombia and Ecuador (Fig. 1).

## Discussion

*Nasuella olivacea* has been reported in several research and technical reports along the Andes of Colombia and Ecuador above 1,300 m elevation. No documents specifically focused on the species address distribution and threats, but some give information about biology (morphology, diet), ecology (habitat, population) and behaviour; such specific projects are limited to only two zones and protected areas where it occurs (Cundinamarca and Caldas, Colombia). The rest of the information stems from occasional observations and inferences from its close relative the South American Coati. The species seems to be fairly common because it is listed in most inventories, species compositions and collection reviews.

The full distribution of the species remains to be documented, but known records imply the species occurs along the Andes range in the two countries, and we estimate a relatively large area where it could be present. Pressures and threats are not well researched. The species is present in nine protected areas in the Colombian Tropical Andes (10.11%), an important tool for conservation.

The current IUCN Red List Category of Data Deficient could seem appropriate, but even if we consider the species fairly unknown, its inferred and reported characteristics and the limited solid information are enough to define a status for the species at a global scale. Based on these, in light of our extent of occurrence estimate, we suggest the species be considered Near Threatened (NT) using the 2001 Categories and Criteria of the IUCN Red List. Although it has a relatively large area of occupancy, it seems currently in decline, future rates projected at nearly 30% over the next three generations (~20 years) due to accelerating hunting for food and skins, persecution as a pest, and because habitat is being logged and converted to agriculture at accelerating rates across its range. The worst projected scenarios could be VU A3cd, but we consider NT more appropriate given the relatively large range and occurrence in several subpopulations. Numerous data gaps need filling through field exploration for more precise projections.

The critical gaps, abundance, distribution, density, conflict with people, and the effects of ongoing threats on the known populations, are a priority for research. The species should be considered on the national official protection lists (in Colombia by Resolución from the Ministerio de Ambiente, Vivienda y Desarrollo Territorial [MAVDT] and in Ecuador by Registro Oficial from Ministerio de Ambiente de Ecuador [MAE] and national and regional authorities should follow real conservation planning with effective actions to ensure the permanence of the species in healthy populations across its range.

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## References

Alberico, M., Cadena, A., Hernández-Camacho, J. & Muñoz-Saba, Y. 2000. Mamíferos (Synapsida: Theria) de Colombia. *Biota Colombiana* 1 (1): 43–75.

Allen, J. A. 1912. Mammals from western Colombia. *Bulletin of the American Museum of Natural History* 31: 71–95.

Allen, J. A. 1913. New mammals from Colombia and Ecuador. *Bulletin of the American Museum of Natural History* 32: 469–484.

Allen, J. A. 1916. List of mammals collected in Colombia by the American Museum of Natural History expeditions, 1910–1915. *Bulletin of the American Museum of Natural History* 35: 191–238.

Andrade, G. I. 1993. Biodiversidad y conservación en Colombia. Pp. 23–42 in Cárdenas, S. & Correa, H. D. (eds) *Nuestra diversidad biológica*. Fundación Alejandro Escobar, colección María Restrepo Ángel, CEREC, Bogotá, Colombia.

Baillie, J. & Groombridge, B. (eds) 1996. *1996 IUCN Red List of threatened animals*. IUCN, Gland, Switzerland.

Cabrera, A. 1958 (for 1957). Catálogo de los mamíferos de América del

Sur. *Revista del Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", Ciencias Zoológicas* 4(1): i–iv, 1–308.

Cámara Colombiana de Turismo 2001. *Capítulo Eje Cafetero*. <http://www.risaralda.com.co/ecoturismo/losnevados/index_a.php>. Downloaded on 27 February 2009.

[CAR] Corporación Autónoma Regional de Cundinamarca 2009. *Rutas ecoturísticas DMI Cuchilla de Pañas Blancas y el Subia y RFP Cuchilla de Peñas Blancas*. <http://www.car.gov.co/RutasEcoturisticas/Tibacuy.htm>. Downloaded on 27 February 2009

Castaño, J. H., Muñoz-Saba, Y., Botero, J. E. & Vélez, J. H. 2003. Mamíferos del Departamento de Caldas – Colombia. *Biota Colombiana* 4(2): 247–259.

Cifuentes, F. 2003. Propuesta de ordenamiento ambiental para el Santuario de Flora y Fauna Otún Quimbaya. Ministerio del medio ambiente. Unidad administrativa especial parques nacionales naturales. P. 29 in Rodríguez, C. *Abundancia relativa de mamíferos en dos tipos de cobertura vegetal en la margen nor-oriental del Santuario de Flora y Fauna Otún Quimbaya, Risaralda*. Pontifica Universidad Javeriana (B.Sc thesis), Bogotá, Colombia.

Cuartas-Calle, C. A. & Muñoz-Arango, J. 2003. Lista de los mamíferos (Mammalia: Theria) del departamento de Antioquia, Colombia. *Biota Colombiana* 4(1): 65–78.

Decker, D. M. & Wozencraft, W. C. 1991. Phylogenetic analysis of recent procyonid genera. *Journal of Mammalogy* 72: 42–55.

Defler, T. & Rodríguez-Mahecha J. V. 1998. *La fauna de la Orinoquia*. FEN. Edición 1 de 1998. <http://www.lablaa.org/blaavirtual/credencial/enero1990/enero1.htm>. Downloaded on 27 February 2009

Delgado, C. 2009. Non-volant mammals, Reserva de San Sebastián-La Castellana, Valle de Aburrá, Antioquia, Colombia. *Checklist, Brazil* 5(1): 1–4.

Donegan, T., Huertas, B., Briseño, E., Arias, J., Camargo, I. & Donegan, M. 2004. *Colombian EBA Project. Threatened species of Serranía de los Yariguíes Expedition*. Fundación ProAves, Bogotá, Colombia (Colombian EBA Project Report n° 5). <www.proaves.org/IMG/pdf/EBA_5_Serrania_de_los_Yariguies_report_2005.pdf>. Downloaded on 22 April 2009.

Etter, A. 1993. Diversidad ecosistémica en Colombia Hoy. Pp. 43–61 in Cárdenas, S. & Correa, H. D. (eds) *Nuestra diversidad biológica*. Fundación Alejandro Escobar, colección María Restrepo Ángel, CEREC, Bogotá, Colombia.

FAO 2009. *State of the world's forests*. Food and Agriculture Organisation of the United Nations Press, Rome, Italy.

Franco, A. M. & Bravo, G. 2005. Áreas importantes para la conservación de las aves en Colombia. Pp. 117–282 in BirdLife International & Conservation International *Áreas importantes para la conservación de las aves en los Andes tropicales: sitios prioritarios para la conservación de la biodiversidad*. BirdLife International, Quito, Ecuador (Serie de conservación de BirdLife n° 4).

Fulton, T. L. & Strobeck, C. 2007. Novel phylogeny of the raccoon family (Procyonidae: Carnivora) based on nuclear and mitochondrial DNA evidence. *Molecular Phylogenetics and Evolution* 43: 1171–1177.

Glatston, A. 1994. *The Red Panda, olingos, coatis, raccoons and their relatives. Status survey and conservation action plan for procyonids and ailurids*. IUCN/SSC, Gland, Switzerland.

Gompper, M. & Decker, D. 1998. *Nasua nasua*. *Mammalian Species* 580: 1–9.

Goodwin, G. G. 1953. Catalogue of the type specimens of Recent mammals in the American Museum of Natural History. *Bulletin of the American Museum of Natural History* 102: 207–412.

Gray, J. E. 1843. *List of the specimens of Mammalia in the collection of the British Museum*. British Museum, London, U.K.

Gray, J. E. 1865. Revision of the genera and species of Mustelidae contained in the British Museum. *Proceedings of the Zoological Society of London* 1865: 100–154.

Groombridge, B. 1993. *1994 IUCN Red List of threatened animals*. IUCN, Gland, Switzerland, and Cambridge, U.K.

Guzmán-Lenis, A. 2004. Revisión preliminar de la familia Procyonidae en Colombia. *Acta Biológica Colombiana* 9(1): 69–76.

Helgen, K. M., Kays, R., Helgen, L. E., Tsuchiya-Jerep, M. T. N., Pinto, C. M., Koepfli, K.-P. , Eizirik, E. & Maldonado, J. E. 2009. Taxonomic boundaries and geographic distributions revealed by an integrative systematic overview of the mountain coatis, *Nasuella* (Carnivora: Procyonidae). *Small Carnivore Conservation* 41: 65–74.

Hollister, N. 1915. The genera and subgenera of raccoons and their allies. *Proceedings of the United States National Museum* 49: 143–150.

IUCN 2001. *IUCN Red List Categories and Criteria*, version 3.1. IUCN/SSC, Gland, Switzerland.

Janzen, D. H. 1970. Altruism by coatis in the face of predation by *Boa constrictor*. *Journal of Mammalogy* 51: 387–389.

Koepfli, K. P., Gompper, M., Eizirik, E., Ho, C. C., Linder, L., Maldonado, J. E. & Wayne, R. K. 2007. Phylogeny of the Procyonidae (Mammalia: Carnivora): molecules, morphology and the Great American Interchange. *Molecular Phylogenetics and Evolution* 43: 1076–1095.

Lizcano, D., & Cavalier, J. 2004. Características químicas de salados y hábitos alimenticios de la Danta de Montaña (*Tapirus pinchaque* Roulin, 1829) en los Andes centrales de Colombia. *Mastozoología Neotropical* 11(2): 193–201.

Lönnberg, E. 1913. Mammals from Ecuador and related forms. *Arkiv für Zoologi* 8(16): 1–36.

López-Arevalo, H. F. & Montenegro-Díaz, O. L. 1993. Mamíferos no voladores de Carpanta. Pp. 165–187 in Andrade, G. I. (ed.) *Carpanta, selva nublada y páramo*. Fundación Natura, Santa Fé de Bogotá, Colombia.

Meiri, S., Simberloff, D. & Dayan, T. 2005. Insular carnivore biogeography: island area and mammalian optimal body size. *American Naturalist* 165: 505–514.

Mittermeier, R. A., Myers, N. & Mittermeier, C. G. 1999. *Biodiversidad amenazada. Las ecorregiones terrestres prioritarias del mundo*. Cemex and Conservación Internacional, Mexico DF, Mexico.

[MMA] Ministerio del Medio Ambiente 1973. *Resolución 848 de agosto 6 de 1973*. Ministerio del Medio Ambiente, Bogotá, Colombia.

Morales, M., Otero, J., Van Der Hammen, T., Torres, A., Cadena, C., Pedraza, C., Rodríguez, N., Franco, C., Betancourth, J. C., Olaya, E., Posada, E. & Cárdenas, L. 2007. *Atlas de páramos*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá D.C., Colombia.

Mosquera, R., Mosquera, J. & Gallego O. 2001. *Esquema de ordenamiento territorial. Municipio de San José del Palmar*. Alcaldia Municipal de San José del Palmar, Chocó, Colombia.

Newcomer, M. W. & De Farcy, D. D. 1985. White-face Capuchin (*Cebus capucinus*) predation of a nesting Coati (*Nasua narica*) *Journal of Mammalogy* 66: 185–186.

Otálora, A. 2003. Mamíferos de los bosques de roble. *Acta Biológica Colombiana* 8(2): 57–71.

[PNNC] *Parques nacionales naturales de Colombia*. 2009. <http://www.parquesnacionales.gov.co/PNN/portel/libreria/php/decide.php/servicios/swf/libreria/pdf/comun/frame_detalle.php?h_id=560&patron=01.06110702>. Downloaded on 27 February 2009.

Ramírez-Cháves, H., Pérez, W. & Ramírez-Mosquera, J. 2008. Mamíferos presentes en el municipio de Popayán, Cauca, Colombia. *Boletín Cientifico Museo Historia Natural* 12: 65–89.

Reid, F. & Helgen, K. 2008. *Nasuella olivacea*. In *2008 IUCN Red List of Threatened Species*. <www.iucnredlist.org>. Downloaded on 8 May 2009.

Rodríguez, C. 2005. *Abundancia relativa de mamíferos en dos tipos de cobertura vegetal en la margen nororiental del Santuario de Flora y Fauna Otún Quimbaya, Risaralda*. Pontifica Universidad Javeriana (B.Sc thesis), Bogotá, Colombia.

Rodríguez-Bolaños, A. & Cadena, A. 1994. Mountain Coati project in Colombia. *Small Carnivore Conservation* 10: 15.

Rodríguez-Bolaños, A, Cadena, A. & Sánchez, P. 2000. Trophic characteristics in social groups of the Mountain Coati, *Nasuella olivacea* (Carnivora: Procyonidae). *Small Carnivore Conservation* 23: 1–5.

Rodríguez-Bolaños, A., Sánchez, P. & Cadena, A. 2003. Patterns of activity and home range of Mountain Coati *Nasuella olivacea*. *Small Carnivore Conservation* 29: 16–19.

Rodríguez-Mahecha, J. V., Hernández-Camacho, J., Defler, T. R., Alberico, M., Mast, R., Mittermeier, R. A. & Cadena, A. 1995. Mamíferos Colombianos: sus nombres comunes e indígenas. *Conservation International Occasional Papers in Conservation Biology* 3: 1–56.

Rodríguez-Mahecha, J. V., Salaman, P., Jørgensen, P., Consiglio, T., Forno, E., Telesca, A., Suárez, L., Arjona, F., Rojas, F., Bensted-Smith, R. & Inchausty, V. H. 2004. Tropical Andes. Pp.? 193–197 in Mittermeier, R. A., Robles Gil, P., Hoffmann, M., Pilgrim, J., Brooks, T., Goettsch-Mittermeier, C., Lamoreux, J. & da Fonseca, G. A. (eds) *Hotspots revisited: Earth's biologically richest and most endangered terrestrial ecoregions*. Cemex and Conservation International, Mexico DF, Mexico.

Russell, J. K. 1982. Timing of reproduction by Coatis (*Nasua narica*) in relation to fluctuations in food resources. Pp. 413–431 in Leigh, E. G., Rand, A. S. & Windsor, D. M. (eds) *The ecology of a tropical forest: seasonal rhythms and long-term changes*. Smithsonian Institution Press, Washington, D.C., U.S.A.

Sánchez, F. 2000. Inventario de mamíferos de un bosque andino del departamento de Caldas Colombia. *Boletín Cientifico Museo Historia Natural* 4: 19–25.

Sánchez, F. & Alvear, M. 2003. Comentarios sobre el uso del hábitat, dieta y conocimiento popular de los mamíferos en un bosque andino en el departamento de Caldas, Colombia. *Boletín Cientifico Museo Historia Natural* 7: 121–144.

Sánchez, F., Sánchez-Palomino, P. & Cadena A. 2004a. Inventario de mamíferos en un bosque de los andes centrales de Colombia. *Caldasia* 26(1): 291–309.

Sánchez, L., Rodríguez, P., Solano, F., Torres, S., Gelviz, S. & Alvarado, F. 2004b. *Inventarios de flora y fauna en los bosques de Pridecu (Pamplona) y Palmarito (Cúcuta) e implementación de una página web sobre manejo sostenible del bosque*. Grupo de Recursos Naturales Instituto de Ciencias Naturales y Biotecnología, Vicerrectoria de Investigaciones Universidad de Pamplona, Pamplona, Colombia.

Sánchez, F., Sánchez-Palomino, P. & Cadena, A. 2008. Species richness and indices of abundance of medium-sized mammals in Andean Forest and reforestation with Andean Alder: a preliminary analysis. *Caldasia* 30: 197–208.

Schipper, J., Hoffmann, M., Duckworth, J. W. & Conroy, J. 2008. The 2008 IUCN Red Listings of the world's small carnivores. *Small Carnivore Conservation* 39: 29–34.

Thomas, O. 1901. On mammals obtained by Mr. Alphonse Robert on the Rio Jordao, Minas Geraes. *Annals and Magazine of Natural History* (7)8: 526–536.

Vélez-Sosa, M. 2004. Diagnóstico del uso de la fauna silvestre en las veredas de Mundo Nuevo, El Manzano y La Jangana en la Reserva Forestal Protectora de los ríos Blanco y Negro en el municipio de La Calera (Cundinamarca-Colombia). Pp. 330–335 in UNAP *MEMORIAS: VI Congreso Internacional sobre Manejo de Fauna Silvestre en Amazonía y Latinoamérica*. Universidad Nacional de la Amazonía Peruana, Iquitos, Perú.

Wilson, D. E. & Reeder, D. M. (eds) 2005. *Mammal species of the world: a taxonomic and geographic reference*, 3rd edn. Johns Hopkins University Press, Baltimore, U.S.A.

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# Distribution and habitat modelling for Colombian Weasel *Mustela felipei* in the Northern Andes

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## Abstract

The Colombian Weasel *Mustela felipei* is known only from six confirmed localities in Colombia and Ecuador and is considered Vulnerable (B1ab (ii, iii)) on the *2008 IUCN Red List of Threatened Species*. Its true distribution, extent of occurrence and natural history are unknown, so this conservation status reflects a precautionary principle more than actual information. Here we present the first habitat/niche model based on the known records and the first geographical-based approach for the species. Based on six confirmed and five unconfirmed records, a Maximum Entropy niche model was developed, and the datasets were cross-validated using the Area Under the ROC Curve (AUC). A good prediction index (0.835) was estimated for the entire model. Within the potential distribution there are 34 protected areas, 20 for Colombia and 14 for Ecuador. Only 10 are over 1,000 km²; these are distributed through both countries. There is differential conservation representativeness in the two countries and are probably serious threats to the species in the modelled area. Also, we propose core regions for conservation of the species, recommend validation of this model as an important tool for conservation assessment of the species, and suggest a criteria change for the species against the *IUCN Red List of Threatened Species* as B2ab (ii, iii, iv), but keeping it as Vulnerable.

*Keywords*: Colombia, Ecuador, MAXENT, Vulnerable, Niche modelling, threats

### Distribución y modelación de hábitat de la Comadreja Colombiana *Mustela felipei* en los Andes del Norte

## Resumen

*Mustela felipei,* la Comadreja Colombiana, se conoce solo de seis localidades confirmadas en Colombia y Ecuador y actualmente se encuentra listada como Vulnerable (B1ab (ii, iii)) por la UICN. La distribución, extensión de ocurrencia y la historia natural de la especie aún permanecen desconocidos, por ende su estado de conservación está basado en decisiones precautorias más que en información disponible. Presentamos el primer modelo de hábitat/nicho basado en registros conocidos en ambos países y el primer acercamiento geográfico para la especie. Basados en seis registros confirmados y cinco sin confirmar se construyó un modelo de hábitat/nicho de Máxima Entropía y los datos fueron validados usando validación cruzada con el Área Bajo la Curva ROC (AUC). Se estimó un índice predictivo bueno (0.835) para todo el modelo. Sobre la distribución potencial hay 34 áreas protegidas, 20 en Colombia y 14 en Ecuador, sin embargo, solo 10 cubren áreas mayores a 1.000 km² y estas están distribuidas diferenciadamente a lo largo de ambos países. Encontramos una representatividad de conservación diferenciada para ambos países y amenazas severas para el área modelada, a la vez identificamos regiones núcleo para la especie y recomendamos este modelo sea validado en campo como herramienta útil para la evaluación de conservación de la especie. También, sugerimos cambiar los criterios de acuerdo a la Lista Roja de Especies Amenazadas de UICN a B2ab (ii, iii, iv) y manteniendo esta como Vulnerable.

*Palabras clave*: Colombia, Ecuador, MAXENT, Modelo de Nicho, Vulnerable, amenazas

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## Introduction

The Colombian Weasel *Mustela felipei* is one of the least-known carnivore species in the Americas (Schrieber *et al.* 1989, Tirira & González-Maya 2009). Known from only a few records, it is expected to have a larger distributional range than currently confirmed, but research and survey for the status has been minimal. It is inferred to be elusive and cryptic, and thus difficult to detect during general surveys; and there is high risk of confusion with the Long-tailed Weasel *M. frenata*. Most of the few records associate the species with water-courses and water bodies (but see Alberico 1994). It is suspected to be threatened by habitat fragmentation across the Andes, and by poisoning of water during fishing practices, and mercury release during gold mining.

According to Anderson & Martinez-Meyer (2004), modelling species' environmental requirements through GIS-based models with occurrence data can provide reliable estimates of species distribution. This represents an important tool for conservation assessments. In the absence of any other information regarding the range, threats or current conservation status of the Colombian Weasel, habitat modelling may provide a base from which to begin designing conservation policies and actions, and furthermore to guide the determination of its global conservation status. However, modelling cannot remove the need for further field investigation, which remains a priority.

Here we present the first potential habitat modelling for the Colombian Weasel based on confirmed and unconfirmed reports from Ecuador and Colombia, and we infer the status of the species according to protected areas and habitat fragmentation across its potential range. As the first geographic-based approach for the species it aims to provide a geographical reference for further research and analyses of the species.

## Materials and Methods

*Study Area*

Modelling covered Colombia and Ecuador, the only countries confirmed to hold the species. They lie in the northern part of western South America and share, as defining character, the northernmost part of the Andes mountain range (Fig. 1). Both countries include several types of ecosystems, with a variety of elevation gradients ranging from tropical lowland forests and grasslands to high Andean páramo and Oak *Quercus* forests. Following the known records of the species, this study focused on the Andean portion of the study area, predominantly the high-elevation ecosystems northwards from Ecuador across the three branches of the Andes in Colombia.

Fig. 1. Colombia and Ecuador in the regional context.

*Methodology*

In total, eleven indications from Colombia and Ecuador were used to develop potential habitat and distribution range models for the Colombian Weasel. Six are records confirmed by specimens and five are direct observations and other unconfirmed reports (Fig. 2; Table 1).

A validation method was used to assess the reliability of the unconfirmed data using an outliers data analysis with the *Modeling* option from DIVA-GIS 5.4, contrasting the locality registers with climatic information obtained from Worldclim (Hijmans

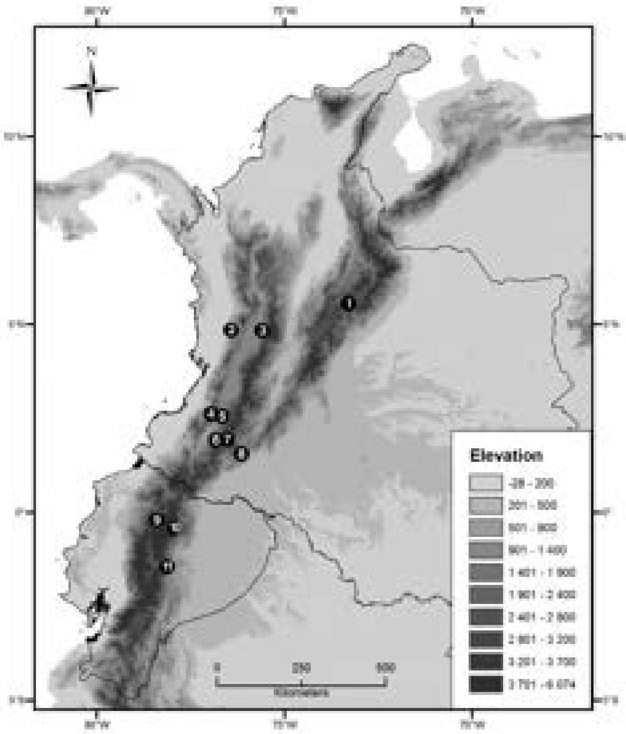

*Fig. 2. Records in Colombia and Ecuador over an elevation layer; numbers correspond to those in Table 1. Note that 1, 2, 4, 6 and 8 are non-confirmed localities. Elevations in meters.*

*Table 1. Confirmed and unconfirmed records used for the potential habitat modelling.*

| Record | Site | Type | Province / Department | Country | Reference | Voucher |
|---|---|---|---|---|---|---|
| 1 | Chivatá | Not Confirmed | Boyacá | Colombia | Bernal 2004 | None |
| 2 | Santa Rosa de Cabal | Not Confirmed | Risaralda | Colombia | Lopez & Ramirez 2008 | None |
| 3 | Alto Galápagos | Record | Valle del Cauca | Colombia | Alberico 1994 | UV 7483 |
| 4 | Munchique | Not Confirmed | Cauca | Colombia | Casas 2007 | None |
| 5 | Popayán | Record | Cauca | Colombia | Izor & de la Torre 1978 | FMNH 86745 |
| 6 | Almaguer | Not Confirmed | Cauca | Colombia | FONADE s.f. | None |
| 7 | Santa Marta | Record | Huila | Colombia | Izor & de la Torre 1978 | FMNH 70999 |
| 8 | Cueva Guácharos | Not Confirmed | Huila | Colombia | Mesa-González 2006 | None |
| 9 | Valle de Tumbaco | Record | Pichincha | Ecuador | Schreiber *et al*. 1989 | MEPN n/c |
| 10 | Baeza | Record | Napo | Ecuador | Hall 1951 | AMNH 63839 |
| 11 | Mera | Record | Pastaza | Ecuador | Rageot & Albuja 1994 | USNM 548396 |

*et al.* 2005) with a 30 seconds resolution (approximately 1 km side).

To obtain the potential distribution of the species we modelled all the records and reports using the Maximum Entropy algorithm included in *MAXENT* software (Phillips *et al.* 2006) and 19 bioclimatic variables with a 30 seconds resolution (Hijmans *et al*. 2005). In order to validate the models, we divided the total number of records in five bootstrapping repetitions with calibration datasets (70% random selection of the data) and evaluation datasets (30%). We then obtained the area under the curve (AUC) on each repetition to evaluate the capacity of each repetition of producing a model, built from the calibration dataset, and that could predict the presence of the evaluation records in the correspondent subgroup.

In addition, we built a model using only the confirmed records in order to verify, using the AUC, the capacity of these records to predict the unreliable records. Finally, a model was constructed using all the records creating the most suitable area for the species and the most adjusted habitat inference based on its climatic requirements (fundamental niche; Anderson *et al.* 2003). After obtaining the complete model we adjusted it to those areas connected within the model above 1,500 m, so several areas across the Andes could be excluded, and the model *per se* could follow a logical pattern of habitat continuity.

We used the World Database on Protected Areas (WDPA 2009) to estimate the protected areas of the potential distribution model.

## Results

The validation procedure did not report outlier data among the unconfirmed records. In the evaluation of the generated models, with the five replacement sampling repetitions, a 0.814 mean AUC was estimated, demonstrating the high prediction capacity of the models (81.4 %). Similarly, the calibration of the models with confirmed records and the prediction capacity of the non-confirmed records evaluation estimated a 0.835 mean AUC (Fig. 3).

