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A camera trap assessment of terrestrial mammals in Machalilla National Park, western Ecuador

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Abstract: Understanding the abundance, geographic distribution, and conservation status of terrestrial mammals is vital to promote effective wildlife management in protected areas. Located in the Tumbes-Chocó-Magdalena hotspot of western Ecuador, Machalilla National Park contains high levels of biodiversity and endemism but suffers from habitat loss and degradation. This study provides an updated inventory of medium-sized to large mammals in the park and assesses changes in species richness over the past 20 years. Surveying 70% of Machalilla's 562-km^2 terrestrial area with 60 camera trap points, we detected 18 species of mammals belonging to 13 families. Richness of terrestrial species has declined in recent decades, due to the disappearance of keystone species like Jaguar (*Panthera onca*), White-lipped Peccary (*Tayassu pecari*), and possibly the Sechuran Fox (*Lycalopex sechurae).* We recommend specific management improvements to ensure conservation of the unique ecosystems and biodiversity of Machalilla, the only national park in Ecuador containing dry forest.

Key words: regional list; tropical dry forest; Tumbes-Choco-Magdalena; conservation; protected area; wildlife management

INTRODUCTION

Understanding the abundance, geographic distribution, and conservation status of mammal species is essential to promote effective wildlife management in protected areas (Tobler et al. 2008; Jenkins et al. 2013). Mammals exploit a broad range of niches and play crucial ecological roles that influence community structure and ecosystem function (Ripple et al. 2014). Ensuring their protection begins with accurate, up-to-date information on which species are present in an area (Antos and Yuen 2014). Presence-absence data provide baseline information about the conservation status and distribution of species inhabiting an area with relatively minimal effort (Manel et al. 2001; Guisan and Thuiller 2005). This information is especially important for species that are at risk from overexploitation and habitat loss.

The western lowlands of Ecuador compromise part of the Tumbes-Chocó-Magdalena hotspot (Myers et al. 2000), a region containing high levels of species richness and endemism but suffering continuous habitat loss and degradation (Dodson and Gentry 1991). The southern portion of this hotspot, known as the Tumbesian region, encompasses tropical dry forest (Pennington et al. 2000) that harbors 16, 39 and 136 endemic mammal, bird, and woody plant species, respectively (Aguirre-Mendoza et al. 2006a; Aguirre-Mendoza et al. 2006b; BirdLife International 2015; Espinosa et al. 2012; Loaiza 2013). As the only national park in the region, Machalilla National Park (MNP) has a fundamental role in protecting the unique dry forest ecosystem and biodiversity of the Tumbes-Chocó-Magdalena hotspot.

Obtaining information on the presence and conservation status of mammals in MNP is especially important given their roles as herbivores (Camargo-Sanabria et al. 2014), seed dispersers (Keuroghlian and Eaton 2008), and regulators of prey populations (Jorge et al. 2013). Yet despite being a national park located within an internationally recognized hotspot, few ecological studies have been conducted in MNP and knowledge of the conservation status of even well-known taxa remains lacking. In the case of mammals, the last inventories conducted date from 20 years ago. Parker and Carr (1992) reported 47 mammal species in MNP, including 25 medium-sized and large terrestrial mammals (0.470–120 kg), while Albuja (1997) reported 62 mammal species, 27 of which were medium-sized to large. Comparing these reports with a recent survey is necessary to evaluate changes in the mammal community of the park.

To update the regional mammal list for MNP, we used camera traps to confirm the presence of medium-sized to large mammals and compare changes in richness based on previous studies (Parker and Carr 1992; Albuja 1997). By maximizing encounter rate — especially of cryptic species — camera traps provide an effective tool for studying small to large mammals and are relatively inexpensive, efficient, and easy to use (Tobler et al. 2008; Ahumada et al. 2013; Rovero et al. 2014). The results presented here provide the basis for improving wildlife management and conservation in one of the world's tropical dry forest hotspots.

MATERIALS AND METHODS

Study site

Located in Manabí province of western Ecuador, Machalilla National Park (01°32′ S, 080°40′ W) was established in 1979 and encompasses more than 700 km^2, 80% of which is terrestrial and 20% marine (Figure 1). The climate is seasonally dry, with a mean annual temperature of 24°C and mean annual precipitation oscillating between 100 and 1,000 mm (CLIRSEN-SENPLADES 2012). The seasonality is governed by two oceanic currents: the warm Panama Current, which produces higher rainfall between January and April, and the cold Humboldt Current, which induces dry conditions from May to December (Josse and Balslev 1994; Pourrut and Gómez 1998). During the dry season, a persistent fog called *garúa* forms at higher elevations and contributes to a gradient of increasing humidity with elevation (Becker 1999). This gradient, in turn, determines the distribution of vegetation types in the park, ranging from coastal deciduous dry scrub located between sea level and 300 m, deciduous dry forest between 150 and 300 m, transitional semi-deciduous forest between 300 and 350 m, and evergreen cloud forest between 350 and 840 m (Cerón-Martínez and Montalvo 1997; INEFAN 1998).