Following confirmation of the prediction capacity of the dataset, a complete potential distribution model was generated. The entire model predicted an area of 173,921 km², with a total area of 108,164 km² for Colombia and 65,757 km² for Ecuador. Even with a relatively good prediction capacity of the model, certain geographical, human and ecological barriers predict some areas of the model to lie outside the species's actual range. After the elevation adjustments (>1,500 m) several large areas were excluded from the model, including Perijá Mountain range, some areas in Venezuela and other parts in Colombia, so a continuous model could be defined. Three of the unconfirmed records' areas that were predicted by the model were excluded because of their isolation. One of the unexpected polygons was the one containing the record from Alberico (1994) that was also completely isolated from the continuous model; however the polygon containing the record was retained.

The adjusted model was estimated on 107,200 km² (105,000 km² for the main polygon and 1,200 km² for the disconnected Alberico record) approximately (Fig. 4). Colombia has about 52% of the potential habitat and Ecuador the remaining 48%.

A significant portion of the predicted occurrence is protected under various management categories in both countries, where 34 protected areas are present within the model, 20 in Colombia and 14 in Ecuador, covering approximately 27,700 km², representing 25.8% of the entire potential distribution (Table 2).

Ten protected areas over 1,000 km² occur within the predicted area of occupancy, seven within Ecuador and three within Colombia (Fig. 4); the Sangay National Park in Ecuador and the Nevado del Huila National Park in Colombia are the largest areas protected in the species's potential range (5,177 km² and 1,580 km² respectively). The conservation status of the modelled range is highly heterogeneous, with less than 48% under natural cover, excepting the protected areas.

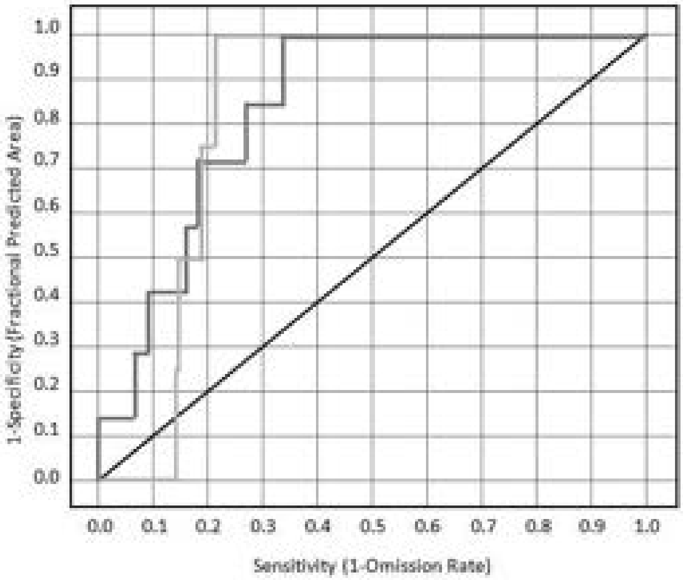

*Fig. 3. Models' AUC; the light gray line corresponds to the evaluation set (AUC= 0.814), the dark gray line corresponds to the calibration set (AUC= 0.835) and the diagonal black line corresponds to the random prediction (AUC= 0.5).*

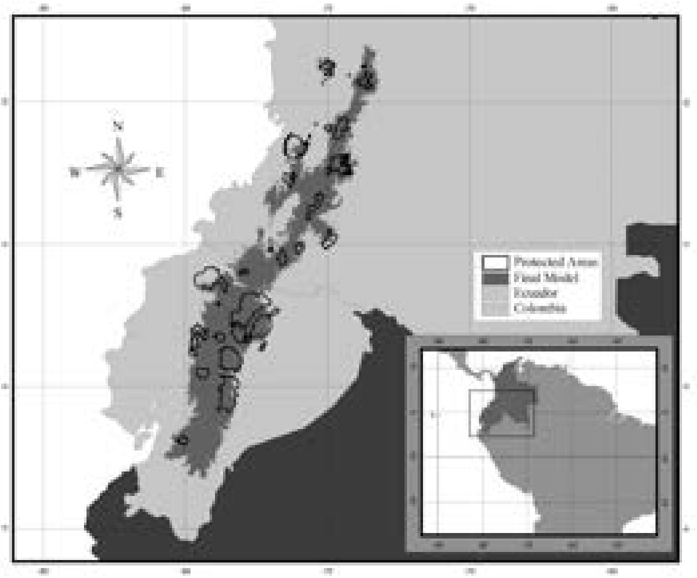

*Fig. 4. The potential distribution model of the Colombian Weasel* Mustela felipei *adjusted in Colombia and Ecuador. Protected areas falling within the projected range are also indicated.*

*Table 2. Protected area categories per country, their total area per country, and its percentage of the country's total land area. The bi-national total indicates the percentage of protected areas coverage compared with both countries summed. *Percentage of protected areas overlapped with the model compared with the total model for each country.*

| Country | Category | Number of Areas | Area (km²) | % Country | % Bi-national |
|---|---|---|---|---|---|
| Colombia | National parks | 9 | 7269 | 13.07 | |
| | Sanctuaries | 2 | 7623 | 13.70 | |
| | National protective forest reserves | 9 | 819.69 | 1.47 | |
| **Total** | 4 | 20 | 15711.69 | 80.08 | 44.49 |
| Ecuador | Ecological reserves | 5 | 8931.38 | 17.32 | |
| | Fauna production reserve | 1 | 585.6 | 1.14 | |
| | Geobotanical reserve | 1 | 33.85 | 0.07 | |
| | National parks | 6 | 10048.82 | 19.48 | |
| | Recreational national area | 1 | 4 | 0.01 | |
| **Total** | 6 | 14 | 19603.65 | 110.80 | 55.51 |
| **Bi-national total** | | 34 | 35315.34 | | 100 |

## Discussion

The Colombian Weasel is considered Vulnerable (B1ab (ii, iii)) on the *2008 IUCN Red List of Threatened Species* (Emmons & Helgen 2008, Schipper *et al.* 2008). Existing records indicate that the species might be very restricted and rare across its range. However potential habitat suitability modelling presented herein indicates that it potentially has a wider distribution. Despite the results of the modelling, the low rate of reports suggests that the species may be very rare. Furthermore, the low availability of remaining natural cover within the predicted range is worrying because the basic ecology and distribution are so poorly known that this species might be seriously threatened by habitat loss, fragmentation and human disturbance.

As for other small carnivores inhabiting the Andes, several threats are affecting the species, including hunting, human–weasel conflicts (resulting in intentional poisoning) and habitat loss, including habitat conversion to agriculture, timber harvesting, urbanisation and general fragmentation. Some probably die in the widespread human-wildlife conflicts and resulting pest control activities for Long-tailed Weasel (with which it is easily confused), which people perceive as a pest (Tirira & González-Maya 2009), but population-level effects, if any, on Colombian Weasel are entirely unknown.

Cavalier & Etter (1995 *apud* Mesa-Gonzalez 2006) indicated that the species could be threatened by the cultivation of illegal crops of amapola *Papaver*; this is suspected to be abundant within the projected elevational range. The modelled distribution also has a high human density (Mesa-Gonzalez 2006): urbanisation and infrastructure development is widespread and thus an additional threat. These numerous land use changes and human activities leave a discontinuous remaining habitat and likely fragmentation of subpopulations. The modelled habitat suitability is mainly based on bioclimatic data, and does not account for biotic interactions (e.g. competition or predation), geographic barriers or human interactions in predicting the final surface. We tried to avoid these biases by cropping the model to the most probable reality. Further research is urgently needed to 1) establish the distribution and subpopulation limits; 2) determine the severity of the numerous suggested threats; and 3) study population structure and even basic ecology.

Nevertheless, the species's inferred presence in many protected areas is a positive signal. Although most of these protected areas overlap only partly with the modelled range (two of the largest areas include only small portions), it is possible that many protected areas retain viable populations. Spatially, those closer to the border in Ecuador (Cayambe Coca Ecological Reserve, Sumaco Napo Galeras, Llanganates and Sangay National Parks) form a large area in combination and thus may be very healthy populations of the species. Further investigation is needed in this region to confirm occupancy. For Colombia there is no cluster of protected areas such as in Ecuador, however, more than 12 protected areas are included in the model, representing potential habitat for this species.

There is a differential conservation representativeness between the protection areas in Colombia and Ecuador, where the total areas under protection are higher respecting the total model in Ecuador (55.5% protected within the 48% of the model) than in Colombia (44.5% protected within the 52% of the model; Table 2). This represents an important difference that requires attention because, probably, there are important gaps across its range, at least for Colombia.

*Conservation recommendations*

There is legal protection in each country of confirmed occurrence, but research and conservation remain priorities. Reliable presence/non-detection surveys are needed to calibrate the current model's predictions, to assess the species's extent of occurrence, areas of occupancy and to allow site-based conservation, particularly maintenance of habitat. According to the current conservation status of areas within the model, the species may be threatened by numerous factors and the little area with natural cover remaining within the range indicates, depending on the species's adapatability, potential population deterioration.

The above information implies that Colombian Weasel should remain in as Vulnerable, but due to the inferred extent of occurrence the criteria should also include B2ab(ii, ii, iv) since its Area of Occupancy and number of localities is highly restricted (IUCN 2001). We also highly recommend active and strong measures and actions, it being more than 10 years from the last report of the species.

## Acknowledgements

We would like to thank Jan Schipper and an anonymous reviewer for their review and comments on the manuscript. Amancay Cepeda for her review of earlier versions and continuous support. José González-Maya would like also to thank all ProCAT Colombia staff for their support, review and help.

## References

Alberico, M. 1994. New locality record for the Colombian Weasel (*Mustela felipei*). *Small Carnivore Conservation* 10: 16–17.

Anderson, R. P. & Martinez-Meyer, E. 2004. Modelling species' geographic distributions for preliminary conservation assessments: an implementation with the spiny pocket mice (*Heteromys*) of Ecuador. *Biological Conservation* 116: 167–179.

Anderson, R. P., Lew, D. & Peterson, A. T. 2003. Evaluating predictive models of species' distributions: criteria for selecting optimal models. *Ecological Modelling* 162: 211–232.

Bernal, E. 2004. *Plan de Desarrollo Chivatá-Boyacá*. Alcaldía Municipal de Chivatá, Chivatá, Boyacá, Colombia.

Casas, C. 2007. *Fauna y flora del corredor de conservación biológica y multicultural Munchique Pinche, departamento del Cauca. Technical Report*. Fundación ProSelva, Grupo de Estudios en Geología, Ecología y Conservación, CIPAV, Popayán, Colombia.

Emmons, L. H. & Helgen, K. 2008. *Mustela felipei*. In *2008 IUCN Red List of Threatened Species*. <http://www.iucnredlist.org>. Downloaded on 10 April 2009.

FONADE s.f. *Esquema de ordenamiento territorial de Almaguer – Cauca*. Argelia y Almaguer en el ordenamiento territorial del Cauca (Colombia). Fondo Financiero de Proyectos de Desarrollo, Contrato n° 2043936, Popayán, Colombia.

Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G. & Jarvis, A. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25: 1965–1978.

IUCN 2001. *Categorías y Criterios de la Lista Roja de la UICN*, versión 3.1. IUCN/SSC, Gland, Switzerland.

López, B. & Ramírez, D. 2008. *Propuesta para la conformación de de la Reserva Natural de la Sociedad Civil en el predio de los Genaros, Santa Rosa de Cabal*. Universidad Tecnológica de Pereira (BSc Thesis), Pereira, Colombia.

Mesa-Gonzalez, E. 2006. Comadreja Colombiana. Pp. 139–144 in Rodriguez-Mahecha, J. V., Alberico, M., Trujillo, F. & Jorgenson, J. (eds) *Libro Rojo de los mamíferos de Colombia*. Serie Libros Rojos de los Mamíferos de Colombia. Conservación Internacional and MAVDT, Bogotá, Colombia.

Phillips S. J., Anderson, R. P. & Schapire, R. E. 2006. Maximum entropy modelling of species geographic distributions. *Ecological Modelling* 190: 231–259.

Rageot, R. & Albuja, L. 1994. Mamíferos de un sector de la alta Amazonía ecuatoriana: Mera, provincia de Pastaza. *Revista Politécnica* 19(2): 165–208.

Schipper, J., Hoffman, M., Duckworth, J. W. & Conroy, J. 2008. The 2008 IUCN red listing of the word's small carnivores. *Small Carnivore Conservation* 39: 29–34.

Schreiber, A., Wirth, R., Riffel, M. & Van Rompaey, H. 1989. *Weasels, civets, mongooses, and their relatives. An action plan for the conservation of mustelids and viverrids*. IUCN/SSC, Gland, Switzerland.

Tirira, D. & González-Maya, J. F. 2009. Distribution, knowledge and threats to the rarest carnivore in South America: *Mustela felipei* in Colombia and Ecuador. *Small Carnivore Conservation* 41: 46–50.

WDPA 2009. *World Database on Protected Areas*. United Nations Environment Programme, World Conservation Monitoring Centre, International Union for Conservation of Nature, World Commonwealth on Protected Areas. <http://www.wdpa.org/>. Downloaded on 31 March 2009.

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# Current state of knowledge of the least-known carnivore in South America: Colombian Weasel *Mustela felipei* in Colombia and Ecuador

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## Abstract

The Colombian Weasel *Mustela felipei* is among the least known carnivores in the Americas, with only six confirmed records, from high elevations in the northern Andes of Colombia and Ecuador. Review of available published and unpublished literature yields no quantitative information regarding conservation, population status or natural history: current knowledge is restricted to anecdotal information regarding collection records and inferences based on them. The conservation status of this species has been evaluated globally and nationally for both countries since 1994. Its current global conservation status is Vulnerable (VU) on the *2008 IUCN Red List of Threatened Species*. Its official national conservation status is Endangered (EN) in Colombia and Data Deficient (DD) in Ecuador. These national status designations mean that hunting, trade and transportation of this species is legally forbidden. We recommend priority actions to establish the current status and distribution, and educational activities, within both countries to conserve this threatened carnivore.

*Keywords*: IUCN Red List, Mustelidae, threats, Vulnerable

### Estado actual del conocimiento del carnívoro menos conocido de Sudamérica: la Comadreja Colombiana *Mustela felipei* en Colombia y Ecuador

## Resumen

*Mustela felipei*, la Comadreja Colombiana, es uno de los carnívoros menos conocidos del continente. Se tienen solamente seis registros confirmados en Colombia y Ecuador, todos ellos en las partes altas de la cordillera de los Andes. Revisamos toda la información publicada disponible hasta hoy de la especie en ambos países e internacionalmente. No existe información acerca de su estado de conservación o poblacional, ni de la historia natural de la especie y toda la información disponible está relacionada con los registros de colecta e inferencias de varios autores. El estado de conservación de la especie ha sido evaluado globalmente y en ambos países desde 1994. Globalmente la especie es considerada Vulnerable en la Lista Roja de Especies Amenazadas de UICN y está legalmente incluida en las 'Listas Rojas' o listas de fauna amenazada de ambos países (Colombia – EN, Ecuador – DD). Este estatus legal le confiere protección oficial y por ende su cacería, comercialización o transporte es penado legalmente. Recomendamos acciones prioritarias para establecer el estado actual, la extensión de ocurrencia y actividades educativas en ambos países como acciones precautorias para preservar este raro carnívoro.

*Palabras clave*: amenazas, Mustelidae, Lista Roja, Vulnerable

## Introduction

The Colombian Weasel *Mustela felipei* is one of the least known and rarest carnivores in South America (Schreiber *et al*. 1989). It was named relatively recently, by Izor & de la Torre (1978), and remains known from few records. Research and collection efforts have been opportunistic, but suggest that the species is rare, occurs at low densities, and can be easily confused with the Long-tailed Weasel *M. frenata* (thus, its reported presence in several areas remains unconfirmed).

Colombia and Ecuador, the only countries with records of the species, have large data gaps concerning overall biodiversity because multiple political and social factors have limited the development of science and research in both countries. The lack of knowledge about the Colombian Weasel exemplifies the generally poor knowledge of most species in these countries (Martinez-Moscoso 2002). Herein we present the first account of the Colombian Weasel using information from published and unpublished reports, and propose research and conservation needs to maintain it across its range.

*Names*

English names: Colombian Weasel (Izor & de la Torre 1978), Don Felipe's Weasel (Tirira 2001a), Felipe's Weasel (Tirira 1999).

Spanish names: Comadreja colombiana (various), Comadreja de Don Felipe (Tirira 2001a), Comadreja de Felipe (Tirira 1999), Chucuri de Don Felipe (Tirira 2001a).

Local or native names: Chucuri (Tirira 1999), Comadreja (Rodríguez-Mahecha *et al.* 1995, Tirira 2004), Chucuro (Mesa-González 1997), Cundumí (Mesa-González 1997). Fawcett *et al.* (1996) documented within the range of this species the use for weasels of Chucurí and Condumbí, but expicitly could not associate them with particular species. The extent (if any) to which the other local names are tied to this species is unclear.

## State of knowledge

The population status is unknown across its entire range and there are only records and inferences about its habitat and ecology. Because of its morphological resemblance to the Long-tailed Weasel, some authors consider that its habits are likely to be very similar. However, the Colombian Weasel is much more geographically restricted and more ecologically restricted to montane habitats than is the Long-tailed Weasel.

No specific studies of the distribution, range or population status of this species have been conducted (Tirira 1995–2009,

*Table 1. Confirmed specimens of Colombian Weasel. Collection acronyms: UV = Universidad del Valle Collection of Mammals, Cali, Colombia; FMNH = Field Museum, Chicago, U.S.A.; MEPN = Museo Escuela Politécnica Nacional, Ecuador; AMNH = American Museum of Natural History, New York, U.S.A.; NMNH = National Museum of Natural History, Washington D.C., U.S.A.*

| # | Site | Province/ Department | Country | Voucher | Elevation (m) | Location | Reference |
|---|---|---|---|---|---|---|---|
| 1 | Alto Galápagos | Valle del Cauca | Colombia | UV 7483 | 2000 | 4°51′N, 76°25′W | Alberico 1994 |
| 2 | Popayán | Cauca | Colombia | FMNH 86745 | 1750 | 1°55′N, 76°31′W | Izor & De la Torre 1978 |
| 3 | Santa Marta | Huila | Colombia | FMNH 70999 | 2700 | 2°33′N, 76°39′W | Izor & De la Torre 1978 |
| 4 | Valle de Tumbaco | Pichincha | Ecuador | MEPN n/c | 2500 | 0°13′S, 78°24′W | Schreiber et al. 1989 |
| 5 | Baeza | Napo | Ecuador | AMNH 63839 | 1525 | 0°25′S, 77°55′W | Hall 1951 |
| 6 | Mera | Pastaza | Ecuador | USNM 548396 | 1123 | 1°27′S, 78°07′W | Albuja & Rageot 1994 |

2008, Mesa-González 2006). Consequently, published statements contain many contradictions regarding habitat and ecology, most of which are speculations not based on data. Schreiber *et al.* (1989) suggested that the species is associated with water bodies and riparian forests because it has inter-digital webbing and collection sites were near water; by contrast, Alberico (1994) argued that since his record was away from any water course, the species is more adaptable than previously suggested and may be more related to a specific forest type than to water.

## Distribution

There are three confirmed localities for the species in each for Colombia and Ecuador; all lie within 1,123–2,700 m elevation (Table 1). It occurs in Colombia from Serrania de los Paraguas in the limits between the Chocó and Valle del Cauca departments (4°51′N, 76°25′W) through the Northern Andes of Ecuador in Mera in the province of Pastaza (1°27′S, 78°05′W; Schreiber *et al.* 1989, Wozencraft 2005).

In Colombia, it is only known from three confirmed locations, in three departments of the country (Cauca, Valle del Cauca and Huila). All specimens were collected on the Central (two) and Occidental (one) mountain ranges of the Andes in Colombia, and between 1,750 and 2,700 m. All sites fall within the Northern Andes ecoregion complex but animals were collected within various habitats such as high Andean and montane forests, including riparian habitats. The holotype came from Santa Marta, elevation 2,700 m, near San Agustin, Huila, Colombia, and the paratype from Popayán, elevation 1,750 m, at Popayán, Cauca, Colombia, 70 km from the holotype (Izor & de la Torre 1978). There is a subsequent record from Alto Galapagos, elevation 2,000 m, on the border between Chocó and Valle del Cauca Departments, Colombia (Alberico 1994).

In Ecuador it is known only from three localities, between 1,123 and 2,500 m, corresponding also to the Northern Andes ecoregion complex and the Eastern subtropical and Inter-Andean temperate zoogeographic zones. Schreiber *et al*. (1989) first documented the species in Ecuador, based on one identified by R. J. Izor in the American Museum of Natural History, New York (AMNH 63839), collected in 1923 by Olalla and sons in Baeza (0°25′S, 77°55′W, 1,525 m), Napo province, east-northern versant of the Andes. Albuja & Rageot (2005) added two new records; the first from the Inter-Andean valley of Tumbaco (0°13′S, 78°24′W, 2,500 m), 20 km east of Quito, Pichincha province, based in a collected specimen in 1947 by T. Mena (MEPN n/c); and the second (USNM 548396) from Mera (1°27′S, 78°07′W, 1,123 m), 12 km west of Puyo, Pastaza province, Eastern of the Real Andes, collected in 1981 by R. H. Rageot (see Rageot & Albuja 1994: 199). All three Ecuadorean specimens were originally incorrectly identified as *M. frenata*, which is itself known from the Tumbaco (FMNH 053526; Izor & de la Torre 1978) and Mera (EPN RH 57; Rageot & Albuja 1994, Albuja & Rageot 2005) localities. The first inclusion of the species by name in a faunal list of Ecuador and the first Ecuadorian publication documenting the species in the country was Tirira (1999: 100).

The entire estimated (Emmons & Helgen 2008) and modelled (Burneo *et al.* 2009) distribution of Colombian Weasel lies within the Long-tailed Weasel's, and it seems that the latter lives in all habitats occupied by the former (Fig. 1). Burneo *et al.* (2009) modelled the distribution using several environmental variables, suggesting that a large portion of the Northern Andes, including multiple protected areas, is suitable for *M. felipei* (Fig. 1), but there are important geographic barriers within this modelled distribution (Burneo *et al.* 2009)

## Current threats

No information is available, but it can be inferred that the primary threats to the species are hunting and habitat loss through urban expansion, conversion to agriculture, cattle ranching and logging, which can cause direct mortality of mature individuals and result in the fragmentation of remaining subpopulations. The three areas where the species has been collected in Ecuador correspond to areas now with heavy human intervention: Baeza and Mera forests have been almost entirely transformed for pastures and cattle, the Tumbaco valley currently corresponds to one of the fastest growing population areas in the country, with extensive urbanisation, and a few areas for crops (flowers and fruit-trees) and eucalyptus and pine plantations (D.G.T. pers. obs). Thus its continued presence at these locations is uncertain.

Mining is projected to be a threat in the near future due to the potential development of many large- and small-scale mines along the eastern flanks of the Ecuadorian Andes. Furthermore, if the species is in fact associated with aquatic, riparian or water-related habitats, as suggested by Izor & de la Torre (1978), the potential impacts of petroleum/oil spills occurred near Baeza (Ecuador) in recent years could directly affect the species. Also, Wirth (1990) postulated that in this case it could also be threatened by mercury pollution from gold panning in some areas of Ecuador (specifically Podocarpus National Park).

In Colombia the situation is little better, with numerous potential threats. Fawcett *et al.* (1996) deployed 3,380 trap-days

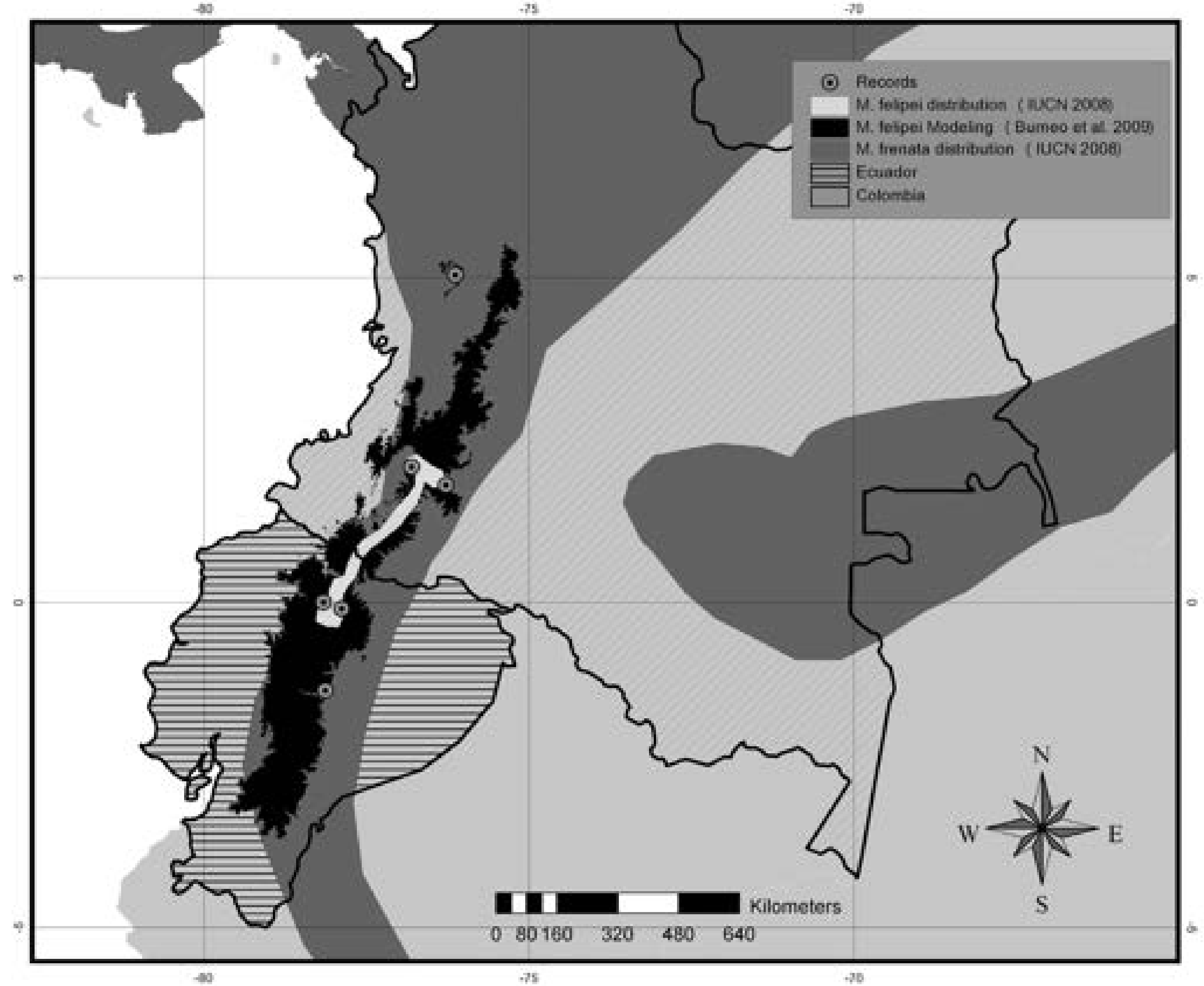

*Fig. 1. Mustela felipei distribution of records, habitat suitability modelling (Burneo et al. 2009) and IUCN Red List range map. Also shows M. frenata (IUCN Red List range map) distribution across the Northern Andes to highlight overlap.*

in the four sites with confirmed records yet no individuals were captured, suggests that it is rare and/or elusive. As Fawcett *et al.* (1996) pointed out, capture and research methods employed in such surveys should be modified to improve chances of finding the species.

Retaliatory hunting is inferred to be a threat because weasels are perceived to threaten small domestic animals such as chickens and domestic Guinea-pigs *Cavia porcellus*. Active persecution of Long-tailed Weasels by local people is common and presumably also affects sympatric Colombian Weasels. According to Mesa-González (1997) and Fawcett *et al.* (1996) it is highly probable that the species is used, like the Long-tailed Weasel, as a traditional medicine for asthma, infertility and 'magical arts' treatment in some departments of Colombia.

## Conservation measures

National conservation status classifications have varied within both countries, reflecting the limited information available to assess status. However, the species has consistently been 'listed', threatened or Data Deficient since 1986 (Table 2).

In Ecuador, despite the first identification being in 1987 (Schreiber *et al.* 1989), not until 1999 was the species placed on the national threatened mammal list (Tirira 1999). Consequently, it was not included on previous documents of endangered fauna (Albuja 1983: 35–67, Suárez & García 1986, 1st TGEME 1996 *in* Tirira 1999). The first national conservation assessment for the species occurred in 2000 at the 2nd Workshop of the Ecuadorian Mammals Specialists Group (WEMSG), where it was included in the first edition of the Ecuadorian Mammals Red Book (Tirira 2001b) and was considered Critically Endangered (CR). This category was selected based on the then suspected small area of occupancy (<10 km²), heavily fragmented habitat and because it was known from only one locality; furthermore a severe population decline was inferred.

This stance was re-evaluated in the 3rd WEMSG held in 2007 (Tirira & Burneo in prep.), where it was suggested that Data Deficient (DD) was the most appropriate assessment. This national assessment was supported by consideration that the two records reported by Albuja & Rageot (2005) were from highly-altered areas, indicating the species is somewhat tolerant to habitat modification. In Ecuador some legal protection is afforded to the spe-

*Table 2. Evolution of the national IUCN Red List status for the Colombian Weasel in Ecuador and Colombia.*

| **Country/ Year** | **Category** | **Author** |
|---|---|---|
| Colombia | | |
| 1986 | Listed | Rodríguez-Mahecha *et al.* 1986 |
| 1998 | Data Deficient | Rodríguez-Mahecha 1998 |
| 2002 | Endangered | Res. 0584 Junio de 2002 - MAVDT 2002 |
| 2005 | Endangered | Res. 0572 Mayo de 2005 - MAVDT 2005 |
| 2006 | Endangered | Rodríguez-Mahecha *et al.* 2006 |
| Ecuador | | |
| 1983*,[1] | Not evaluated | Albuja 1983 |
| 1986*,[1] | Not evaluated | Suárez and García 1986 |
| 1999* | Not evaluated | 1st WEMSG 1996 in Tirira 1999 |
| 2001 | Critically Endangered | 2nd WEMSG 2000 in Tirira 2001b |
| 2007 | Data Deficient | 3rd WEMSG 2007 in Tirira & Burneo in prep. |

*not then reported for Ecuador, [1]IUCN criteria not used.

cies. The capture, hunting, trade and transport of live individuals, constitutive elements and sub-products of all the species included in the Red Book of Ecuadorian Mammals is forbidden following the Decreto No. 50, October 8 2002 (Registro Oficial No. 679; Tirira 2001b).

In Colombia the species is legally protected by law (MAVDT 2005) because it is included in the official National Red List by the Ministerio de Ambiente, Vivienda y Desarrollo Territorial (MAVDT) and its hunting, persecution and trade are not permitted in the national territory.

Globally, the species is considered Vulnerable (VU) B1ab (ii, iii) on the *IUCN Red List of Threatened Species* (Emmons & Helgen 2008, Schipper *et al.* 2008) due to restricted Extent of Occurrence, severe habitat fragmentation and small number of records. Previous global assessments were Endangered (Groombridge 1993, Baillie & Groombridge 1996). It is not included in any appendix of CITES (2008).

## Occurrence in protected areas

In Colombia, the species was collected once in a protected area (Cueva de los Guacharos Natural National Park), twice near protected areas (Munchique Natural National Park and Purace Natural National Park) and once outside any protected area. In Ecuador, Colombian Weasels have not been reported in any protected area; however, locations of records suggest it might occur in Llanganates National Park (near Mera), and Cayambe-Coca and Antisana Ecological Reserves (near Baeza; Tirira 2007).

According to Burneo *et al.* (2009), who modelled the species's potential distribution based on habitat suitability, the species could occur in as many as 34 protected areas (20 in Colombia and 14 in Ecuador) with approximately 27,700 km² of potential distribution under some protection. Of these areas, only 10 are >1,000 km²; the largest is in Ecuador (5,177 km²) and the second-largest in Colombia.

## Future research and conservation

The Colombian Weasel lacks data on even basic ecology. Future research and conservation priorities needs to first fill some of the massive data gaps to understand the impact of the numerous possible threats and to investigate its possible presence in numerous protected areas. Population monitoring is a priority near human-dominated areas to see the effects of human–weasel conflict and habitat-use change. The few records have driven inferential comparisons with the Long-tailed Weasel, which may be incorrect as the latter occurs from Canada to Bolivia across a wide range of habitats. Furthermore, the frequent confusion between Colombian Weasel and Long-tailed Weasel can lead to misidentification and further confound field records and reports. Thus a priority for research is to collect more voucher specimens across the potential range and to implement camera-trap research so that objectively identifiable and permanent non-invasive records can be collected.

Further research priorities include surveys inside and outside protected areas and near known localities to estimate the actual distribution, conservation status and population trends. Larger-scale surveys are required to determine if the species is distributed across the three Andean ranges of Colombia and all of Andean Ecuador (and possibly Peru) as habitat models suggest (Burneo *et al.* 2009) or if it is truly restricted. In the event that one or more populations are discovered, population monitoring and site-specific conservation plans may be necessary to ensure persistence.

The clear uncertainty over the rarity of the species, is confounded by other studies that we suggest have misidentified the species as Long-tailed Weasel. Therefore, we also recommend a survey of existing specimens of Long-tailed Weasel from Colombia, Ecuador and Peru for other thus-far misidentified records.

Because this species is one of the least known, and potentially rarest and most threatened small carnivores, educational campaigns are proposed as a precautionary measure in both countries, focusing on the communities and areas that the species is potentially present. It is also important to begin trans-national efforts to study the habits, population status and actual extent of occurrence of the Colombian Weasel, and to estimate the habitat loss and main threats to this Northern Andean ecoregion.

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### References

Alberico, M. 1994. New locality record for the Colombian Weasel (*Mustela felipei*). *Small Carnivore Conservation* 10: 16–17.

Albuja, L. 1983. *Mamíferos ecuatorianos considerados raros o en peligro de extinción.* Programa Nacional Forestal, Ministerio de Agricultura y Ganadería, Quito, Ecuador.

Albuja, L. & Rageot, R. 2005. Nuevos registros de *Mustela felipei* (Carnivora: Mustelidae) para el Ecuador. *Revista Politécnica (Biología 6)* 26(1): 170–172.

Baillie, J. & Groombridge, B. 1996. *1996 IUCN Red List of threatened animals*. IUCN, Gland, Switzerland.

Burneo, S., González-Maya, J. F. & Tirira, D. 2009. Distribution and habitat modelling for Colombian Weasel *Mustela felipei* in Northern Andes. *Small Carnivore Conservation* 41: 41–45.

CITES 2008. *Convention on International Trade in Endangered Species of Wild Fauna and Flora. Appendices I, II, III.* <http://www.cites.org/eng/app/appendices.shtml>. Downloaded on 29 January 2009.

Emmons, L. H. & Helgen, K. 2008. *Mustela felipei*. In *2008 Red List of Threatened Species*. <http://www.iucnredlist.org>. Downloaded on 10 April 2009.

Fawcett, D. 1993. Colombian Weasel project. *Small Carnivore Conservation* 8: 18.

Fawcett, D., Rojas-Dias, V. & Montero, H. 1996. Colombian Weasel. *Small Carnivore Conservation* 14: 7–10.

Groombridge, B. 1993. *1994 IUCN Red List of threatened animals*. IUCN, Gland, Switzerland, and Cambridge, U.K.

Hall, E. R. 1951. American weasels. *University of Kansas Publications, Museum of Natural History* 4: 1–466.

Izor, R. J. & de la Torre, L. 1978. A new species of weasel (*Mustela*) from the highlands of Colombia, with comments on the evolution and distribution of South American weasels. *Journal of Mammalogy* 59: 92–102.

Martínez-Moscoso, J. 2002. Carnívoros del Ecuador: Anatomía, morfología y clave grafica de identificación. *Universidad-Verdad* 29: 133–144.

[MAVDT] Ministerio de Ambiente, Vivienda y Desarrollo Territorial 2002. *Resolución 0584 26 de Junio de 2002*. Ministerio de Ambiente, Vivienda y Desarrollo Territorial, Bogotá, Colombia.

[MAVDT] Ministerio de Ambiente, Vivienda y Desarrollo Territorial 2005. *Resolución 0572 4 de Mayo de 2005*. Ministerio de Ambiente, Vivienda y Desarrollo Territorial, Bogotá, Colombia.

Mesa-González, E. 1997. Rango de acción, uso del hábitat y anotaciones sobre el conocimiento popular del Chucuro (*Mustela frenata*) en una zona de El Tambo, Cauca. Universidad Nacional de Colombia (Tesis de pregrado), Bogotá, D.C. Colombia.

Mesa-González, E. 2006. Comadreja Colombiana. Pp. 139–144 in Rodriguez-Mahecha, J. V., Alberico, M., Trujillo, F. & Jorgenson, J. (eds) *Libro Rojo de los mamíferos de Colombia*. Serie Libros Rojos de los Mamíferos de Colombia. Conservación Internacional y MAVDT, Bogotá, Colombia.

Rageot, R. & Albuja, L. 1994. Mamíferos de un sector de la alta Amazonía ecuatoriana: Mera, provincia de Pastaza. *Revista Politécnica* 19(2): 165–208.

Rodríguez-Mahecha, J. V. 1998. Listas preliminares de mamíferos colombianos con algún riesgo a la extinción. Informe final presentado al Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. <http://www.humboldt.org.co/conservacion/Listas_Preliminares.htm>. Downloaded on 31 March 2009.

Rodríguez-Mahecha, J. V., Hernández-Camacho, J. I., Rueda, J. V. & Morales, J. 1986. Colombia: fauna en peligro. *Revista Procam – Inderena* 1: 1–17.

Rodríguez-Mahecha, J. V., Hernández-Camacho, J. I., Defler, T. R., Alberico, M., Mast, R. B., Mittermeier, R. A. & Cadena, A. 1995. Mamíferos colombianos: sus nombres comunes e indígenas. *Conservation International Occasional Papers in Conservation Biology* 3: 1–56.

Rodríguez-Mahecha, J. V., Alberico, M., Trujillo, F. & Jorgenson, J. (eds) 2006. *Libro Rojo de los mamíferos de Colombia*. Serie de Libros Rojos de Especies Amenazadas de Colombia. Conservación Internacional Colombia & Ministerio de Ambiente, Vivienda y Desarrollo Territorial, Bogotá, Colombia.

Schipper, J., Hoffman, M., Duckworth, J. W. & Conroy, J. 2008. The 2008 IUCN red listing of the word's small carnivores. *Small Carnivore Conservation* 39: 29–34.

Schreiber, A., Wirth, R., Riffel, M. & Van Rompaey, H. 1989. *Weasels, civets, mongooses, and their relatives. An action plan for the conservation of mustelids and viverrids*. IUCN, Gland, Switzerland.

Suárez, L. & García, M. 1986. *Extinción de animales en el Ecuador, descripción de 60 especies amenazadas*. Fundación Natura, Quito, Ecuador.

Tirira, D. 1995–2009. *Red Noctilio*. Base de información no publicada sobre los mamíferos del Ecuador. Murciélago Blanco, Quito, Ecuador.

Tirira, D. (ed.) 1999. *Mamíferos del Ecuador*, 1st edn. Museo de Zoología, Pontificia Universidad Católica del Ecuador y SIMBIOE, Quito, Ecuador (Publicación Especial sobre los mamíferos del Ecuador n° 2).

Tirira, D. 2001a. Chucuri de Don Felipe (*Mustela felipei*). Pp. 59–60 in Tirira, D. (ed.) *Libro rojo de los mamíferos del Ecuador*, 1st edn. SIMBIOE, EcoCiencia, Ministerio del Ambiente & UICN, Quito, Ecuador (Publicación Especial sobre los mamíferos del Ecuador n° 4).

Tirira, D. (ed.) 2001b. *Libro rojo de los mamíferos del Ecuador*, 1st edn. SIMBIOE, EcoCiencia, Ministerio del Ambiente & UICN, Quito, Ecuador (Publicación Especial sobre los mamíferos del Ecuador n° 4).

Tirira, D. 2004. *Nombres de los mamíferos del Ecuador*. Ediciones Murciélago Blanco & Museo Ecuatoriano de Ciencias Naturales, Quito, Ecuador (Publicación Especial sobre los mamíferos del Ecuador n° 5).

Tirira, D. 2007. *Guía de campo de los mamíferos del Ecuador*. Ediciones Murciélago Blanco, Quito, Ecuador (Publicación Especial sobre los mamíferos del Ecuador n° 6).

Tirira, D. 2008. *Estado actual del conocimiento de los mamíferos del Ecuador*. Memorias, XXXII Jornadas Nacionales de Biología, Universidad Técnica Particular de Loja, Loja, Ecuador.

Tirira, D. & Burneo, S. (eds) in prep. *Libro rojo de los mamíferos del Ecuador*, 2nd edn. Fundación Mamíferos y Conservación, PUCE & Ministerio del Ambiente, Quito, Ecuador (Publicación Especial sobre los mamíferos del Ecuador n° 9).

Wirth, R. 1990. Colombian Weasel threatened by mercury pollution? *Mustelid and Viverrid Conservation* 2: 15.

Wozencraft, W. C. 2005. Order Carnivora. Pp. 532–628 in Wilson, D. E. & Reeder, D. M. (eds) *Mammal species of the world: a taxonomic and geographic reference*, 3rd edn. Johns Hopkins University Press, Baltimore, U.S.A.

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# Conserving American Marten *Martes americana* winter habitat in sub-boreal spruce forests affected by Mountain Pine Beetle *Dendroctonus ponderosae* infestations and logging in British Columbia, Canada

Gilbert PROULX

## Abstract

Current management plans to clear cut large forest stands of Mountain Pine Beetle *Dendroctonus ponderosae*-infested Lodgepole Pine *Pinus contorta* could adversely affect American Marten *Martes americana* winter habitat. I assessed and predicted winter distribution of American Marten in the Sub-boreal Spruce Biogeoclimatic Zone of central interior British Columbia to estimate the impact of Lodgepole Pine harvesting on this species. I predicted that American Marten would be present in excellent- and high- quality polygons that corresponded to ≥80 years old, undisturbed, conifer-dominated stands with ≥30% canopy closure, ≥20 m²/ha basal area, and circum-mesic soils. Martens would be absent from immature and young forests, and from late-successional pure deciduous, Lodgepole Pine, and Black Spruce *Picea mariana* stands. Habitat use by American Marten was assessed by traversing about 170 km of transects from December to February 2005–2008. A total of 108 American Marten tracks were recorded: 106 in excellent- and high-quality polygons with mature and old mixed coniferous and conifer-dominated mixed stands, and two in low-quality polygons with mature Lodgepole Pine stands. The observed frequency of tracks per habitat type differed ($P < 0.05$) from expected. American Marten tracks were found in stands that were, on average, 156.6 years old with 52.3% canopy closure, and 39.9 m²/ha basal area. Most stands (92.6%) had 20–49 cm dbh trees, and <20% shrub cover. Lodgepole Pine was present, and often was the dominant species in most mixed coniferous stands used by American Martens. The extensive logging of stands where Lodgepole Pine is mixed with other conifers would undoubtedly have a negative effect on American Marten winter habitat. For effective conservation of American Martens, forest management plans must be based on spatially-explicit data that relate to specific habitat requirements. I demonstrated the ability to predict winter distribution of American Marten in landscapes infested by Mountain Pine Beetle, and to identify stands that should be protected for conservation.

*Keywords*: Habitat conservation, Lodgepole Pine, Sub-boreal Spruce forest

## Conservando el hábitat de invierno de la Marta Americana *Martes americana* en los bosques de abetos sub-boreales, afectados por la infestación del escarabajo de pino *Dendroctonus ponderosae* y la tala extensiva en Columbia Británica, Canadá

## Resumen

Los actuales planes de manejo forestal que incluyen la tala de grandes extensiones de bosques para la producción del pino *Pinus contorta* infestado del escarabajo de pino *Dendroctonus ponderosae* pueden impactar de manera negativa el hábitat de invierno de la marta americana *Martes americana*. El objetivo del presente estudio fue el de evaluar y predecir la distribución en invierno de la marta americana en la zona biogeoclimática de los abetos sub-boreales del interior central de la Columbia Británica, con el fin de determinar el impacto de la producción del *Pinus contorta* sobre esta especie. Se predijo que la marta americana estaría presente en polígonos de alta y excelente calidad, que correspondan a sitios no perturbados por ≥ de 80 años dominados por confieras con ≥ 30% de densidad de dosel, ≥ 20 m²/ha de área basal y suelos de tipo medio con un buen nivel de drenaje. Las martas estarían ausentes en bosques inmaduros o jóvenes y en bosques deciduos puros en estados sucesionales tardíos de *Pinus contorta* y *Picea mariana*. El uso de hábitat por la marta americana fue evaluado en campo y aproximadamente 170 Km de transectos fueron realizados, con seguimiento de rastros en la nieve, desde diciembre hasta febrero entre el 2005 y el 2008. Un total de 108 indicios de la marta americana fueron registrados: 106 en polígonos de alta-excelente calidad en bosques maduros y mixtos viejos de coníferas o bosques mixtos dominados por coníferas, y 2 indicios en polígonos de baja calidad con bosques de *Pinus contorta* maduros. La frecuencia observada de rastros por tipo de hábitat fue significativamente diferente ($P < 0.05$) de lo esperado. Los rastros de la marta americana fueron encontrados en bosques que tienen en promedio 156.6 años de antigüedad, con 52.3% de densidad del dosel y 39.9 m²/ha de área basal. La mayoría de los bosques (92.6%) tienen árboles entre 20 y 49 cm de DAP y < 20% de cobertura de arbustos. *Pinus contorta* estuvo presente y a menudo fue la especie dominante, en la mayoría de los bosques coníferos mixtos utilizados por la marta americana. La tala extensiva de bosques donde *Pinus contorta* está mezclado con otras coníferas tendría sin duda un efecto negativo en el hábitat de invierno de la marta americana. Para que un plan de manejo forestal sea efectivo en cuanto a la conservación de la marta americana, debe estar basado en fuentes de información espacialmente explicitas que relacionen los requerimientos de hábitat de manera específica. Este estudio mostró que es posible predecir la distribución del hábitat de invierno de la marta americana en paisajes infestados por el pino escarabajo de montaña, e identificar bosques que deben ser protegidos para la conservación de la biodiversidad.

*Palabras clave*: conservación de hábitat, bosques de abetos sub-boreales, hábitat de invierno

## Introduction

In central British Columbia (BC), Canada, recent epidemics of Mountain Pine Beetle *Dendroctonus ponderosae* have resulted in the infestation of at least 4.2 million hectares of mature (≥81 years) and old (≥140 years; DeLong *et al*. 2003, Morgantini & Kansas 2003) Lodgepole Pine *Pinus contorta* stands (Readshaw 2003). Using clear cuts (40–60 ha or larger in landscapes damaged by fire, insects or wind; BC Forest Practices Code 2006), government and industry plan salvage harvesting of beetle-infested trees in much of the Central Interior to extract as much timber value as possible before the wood deteriorates. Because Mountain Pine Beetles prefer large diameter trees (Safranyik 2004), harvesting beetle-infested trees adversely affects the distribution and structure of late-successional forests (Safranyik *et al*. 1974). This would be likely to have a negative effect on American Marten *Martes americana*, a forest specialist that is associated with late-successional, circum-mesic coniferous or conifer-dominated mixed forests in western North America (Proulx *et al*. 2004). Considering that the American Marten is an economically important species (Proulx 2000) associated with numerous species in late-successional forests (Gyug 1996, Lawlor 2003), extensive clear cutting is a source of concern to wildlife managers (Proulx *et al*. 2004).

To estimate the effect of extensive Lodgepole Pine logging on American Marten winter habitat in the Central Interior, I investigated the species's habitat requirements in winter when harsh environmental conditions increase the animals' requirements for energy, nutrients, shelter and security (Proulx *et al*. 2004). My objective was to assess and predict late-winter distribution of American Marten in the BC Sub-boreal Spruce Biogeoclimatic Zone by: 1) rating the potential of forest stands according to their composition and structural characteristics and 2) verifying habitat use by Marten using snowtracking.

## Study Area

The study was conducted in central interior BC, in four supply blocks of Canadian Forest Products Ltd in the Prince George Forest District (53°55′N, 122°44′W). Field investigations occurred in Supply Block F (700,000 ha of forests) in the southwest portion of the district, and in Supply Block E (905,000 ha) in the north (Fig. 1). In Fort St. James District (54°27′N, 124°15′W), the study was conducted in Supply Block C (638,000 ha of forests) in the southern portion of the district, and the southern portion of Supply Block B (70,000 ha) in the north (Fig. 1). All study areas were located within the Sub-boreal Spruce Biogeoclimatic Zone where hybrid White Spruce *Picea engelmanii* x *glauca* and Subalpine Fir *Abies lasiocarpa* were the dominant climax tree species (Meidinger *et al*. 1991). Lodgepole Pine occurred in mature forests in the drier parts of the zone, and both Lodgepole Pine and Trembling Aspen *Populus tremuloides* were pioneer species in many early-successional stands. Lodgepole Pine represented >35% of the merchantable wood in Supply Block E, and >50% in other supply blocks. Douglas-fir *Pseudotsuga menziesii* was at the northernmost border of its natural range and sporadically occurred on dry, warm and rich soils at lower elevations. Black Spruce *Picea mariana* was occasionally found in climax upland forests (Meidinger *et al*. 1991).

## Methods

*Rating forest stands and polygons*

I used the variables of Proulx *et al.* (2006) to identify forest stands that usually have coarse woody debris and a developed understory (Table 1). Minimum levels of canopy closure and basal area allowed me to reject stands with too much disturbance. I subjectively allocated weight values to selected variables based on my

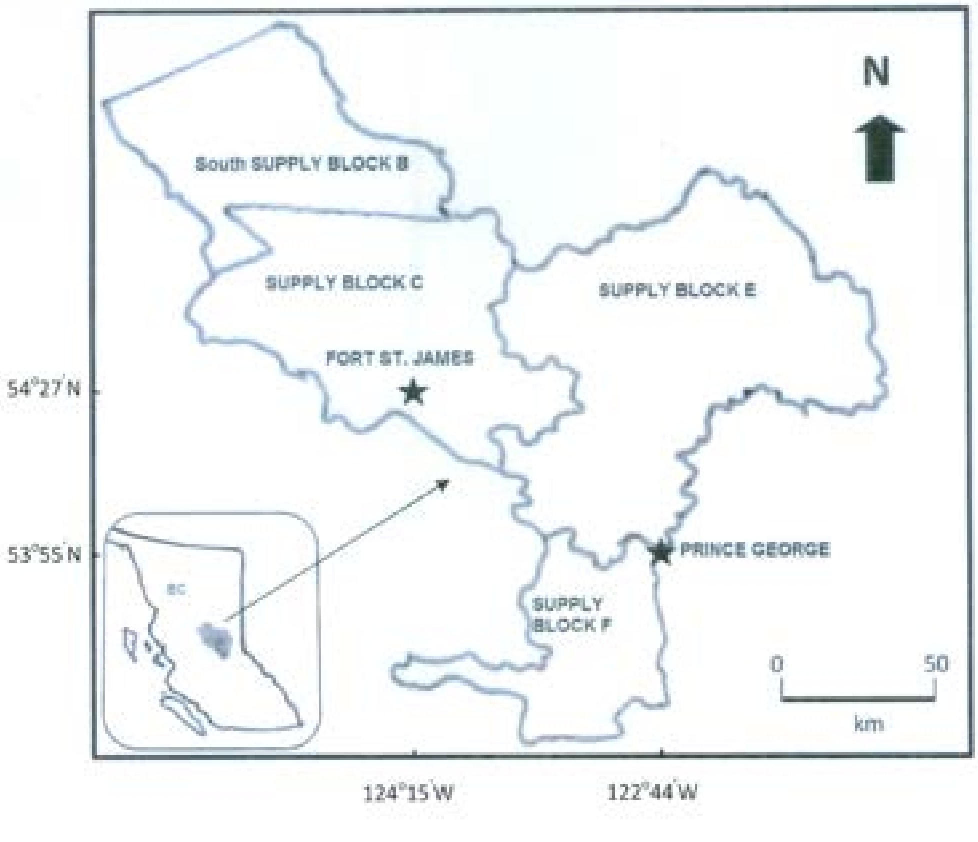

*Fig. 1. Location of study areas in central interior British Columbia (BC), Canada.*

*Table 1. Habitat variables used to rate polygons for American Marten in Sub-boreal Spruce forests of British Columbia (Proulx* et al. *2006).*

| Criterion | Weight given | |
|---|---|---|
| | 1 | 0 |
| Forest type | Pure or mixed coniferous (spruce, fir) or conifer-dominated mixed stands | Pure deciduous, Black Spruce or Lodgepole Pine stands. |
| Age (years) | ≥80 | <80 |
| Crown closure | ≥30% | <30% |
| Basal area | ≥20 m²/ha | <20 m²/ha |
| Soil | Circum-mesic | Hygric or xeric |
| Disturbance | Cutblock (except partial logging <1970) or road—Rejected. | |

evaluation of their importance to American Marten (Proulx *et al.* 2006). The sum of weights allowed the classification of vector map polygons (i.e. homogenous areas with similar forest stand characteristics) into four categories of potential winter habitat: (1) excellent, 5 points; (2) high, 4 points; (3) medium, 3 points; and (4) low, ≤2 points.