Despite its status as a national park, MNP is subject to illegal wood extraction, charcoal production, livestock grazing, and subsistence agriculture by local residents (INEFAN 1998). The 11 communities living within the park comprise an estimated population of 16,278, while another 17 communities are located in the surrounding area (INEC 2010). With an unsatisfied basic needs index of 94.6% in the canton, these communities are relatively poor and subsist mainly on extractive activities and part-time employment (Fiallo and Jacobson 1995; GADM 2011).

Data collection

We placed camera traps along a regular grid of 60 sampling points at a density of one camera per 2 km^2 (Figure 1), following the methodology of the Tropical Ecology Assessment and Monitoring Network (TEAM Network 2011). We deployed camera traps in three sequential arrays of 20 points each from September 2014 to January 2015, leaving the cameras in the field for 30–45 days. We used digital camera traps (Moultrie M990i) programmed to take pictures at 5-second intervals. Camera traps were positioned at 30–50 cm above the ground and angled to maximize the field of view. In the case of sampling points assigned to inaccessible areas, cameras were located no more than 100 m from the allotted point. To minimize disturbance to wildlife and avoid any bias related to human presence, we did not check cameras while they were deployed in the field (Rovero et al. 2014).

We organized and stored images using the software OpenDeskTEAM (version 0.6.0), which is designed for managing camera trap survey data (Fegraus et al. 2011). We identified species based on field guides (Emmons 1997; Eisenberg and Redford 2000; Tirira 2007) and consultation with experts. Here we report all wild mammals photographed by the cameras and observed directly during fieldwork. To conduct this study we obtained a research permit (# 013-2014-DPAM-MAE) from the Ecuadorian Ministry of the Environment.

RESULTS

The array of 60 camera traps covered a minimum convex polygon of 391 km^2, which represents 70% of the terrestrial area of MNP. Total sampling effort was 6840 camera trap sampling days, which yielded 1537 images of 18 wild mammal species belonging to 13 families (Table 1). The species accumulation curve confirms sample effort was adequate as the curve reaches its asymptote between 30 and 40 sampled point. Consecutive images of the same species at the same station were considered independent events if they were separated by at least 1 hour (Tobler et al. 2008).

We identified closely related species based on the following characteristics. Ocelot (*Leopardus pardalis*) has a longer body but proportionally shorter tail compared to Margay (*Leopardus wiedii*), as well as smaller eyes (Oliveira 1998). White-tailed Deer (*Odocoileus virginianus*) and Red Brocket (*Mazama americana*) were distinguished by color pattern, body shape, and shape of the antlers. White-tailed Deer (*O. virginianus*) is uniformly brown while Red Brocket is reddish brown with greyish coloration on the neck (Smith 1991). Red Brocket is relatively smaller and shorter than White-tailed Deer and has an elongated face and slender legs (Weber and Gonzalez 2003). The antlers of Red Brocket are short and straight while those of White-tailed Deer are long and branched (Smith 1991).

Thirty or more events were recorded for six species in the following decreasing order: Central American Agouti (*Dasyprocta punctata*), Guayaquil Squirrel (*Simosciurus*