*Field assessment of potential American Marten habitats*

Because of the size of areas surveyed, field assessments were conducted over two winters in Supply Blocks F (43 transects), E (32 transects), and C (54 transects). Surveys in Supply Block B (17 transects) were conducted during one winter only in the southern portion of the block that was contiguous with Supply Block C. A random stratified approach (Krebs 1978) was used to locate transects averaging ≥1- km long on a yearly basis, and ≥1-km apart that crossed all polygon types. Transects were plotted on predictive maps, and starting points were located using compass bearings and distance to distinct topographic features. Transects were inventoried (snowshoed) (snow depths: 45–180 cm; temperatures: -25 °C to 2 °C) using a compass, 1:50,000 scale maps, and a hip chain (device with filament used to record linear distances). Forest composition was recorded along survey transects: coniferous (coniferous species >75%; pure if only one species), deciduous (deciduous species >75%), or mixed (neither type >75%). Successional stages corresponded to immature-pole (open areas and new stands; pole corresponded to 7.5–12.4 cm dbh trees; about 0–40 years), young (achievement of dominance by some trees and death of others, uneven dbh, multi-storied canopy; about >40–80 years), mature (even canopy of trees, developed understory as the canopy opens up; about >80–140 years), and old (structurally complex, established shade-tolerant species, mortality of tall and large canopy trees, canopy gaps, large down woody material; about >140 years but variable with species) (Proulx & Kariz 2005). Only fresh tracks (i.e. ≤48 hours old from most recent snowfall) crossing transects were recorded. Due to the similarity between Fisher *Martes pennanti* and American Marten footprints (Halfpenny *et al.* 1995), when mustelid tracks were encountered, they were investigated on both sides of transects and within forest stands to find the best tracks available. The combination of footprint (pattern and size, presence/absence of toe pad prints) and trail (gait, distance between jumps, and dragging of the feet) characteristics was used to identify all tracks (see Murie 1975, Rezendes 1992, Halfpenny *et al.* 1995). American Marten tracks are usually smaller, although the footprints of female Fishers and male American Martens may be of similar size. In winter, the undersurface of American Marten's feet is heavily covered with hair and toe pads do not show (Murie 1975, Rezendes 1992). The undersurface of Fisher's feet has sparse hair, and pads show well in clear prints (Halfpenny *et al.* 1995). Approximate locations along transects were determined using hip chain distances and forestry maps. Track locations were entered into the Vegetation Resources Inventory (VRI) database to identify site attributes. VRI is the standard for assessing the quantity and quality of timber and other vegetation resources in BC. It uses photo interpretation and detailed ground sampling to estimate timber volume and other vegetation resources within a predefined unit (BC Forest Investment Account 2009). The VRI information was compared to field observations to ensure that polygon classification was appropriate.

*Data analyses*

The proportion of inventory transects within each polygon type or habitat type was used to determine the expected frequency of tracks per polygon or habitat type. Chi-square statistics with Yates's correction and the Fisher Exact Probability Test (Zar 1999) were used to compare observed to expected frequencies of track intersects per polygon or habitat type (Proulx *et al.* 2006, Proulx & O'Doherty 2006). Probability values ≤ 0.05 were considered statistically significant.

Autocorrelation is often present in ecological data and may not be totally avoidable (Legendre 1993, Bowman & Robitaille 1997). It potentially occurs during analysis of track survey data because of the uncertainty in whether one or more animals have made the tracks being counted. Although some investigators (e.g. Thompson 1949, de Vos 1952) recommended not counting repeated crossings by the same animals, it is sometimes difficult to confirm that a series of tracks along a transect belong to the same animal (de Vos 1951) because home ranges overlap (Buskirk & Ruggiero 1994) and winter dispersal movements can occur (Clark & Campbell 1976). Because of rugged environmental conditions, we did not follow tracks that crossed close together to learn whether the same animal made them. However, based on track characteristics, we deduced that two different animals could be as close as 100 m apart along the same transect. To minimize spatial autocorrelation, only tracks ≥100 m apart within the same forest stand were recorded (Bowman & Robitaille 1997).

## Results

*Field assessment of polygons*

Approximately 20 km of transects were inventoried every year in each Supply Block, for a total of 170,264 m (Table 2). The observed distribution of tracks per polygon type differed ($P < 0.05$) from expected. In Supply Block F, 30 (93.8%) of 32 tracks were located in excellent- and high- quality polygons; two were found in low-quality polygons. In other Supply Blocks, all tracks ($n$ = 76) were in excellent- and high- quality polygons (Table 2).

*Habitats with American Marten tracks*

Most (98.2%) American Marten tracks were found in circum-mesic, mature, and old mixed coniferous and conifer-dominated mixed stands (Table 2). Only two tracks were found in pure mature Lodgepole Pine stands (Table 2). The observed frequency of tracks per habitat type differed from expected ($P < 0.05$), with 94

*Table 2. Winter distribution of American Marten tracks according to polygon and habitat types, central interior British Columbia.*

| Unit | Supply blocks | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | F (2005–2007) | | E (2006–2008) | | C & B (2006–2008) | | All (2005–2008) | |
| | Total transect length – m (%) | Number of American Marten tracks (%) | Total transect length – m (%) | Number of American Marten tracks (%) | Total transect length – m (%) | Number of American Marten tracks (%) | Total transect length – m (%) | Number of American Marten tracks (%) |
| *Polygon type* | | | | | | | | |
| Low | 13,887 (34.2) | 2 (6.3) | 16,837 (39.5) | 0 (0) | 29,968 (34.4) | 0 (0) | 60,692 (35.7) | 2 (1.9) |
| Medium | 2,265 (5.6) | 0 (0) | 2,700 (6.3) | 0 (0) | 12,930 (14.9) | 0 (0) | 17,895 (10.5) | 0 (0) |
| High | 5,391 (13.3) | 5 (15.6) | 13,711 (32.2) | 12 (80) | 21,441 (24.6) | 27 (44.3) | 40,543 (23.8) | 44 (40.7) |
| Excellent | 19,017 (46.9) | 25 (78.1) | 9,373 (22) | 3 (20) | 22,744 (26.1) | 34 (55.7) | 51,134 (30) | 62 (57.4) |
| Total | 40,560 (100) | 32 (100)* | 42,621 (100) | 15 (100)* | 87,083 (100) | 61 (100)* | 170,264 (100) | 108 (100)* |
| *Habitat type* | | | | | | | | |
| Immature-pole | 9,322 (23) | 0 (0) | 13,021 (30.6) | 0 (0) | 25,784 (29.6) | 0 (0) | 48,127 (28.3) | 0 (0) |
| Young | 3,770 (9.3) | 0 (0) | 2,368 (5.6) | 0 (0) | 12,685 (14.6) | 0 (0) | 18,823 (11.1) | 0 (0) |
| Mature + old pure Lodgepole Pine or Black Spruce | 2,974 (7.3) | 2 (6.3) | 2,510 (5.9) | 0 (0) | 1,674 (1.9) | 0 (0) | 7,158 (4.2) | 2 (1.9) |
| Mature + old mixed coniferous + conifer-dominated mixed stands | 24,494 (60.4) | 30 (93.7) | 24,722 (58) | 15 (100) | 46,940 (53.9) | 61 (100) | 96,156 (56.5) | 106 (98.1) |
| Total | 40,560 (100) | 32 (100)* | 42,621 (100) | 15 (100)* | 87,083 (100) | 61 (100)* | 170,264 (100) | 108 (100)* |

*Observed American Marten track distribution significantly different from expected ($P < 0.05$).

(87%) tracks recorded in mixed coniferous stands (Fig. 2). Lodgepole Pine was present in 64 (68%) of these stands, and was the dominant species in 26 (27.7%) of them.

American Marten tracks were found in stands that were, on average, 156.6 years old ($n = 107$, $SD = 44.7$; median = 150.5 years), with a 52.3% (± 10.4%; range = 30–75%) canopy closure, and a 39.9 m²/ha (± 12.4 m²/ha) basal area (Fig. 2). Most stands (92.6%) had 20–49 cm dbh trees, and <20% shrub cover (Fig. 2).

## Discussion

In this study, American Martens in the Sub-boreal Spruce Biogeoclimatic Zone used late-successional conifer-dominated stands in winter, as was previously found (Lofroth 1993, Proulx *et al*. 2006). Martens selected mixed-coniferous stands with well-developed ground structure (i.e. accumulations of coarse woody debris, including large logs and decaying stumps, shrubs and shade-tolerant

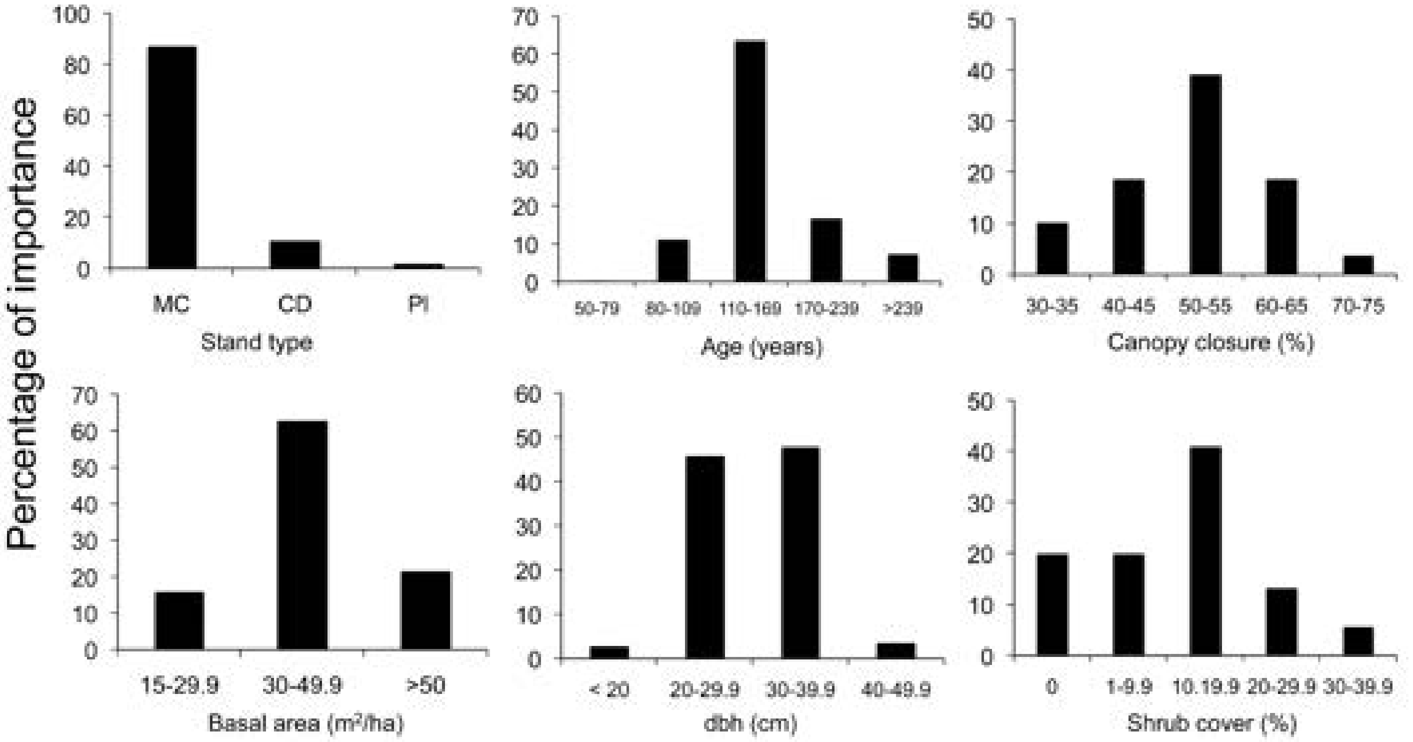

*Fig. 2. Characteristics of stands used by American Marten in winter in Sub-boreal Spruce forests of British Columbia, December to February 2005–2008 (MC – mixed coniferous; CD – coniferous–deciduous; Pl – Lodgepole Pine).*

seedlings), and a multi-storied canopy over pure Lodgepole Pine stands that have little ground structure (open grounds with poor coarse woody debris and scattered shrubs) and a single-storied canopy (Burnett 1981, Buskirk *et al*. 1989, Fager 1991, Wilbert 1992).

Lodgepole Pine was present, and often was the dominant species, in mixed coniferous stands used by American Martens. The extensive logging of stands where Lodgepole Pine occurred with other conifers would be likely to affect American Marten winter habitat adversely. In the last decade, based on various guidelines, discussion papers, and an intent to emulate natural disturbance events such as fire (BC Environment and Forests 1995, DeLong & Tanner 1996, MSRM 2004), forestry companies have harvested large tracts of land in central British Columbia, often leaving only small, disconnected patches of late-successional coniferous forests. Habitat fragmentation (often measured by the percentage of the landscape that is unforested) even at low levels (i.e. 20–30%) of a Marten's home range, and the loss of forest interior (sheltered, secluded environment away from the influence of forest edges and open habitats) have negative effects on American Martens (Thompson & Harestad 1994, Hargis & Bissonette 1997, Chapin *et al*. 1998, Potvin *et al*. 2000). The loss of contiguous late-successional forests may result in local extirpation of American Martens (Bissonette *et al*. 1997). Because habitat loss alters landscape connectivity, Martens may be unable to disperse in fragmented habitats. In Supply Block F, Proulx (2007) reported a drastic landscape change due to extensive logging of Lodgepole Pine in spruce- and Douglas-fir-dominated stands. He noted that forests valuable for American Martens were getting smaller in size and more disconnected from each other. While in the winter of 2005–-2006 he recorded one American Marten track per 518 m of snowtracking in late-successional forest stands, in the winter of 2006–2007, when timber harvesting was more extensive and removed long-established connectivity corridors (Proulx 1999), he recorded one American Marten track per 1,045 m of snowtracking. Proulx (2008) surveyed American Marten tracks in three 250-m-wide corridors comprised of late-successional mixed coniferous stands. He also inventoried furbearer tracks in immature and young stands located immediately adjacent to the corridors. Proulx (2008) found American Marten tracks only in the corridors. Martens did not use immature and young forests to travel across fragmented landscapes. The extensive harvesting of habitats suitable to American Martens may isolate animals into metapopulations (Dykstra 2004) or force them to use less ecologically valuable younger forests (Proulx 2006a), and ultimately impact on the species's persistence in managed landscapes (Dykstra 2004).

Current forestry practices in this study area appear incompatible with the conservation of American Marten winter habitat. American Marten tracks were most numerous in ≥110 year-old stands. Sustainable management plans in the Central Interior are generally based on 80-year rotations; therefore, stands that are beginning to provide Martens with mature habitat characteristics are harvested. There are no minimum requirements for canopy closure or basal area in stands left as reserves in managed landscapes (BC Environment and Forests 1995). There is little concern about the size and spatial distribution of stands that are adjacent to extensive clear cut blocks (Proulx in press).

More importantly, American Martens select resources at different spatial scales, including region, home range, stands within home range, and particular sites within stands (Johnson 1980, Lofroth 1993). Marten home ranges consist of a series of late-successional stands that are either contiguous or connected by adequate natural corridors. Like most carnivores, American Martens have cognitive maps (Peters 1978, Powell 2000, Proulx 2005) of where they live, in that they do not use space within their home range randomly. Today, forestry companies use quasi-spatial forest management models that retain discrete 'representative' ecosystems independent of specific habitat requirements (e.g. Bunnell *et al*. 2003, Huggard 2004, MSRM 2004), and focus on the conservation of a few stand elements (e.g. Bunnell *et al*. 1999), that do not incorporate multi-scale habitat requirements of animals. For a forest management plan to be effective for the conservation of American Marten, it must be based on spatially-explicit data that relate to specific habitat requirements. Winter habitat requirements of American Marten are well known, and with the use of forest inventory datasets such as VRI, winter distribution across landscapes can be predicted. Forests used by American Martens in winter are also preferred by Fisher (Proulx 2006b), a species at risk in BC; Mule Deer *Odocoileus hemionus* (Proulx in press); woodpeckers and other birds associated with late-successional forests (Davis *et al*. 1999, Gyug 1996, Proulx 2006c). Conserving American Marten winter habitat is also, therefore, conserving a wealth of sympatric species across landscapes.

American Martens are easily trapped and susceptible to overharvest because of their relatively low natality and large home ranges (Banci & Proulx 1999). When subjected to both habitat degradation and intense trapping pressure, species's resilience may decrease and populations may be compromised (Banci & Proulx 1999). This is particularly true in managed forests where expanding road networks associated with timber harvesting increase trapper access (Soukkala 1983, Hodgman *et al*. 1994, Thompson 1994). Knowing that winter habitat of American Marten may be compromised in central interior British Columbia, conservation efforts should focus on the development of sound forest management plans to ensure that this species does not join the provincial list of species at risk.

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## References

Banci, V. & Proulx, G. 1999. Resiliency of furbearers to trapping in Canada. Pp. 175–203 in Proulx G. (ed.) *Mammal trapping*. Alpha Wildlife Publications, Sherwood Park, Alberta, Canada.

Bissonnette, J. A., Harrison, D. J., Hargis, C. D. & Chapin, T. G. 1997. The influence of spatial scale and scale-sensitive properties on habitat selection by American Marten. Pp. 368–385 in Bissonette, J. A. (ed.) *Wildlife and landscape ecology – effects of pattern and scale*. Springer-Verlag New York Inc., New York, USA.

Bowman, J. C. & Robitaille, J. F. 1997. Winter habitat use of American Martens *Martes americana* within second-growth forest in Ontario, Canada. *Wildlife Biology* 3: 97–105.

[BC Environment and Forests] British Columbia Environment and Forests 1995. *Biodiversity guidebook*. Forest Practice Code of British Columbia, Victoria, British Columbia, Canada.

[BC Forest Investment Account] British Columbia Forest Investment Account 2009. *Vegetation resources inventory standards*. Victoria, British Columbia, Canada. Available at http://www.for.gov.bc.ca/hts/fia/vri.htm#standards.

[BC Ministry of Forests] British Columbia Ministry of Forests. 2006. *Forest practices code*, Victoria, British Columbia, Canada.

Bunnell, F. L., Dunsworth, B. G., Huggard, D. J. & Kremsater, L. L. 2003. *Learning to sustain biological diversity on Weyerhaeuser's coastal tenure*. The forest project. Centre for Applied Conservation Biology, University of British Columbia, Canada (report prepared for Weyerhaeuser Company Ltd, Nanaimo, British Columbia).

Bunnell, F. L., Kremsater, L. L. & Wind, E. 1999. Managing to sustain vertebrate richness in forests of the Pacific Northwest: relationships with stands. *Environmental Review* 7: 97–46.

Burnett, G. W. 1981. *Movements and habitat use of the American Marten in Glacier National Park, Montana.* University of Montana (M.S. Thesis), Missoula, Montana, USA.

Buskirk, S. W., Forrest, S. C., Raphael, M. G. & Harlow, H. J. 1989. Winter resting site ecology of Marten in the central Rocky Mountains. *Journal of Wildlife Management* 53: 191–196.

Buskirk, S. W. & Ruggiero, L. F. 1994. American Marten. Pp. 7–37 in Ruggiero, L. F., Aubry, K. B., Buskirk, S. W., Lyon, L. J. & Zielinski, W. J. (eds) *American Marten, Fisher, Lynx, and Wolverine in the Western United States*. United States Department of Agriculture, Forest Service (General Technical Report RM-254), USA.

Chapin, T. G., Harrison, D. J. & Katnik, D. F. 1998. Influence of landscape pattern on habitat use by American Marten in an industrial forest. *Conservation Biology* 12: 1327–1337.

Clark, T. W. & Campbell, T. M. 1976. Population organization and regulatory mechanisms of Pine Martens in Grand Teton National Park, Wyoming. Pp. 293–295 in Linn, R. M. (ed.) *Conference on scientific research in national parks*, vol. 1. National Park Service Transactions Proceedings Series N° 5, Washington, D.C., USA.

Davis, L. R., Waterhouse, M. J. & Armleder, H. M. 1999. *A comparison of the breeding bird communities in seral stages of the Engelmann Spruce–Sub-alpine Fir Zone in east central British Columbia*. British Columbia Ministry of Forest (Research Branch paper 39/1999), Victoria, British Columbia, Canada.

DeLong, S. C., Arocena, J. M. & Massicotte, H. B. 2003. Structural characteristics of west montane forests in east-central British Columbia. *The Forestry Chronicle* 79: 342–351.

DeLong, S. C. & Tanner, D. 1996. Managing the pattern of forest harvest: lessons from wildfire. *Biodiversity and Conservation* 5: 1191–1205.

de Vos, A. 1951. Tracking of Fisher and Marten. *Sylva* 7: 15–19.

de Vos, A. 1952. Ecology and management of Fisher and Marten in Ontario. *Technical Bulletin Wildlife Series* N° 1. Ontario Department Lands and Forests, Toronto, Ontario, Canada.

Dykstra, P. R. 2004. *Thresholds in habitat supply: a review of the literature*. British Columbia Ministry of Sustainable Resource Management, Biodiversity Branch (Wildlife Report No. R-27), Victoria, British Columbia.

Fager, C. W. 1991. Harvest dynamics and winter habitat use of the Pine Marten in southwest Montana. Montana State University (M.S. Thesis), Bozeman, Montana, USA.

Gyug, L. W. 1996. *Donna Creek forestry/biodiversity project: breeding bird point counts 1995*. Peace/Williston Fish & Wildlife Conservation Program (BC Hydro PWFWCP Report No.53), Prince George, British Columbia.

Halfpenny, J. C., Thompson, R. W., Morse, S. C., Holden, T. & Rezendes, P. 1995. Snow tracking. Pp. 91–163 in Zielinski, W. J. & Kucera, T. (eds) *American Marten, Fisher, Lynx and Wolverine: survey methods for their detection*. Department of Agriculture, Forest Service Pacific Southwest Research Station (General Technical Report PSW-GTR-157).

Hargis, C. D. & Bissonette, J. A. 1997. Effects of forest fragmentation on populations of American Marten in the intermountain west. Pp. 437–451 in Proulx, G., Bryant, H. N. & Woodard, P. M. (eds) Martes*: taxonomy, ecology, techniques, and management.* Provincial Museum of Alberta, Edmonton, Alberta, Canada.

Hodgman, T. P., Harrison, D. J., Katnik, D. D. & Elowe, K. D. 1994. Survival in an intensively trapped Marten population in Maine. *Journal of Wildlife Management* 58: 593–600.

Huggard, D. 2004. *Establishing representative ecosystems within a managed landscape: an approach to assessment of non-harvestable areas*. Sustainable Forest Management Network mimeograph, University of Alberta, Edmonton, Alberta.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resources preference. *Ecology* 61: 65–71.

Krebs, C. 1978. *Ecology: the experimental analysis of distribution and abundance*, 2nd edition. Harper & Row, New York, USA.

Lawlor, T. E. 2003. Faunal composition and distribution of mammals in western coniferous forests. Pp. 41–80 in Zabel, V & Anthony, R. G. (eds) *Mammal community dynamics*. Cambridge University Press, Cambridge, UK.

Legendre, P. 1993. Spatial autocorrelation: trouble or new paradigm? *Ecology* 74: 1659–1673.

Lofroth, E. C. 1993. Scale dependent analyses of habitat selection by Marten in the Sub-boreal Spruce Biogeoclimatic Zone, British Columbia. Simon Fraser University (M.S. Thesis), Burnaby, British Columbia, Canada.

Meidinger, D., Pojar, J. & Harper, W. L. 1991. Sub-boreal spruce zone. Pp. 209–221 in Meidinger, D. & Pojar, J. (eds) *Ecosystems of British Columbia*. British Columbia Ministry Forestry (Special Report Series 6), Victoria, British Columbia, Canada.

Morgantini, L. E. & Kansas, J. L. 2003. Differentiating mature and old-growth forests in the Upper Foothills and Subalpine Subregions of west-central Alberta. *The Forestry Chronicle* 79: 602–612.

[MSRM] Ministry of Sustainable Resource Management 2004. *Background information and supporting documentation for the process involved in developing the recommended biodiversity objectives in the PG TSA*. Mimeograph, Ministry of Sustainable Resource Management, Northern Interior Region, Prince George, British Columbia, Canada.

Murie, O. J. 1975. *A field guide to animal tracks*. Houghton Mifflin Co., Boston, Massachusetts, USA.

Peters, R. 1978. Communication, cognitive mapping, and strategy in wolves and hominids. Pp. 95–108 in Hall, R. L. & Sharp, H. S. (eds) *Wolf and Man: evolution in parallel*. Academy Press, New York, New York, USA

Potvin, F., Bélanger, L. & Lowell, K. 2000. Marten habitat selection in a clearcut boreal landscape. *Conservation Biology* 14: 844–857.

Powell, R. A. 2000. Animal home ranges and territories and home range estimators. Pp. 65–110 in Boitani, L. & Fuller, T. K.(eds) *Research techniques in animal ecology – controversies and consequences*. Columbia University Press, New York, New York, USA.

Proulx, G. 1999. *Connectivity corridors in Northwood's Operating Areas, Prince George Forest District.* Alpha Wildlife Research & Management Ltd (report prepared for Northwood Wood Products Group), Fraser Region, Prince George, British Columbia, Canada.

Proulx, G. 2000. The impact of human activities on North American mustelids. Pp. 53–75 in Griffiths, H. I. (ed.) *Mustelids in a modern world. Management and conservation aspects of small carnivore: human interactions*. Backhuys Publishers, Leiden, The Netherlands.

Proulx, G. 2005. Long-tailed Weasel, *Mustela frenata*, movements and diggings in alfalfa fields inhabited by Northern Pocket Gophers, *Thomomys talpoides*. *Canadian Field-Naturalist* 119: 175–180.

Proulx, G. 2006a. Winter habitat use by American Marten *Martes americana*, in western Alberta boreal forests. *Canadian Field-Naturalist* 120: 100–105.

Proulx, G. 2006b. Using forest inventory data to predict winter habitat use by Fisher *Martes pennanti* in British Columbia, Canada. *Acta Theriologica* 51: 275–282.

Proulx, G. 2006c. *Moose, furbearers and woodpeckers winter habitat use in TFL 30.* Alpha Wildlife Research & Management Ltd (report submitted to Canadian Forest Products Ltd), Prince George Division, British Columbia, Canada.

Proulx, G. 2007. *Wolverine, Marten and Fisher habitat use in Supply Block F within the PGTSA– 2nd year (winter 2006–07)*. Alpha Wildlife Research & Management Ltd (report submitted to Canadian Forest Products Ltd), Prince George Division, British Columbia, Canada.

Proulx, G. 2008. *Establishing connectivity corridors in the southern region of the Fort St. James Forest District – Year 2*. Alpha Wildlife Research & Management Ltd (report submitted to Pope & Talbot Ltd), Fort St. James Division, British Columbia, Canada.

Proulx, G. in press. Late-winter habitat use by Mule Deer, *Odocoileus hemionus*, in Central Interior British Columbia. *Canadian Field-Naturalist* 122 (2).

Proulx, G., Aubry, K. B., Birks, J., Buskirk, S. W., Fortin, C., Frost, H. C., Krohn, W. B., Mayo, L., Monakhov, V., Payer, D., Saeki, M., Santos-Reis, M., Weir, R. & Zielinski, W. J. 2004. World distribution and status of the genus *Martes* in 2000. Pp. 21–76 in Harrison D. J., Fuller A. K. & Proulx G. (eds) *Martens and Fisher (*Martes*) in human-altered landscapes: an international perspective*. Springer, New York, New York, USA.

Proulx, G. & Kariz, R. 2005. Winter habitat use by Moose, *Alces alces*, in central interior British Columbia. *Canadian Field-Naturalist* 119: 186–191.

Proulx, G., Kariz, R. & Farkvam, J. 2006. Using forest inventory data to predict American Marten distribution. Pp. 77–88 in Santos-Reis, M., Birks, J. D. S., O'Doherty, E. C. & Proulx, G. (eds) Martes *in carnivore communities*. Alpha Wildlife Publications, Sherwood Park, Alberta, Canada.

Proulx, G. & O'Doherty, E. C. 2006. Snowtracking to determine *Martes* winter distribution and habitat use. Pp. 211–224 *in* Santos-Reis, M., Birks, J. D. S., O'Doherty, E. C. and Proulx, G. (eds) Martes *in carnivore communities*. Alpha Wildlife Publications, Sherwood Park, Alberta, Canada.

Readshaw, K. 2003. *Timber supply analysis, Mountain Pine Beetle infestation*. Mimeograph, British Columbia Ministry of Forests, Victoria, British Columbia, Canada.

Rezendes, P. 1992. *Tracking and the art of seeing*. Camden House Publishing, Inc., Vermont, USA.

Safranyik, L. 2004. Mountain Pine Beetle epidemiology in Lodgepole Pine. Pp. 33–40 in Shore, T. L., Brooks, J. E. & Stone, J. E. (eds) *Mountain Pine Beetle symposium: challenges and solutions*. Natural Resources Canada, Canadian Forestry Service, Pacific Forestry Centre, (Information report BC-X-399), Victoria, British Columbia, Canada.

Safranyik, L., Shrimpton, D. M. & Whitnet, H. S. 1974. *Management of Lodgepole Pine to reduce losses from the Mountain Pine Beetle*. Environment Canada Forest Service (Forest Technical Report 1), Victoria, British Columbia, Canada.

Soukkala, A. M. 1983. The effects of trapping on Marten populations in Maine. University of Maine (M. S. Thesis), Orono, Maine, USA.

Thompson, I. D. 1994. Marten population in uncut and logged boreal forests in Ontario. *Journal of Wildlife Management* 58: 272–280.

Thompson, I. D. & Harestad, A. S. 1994. Effects of logging on American Martens, and models for habitat management. Pp. 355–367 in Buskirk, S. W., Harestad, A. S., Raphael, M. G. & Powell, R. A. (eds) *Martens, Sables, and Fishers: biology and conservation*. Cornell University Press, Ithaca, New York, USA.

Thompson, W. K. 1949. A study of Martens in Montana. Pp. 181–188 in *Proceedings 29th Annual Conference of Western Association State Game and Fish Commissioners*, Seattle, Washington, USA.

Wilbert, C. J. 1992. Spatial scale and seasonality of habitat selection by Martens in southeastern Wyoming. University of Wyoming (M.S. Thesis), Laramie, Wyoming, USA.

Zar, J. H. 1999. *Biostatistical analysis*, 4th edition. Prentice Hall, New Jersey, USA.

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# Reintroducing the Black-footed Ferret *Mustela nigripes* to the Great Plains of North America

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## Abstract

Once extinct in the wild, great progress has been made over the past 18 years at reintroducing Black-footed Ferrets *Mustela nigripes* within historical habitats of North America. Since 1987, more than 6,000 Ferrets have been produced in captive breeding centres, facilitating the release of 3,094 captive-born Ferrets at 18 reintroduction sites across the western United States and northern Mexico. In addition, 147 wild Ferrets have been translocated from existing reintroduction sites to start or supplement other reintroduced Ferret populations. Allocations of Ferrets to reintroduction sites are determined by the U.S. Fish and Wildlife Service in consultation with the Black-footed Ferret Recovery Implementation Team, an advisory group comprised of 72 members representing 48 government agencies, Indian tribes, universities and conservation organisations. Allocation decisions are made using a ranking matrix consisting of biological, primary, factors (e.g. habitat and survival) and non-biological, secondary and tertiary, factors (e.g. planning, funding, and other project capabilities). Currently, there is an estimated minimum wild population of at least 824 individuals. However, only approximately 300 of those individuals are adult animals and contribute to the 'down-listing' goal of 1,500 breeding adults. In addition, only four sites have documented the ability to maintain at least 30 breeding adults over multiple years and thus contribute to the second 'down-listing' goal of maintaining at least 10 separate populations. Despite considerable progress, the programme faces obstacles such as disease and public acceptance of the Ferret's principal prey, prairie dogs *Cynomys*. Full recovery of the species will require continued vigilance of many involved partners, and greater support by the public, state and federal agencies, tribes, and non-governmental organisations to maintain and increase habitat for prairie dogs and Ferrets across the former ranges of these species.

*Keywords*: allocation, endangered species, ranking criteria, recovery

## Reintroduciendo el Hurón de Patas Negras en las Grandes Planicies de Norte América

## Resumen

Luego de haberse extinguido en estado silvestre, desde hace 18 años se ha logrado un gran avance en la reintroducción del Hurón de Patas Negras *Mustela nigripes* en su antiguo hábitat en Norteamérica. Desde 1987, más de 6.000 hurones han sido producidos en centros de reproducción, facilitando la liberación de 3.005 individuos nacidos en cautiverio en 18 localidades de reintroducción a lo largo del oeste de los Estados Unidos y norte de México. Adicionalmente, 147 hurones silvestres han sido trasladados desde localidades de reintroducción existentes para comenzar o como suplemento para otras poblaciones de hurones reintroducidas. La ubicación de los hurones en las localidades de reintroducción lo decide el Servicio de Pesca y Vida Silvestre de los Estados Unidos (USFWS) con el apoyo del Equipo de Implementación para la Recuperación del Hurón de Patas Negras (BFRIT), un grupo asesor conformado por 72 miembros que representan 48 agencias gubernamentales, tribus indígenas, universidades y organizaciones de conservación. La decisión de la ubicación se realiza usando una matriz de categorías que considera factores biológicos primarios (ej. hábitat y supervivencia) y factores secundarios y terciarios no-biológicos (ej. planes, fondos y capacidad de los proyectos). Actualmente, se estima una población silvestre mínima de 823 individuos. Sin embargo, solo aproximadamente 300 de estos individuos son adultos y contribuyen a la meta de bajar de categoría a la especie con 1.500 adultos reproductivos. Además, solo en 3 localidades se ha documentado la capacidad de mantener por lo menos 30 adultos reproductivos a lo largo de los años, con lo que se contribuye a la segunda meta de bajar de categoría a la especies manteniendo por lo menos 10 poblaciones separadas. A pesar del considerable progreso, el programa enfrenta obstáculos como enfermedades y la aceptación por el público de su principal presa, el Perrito de la Pradera *Cynomys spp.* La recuperación total de la especie va a requerir de la vigilancia continua por parte de muchos asociados y un gran apoyo por parte del público, agencias Estatales y Federales, Tribus y organizaciones no-gubernamentales, para mantener e incrementar el hábitat de los perritos de la pradera y hurones a lo largo de su antigua distribución.

*Palabras clave*: Ubicación, especies amenazadas, criterios de categorización, recuperación

## Introduction

Once considered Extinct in the Wild, the Black-footed Ferret *Mustela nigripes* has made progress towards recovery through captive breeding and reintroduction projects. Dozens of popular articles, journal articles, book chapters, and four books have been written about the rediscovery and subsequent capture of the last 18 wild Black-footed Ferrets (Ferret), and the natural history and management of Ferrets in the wild (Seal *et al*. 1989, Miller *et al*. 1996, Clark 1997). However, little has been written about progress to reintroduce this species to the wild over the past 18 years.

Management of Ferrets has been a source of controversy and criticism since their rediscovery in 1981 near Meeteetse, Wyoming (Clark 1997). The Ferret was one of the first species to receive protection in the U.S. under the Endangered Species Preservation Act of 1967, the Endangered Species Conservation Act of 1970, and the Endangered Species Act of 1973. Early efforts to develop a Ferret recovery programme were critically scrutinised and became emblematic of "the dynamic and complex nature of endangered species recovery programs" (Clark 1997). At its beginning, the recovery programme had to overcome significant obstacles, including controversial removal of surviving wild Ferrets to a captive breeding centre, low initial captive breeding success, and conflicts between partners (Miller *et al.* 1996). Many of these problems were resolved and the original 1979 recovery plan, revised in 1988, identified goals, objectives, management options, proposed courses of action, and a timetable for implementation (U.S. Fish and Wildlife Service 1988). The 1988 recovery plan also assigned responsibilities for actions to appropriate agencies, groups and individuals (Clark 1997). Many of the early programme recovery efforts, especially initial captive breeding attempts, were accomplished through efforts by the Wyoming Game and Fish Department (WGFD). Overall programme progress achieved to date is a result of involvement of numerous partners in all phases of programme planning and implementation.

In 1996, the U.S. Fish and Wildlife Service (USFWS) established the Black-footed Ferret Recovery Implementation Team (BFFRIT), then comprised of 27 entities including state and federal agencies and conservation organisations across the U.S.A., Canada, and Mexico. The BFFRIT provides recommendations to the USFWS on all matters related to Ferret recovery and is organised into an Executive Committee (EC) and three technical subcommittees: the Conservation Subcommittee (CS), the Species Survival Plan Subcommittee (SSP), and the Education and Outreach Subcommittee (EOS). Functions of the EC include addressing broad-based policy issues, political problem-solving, development and approval of annual and long-term management plans, review of overall organisational structural efficiency, funding issues, and recommendations to USFWS regarding recovery direction. The CS provides a forum for discussion and recommendations regarding the reintroduction and management of Ferrets in the wild. The SSP provides a management forum for ongoing captive breeding efforts. The EOS plans and coordinates public relations and education efforts for the programme.

The overall goal of the USFWS and the BFFRIT is Ferret recovery. The USFWS has defined goals for down-listing from 'endangered' to 'threatened' status (as defined by United States legislation) within the Recovery Plan as the establishment of 1,500 free-ranging, breeding adult Ferrets distributed in ≥10 populations over the historical range of the species, with no less than 30 breeding adults in each population (U. S. Fish and Wildlife Service 1988). The USFWS and BFFRIT work toward Ferret recovery by: (1) maintaining a captive Ferret population of optimal size and structure to support genetic management and reintroduction projects; (2) establishing free-ranging populations of Ferrets to meet the defined down-listing goals and delisting goals (as proposed in a pending recovery plan revision); (3) reducing disease-related threats to wild Ferret populations and associated species; (4) promoting the management of sufficient habitat to support a wide distribution of self-sustaining Ferret populations, and (5) expanding partner involvement and adaptive management through regular programmatic reviews and outreach.

In this paper we review how reintroduction sites are identified and prioritised, and the process used to allocate Ferrets among those sites. We also summarise reintroduction attempts over the past 18 years (1991–2008) and review the current status of Ferrets. Finally, we discuss obstacles to species recovery that must be addressed to achieve recovery goals and objectives.

## The reintroduction process

Success in captive breeding has enabled development of a large-scale reintroduction programme. From a 'founder' population of only seven animals, >6,000 Ferrets have been produced in captivity since 1987 (Fig. 1). Primary goals of the Ferret captive breeding programme have been to maintain genetic diversity and to provide Ferrets for release to the wild (Ballou & Oakleaf 1989). Reintroduction sites are initially identified by various entities, ranging from private landowners to tribes, and state and federal agencies. In exercising oversight of the reintroduction process, the USFWS solicits reintroduction proposals each January from entities interested in obtaining an allocation of Ferrets for release. Proposals provide specific information about the biological suitability and management conditions of sites that is used in an adaptive ranking matrix to make preliminary Ferret allocation decisions by the USFWS.

The development of an adaptive allocation matrix for distributing captive-born Ferrets among reintroduction sites has been important given the need: (1) for a transparent process in allocating and distributing Ferrets to partners; 2) to maintain partner involvement and input in decision making; 3) to be able to modify matrix categories and values based on new findings; and 4) to reintroduce Ferrets in new areas to achieve distributional and population recovery objectives, as well as to increase partner involvement and support. The factors included in the ranking matrix are developed and weighted by the BFFRIT to evaluate best the site-specific project attributes that are known to be critical to successful reintroduction. These attributes include biological, management and research elements, which are ranked on a scale of 0–5 (Table 1). The total number of points received establishes the level of priority for a site to receive captive-born Ferrets.

Primary factors for assessing the suitability of a site to receive Ferrets are habitat quality, occurrence and current status of sylvatic plague outbreaks, documented kit production and adult survivorship. Biological attributes are deemed most important for reintroduction success and are multiplied by a factor of four to weight their overall importance within the matrix. The Ferret is an extremely specialised carnivore relying on prairie dogs *Cynomys* for food and shelter and occurring exclusively in prairie dog colonies (Biggins *et al.* 2006). Habitat characteristics of prairie dog species, such as colony size and average burrow density, are

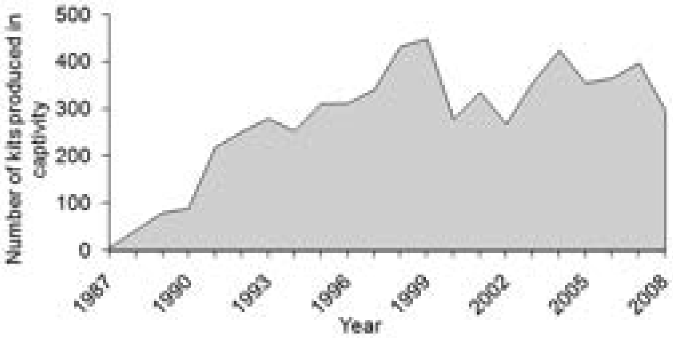

*Fig. 1. Annual production of Ferret kits at captive breeding facilities from 1987 to 2008.*

*Table 1. Factors incorporated into matrix for prioritising the allocation of Ferrets to reintroduction sites. Each site is evaluated in each category and ranked on a scale of 1–5. Primary factors are weighted by 4, secondary factors are weighted by 2, and tertiary factors are not weighted.*

| Primary Factors* | Secondary Factors | Tertiary Factors |
|---|---|---|
| Habitat suitability | Long-range site conservation | Pre-conditioning capabilities |
| Plague status | Ferret monitoring | Contingency planning |
| Documented kit production | Habitat monitoring | Veterinary and husbandry support |
| Ferret survivorship | Disease monitoring/ management | Reintroduction proposal quality |
|  | Research benefits | Project resource availability |

*Alternative primary factors used in place of documented kit production and Ferret survivorship when considering new sites are (1) proposed project benefits and (2) management/legal status.

thought to be critical components for predicting site success and maintaining viable Ferret populations (Biggins *et al.* 1993). Risk to Ferret populations due to current, historic, or nearby presence of sylvatic plague *Yersinia pestis* at Ferret reintroduction sites also strongly influences reintroduction success (Godbey *et al.* 2006). Epizootic outbreaks of sylvatic plague devastate prairie dog populations (Ubico *et al.* 1988, Pauli *et al.* 2006) and Ferrets are particularly vulnerable to plague exposure (Williams *et al.* 1994). Allocation criteria place a priority on areas with no history of plague, which are located primarily in the eastern portion of the historical range of Ferrets and Black-tailed Prairie Dogs *Cynomys ludovicianus* (Gage & Kosoy 2006). Characterising existing kit production and Ferret survivorship at a site also is important in assessing how further reintroductions could assist in permanently establishing Ferret populations.

Non-biological secondary and tertiary factors are ranked similarly to biological primary factors. Secondary factors include long-term site conservation potential, monitoring of habitat and disease, and expected research benefits; they are multiplied by a factor of two to give them additional weight within the matrix. These factors reflect the importance of on-the-ground monitoring, management, and conservation of reintroduction sites. Tertiary factors relate to availability of logistical resources and the extent of planning before reintroduction. Scores for these factors are not given additional weight, and their original values are used within the matrix.

Although the recovery programme seeks new reintroduction sites, in the original design of the matrix new sites typically ranked low compared to established projects, primarily due to the inability of new sites to report litter production and Ferret survivorship. In 2007, the USFWS and BFFRIT adopted alternatives to those factors for evaluating new reintroduction sites: expected benefits of the proposed site to the overall recovery programme, and status of any pending permits or agreements that must be in place before implementing a reintroduction project. These factors were evaluated and weighted as a primary factor (i.e. multiplied by four) similar to the biological factors (Ferret survivorship and litter production) that they replaced. The USFWS distributes annual allocation proposals to BFFRIT members for review and their comments are summarised, analysed, and considered in the allocation process. The USFWS circulates paraphrased or quoted comments by reviewers without identifying individuals and provides detailed responses to comments. Final allocation decisions in late summer are based on the number of kits produced and available for release, partner comments, allocation matrix scores, and resolution of outstanding concerns regarding reintroduction projects. Although the allocation matrix is used to assess many project attributes, the USFWS also considers the role of projects in enhancing the distribution of recovery sites across the historical range of Ferrets and in increasing the number of recovery partners when it determines final annual allocations of Ferrets.

Before the annual fall release of captive-born Ferrets, they are held in semi-natural conditions in outdoor pens to give them experience with prairie dog burrow systems and live prey (Fig. 2). Preconditioning pens have been developed and used in least eight locations in six states over the past 18 years, with designs varying between sites over time but always containing burrow systems and fencing or barriers both above and below ground to prevent Ferret escapes and depredation. Currently, nearly all preconditioning occurs at the Ferret Conservation Center operated by the USFWS in Wellington, Colorado. Post-release monitoring has shown that Ferrets receiving preconditioning treatment have at least a three-fold increase in survival relative to Ferrets that have not received such treatment (Biggins *et al.* 1998).

*Fig. 2. A captive-born Ferret emerging from a prairie dog burrow in a preconditioning pen at Malta, Montana, U.S.A. (Photo: David Jachowski)*

## Progress towards recovery

Ferret releases occur annually at a growing number of reintroduction sites within their historical range. From 1991 to 2008, approximately 3,094 captive-born Ferrets were released and 147 wild Ferrets were translocated to initiate or bolster Ferret populations at 18 sites in eight states in the United States and 1 site in Mexico, under various land ownerships (Table 2; Fig 3). Sites have been established on federal public lands managed by the U.S. National Park Service, USFWS, U.S. Bureau of Land Management, and U.S. Forest Service. Tribal lands are well represented, with Ferrets being reintroduced on five Indian reservations. Three reintroduction sites are composed mainly of private lands, and several projects occur in areas with a mix of state, private and federally

*Table 2. Reintroduction sites of Ferrets, including year reintroduction was initiated, land management status, number of Ferrets released and estimated current population size as of December 2008.*

| Site number | Reintroduction site | Year reintroduction began | Land management status | Total number of Ferrets released[a] | Estimated current population[b] |
|---|---|---|---|---|---|
| 1 | Shirley Basin, Wyoming | 1991 | Private and Bureau of Land Management | 518 | 239[c] |
| 2 | Badlands National Park, South Dakota | 1994 | National Park Service | 244 | 22 |
| 3 | UL Bend National Wildlife Refuge, Montana | 1994 | US Fish and Wildlife Service | 229 | 10 |
| 4 | Conata Basin, South Dakota | 1996 | US Forest Service | 167 | 239 |
| 5 | Aubrey Valley, Arizona | 1996 | Private | 306 | 66[d] |
| 6 | Fort Belknap Indian Reservation, Montana | 1997 | Tribal | 167 | 0 |
| 7 | Coyote Basin/Snake John, Utah | 1999 | Bureau of Land Management | 332 | 11 |
| 8 | Cheyenne River Indian Reservation, South Dakota | 2000 | Tribal | 185 | 75[e] |
| 9 | Wolf Creek, Colorado | 2001 | Bureau of Land Management | 239 | 13 |
| 10 | 40-Complex, Montana | 2001 | Bureau of Land Management | 95 | 0 |
| 11 | Janos, Chihuahua, Mexico | 2001 | Private | 257 | 17 |
| 12 | Rosebud Indian Reservation, South Dakota | 2004 | Tribal | 139 | 28[d] |
| 13 | Lower Brule Indian Reservation, South Dakota | 2006 | Tribal | 62 | 26 |
| 14 | Wind Cave National Park, South Dakota | 2007 | National Park Service | 49 | 18 |
| 15 | Espee Ranch, Arizona | 2007 | Private | 51 | 20[d] |
| 16 | Logan County, Kansas | 2007 | Private | 74 | 15 |
| 17 | Northern Cheyenne Indian Reservation, Montana | 2007 | Tribal | 38 | 8[d] |
| 18 | Vermejo Ranch, New Mexico | 2008 | Private | 89[f] | 17 |

[a] Combination of captive-born releases and wild-born translocations
[b] Minimum number known alive through annual surveys as of December 2008 (unless otherwise noted)
[c] Based on monitoring only 15% of habitat.
[d] Based on 2007 estimate because 2008 monitoring was not performed
[e] Based on monitoring only 45% of habitat
[f] Total number of Ferrets released that were not removed for translocation to other sites during the same year

managed lands.

The recovery programme is currently about one-quarter of the way toward the goal defined by the 1988 Recovery Plan of 1,500 breeding adult Ferrets distributed in ≥10 populations over the historical range of the species, with no less than 30 breeding adults in each population. With the aid of new reintroductions and continued augmentation, Ferret populations have continued to increase since reintroductions began, resulting in a total minimum population of 824 individuals as of December 2008 (Fig. 4). However, only about 300 of those animals are adults. It is difficult to determine if individual Ferret reintroduction sites have succeeded in terms of establishing self-sustaining populations because of a lack of background information on wild populations and a limited understanding of the stability of current, reintroduced Ferret populations. While official down-listing goals require ≥30 adults at each site (or population), experience has shown that defining a self-sustaining population of Ferrets is extremely difficult. From a biological perspective, a population of 40 adult individuals has a 57% chance of extinction whereas a population of at least 100 adult individuals has less than 10% chance of extinction over 100 years (Conservation Breeding Specialist Group 2004). From a management perspective, sites are considered successful when they have relatively large populations of ferrets over multiple years without augmentation of their populations, or when they can be used as a donor site for translocation of wild-born kits to other sites (Lockhart *et al*. 2006). Using these criteria, four reintroduction sites (Shirley Basin, Conata Basin, Cheyenne River Indian Reservation, and Aubrey Valley) currently are self-sustaining.

Ferret populations at some reintroduction sites have increased dramatically to become large in recent years, despite poor initial survival. Grenier *et al*. (2007) documented a dramatic rise in Ferret numbers at Shirley Basin, Wyoming, after 11 years of reintroduction efforts. Similarly, Ferret reintroductions at Aubrey Valley in Arizona continued for 8–10 years with little documented success before a dramatic rise in 2006 (Lockhart *et al*. 2006). These examples suggest that reintroduction success might rely on multiple sustained releases that either meet a minimum population size threshold, or take advantage of annual variations in site suitability. These results also suggest that we have a poor understanding of what specific attributes contribute to recovery and that more accurate assessments of reintroduction sites could forewarn us if the likelihood of reintroduction success is low.

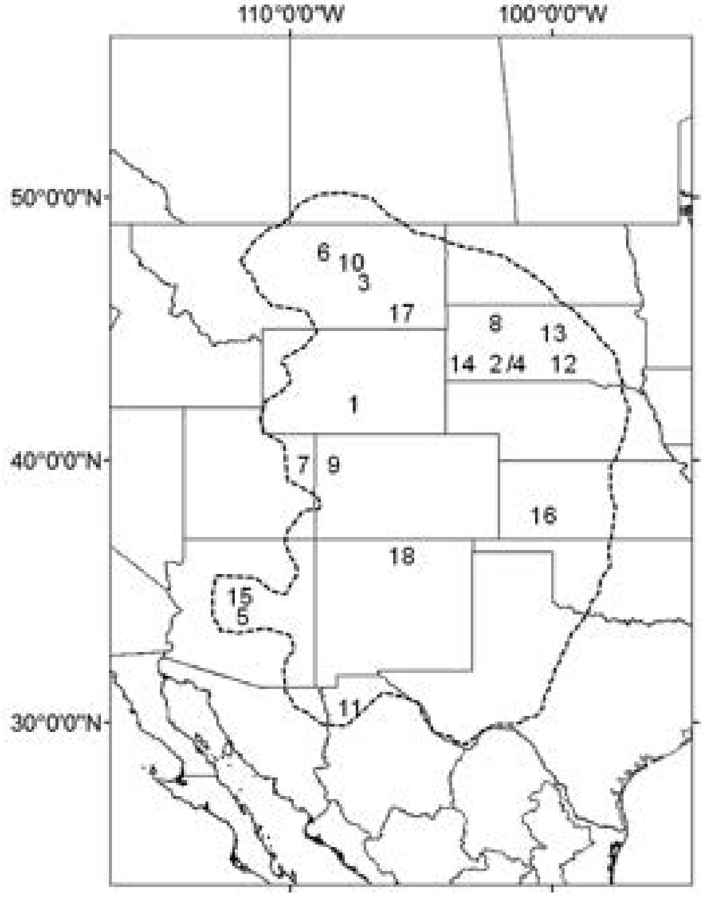

*Fig. 3. Great Plains of North America, with state and international boundary lines, showing the historic range of prairie dogs (dashed line) and the 18 Ferret reintroduction sites numbered in chronological order (see Table 2).*

Although not yet contributing directly to down-listing, some sites with small Ferret populations, such as UL Bend in north-central Montana, have benefited the recovery programme by advancing our understanding of Ferret behaviour (Biggins *et al*. 2006), resource selection (Jachowski 2007), and the influence of sylvatic plague on both Ferret (Matchett *et al*. in prep.) and prairie dog populations (Collinge *et al*. 2005, Augustine *et al*. 2008).

Increased attention in recent years has focused on identifying potential reintroduction sites in the eastern portion of the Ferret's historical range. In contrast to more westerly sites, eastern prairie dog complexes typically have higher densities and less susceptibility to sylvatic plague (Gage & Kosoy 2006). However, such sites usually are small, more fragmented in distribution, and privately owned. Emergence of several new potential recovery sites has necessitated development of innovative USFWS authorisation and permitting procedures to enable the programme to take advantage of time-sensitive recovery opportunities and to exercise greater flexibility in managing reintroduced Ferret populations without imposing adverse restrictions on cooperating and adjacent landowners. By releasing Ferrets under the status of 'experimental populations', the USFWS has been able to provide assurances to landowners and other parties that Ferrets can be removed from a reintroduction site after an experimental 5-year period. This approach has been valuable in getting Ferrets reintroduced relatively quickly onto sites where concerns exist regarding Ferrets and the ramifications of the Endangered Species Act. For example, this approach was particularly valuable at Logan County in Kansas, where Ferret reintroduction was envisioned and achieved through the determination of private landowners despite political hurdles at the county, state, and federal levels.

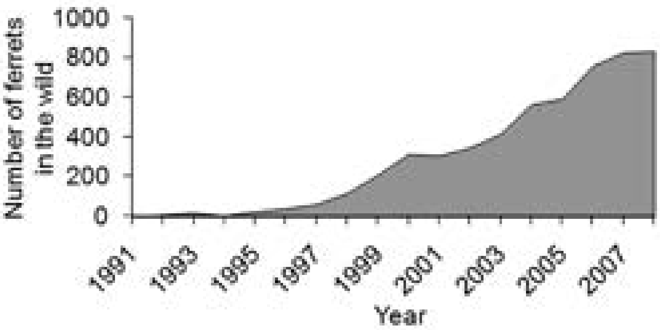

*Fig. 4. Minimum number of Ferrets known to be alive in the wild each year since reintroductions began in 1991.*

Ferret reintroduction efforts have led to advancements in prairie dog management and conservation. Few prairie dog populations of sufficient size to be Ferret reintroduction sites currently exist (Forrest 2005), thus management that focuses on conserving or enlarging those populations is of critical importance. The endangered status of Ferrets and the public interest they generate has led to significant progress in monitoring and conserving prairie dog populations where Ferrets have been reintroduced. At Conata Basin in southwestern South Dakota, the US Forest Service used a series of land exchanges subsequent to their first Ferret reintroduction in 1996 to consolidate public holdings for larger prairie dog habitats, resulting in an exceptional recovery area (Livieri 2006). At 40-Complex, on lands managed by the Bureau of Land Management in north-central Montana, Ferret reintroductions in 2001 led to increased prairie dog monitoring and temporary prairie dog poisoning and shooting prohibitions.

As new Ferret reintroduction sites were identified or explored, more partners became involved in the recovery programme. When the BFFRIT was created in 1996, its membership included representatives of 27 state and federal agencies and conservation organisations. Partner involvement has increased since that time. As of 2008 the BFFRIT included 72 members representing 48 different government agencies, conservation organisations, zoos, Indian tribes, and universities.

## Problems ahead

The two greatest remaining obstacles to Ferret recovery are disease and limited suitable habitat. Sylvatic plague has spread across much of the historical range of Ferrets over the past century. An effective plague vaccine for Ferrets and prairie dogs has been developed and tested (Rocke *et al*. 2008), but there currently is no feasible method of applying it to protect large prairie dog complexes. Plague epizootic outbreaks have reduced entire Ferret reintroduction sites to a fraction of their former habitat extent in less than a year (Fig. 5). Epizootic outbreaks reduced the area occupied by prairie dogs at UL Bend by 40%, from 1,264 ha in 2006 to 763 ha in 2008. Similar reductions due to epizootic outbreaks were observed at 40-Complex (56%), Fort Belknap (53%), Shirley Basin (49%), and Conata Basin (31%) reintroduction sites. There is some indication that prairie dog and Ferret populations can recover from plague events if unaffected pockets of prairie dogs and Ferrets persist and repopulate vacated habitat (Grenier

*Fig. 5. Prairie dog colony perimeter boundary in 2006 (light grey) and after a plague epizootic in 2007 (black) for the Valentine colony on UL Bend National Wildlife Refuge, Montana. Prairie dog colony size decreased by 97%, from 353.6 ha in 2006 to 9.2 ha in 2007.*

*et al*. 2007). However, evidence from other studies suggests that if prairie dog populations rebound following plague epizootics, outbreaks are likely to recur every 4–5 years (Barnes 1993, Cully *et al*. 2007). Therefore, the development of tools to mitigate the occurrence and outbreak of sylvatic plague on prairie dog colonies will be critical for achieving Ferret recovery.

The second pressing issue for Ferret recovery is the need for broader public acceptance or tolerance of prairie dogs. Where large blocks of suitable habitat exist, Ferret reintroductions frequently are met with public and political opposition (Lockhart *et al*. 2006). At two reintroduction sites, where prairie dog shooting and poisoning were prohibited to benefit Ferrets, these measures were revoked following plague epizootics and the halting of Ferret reintroductions. Such action is counter to the long-term need to restore prairie dog habitats important for Ferret recovery and for many other sensitive and declining prairie wildlife species (Miller *et al*. 1994). Management of prairie dog complexes is needed because most, if not all, of the remaining large prairie dog complexes in North America have been identified and Ferret reintroductions have been attempted on most of them (Forrest 2005, Luce 2006). As most wild Ferrets occur only at four sites, there is a great need to expand Ferret populations at additional sites. Further conservation efforts will be required to protect existing prairie dog colonies, expand current populations, and create new colonies if the Ferret recovery programme is to succeed. These steps can be made only with strong public and political support for prairie dog conservation.

## Conclusion

From early struggles to locate extant Ferrets, to successful captive breeding and subsequent reintroduction, the recovery programme has overcome many significant obstacles. Progress over the past 18 years in reintroducing Black-footed Ferrets to the wild and broader partner participation suggests that full recovery is possible. However, full recovery requires continued vigilance and support by the many partners (Reading & Kellert 1993), as well as increased support by the public, and federal, state, and tribal agencies to maintain and increase prairie dog and Ferret habitat across the former range of these species. Only through continued commitment from current recovery partners, expanded involvement of new partners, careful evaluation of programme progress and continued effective management and research can recovery be achieved.

## Acknowledgments

We thank the many persons who contributed to the reintroduction of Ferrets across the western United States. While we cannot list here all those individuals involved in Ferret recovery efforts, we wish to acknowledge the agencies, organisations and tribes involved in recovery through the current BFFRIT and prospective new members including: US Fish and Wildlife Service, Bureau of Land Management, US Forest Service, National Park Service, US Army, US Geological Survey, US Department of Agriculture Wildlife Services, Arizona Game Fish and Parks, Colorado Division of Wildlife, Kansas Department of Wildlife and Parks, Montana Fish, Wildlife, and Parks, Nebraska Game and Parks Commission, North Dakota Game and Fish Department, New Mexico Department of Game and Fish, South Dakota Department of Game, Fish and Parks, Utah Department of Natural Resources, Wyoming Game and Fish Department, Grasslands National Park Canada, Instituto de Ecologia Mexico, Cheyenne River Sioux Tribe, Gros Ventre and Assiniboine Tribe, Lower Brule Sioux Tribe, Northern Cheyenne Tribe, Rosebud Sioux Tribe, Navajo Nation, Hualapai Tribe, Cheyenne Mountain Zoological Park, National Zoological Park, Phoenix Zoo, Calgary Zoo, Toronto Zoo, Henry Doorly Zoo, Louisville Zoo, Defenders of Wildlife, National Wildlife Federation, Prairie Wildlife Research, Turner Endangered Species Fund, The Nature Conservancy, World Wildlife Fund, and Association of Zoos and Aquariums. Finally, we thank the private landowners whose growing support is critical to the future success of reintroduction projects and eventual species recovery.

## References

Augustine, D. J., Matchett, M. R., Toombs, T. P., Cully, J. F., Johnson, T. L. & Sidle, J. G. 2007. Spatiotemporal dynamics of Black-tailed Prairie Dog colonies affected by plague. *Landscape Ecology* 23: 255–267.

Ballou, J. D. & Oakleaf, B. 1989. Demographic and genetic captive breeding recommendations for Black-footed Ferrets. Pp. 247–267 in Seal, U. S., Thorne, E. T., Bogan, M. A. & Anderson S. (eds) *Conservation biology of the Black-footed Ferret*. Yale University Press, New Haven, Connecticut, USA.

Barnes, A. 1993. A review of plague and its relevance to prairie dog populations and the Black-footed Ferret. Pp. 28–37 in Oldemeyer, J., Biggins, D. E., Miller, B. J. & Crete, R. (eds) *Management of prairie dog complexes for the reintroduction of the Black-footed Ferret*. US Fish and Wildlife Service Biological Report 13, Washington, D.C., USA.

Biggins, D. E., Miller, B., Hanebury, L., Oakleaf, R., Farmer, A., Crete, R. & Dood, A. 1993. A technique for evaluating Black-footed Ferret habitat. Pp. 73–78 in Oldemeyer, J., Miller, B. & Crete, R. (eds) *Management of prairie dog complexes for reintroduction of the Black-footed Ferret*. U.S. Fish and Wildlife Service Biological Report 13, Washington, D.C., USA.

Biggins, D. E., Godbey, J. L., Hanebury, L. R., Luce, B., Marinari, P. E., Matchett, M. R. & Vargas, A. 1998. The effect of rearing methods on survival of reintroduced Black-footed Ferrets. *Journal of Wildlife Management* 62: 643–653.

Biggins, D. E., Godbey, J. L., Matchett, M. R. & Livieri, T. M. 2006. Habitat preferences and intraspecific competition in Black-footed Ferrets. Pp. 129–142 in Rolle, J. E., Miller, B. J., Godbey, J. L. & Biggins, D. E. (eds) *Recovery of the Black-footed Ferret – progress and continuing challenges*. U.S. Geological Survey Scientific Investigations Report 2005–5293, Washington, D.C., USA.

Clark, T. W. 1997. *Averting extinction: reconstructing endangered species recovery*. Yale University Press, New Haven, CT, USA.

Collinge, S. K., Johnson, W. C., Ray, C., Matchett, M. R., Grensten, J., Cully, J. F., Gage, K. L., Kosoy, M. Y., Loye, J. E. & Martin, A. P. 2005. Landscape structure and plague occurrence in Black-tailed Prairie dogs on grasslands of the western USA. *Landscape Ecology* 20: 94–955.

Conservation Breeding Specialist Group 2004. *Black-footed Ferret population management planning workshop: final report*. IUCN/SSC Conservation Breeding Specialist Group, Apply Valley, Minnesota, USA.

Cully, J. F., Biggins, D. E. & Seery, D. B. 2007. Conservation of prairie dogs in areas with plague. Pp. 157–168 in Hoogland, J. L. (ed.) *Conservation of the Black-tailed Prairie Dog*. Island Press, Washington D.C., USA.

Forrest, S. 2005. Getting the story right: a response to Vermeire and colleagues. *Bioscience* 55: 526–530.

Gage, K. L. & Kosoy, M. Y. 2006. Recent trends in plague ecology. Pp. 213–231 in Roelle, J. E., Miller, B. J., Godbey, J. L. & Biggins, D. E. (eds) *Recovery of the Black-footed Ferret – progress and continuing challenges*. U.S. Geological Survey Scientific Investigations Report 2005–5293, Washington, D.C., USA.

Godbey, J. L., Biggins, D. E. & Garelle, D. 2006. Exposure of captive Black-footed Ferrets to plague and implications for species recovery. Pp. 233–237 in Roelle, J. E., Miller, B. J., Godbey, J. L. & Biggins, D. E. (eds) *Recovery of the Black-footed Ferret – progress and continuing challenges*. U.S. Geological Survey Scientific Investigations Report 2005-5293, Washington, D.C., USA.

Grenier, M. B., McDonald, D. B. & Buskirk, S. W. 2007. Rapid population growth of a critically endangered carnivore. *Science* 313: 779.

Jachowski, D. S. 2007. *Resource selection by Black-footed Ferrets in relation to the spatial distribution of prairie dogs*. University of Missouri (M.S. Thesis), Columbia, Missouri, USA.

Livieri, T. M. 2006. *Ten-year history of the Conata Basin Black-footed Ferret population: 1996–2005*. Prairie Wildlife Research, Wall, South Dakota, USA.

Lockhart, J. M., Thorne, E.T. & Gober, D.R. 2006. A historical perspective on recovery of the Black-footed Ferret and the biological and political challenges affecting its future. Pp. 6–20 in Roelle, J. E., Miller, B. J., Godbey, J. L. & Biggins, D. E. (eds) *Recovery of the Black-footed Ferret – progress and continuing challenges*. U.S. Geological Survey Scientific Investigations Report 2005-5293, Washington, D.C., USA.

Luce, R. J. 2006. Areas where habitat characteristics could be evaluated to identify potential Black-footed Ferret reintroduction sites and develop conservation partnerships. Pp. 69–88 in Roelle, J. E., Miller, B. J., Godbey, J. L. & Biggins, D. E. (eds) *Recovery of the Black-footed Ferret – progress and continuing challenges*. U.S. Geological Survey Scientific Investigations Report 2005-5293, Washington, D.C., USA.

Matchett, M. R., Biggins, D. E., Kopcso, V., Powell, B. & Rocke, T. in prep. Enzootic plague reduces Black-footed Ferret (*Mustela nigripes*) survival in Montana.

Miller, B., Ceballos, G. & Reading, R. P. 1994. The prairie dog and biotic diversity. *Conservation Biology* 8: 677–681.

Miller, B., Reading, R. P. & Forrest, S. 1996. *Prairie night: Black-footed Ferrets and the recovery of endangered species*. Smithsonian Institution Press, Washington, D.C., USA.

Pauli, J. N., Buskirk, S. W., Williams, E. S. & Edwards, W. H. 2006. A plague epizootic in the Black-tailed Prairie Dog (*Cynomys ludovicianus*). *Journal of Wildlife Disease* 42: 415–420.

Reading, R. P. & Kellert, S. R. 1993. Attitudes toward a proposed Black-footed Ferret (*Mustela nigripes*) reintroduction. *Conservation Biology* 7: 569–580.

Rocke, T. E., Smith, S., Marinari, P., Kreeger, J., Enama, J. T. & Powell, B. S. 2008. Vaccination with F1-V fusion protein protects Black-footed Ferrets (*Mustela nigripes*) against plague upon oral challenge with *Yersinia pestis*. *Journal of Wildlife Disease* 44: 1–7.

Seal, U. S., Thorne, E. T., Bogan, M. A. & Anderson, S. H. 1989. *Conservation biology of the Black-footed Ferret*. Yale University Press, New Haven, CT, USA.

Ubico, S. R., Maupin, G. O., Fagerstone, K. A. & McLean, R. G. 1988. A plague epizootic in the White-tailed Prairie Dogs (*Cynomys leucurus*) of Meeteetse, Wyoming. *Journal of Wildlife Disease* 24: 399–406.

U. S. Fish and Wildlife Service 1988. *Black-footed Ferret recovery plan*. United States Department of the Interior, Washington, D.C., USA.

Williams, E. S., Mills, K., Kwiatkowski, D. R., Thorne, E. T. & Boerger-Fields, A. 1994. Plague in a Black-footed Ferret (*Mustela nigripes*). *Journal of Wildlife Disease* 30: 581–585.

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# Taxonomic boundaries and geographic distributions revealed by an integrative systematic overview of the mountain coatis, *Nasuella* (Carnivora: Procyonidae)

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## Abstract

The procyonid taxon *Nasuella* Hollister, 1915, is currently recognized as a monotypic genus comprising the single species *N. olivacea* (Gray, 1865), the Mountain Coati, found in montane habitats (*circa* 1300-4250 m) in the Andes of Venezuela, Colombia, and Ecuador. In this study we utilize museum specimens to examine the phylogenetic relationships, taxonomy and geographic distribution of *Nasuella* populations with an integrative systematic approach. Drawing on morphological comparisons of pelage, cranial, and dental characters, and molecular comparisons of the mitochondrial gene *cytochrome b* (from recent and historical samples), we confirm that *Nasuella* is closely related to other coatis (*Nasua*) and show that there are two deeply divergent lineages represented within the taxonomic bounds of *Nasuella*. We recognize and diagnose these taxa as two distinctive mountain coati species, corresponding to the Eastern Mountain Coati *Nasuella meridensis* (Thomas, 1901), endemic to the Venezuelan Andes, and the Western Mountain Coati *N. olivacea*, distributed in the Andes of Colombia and Ecuador. We use locality and habitat data associated with museum specimens to model the global geographic range of both species. From this we predict areas of undocumented (i.e., currently unvouchered) occurrence, areas of habitat loss associated with land use changes, and the geographic barrier separating the distributions of *N. meridensis* and *N. olivacea.* This newfound understanding of taxonomy and distribution should allow for a revised conservation assessment for mountain coatis.

*Keywords*: Andes, *cytochrome b*, ecomorphology, geographic range modeling, *Nasua*, *Nasuella*, phylogenetics, taxonomy

## Barreras taxonómicas y distribución geográfica reveladas por una revisión integrativa y sistemática del Coatí de Montaña, *Nasuella* (Carnivora: Procyonidae)

## Resumen

El grupo taxonómico prociónido actualmente reconocido como *Nasuella* Hollister, 1915, se encuentra considerado como un genero monotípico que abarca solamente a la especie *N. olivacea* (Gray, 1865), el Coatí de Montaña, y esta distribuido únicamente en hábitat montañoso (*circa* 1300-4250 m) de los andes de Venezuela, Colombia, y Ecuador. En este estudio utilizamos especímenes almacenados en museos internacionales para examinar las relaciones filogenéticas, la distribución geográfica y la taxonomía de poblaciones de *Nasuella* desde un punto de vista integratívo y sistemático. Nuestros resultados basados en comparaciones morfológicas de caracteres craneales y dentales, y de datos moleculares basados en secuencias del gen mitocondrial de *Citocromo b* (derivadas de ADN extraído de tejidos de especimenes congelados recientemente y de especimenes almacenados en etanol y también de hueso de ejemplares derivados de especímenes históricos utilizando protocolos de extracción de ADN antiguo) confirman que el género *Nasuella* se encuentra cercanamente relacionado a otros coatís del género *Nasua* y demuestran que hay dos linajes divergentes representados dentro de los márgenes taxonómicos de *Nasuella*. Reconocemos y diagnosticamos a estos dos grupos taxonómicos como especies distintas de Coatís de Montaña, correspondiente al Coatí de Montaña Oriental *Nasuella meridensis* (Thomas, 1901), endémico a los Andes de Venezuela; y al Coatí de Montaña Occidental *N. olivacea*, distribuido en los Andes de Colombia y Ecuador. Utilizamos datos de hábitat de cada localidad asociada con los ejemplares de museo para modelar el rango geográfico global de ambas especies; y para predecir las áreas en donde es posible que ocurran y que aun no han sido documentadas (*ej.* a base de ejemplares de museos), áreas de perdida de hábitat asociadas con cambios del uso de la tierra, y las barreras geográficas que separan la distribución de *N. meridensis* y *N. olivacea.* Este nuevo entendimiento de sus relaciones filogenéticas, distribución y taxonomía deben de permitir una revisión de la evaluación del estatus de conservación para los Coatís de Montaña.

*Palabras clave*: Andes, *Citocromo b*, ecomorfología, filogenia, modelamiento de rango geográfico, *Nasua, Nasuella*, taxonomía

## Introduction

Of the six extant genera currently recognized in the carnivore family Procyonidae (*Bassaricyon* J. A. Allen, 1876; *Bassariscus* Coues, 1887; *Nasua* Storr, 1780; *Nasuella* Hollister, 1915; *Potos* E. Geoffroy Saint-Hilaire & F. G. Cuvier, 1795; and *Procyon* Storr, 1780), the geographically restricted *Nasuella* is by far the least studied. It is represented by a single recognized Andean endemic species - the Mountain Coati *N. olivacea* (Gray, 1865). Very little information about this intriguing procyonid has been published, such that it might be fairly argued that *Nasuella* is the least-studied carnivore genus globally.

Even the discovery and introduction of the scientific name of the species is shrouded in obscurity. The name first appeared, as *Nasua olivacea*, on the last page of an appendix to a listing of mammal specimens in the British Museum by John Edward Gray

(1843). Gray used the name without providing any description or clarification whatsoever (noting only the locality where the sole available specimen had been collected—"Santa Fé de Bogota", Colombia), so this initial presentation of the name is regarded as a *nomen nudum*, unavailable for use in nomenclature. A more official introduction of this name did not appear for another two decades, when, discussing the taxonomy of bears and raccoons, Gray (1865) introduced what is still essentially the current species-level taxonomy for coatis, and provided a very short accompanying description validating the use of *olivacea* for the Mountain Coati. Gray's description mentioned only the pelage coloration of the animal (rather than its small body size or highly distinctive skull and teeth—its principal distinguishing features): "olive-brown, grizzled; hairs black-brown, with a yellowish sub-terminal ring; under fur black; face pale; orbits, legs, and feet blackish brown; chest yellowish grey; tail short, with black rings and a black tip" (Gray 1865:703; reprinted a few years later in another museum catalogue: Gray 1869).

Probably because Gray's description offered no clear distinguishing features, and no other specimens became available, subsequent nineteenth century reviewers were forced to conclude that *N. olivacea* was a synonym of the more widespread South American coati *Nasua nasua* (referred to in literature at the time as "*Nasua rufa*") (e.g., Allen 1880, Sclater 1891). It was not until the beginning of the twentieth century, starting with a paper by Oldfield Thomas, that *olivacea* was recognized as a distinctive coati species (Thomas 1901) with several supposed subspecies (Thomas 1901, Allen 1913, Lönnberg 1913), and ultimately removed from other coatis to its own genus, *Nasuella* (Hollister 1915). Despite the improvement of this taxonomic understanding a century ago, the obscurity of *Nasuella* remains. The lack of any detailed information on *Nasuella* is striking, and pertains to all aspects of its biology. For example, as far as we are aware, the skull of *Nasuella* has only been figured once in the literature, and only in a single view, from a single specimen (the ventral view of the cranium, provided in the generic description of *Nasuella*) (Hollister 1915: plates 38-39). Even though reasonable samples of skins and skulls of *Nasuella* are available in world museum collections, no author has discussed patterns of geographic variation in the genus based on data from a variety of specimens encompassing its known geographic distribution, so it remains unclear if subspecies should be recognized within *N. olivacea* (Mondolfi 1987). *Nasuella* is the only procyonid genus (and one of very few carnivoran genera) that has not been featured in molecular genetic comparisons of any kind (Koepfli *et al*. 2007, Fulton & Strobeck 2007). Some fundamental references and field guides on Neotropical mammals do not illustrate or include accounts for *Nasuella* (Emmons & Feer 1990, 1997) or even mention it at all (Lord 2007); those that do discuss *Nasuella* offer very brief accounts (e.g., Eisenberg 1989, Eisenberg & Redford 1999). The most lengthy overview of coati taxonomy yet written, that of Decker (1991), does not mention *Nasuella* at all. (We note that Decker largely overlooked, or at least did not test, the taxonomic divisions among coatis briefly put forward earlier by Tate [1939:199–200], which we regard as the best appreciation of patterns of biological diversity in coatis published to date).

Lack of any detailed research to date on *Nasuella* also means that its conservation status is poorly understood. Indeed, a recent effort to rigorously document the current conservation status of all extant mammals (Schipper *et al*. 2008) classified it as "Data Deficient" (Reid & Helgen 2008), making it one of very few generic-level carnivoran lineages so categorized. In total, previously published accounts of *Nasuella* involve only very cursory discussions of geographic variation (Gray 1865, Thomas 1901, Allen 1913, Lönnberg 1913, Cabrera 1958, Mondolfi 1987); comments on geographic distribution (Thomas 1901, Allen 1912, 1913, 1916, Lönnberg 1913, Bisbal 1989, Linares 1998, Eisenberg & Redford 1999, Guzmán-Lenis 2004, Ramírez-Chaves *et al*. 2008, Balaguera-Reina *et al*. 2009); brief anatomical and ecomorphological comparisons (Hollister 1915, Tate 1939, Mondolfi 1987, Decker & Wonzencraft 1991, Friscia *et al*. 2007); and limited discussions of ecology and behavior (Rodríguez-Bolaños 2000, 2003, Jarrín-V. 2001).

Our approach in this study has been to use information associated with museum specimens to provide the first detailed review of *Nasuella* across the known geographic range of the genus. First, we draw on skins and skulls stored in selected museums to review patterns of morphological geographic variation (and the appropriateness of trinomial distinctions) in *Nasuella*. Second, we undertake molecular comparisons of the mitochondrial gene *cytochrome b* (abbreviated *cyt b*), extracted both from recently-collected frozen and ethanol-stored tissues, and from historical museum samples using ancient DNA protocols, to offer an independent perspective on geographic variation and intrageneric divergences. Third, we utilize locality and habitat data derived from museum specimen labels to predict the global geographic distribution of *Nasuella*. Crucially, all three approaches (morphological observations, mitochondrial DNA comparisons, and geographic range modeling) identify remarkable disjunction (morphological, genetic, and geographic) between *Nasuella* samples collected in the Andes of Venezuela and those collected in the Andes of Colombia and Ecuador. This marked divergence, unanticipated in previous discussions of *Nasuella*, necessitates changes to the species-level taxonomy of *Nasuella* and requires a re-evaluation of the conservation status of the implicated taxa.

## Methods

### *Morphology*

We have studied all *Nasuella* specimens in the collections of the American Museum of Natural History, New York (AMNH); the Natural History Museum, London (BMNH); the Museo de Zoologia, Universidad Politecnica, Quito, Ecuador (EPN); the Field Museum of Natural History, Chicago (FMNH); the Naturhistoriska Riksmuseet, Stockholm, Sweden (NMS); the Museo de Zoología, Pontificia Universidad Católica del Ecuador, Quito, Ecuador (QCAZ); and the National Museum of Natural History, Smithsonian Institution, Washington, D.C. (USNM). This includes the type specimens of all named taxa within *Nasuella*, almost all specimens previously reported in the literature, and many never previously reported. As far as we are aware, these holdings represent the great majority (>90%) of Mountain Coati specimens in museums, but we also recognize that we have missed important holdings in Colombian and Venezuelan collections in preparing this study (cf. Linares 1998, Guzmán-Lenis 2004).

Standard external measurements for museum specimens—head-body length (HB) and tail length (TV)—were recorded by the original museum collectors in the field, as noted on museum specimen tags and labels. Craniodental variables were measured by the first author with digital calipers to the nearest 0.1 mm.

*Table 1. Selected external, cranial, and dental measurements and ratios in adult specimens of the two species of Mountain Coatis,* Nasuella olivacea *and* N. meridensis *(see Methods for abbreviations; based on specimens at AMNH, BMNH, FMNH, NMS, and USNM). The two species differ little in overall skull size, but* N. meridensis *has markedly smaller teeth than* N. olivacea*, both absolutely and proportionally.*

| Variable | ***N. olivacea*** **Colombia, Ecuador** | ***N. meridensis*** **Venezuela** |
|---|---|---|
| HB | 449 ± 19.4 | 479 ± 50.7 |
| | 409 – 487 | 430 – 540 |
| | *n* = 15 | *n* = 4 |
| TV | 247 ± 14.5 | 242 ± 53.9 |
| | 220 – 270 | 192 – 300 |
| | *n* = 15 | *n* = 4 |
| TV/HB | 55% | 50% |
| | 49 – 61% | 43 – 60% |
| | *n* = 15 | *n* = 4 |
| GLS | 106.2 ± 6.19 | 107.5 ± 5.27 |
| | 96.7 – 115.9 | 101.0 – 115.3 |
| | *n* = 19 | *n* = 7 |
| ZYG | 50.4 ± 5.42 | 47.1 ± 4.02 |
| | 40.5 – 57.5 | 43.4 – 53.8 |
| | *n* = 22 | *n* = 9 |
| ZYG/GLS | 47% | 44% |
| | 41 – 55% | 41 – 48% |
| | *n* = 19 | *n* = 7 |
| M1 L | 5.24 ± 0.27 | 4.38 ± 0.22 |
| | 4.6 – 5.7 | 4.1 – 4.6 |
| | n = 31 | n = 9 |
| M1 W | 4.54 ± 0.25 | 3.93 ± 0.15 |
| | 4.1 – 5.9 | 3.7 – 4.1 |
| | n = 32 | n = 9 |

Tabled values are mean ± SD, range and sample size (*n*).

Single-tooth measurements are measured across the crown. All measurements of length are in millimeters. Measurements reported here include greatest length of skull (GLS), zygomatic width (ZYG), length of the first upper molar (M1 L), and width of the first upper molar (M1 W). Limited sexual dimorphism is evident in sexed *Nasuella* samples from the same region (with only zygomatic width significantly larger in males in *t*-test comparisons), such that external and craniodental measurements are pooled in our summary statistics, which are intended to demonstrate a few key points of comparison between *N. olivacea* and *N. meridensis* (Table 1). In addition to measuring skulls and teeth, we examined variation in qualitative morphological attributes between *Nasuella* populations.

### *DNA Sequencing*

Sequences for *Nasuella olivacea* and *N. meridensis* have not previously been reported in the literature and were newly generated from fresh and historical museum materials for this study. “Fresh” *Nasuella* tissues were sampled from recently collected voucher specimens from Ecuador at QCAZ and EPN (a skin clip from a whole specimen stored in ethanol and a sample of tongue from a frozen whole specimen, Table 2). Tiny fragments of turbinate bones were also sampled from the nasal cavities of *Nasuella* skulls from Colombia and Venezuela stored at the USNM (Table 2). In addition, we used sequences from representatives of *Nasua nasua* and *Nasua narica* (selecting sequences from widely separated geographic localities in order to capture as much intraspecific divergence as possible within our limited comparative sample). Newly reported *Nasua* sequences were generated in a previous study that examined the phylogeography of South American coatis (Tsuchiya-Jerep 2009) and for a pending study of variation in *N. narica* (Koepfli *in litt*.). We also obtained previously-published *cyt b* sequences for *Nasua* and other procyonid taxa from GenBank (Table 2).

Total genomic DNA from tissue samples was extracted using the QIAGEN DNeasy kit (QIAGEN, Valencia, CA, USA) and the respective protocol for animal tissues. Polymerase chain reaction (PCR) and sequencing reactions were carried out with primers LGL 765 and LGL 766 from Bickham *et al.* (2004) and using an MJ thermocycler (MJ Research, Waltham, MA, USA) under the following conditions, repeated for 35 cycles: denaturation at 94°C for 1 min, annealing at 50°C for 1 min, extension at 72°C for 1

*Table 2. Taxa and samples used in molecular comparisons.*

| Taxon | Locality | Source (catalog/reference) | Genbank number |
|---|---|---|---|
| *Bassaricyon gabbii* | Panama, Limbo plot | Koepfli *et al.* (2007) | DQ660300 |
| *Bassaricyon alleni* | Peruvian Amazon, Rio Cenapa | Koepfli *et al.* (2007) | DQ660299 |
| *Nasua nasua* | Bolivia, Santa Cruz | Koepfli *et al.* (2007) | DQ660303 |
| *Nasua nasua* | Brazil, Ceará | Tsuchiya-Jerep (2009) | GQ214530 |
| *Nasua narica* | Panama | Koepfli *et al.* (2007) | DQ660302 |
| *Nasua narica* | USA, New Mexico | Koepfli *in litt* | unpublished |
| *Nasuella olivacea* | Ecuador, Papallacta | EPN 3414 | GQ169038 |
| *Nasuella olivacea* | Ecuador, Pichincha | QCAZ 8687 | GQ169039 |
| *Nasuella olivacea* | Colombia, Cauca, Malvasa, 3500 m | USNM 309043 | GQ169040 |
| *Nasuella meridensis* | Venezuela, Timotes, Merida, 3 km W near Paramiro, 3000 m | USNM 372854 | GQ169041 |

min. The PCR reagents in a 25 µL reaction were 0.2 µL AmpliTaq (5 units $\mu L^{-1}$, Applied Biosystems, Foster City, CA, USA), 1µL per primer (10 µM), 2.5 µL dNTP (2 µM), 2 µL $MgCl_2$ (25 mM), 2.5 µL AmpliTaq Buffer (Applied Biosystems), 2µL BSA (0.01 mg/µL), 1 µL genomic DNA and 12.8 µL sterile water.

Total genomic DNA from turbinate bone samples was extracted following ancient DNA protocols established by Wisely *et al.* (2004). All pre-PCR protocols were conducted in an isolated ancient DNA laboratory located in a separate building from the one containing the primary DNA laboratory. Polymerase chain reaction and sequencing of ancient DNA samples were carried out using an additional pair of internal primers designed from procyonid sequences generated in this study. A 427 bp fragment of the 5' end of *cyt b* was amplified using primer LGL 765 from Bickham *et al.* (2004) as the forward primer and H15149Pro as an internal reverse primer (5'-CTCCTCAAAAGGATATTTGYCCTCA -3': the 3' end corresponds to base 14,576 of the *Canis lupus* [Wolf] mtDNA sequence). The PCR profile was modified to include 50 cycles, with reagents as described above.

Polymerase chain reaction products were amplified for sequencing using a 10 µL reaction mixture of 2 µL of PCR product, 0.8 µL of primer (10 µM), 1.5 µL Big Dye 5 x Buffer (Applied Biosystems), 1 µL Big Dye version 3 (Applied Biosystems) and 4.7 µL sterile water. The reaction was run using an MJ thermocycler (MJ Research) with denaturation at 96°C for 10 s, annealing at 50°C for 10 s and extension at 60°C for 4 min: this was repeated for 25 cycles. The product was cleaned using a sephadex-based filtration method, and sequences of both strands were resolved in a 50 cm array using the ABI PRISM 3130 Genetic Analyzer (Applied Biosystems). Sequences were aligned and edited in Sequencher version 4.7 (Gene Codes Corporation).

### *Phylogenetic analyses*

Phylogenetic analyses were conducted using two approaches. First, we used sequences from a 366-bp fragment from the 5' end of *cyt b*, enabling the inclusion of the two *Nasuella* sequences obtained from the turbinate samples while reducing the effect of missing information due to the short length of the sequences. Second, short sequences were excluded from the analyses, and only samples for which the entire *cyt b* gene had been sequenced were used to assess the strength of the generic relationships and to provide further evidence for branch support and divergence estimates. The sequence data were analyzed using maximum parsimony, maximum-likelihood, Bayesian, and distance methods. PAUP* 4.0b10 (Swofford 2003) was used for neighbor-joining and maximum parsimony analyses; maximum likelihood analyses were conducted using GARLI 0.96b (Zwickl 2006). We used the olingo species *Bassaricyon gabbii* and *B. alleni* as outgroup taxa because *Bassaricyon* has been previously shown to be the sister group to the coatis in recent, more detailed phylogenetic studies (Koepfli *et al.* 2007, Fulton & Strobeck 2007).

A neighbor-joining tree was created using the HKY85 method with pair-wise distances calculated using the Kimura 2-parameter (K2P) model. The branch and bound search method was used for the maximum parsimony analyses. Parsimony bootstrap support was estimated using the heuristic search method with 100 random stepwise taxon additions for 1000 replicates. The maximum likelihood analysis was conducted using the following parameters; rate matrix = (14.127, 187.864, 16.570, 0.728, 335.001, 1.000); base frequencies (A = 0.2714, C = 0.2834, G = 0.1806, T = 0.2646); proportion of invariable sites = 0.0099; gamma distribution shape parameter = 0.2377 for the short *cyt b* sequences. For the entire *cyt b* sequences, the parameters were: rate matrix = (2.688, 104.784, 3.938, 0.182, 80.935, 1.000); base frequencies (A = 0.3200, C = 0.3109, G = 0.1299, T = 0.2391); proportion of invariable sites = 0.0196; gamma distribution shape parameter = 0.2408. These parameters, and the best model of evolution (GTR+G+I), were estimated using GARLI. Maximum likelihood bootstrap support was estimated with 500 replicates.

MrModeltest version 2.2 (Nylander 2004) was used to find the best model for the Bayesian analyses under the Akaike information criterion. The parameters were then applied in MrBayes version 3.1 (Huelsenbeck & Ronquist 2001). The model parameters were set to nst = 6 with a proportion of invariable sites (GTR + I). Two replicates of the Bayesian analysis were run, each using 1,000,000 generations in four chains, with a heating parameter of 0.05, and sampling frequency of 100 steps.

Molecular divergence estimates were generated in MEGA4 (Tamura *et al.* 2007). A distance tree was generated using the HKY85 model with a constant rate applied across the tree. Divergences were calibrated using the 12 mya estimate of divergence between *Bassaricyon* and *Nasua* calculated by Koepfli *et al.* (2007).

### *Geographic Range Modeling*

We used Maximum Entropy Modeling (Maxent) (Phillips *et al.* 2005) to predict the geographic range of *Nasuella* species based on 33 vouchered localities derived from our specimen examinations (list of localities available on request) and 20 environmental variables representing potential vegetation and climate. Localities were georeferenced with data derived from museum specimen tags, often with clarifying reference to the ornithological gazetteers prepared by Paynter (1982, 1993, 1997). For potential vegetation we used the 15 major habitat types classified as ecological biomes (Olson *et al.* 2001). For climate we used 19 BIOCLIM variables representing annual trends, seasonality, and extremes in temperature and precipitation across portions of Central and South America (derived from Hijmans *et al.* [2005] as described at http://www.worldclim.org/bioclim.htm). Because there were so few records for *N. meridensis*, we constructed the model for the genus and later distinguished the two species based on the location of voucher specimens. We used all vouchered specimen localities in our dataset to train the final model. We also tested model performance by running 10 iterations while randomly withholding 20% of the points as test locations. To produce geographic ranges showing presence/absence of a species we used the average equal training sensitivity and specificity for the 10 test models as our probability cutoff value (Phillips *et al.* 2005). To evaluate the present conservation status in these areas we overlapped predicted ranges with estimates of modern land use (Eva *et al.* 2004).

## Results

### *Morphological comparisons*

Morphological comparisons of *Nasuella* specimens deposited in world museums revealed: 1) outstanding morphological distinctions between *Nasuella* collected in the Venezuelan Andes *versus Nasuella* from Colombia and Ecuador; and 2) more subtle, but consistent, distinctions between *Nasuella* from Ecuador and Colombia.

Distinctions between Venezuelan and other *Nasuella* samples include differences in pelage coloration, differences in qualitative craniodental characteristics, and differences in the size and proportion of the teeth, especially the premolars and molars. Compared to *Nasuella* from Colombia and Ecuador, Venezuelan animals generally have paler, more olive-brown fur (more reddish or blackish in skins from Colombia and Ecuador), a blackish mid-dorsal stripe on the back (not as apparent in skins from Colombia and Ecuador), and a slightly shorter tail on average (Table 1). Qualitative craniodental distinctions between Venezuelan and other *Nasuella* involve the configuration of the bony palate (extending farther behind the molar row) and palatal shelf (less markedly depressed posteriorly), the anterior alveolar foramen (usually extending farther anterior of the infraorbital foramen), and the configuration of the dentary, in which the posterior processes tend to be more broadly dissociated posteriorly (Fig. 1). The most striking distinction between Venezuelan and other *Nasuella* is the grossly reduced dentition of Venezuelan animals, such that each premolar and molar is absolutely smaller in dimensions of length and width compared to Colombian and Ecuadoran *Nasuella* samples (e.g. Figs 1 and 2; Table 1). Because the skull is the same size in Venezuelan animals as in other populations, this distinction in the size of the teeth constitutes a rather extraordinary distinction in proportional terms (Fig. 1, Table 1).

*Fig. 1. Skulls and teeth in the two species of* Nasuella. *Left,* N. meridensis, *USNM 143658 (older subadult or young adult female, from Guache, Montes De La Culata, 3000 m, Merida, Venezuela). Right,* N. olivacea olivacea, *USNM 240034 (adult female, from Choachi, Colombia). Scale bar = 20 mm. From top to bottom, shown are dorsal, ventral, and lateral views of crania, lateral view of the mandibles, and dorsal view of the mandibles with enlarged (circa x 2) view of the mandibular toothrow. White arrows in the ventral view of the crania highlight the palate behind the last molar, which is extended in* N. meridensis *relative to* N. olivacea*, and the smaller teeth of* N. meridensis. *Black arrows in the lateral view of the crania highlight the position of the anterior alveolar foramen (cf. Decker 1991), which is usually situated farther anterior of the infraorbital foramen in* N. meridensis. *White arrows in the lateral view of the mandible illustrate the configuration of the posterior processes of the dentary, in which the juxtaposition of the coronoid and condyloid processes is generally more expansively "excavated" in* N. meridensis. *The ventral view of the mandible and the close-up view of the mandibular toothrow illustrate the much smaller teeth of* N. meridensis *relative to* N. olivacea.

Specimens from Colombia and Ecuador are similar in most aspects, and have teeth that are equivalent in size (e.g., Fig. 2). Relative to Colombian samples, animals from Ecuador have consistently smaller skulls on average (maximum observed skull length is 105 in our Ecuadoran samples, versus 116 in Colombian skulls) and have darker, more blackish fur, and tail rings that are less clearly defined.

*Molecular phylogenetics*

We obtained the same topology and high support values for all analyses (Figs 3 and 4), providing strong support for the monophyly of each species, but paraphyly for the genus *Nasua* with respect to *Nasuella* (*Nasuella* is recovered as the sister lineage to *Nasua narica*; support for this finding is particularly strong for the analyses of the complete *cyt b* sequences—Fig. 4).

All analyses of short sequences produce a single moderate to strongly supported topology for the monophyly of *Nasuella* (Fig. 3). The sequence from the *Nasuella* sample from Venezuela represents a lineage basal to those from Ecuador and Colombia. Within this Ecuador – Colombia clade there is only a 1.9-2.9% sequence divergence under the K2P model, but the divergence between this clade and the Venezuela sequence based on the K2P distance is three times greater ranging from 8.0 to 9.1%. The longer sequences show a 2.1% K2P distance between the two *Nasuella* from Ecuador. The pairwise divergence estimates for the short *cyt b* sequences proved to be similar to divergence estimates from the entire *cyt b* data set. For the other samples, based on analyses

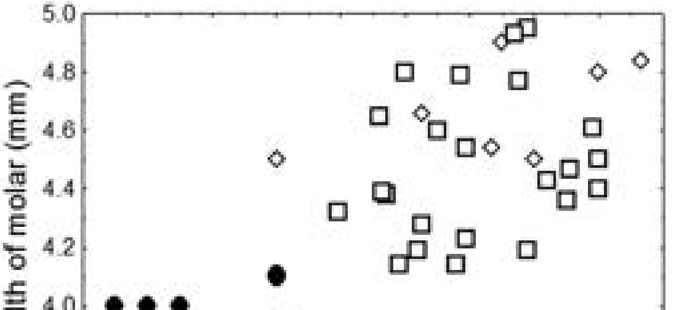

*Fig. 2. Size distinction in the upper first molar (M1) in* N. meridensis *(closed symbols) and* N. olivacea *(open symbols). Symbols: Closed dots* = N. meridensis *(Venezuela); open squares* = N. o. olivacea *(Colombia); open diamonds*= N. o. quitensis *(Ecuador).*

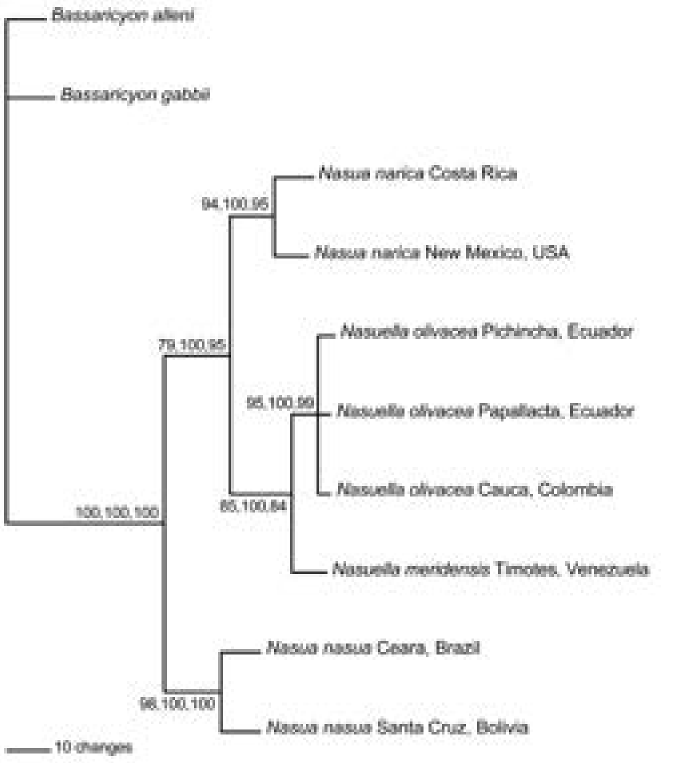

*Fig. 3. Molecular relationships of coatis based on partial* cytochrome b *sequences. One of three most parsimonious trees (length = 167, retention index = 0.763, consistency index = 0.760) from the partial sequence of the* cyt b *gene (366 bp). This comparison allows for the inclusion of the short sequence generated from DNA extracted from the turbinate bones of a specimen of* N. meridensis. *Branch support values represent maximum parsimony and maximum likelihood bootstrap support, followed by Bayesian posterior probabilities values, respectively.*

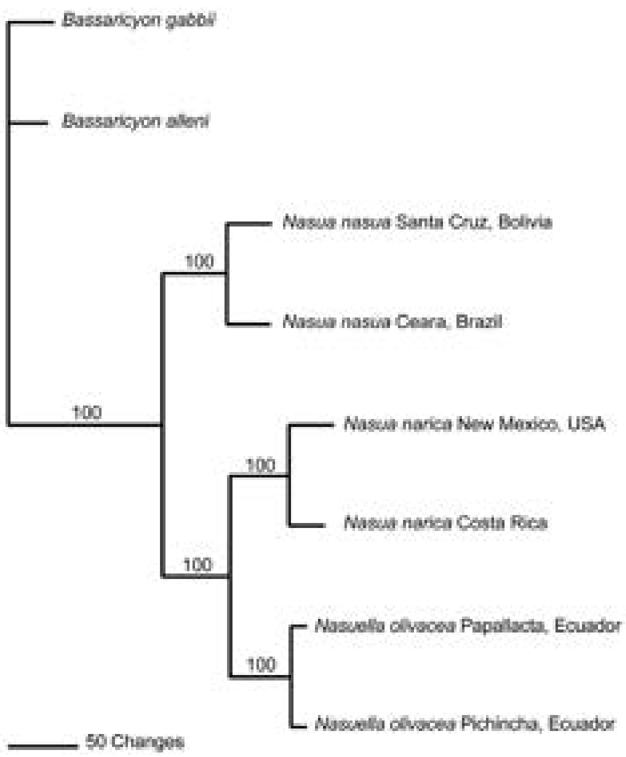

*Fig. 4. Molecular relationships of coatis based on complete cytochrome b sequences. The single most parsimonious tree (length = 495, retention index = 0.764, consistency index = 0.792) from the complete* cyt b *gene (1140 bp). This comparison excludes the short sequence generated from DNA extracted from the turbinate of a specimen of* N. meridensis. *Branch support values shown for all branches were the same in all analyses (maximum parsimony and maximum likelihood bootstrap values and Bayesian posterior probabilities).*

of the short and long sequences, the distance between the two *N. narica* sequences was 4.4% and 4.9% and between the *N. nasua* was 7.4 and 6.0% respectively. The divergence values within *Nasua* were 18.5-19.3%, and the divergence values between *N. narica* and *Nasuella* (Ecuador) was 9.7-12.6%.

### *Geographic range modeling*

The distribution model was judged to have performed well based on high values for area under the curve of the final model (AUC = 0.995) and unregularized training gain (3.986). Models also performed well when we withheld 20% of the locations to test a model built on the remaining 80% of the locations (test AUC = 0.974, unregularized training gain = 3.38). The full Maxent distribution model shows most lowland areas as unsuitable, with some moderately appropriate conditions in the highlands of Central America and the Guianan shield, but the highest quality areas in the Andes (Fig. 5). The relative contributions of the environmental variables were highest for three associated with temperature. Temperature seasonality (estimated as standard deviation) had the highest contribution (40.1%) followed by the maximum temperature of the warmest month (24.0%) and mean temperature of the warmest quarter (22.9%).

To create a presence/absence range map we calculated the average probability value giving equal training sensitivity and specificity averaged across our 10 test models (p = 0.151, Fig. 6). There was a clean break in the predicted range between Venezuela and the rest of the Andes, suggesting that geographic isolation may have contributed to the evolution of two deeply divergent allopatric species, *N. olivacea* and *N. meridensis*, as indicated by our mo-

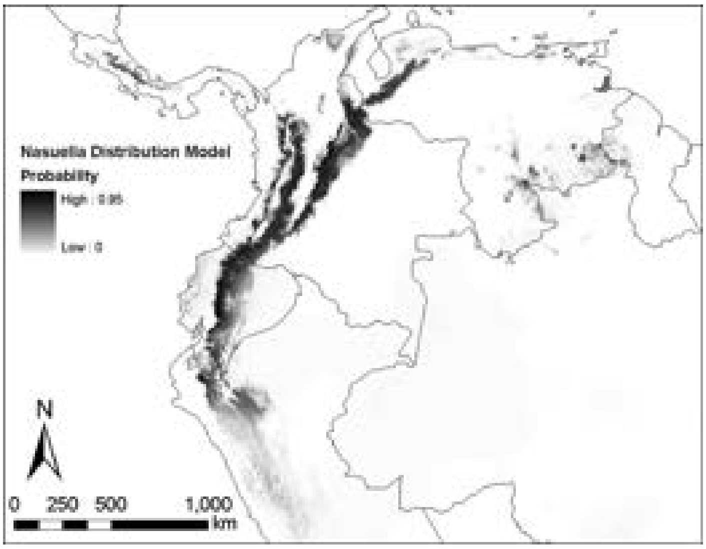

*Fig. 5. Bioclimatic distribution models and localities for* Nasuella. *Generated from Maxent using 33 vouchered occurrence records, 19 bioclimatic variables, and one potential habitat variable.*

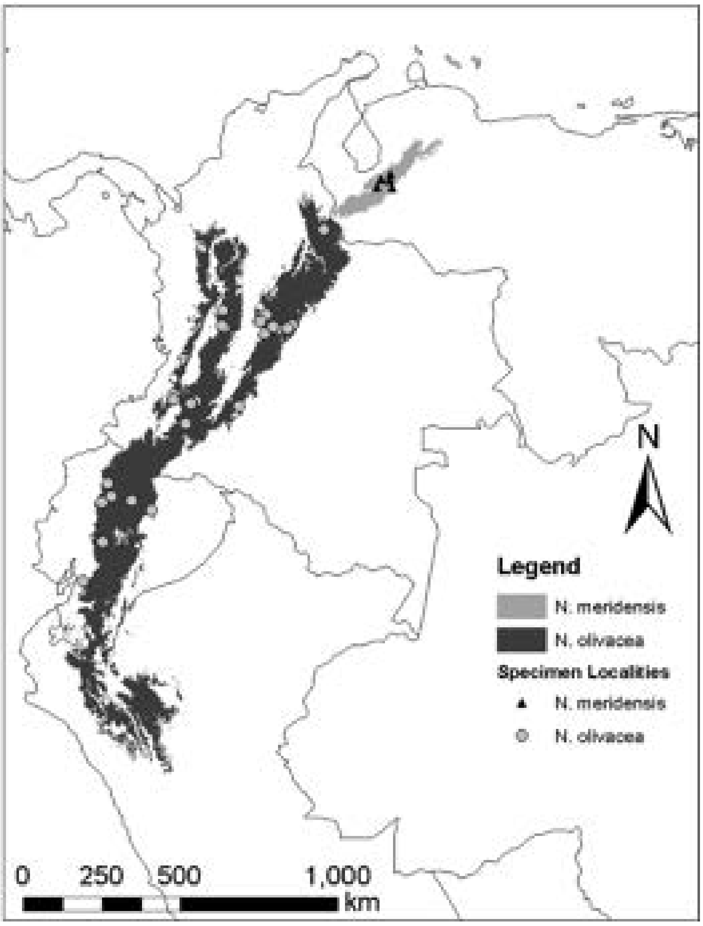

*Fig. 6. Predicted distribution for* Nasuella *based on bioclimatic models. To create these binary maps we used the average minimum training presence for 10 test models as our cutoff. In addition, we excluded areas of high probability that were outside of the known range of the species if they were separated by unsuitable habitat. The distribution model was made using all records for the genus and later divided between the two species based on specimen records.*

lecular and morphological comparisons. Although *N. olivacea* has a relatively large range, only 36% of this area is presently forested (Table 3). Furthermore, these forests are highly fragmented, especially by agriculture along the central axis of its range. *Nasuella meridensis* has a smaller range, but apparently less disturbed by agriculture than *N. olivacea* (Fig. 7).

## Discussion

Our examinations of museum skulls and skins reveal striking qualitative and morphometric distinctions between Mountain Coati populations from the Venezuelan Andes compared to populations from Colombia and Ecuador, which suggest considerable ecomorphological distinction between these forms. Presumably some of these differences, especially the excessively reduced teeth of Venezuelan animals, reflect functionally important distinctions such as differences in feeding mode and ecology, but this awaits further clarifying study.

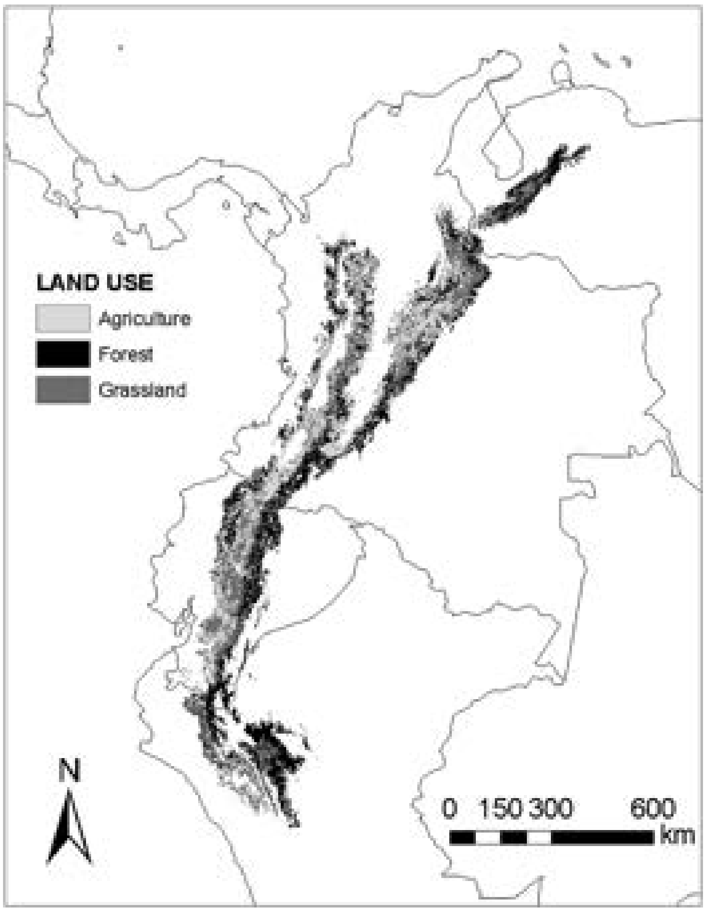

*Fig. 7. Present land use across the predicted geographic distribution of* Nasuella *(*N. olivacea *and* N. meridensis*). Land use data from Eva et al. (2004).*

These morphological distinctions are complemented by remarkably high sequence divergence in the *cytochrome b* gene (8-9%) between Venezuelan and other populations of *Nasuella*. This level of morphological and molecular divergence clearly indicates that these are deeply divergent lineages, and we recommend that they be recognized as two distinct, and clearly diagnosable, allopatric species. Though these taxa have been regarded as conspecific in the past, the name *meridensis*, applied by Thomas (1901) to Mountain Coati populations from the Merida Andes, is an available name for the Venezuelan taxon. The type locality of *N. olivacea* (Gray 1865) is the vicinity of Bogota in Colombia (Cabrera 1958); remaining species-level synonyms of *N. olivacea* include *lagunetae* (J. A. Allen 1913), with type locality "La Guneta (alt. 10,300 ft.), West Quindio Andes, Cauca, Colombia", and *quitensis* (Lönnberg 1913), with syntypes originating from Lloa and Gualea in Ecuador. To us, distinctions between Colombian and Ecuadoran samples of *N. olivacea* in both skull size and pelage (with Ecuadoran animals having significantly smaller skulls and darker fur) and mtDNA (2-3% divergence in *cyt b*) support the traditional recognition (e.g., Lönnberg 1913, Wozencraft 2005) of separate subspecies in Colombia (*N. o. olivacea*) and Ecuador (*N. o. quitensis*); the precise geographic boundaries of these subspecies remain to be determined.

*Nasuella* was originally diagnosed as a genus distinct from *Nasua* especially on the basis of its smaller body size, shorter tail, and more gracile skull and teeth (Hollister 1915), and has been recognized as a separate genus since its description. An intriguing result from analysis of coati *cyt b* sequences is the lack of support for monophyly of the two species classified in the genus *Nasua* (*N. nasua* and *N. narica*) relative to *Nasuella*. Instead, *Nasuella* (i.e., *N. olivacea* + *N. meridensis*) is recovered as the sister line-

*Table 3. Present land use in the predicted range of* N. olivacea *and* N. meridensis. *"Other" includes various inappropriate habitats (urban areas, ice, and lakes). Areas are in square kilometers.*

| | ***N. olivacea*** | | ***N. meridensis*** | |
|---|---|---|---|---|
| | **Area** | **%** | **Area** | **%** |
| Forest | 101,784 | 36.2 | 10,413 | 53.8 |
| Grassland | 75,712 | 26.9 | 5,953 | 30.8 |
| Agriculture | 101,042 | 35.9 | 2,728 | 14.1 |
| Other | 2,445 | 0.9 | 249 | 1.3 |
| Total | 280,983 | | 19,342 | |

age to *N. narica*, with high support. Thus it seems likely that the genus *Nasua* as currently recognized is not monophyletic, and that all coatis may instead be better classified as a single genus, *Nasua* (i.e., with *Nasuella* as a synonym), representing three deeply divergent evolutionary lineages—South American *N. nasua*; North American *N. narica* (with *N. nelsoni* of Cozumel); and Andean *N. olivacea* and *N. meridensis*. We continue to use *Nasuella* as a genus name in this paper pending additional clarifying morphological and genetic comparisons, particularly involving biparental (nuclear DNA) markers, which, in tandem with our mtDNA data, should allow for a more definitive resolution of coati evolutionary history.

Our review of the known and predicted geographic distribution of *Nasuella* identifies a narrow but very clear geographic gap in predicted occurrence between *N. meridensis* and *N. olivacea* in the vicinity of the Colombian-Venezuelan border (Figs 5 and 6). We speculate that this current distributional discrepancy also reflects the ancient biogeographic origin of these two allopatric taxa, for example by a climate-associated vicariant event that isolated these two populations in high montane habitats across this divide. Whatever the origin of the two species' current distributions, their distinctness has clearly been maintained in the face of fluctuating Pleistocene climate episodes during which montane forests may have periodically extended to considerably lower elevations than they do today (e.g., Schubert 1974), perhaps marginalizing the current biogeographic gap between these Andean regions.

One potentially substantive result of the geographic modeling analyses presented here is the identification of areas where, even though geographic records are currently lacking, Mountain Coatis may occur. Priorities for renewed survey efforts aimed at documenting the full geographic distribution of *Nasuella* include the southern portion of the predicted range, which extends into northern Peru. Some authors have previously suggested the possibility that the distribution of *Nasuella* may extend into Peru (e.g., Eisenberg 1989, Eisenberg & Redford 1999), but we know of no vouchered records to date. If present there, Peru might provide some of the largest remaining forested habitat in the range of *N. olivacea*, so this is important to establish. Another priority area for field surveys is the northern extension of the western cordillera of Colombia; candidate habitat is present in this region, but we are not aware of any records from this area to date. Other islands of potential habitat, isolated from the known range of *Nasuella*, are to be found in areas of northern Colombia as well as the Darien Mountains of Panama, and these offer further survey priorities.

We offer this revision of taxonomic boundaries, along with an overview of the geographic distribution of *Nasuella*, as necessary steps along a path toward generating a better understanding of the conservation status of Mountain Coatis, and identifying priorities that may assist in conservation planning and management initiatives for Mountain Coatis. Importantly, recognition of two species of *Nasuella* requires that conservation considerations be made separately for both, and demonstrates that these taxa each have smaller geographic ranges than the combined range of "*N. olivacea*" as previously recognized (e.g., *N. meridensis* has a relatively limited distribution, restricted to high montane habitats in the Venezuelan Andes). The conservation status of "*N. olivacea*" (i.e., embracing both Mountain Coati species) is currently regarded as "Data Deficient", especially because of "ongoing uncertainty surrounding the potential impacts of habitat loss and habitat conversion to agriculture" on Mountain Coati populations (Reid & Helgen 2008, Schipper *et al.* 2008). Our analyses suggest that a large proportion of the potential geographic range of *Nasuella*, especially of the Western Mountain Coati, is dominated by agricultural landscapes, which now fragment cloud forest habitats throughout the Andes—habitats on which *Nasuella* presumably depends (see also Balaguera-Reina *et al.* 2009). We hope that the new information brought to light here can be combined with better "on the ground" knowledge of Mountain Coatis—information such as the presence and security of *Nasuella* populations in protected areas, the extent to which *Nasuella* occurs in agricultural habitats, and the severity of threats such as deforestation and hunting—to provide a more insightful prognosis for the conservation of these remarkable Andean carnivores.

## Taxonomy

### *Nasuella olivacea* (Gray 1865)

**Suggested English common name**: Western Mountain Coati.
**Diagnosis**: Body size smaller, tail shorter, and teeth markedly smaller than in the species of *Nasua*; distinguished from *N. meridensis* in having more saturate pelage (more rufous or blackish), usually without a blackish mid-dorsal stripe; much larger teeth, especially premolars and molars (e.g. Figs 1 and 2); a shorter lateral extension of the palate behind the upper molars (Fig. 1); the (postdental) "palatal shelf" posteriorly depressed; and the anterior alveolar foramen situated within or just anterior to the infraorbital foramen.
**Distribution**: *Nasuella olivacea* is endemic to the Andes of Colombia and Ecuador (Fig. 6), where it is known from cloud forest and paramo habitats, at elevations between 1300 and 4250 meters (specimens at AMNH, BMNH, EPN, FMNH, NMS, QCAZ, USNM, Balaguera-Reina *et al.* 2009). Some information on the ecology and behavior of this species in Colombia has been published in the past decade (Rodríguez-Bolaños 2000, 2003).
**Subspecies**: We recommend that two subspecies can be admitted on current evidence, with the precise geographic boundary between the two currently undefined.
*N. o. olivacea* (Gray 1865). Skull growing larger (greatest length 97-116 mm in adults), pelage paler (more brown), with dark tail rings usually evident on the tail. Distributed throughout the Andes of Colombia (*lagunetae* J.A. Allen 1913, is a synonym; see above).
*N. o. quitensis* (Lönnberg 1913). Skull smaller (greatest length 97-105 mm in adults), pelage darker (more blackish), with dark tail rings less clearly visible on the tail. Distributed throughout the Andes of Ecuador.

### *Nasuella meridensis* (Thomas 1901)

**Suggested English common name**: Eastern Mountain Coati.
**Diagnosis**: Body size smaller, tail shorter, and teeth markedly smaller than in the species of *Nasua*; distinguished from *N. olivacea* in having more olivaceous pelage, usually with a blackish dorsal stripe; much smaller teeth, especially premolars and molars (e.g. Figs 1 and 2); a longer lateral extension of the palate behind the upper molars (Fig. 1); the (postdental) "palatal shelf" less posteriorly depressed; and the anterior alveolar foramen situated farther anterior relative to the infraorbital foramen.
**Distribution**: *Nasuella meridensis* is endemic to the Venezuelan Andes (Fig. 6), where it is known from cloud forest and paramo habitats, at elevations between 2000 and 4000 meters (Thomas 1901, Handley 1976, Bisbal 1989, Linares 1998). We know of no ecological or behavioral studies of *N. meridensis* to date, but selected ecological attributes of their montane habitats have been subject to informative overview studies (e.g., Ataroff & Rada 2000, Barthlott *et al*. 2001, Janzen *et al*. 1976, Kelly *et al*. 1994, Marquez *et al*. 2004, Paoletti *et al*. 1991, Pérez 1992). The species is monotypic (i.e., no subspecies can be recognized).

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## References

Allen, J. A. 1880. On the coatis (genus *Nasua*, Storr). *Bulletin of the United States Geological and Geographical Survey* 5:153–174.

Allen, J. A. 1912. Mammals from western Colombia. *Bulletin of the American Museum of Natural History* 31: 71–95.

Allen, J. A. 1913. New mammals from Colombia and Ecuador. *Bulletin of the American Museum of Natural History* 32: 469–484.

Allen, J. A. 1916. List of mammals collected in Colombia by the American Museum of Natural History expeditions, 1910–1915. *Bulletin of the American Museum of Natural History* 35: 191–238.

Ataroff, M. & Rada, F. 2000. Deforestation impact on water dynamics in a Venezuelan Andean cloud forest. *Ambio* 29: 440–444.

Balaguera-Reina, S. A., Cepeda, A., Zárrate-Charry, D., & González-Maya, J.F. 2009. The state of knowledge of Western Mountain Coati *Nasuella olivacea* in Colombia, and extent of occurrence in the Northern Andes. *Small Carnivore Conservation* 41: 35–40.

Barthlott, W., Schmit-Neuerberg, V., Nieder, J. & Engwald, S. 2001. Diversity and abundance of vascular epiphytes: a comparison of secondary vegetation and primary montane rain forest in the Venezuelan Andes. *Plant Ecology* 152: 145–156.

Bickham, J. W., Patton, J. C., Schlitter, D. A., Rautenbach, I. L. & Honeycutt, R. L. 2004. Molecular phylogenetics, karyotypic diversity, and partition of the genus *Myotis* (Chiroptera: Vespertilionidae) *Molecular Phylogenetics and Evolution* 33: 333–338.

Bisbal, F. J. 1989. Distribution and habitat association of the carnivores in Venezuela. Pp. 339–362 in Redford, K. & Eisenberg, J. (Eds) *Advances in Neotropical Mammalogy*. Sandhill Crane Press. Gainesville, Florida, USA.

Cabrera, A. 1957 (1958). Catálogo de los mamíferos de América del Sur. *Revista del Museo Argentino de Ciencias Naturales "Bernardino Rivadavia", Ciencias Zoológicas*, 4(1):iv + 308 pp.

Decker, D. M. 1991. Systematics of the coatis, genus *Nasua* (Mammalia: Procyonidae). *Proceedings of the Biological Society of Washington* 104: 370–386.

Decker, D. M. & Wozencraft, W. C. 1991. Phylogenetic analysis of Recent procyonid genera. *Journal of Mammalogy* 72: 42–55.

Eisenberg, J. F. 1989. *Mammals of the Neotropics, volume 1. The northern Neotropics—Panama, Colombia, Venezuela, Guyana, Suriname, French Guiana*. University of Chicago Press, Chicago, USA.

Eisenberg, J. F. & Redford, K. H. 1999. *Mammals of the Neotropics, volume 3. The central Neotropics*. University of Chicago Press, Chicago, USA.

Emmons, L. H. & Feer, F. 1990. *Neotropical rainforest mammals: a field guide*. University of Chicago Press, Chicago, USA.

Emmons, L. H., & Feer, F. 1997. *Neotropical rainforest mammals: a field guide*. Second edition. University of Chicago Press, Chicago, USA.

Eva, H. D., Belward, A. S., De Miranda, E. E., Di Bella, C. M., Gond, V., Huber, O., Jones, S., Sgrenzaroli, M. & Fritz, S. 2004. A land cover map of South America. *Global Change Biology* 10: 731–744.

Friscia, A. R., Van Valkenburgh, B. & Biknevicius, A. R. 2007. An ecomorphological analysis of extant small carnivorans. *Journal of Zoology (London)* 282: 82–100.

Fulton, T. L. & Strobeck, C. 2007. Novel phylogeny of the raccoon family (Procyonidae: Carnivora) based on nuclear and mitochondrial DNA evidence. *Molecular Phylogenetics and Evolution* 43: 1171–1177.

Gray, J. E. 1843. *List of the specimens of Mammalia in the collection of the British Museum*. George Woodfall and Son, London, UK.

Gray, J. E. 1865. A revision of the genera and species of ursine animals (Ursidae) founded on the collection in the British Museum. *Proceedings of the Zoological Society of London* 1864: 677–709.

Gray, J. E. 1869. *Catalogue of carnivorous, pachydermatous, and edentate mammals in the British Museum*. Taylor and Francis, London, UK.

Guzmán-Lenis, A. R. 2004. Revisión preliminary de la familia Procyonidae en Colombia. *Acta Biológica Colombiana* 9: 69–76.

Handley, C. O., Jr. 1976. Mammals of the Smithsonian Venezuelan Project. *Brigham Young University Science Bulletin, Biological Series* 20(5): 1–91.

Hijmans, R. J., Cameron, S. E., Parra, J. L., Jones, P. G. & Jarvis, A. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology* 25: 1965–1978.

Hollister, N. 1915. The genera and subgenera of raccoons and their allies. *Proceedings of the United States National Museum* 49: 143–150.

Huelsenbeck, J. P. & Ronquist, F. 2001. MRBAYES: Bayesian inference of phylogenetic trees. *Bioinformatics* 17: 754–755.

Janzen, D. H., Ataroff, M., Farinas, M., Reyes, S., Rincon, N., Soler, A., Soriano, P. & Vera, M. 1976. Changes in the arthropod community along an elevational transect in the Venezuelan Andes. *Biotropica* 8: 193–203.

Jarrín-V., P. 2001. *Mamíferos en la niebla: Otonga, un bosque nublado del Ecuador*. Museo de Zoología, Centro e Biodiversidad y Ambiente, Pontificia Universidad Católica del Ecuador.

Kelly, D. L., Tanner, E. V. J., Nic Lughadha, E. M. & Kapos, V. 1994. Floristics and biogeography of a rain forest in the Venezuelan Andes. *Journal of Biogeography* 21: 421–440.

Koepfli, K. P., Gompper, M. E., Eizirik, E., Ho, C.-C., Linden, L., Maldonado, J. E. & Wayne, R. K. 2007. Phylogeny of the Procyonidae (Mammalia: Carnivora): molecules, morphology, and the Great

American Interchange. *Molecular Phylogenetics and Evolution* 43: 1076–1095.

Linares, O. J. 1998. *Mamíferos de Venezuela*. Sociedad Conservacionista Audubon de Venezuela, Caracas, Venezuela.

Lönnberg, E. 1913. Mammals from Ecuador and related forms. *Arkiv för Zoologi* 8(16): 1–36.

Lord, R. 2007. *Mammals of South America*. Johns Hopkins University Press, Baltimore, Maryland, USA.

Marquez, E. J., Farinas, N. R., Briceno, B. & Rada, F. J. 2004. Distribution of grasses along an altitudinal gradient in a Venezuelan paramo. *Revista Chilena de Historia Natural* 77: 649–660.

Mondolfi, E. 1987. Baculum of the lesser Andean coati, *Nasuella olivacea* (Gray), and of the larger grison, *Galictis vittata* (Schreber). *Fieldiana Zoology* 39: 447–454.

Nylander, J. A. A. 2004. *MrModeltest v2*. Program distributed by the author. Evolutionary Biology Centre, Uppsala University, Uppsala, Sweden.

Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'Amico, J. A., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnutt, T. F., Lamoreux, J. F., Ricketts, T. H., Itoua, I., Wettengel, W. W., Kura, Y., Hedao, P. & Kassem, K. 2001. Terrestrial ecoregions of the world: A new map of life on Earth. *BioScience* 51: 933–938.

Paoletti, M. G., Taylor, R. A. J., Stinner, B. R., Stinner, D. H. & Benzing, D. H. 1991. Diversity of soil fauna in the canopy and forest floor of a Venezuelan cloud forest. *Journal of Tropical Ecology* 7: 373–383.

Paynter, R. A., Jr. 1982. *Ornithological Gazetteer of Venezuela*. Museum of Comparative Zoology, Cambridge, Massachusetts, USA.

Paynter, R. A., Jr. 1993. *Ornithological Gazetteer of Ecuador, second edition*. Museum of Comparative Zoology, Cambridge, Massachusetts, USA.

Paynter, R. A., Jr. 1997. *Ornithological Gazetteer of Colombia, second edition*. Museum of Comparative Zoology, Cambridge, Massachusetts, USA.

Pérez, F. L. 1992. The ecological impact of cattle on caulescent Andean rosettes in a high Venezuelan paramo. *Mountain Research and Development* 12: 29–46.

Phillips, S. J., Anderson, R. P. & Schapire, R. E. 2005. Maximum entropy modeling of species geographic distributions. *Ecological Modelling* 190: 231–259.

Ramírez-Chaves, H., Pérez, W. & Ramírez-Mosquera, J. 2008. Mamíferos presentes en el municipio de Popayán, Cauca, Colombia. *Boletín Cientifico Museo Historia Natural* 12: 65–89.

Reid, F. & Helgen, K. 2008. *Nasuella olivacea*. In: IUCN 2009. *IUCN Red List of Threatened Species*. Version 2009.1. <www.iucnredlist.org>. Downloaded on 25 May 2009.

Rodríguez-Bolaños, A, Cadena, A. & Sánchez, P. 2000. Trophic characteristics in social groups of the Mountain coati, *Nasuella olivacea* (Carnivora: Procyonidae). *Small Carnivore Conservation* 23: 1–25.

Rodríguez-Bolaños, A., Sánchez, P. & Cadena, A. 2003. Patterns of activity and home range of Mountain Coati *Nasuella olivacea*. *Small Carnivore Conservation* 23: 1–5.

Schipper, J. *et al*. 2008. The status of the world's land and marine mammals: diversity, threat, and knowledge. *Science* 322: 225–230.

Schubert, C. 1974. Late Pleistocene Mérida glaciation, Venezuelan Andes. *Boreas* 3: 147–151.

Sclater, W. L. 1891. *Catalogue of Mammalia in the Indian Museum, Calcutta. Part II. Rodentia, Ungulata, Proboscidea, Hyracoidea, Carnivora, Cetacea, Sirenia, Marsupialia, Monotremata.* Trustees of the Indian Museum, Calcutta, India.

Swofford, D. L. 2003. *PAUP*. Phylogenetic Analysis Using Parsimony (*and other methods), Version 4.0b10*. Sinauer Associates, Sunderland, Massachusetts, USA.

Tamura, K., Dudley, J., Nei, M. & Kumar, S. 2007. MEGA4: Molecular Evolutionary Genetics Analysis (MEGA) software version 4.0. *Molecular Biology and Evolution* 24: 1596–1599.

Tate, G. H. H. 1939. The mammals of the Guiana region. *Bulletin of the American Museum of Natural History* 76: 151–229.

Thomas, O. 1901. New Neotropical mammals, with a note on the species of *Reithrodon*. Annals and Magazine of Natural History (series 7) 8: 246–255.

Tsuchiya-Jerep M. T. N. 2009. *Filogeografia, história demográfica e diversidade molecular de duas espécies neotropicais da família Procyonidae (Mammalia, Carnivora):* Nasua nasua *e* Procyon cancrivorus. Pontificia Universidade Catolica do Rio Grande do Sul (M.Sc. thesis), Porto Alegre, Brazil.

Wisely, S. M., Maldonado, J. E. & Fleischer, R.C. 2004. A technique for sampling ancient DNA that minimizes damage to museum specimens. *Conservation Genetics* 5: 105–107.

Wozencraft, W.C. 2005. Order Carnivora. Pp. 532–628. In Wilson, D.E. & Reeder, D.M. (eds.) *Mammal Species of the World*, Third Edition. The Johns Hopkins University Press, Baltimore.

Zwickl, D. J. 2006. Genetic algorithm approaches for the phylogenetic analysis of large biological sequence datasets under the maximum likelihood criterion. Ph.D. dissertation, The University of Texas at Austin. (downloaded from www.bio.utexas.edu/faculty/antisense/garli/Garli.html)

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*Clockwise from bottom left:*
Tayra *Eira barbara* (José F. González-Maya), South American Coati *Nasua nasua,* Crab-eating Raccoon *Procyon cancrivorus,* Greater Grison *Galictis vittata* (Tadeu G. de Oliveira), Black-footed Ferret *Mustela nigripes* (David Jachowski), Western Mountain Coati *Nasuella olivacea* (Abelardo Rodríguez Bolaños), Striped Hog-nosed Skunk *Conepatus semistriatus* (Diego Santana)