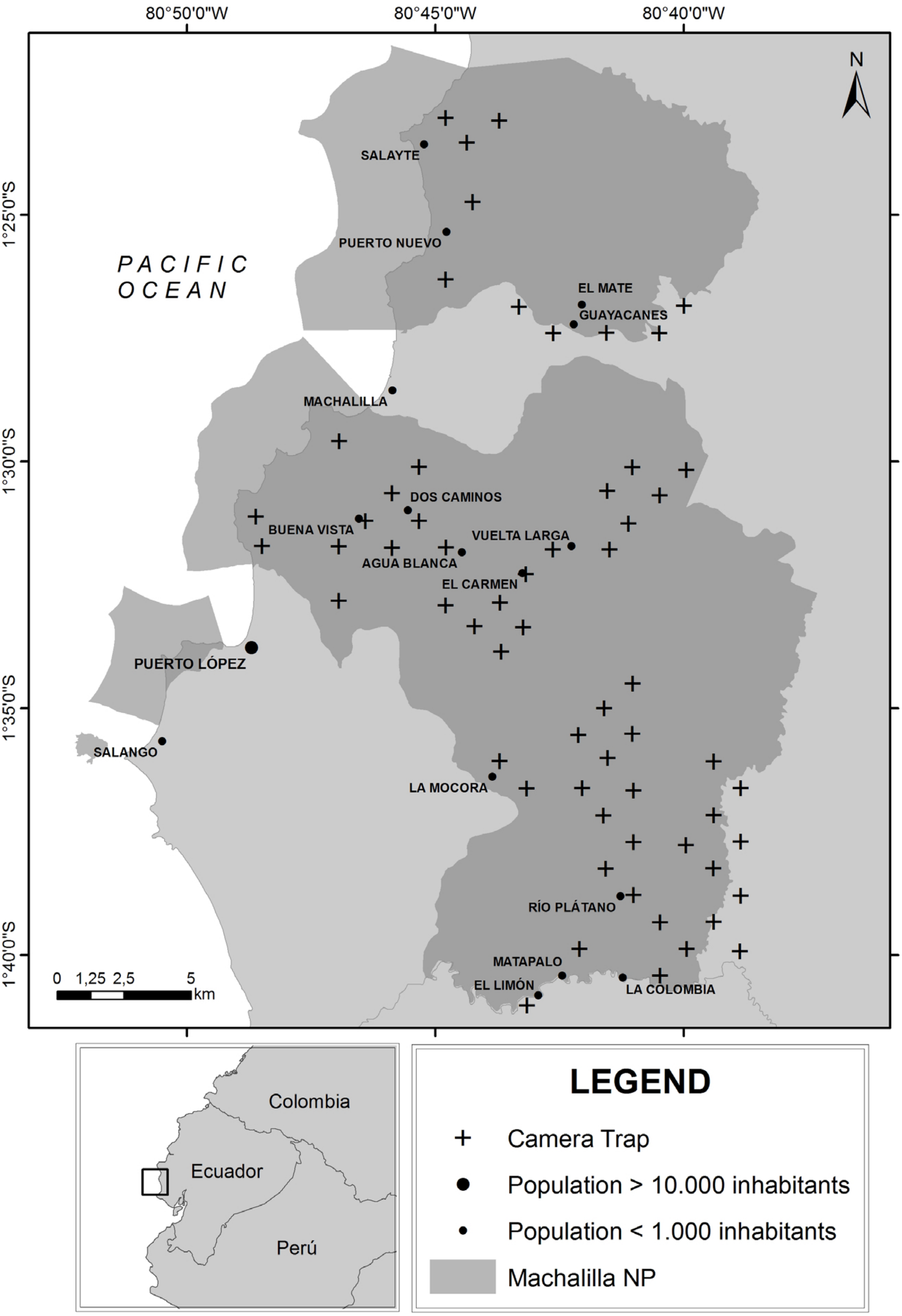

Figure 1. Map of the study area, showing 60 camera trap sampling points (+) and communities within and around Machalilla National Park, Manabí province, Ecuador.

Table 1. Terrestrial mammal species detected in the present study and reported by Albuja et al. (1997 = Study A) and Parker and Carr (1992 = Study B). Conservation status (CS) of each species is based on [1] Tirira (2011) and [2] IUCN (2015). * Information provided by local residents.

Family	Scientific Name	Common name	Present study	Study A	Study B	CS[1]	CS[2]
Cuniculidae	*Cuniculus paca* (Linnaeus, 1766)	Lowland Paca	X	X	X	NT	LC
Canidae	*Lycalopex sechurae* (Thomas, 1900)	Sechuran Fox		X	X*	VU	NT
Atelidae	*Alouatta palliata* (Gray, 1849)	Mantled howler Monkey	X	X	X	EN	LC
Cebidae	*Cebus aequatorialis* (Allen, 1914)	Ecuadorian White-fronted Capuchin	X	X	X	CR	CR
Cervidae	*Mazama americana* (Erxleben, 1777)	Red Brocket	X	X	X	NT	DD
	Odocoileus virginianus (Zimmermann, 1780)	White-tailed Deer	X	X	X	EN	LC
Dasypodidae	*Cabassous centralis* (Miller 1899)	Northern Naked-tailed Armadillo		X*		VU	DD
	Dasypus novemcinctus Linnaeus, 1758	Nine-banded Armadillo	X	X*	X		LC
Dasyproctidae	*Dasyprocta punctata* Gray, 1842	Central American Agouti	X	X	X		LC
Didelphidae	*Caluromys derbianus* (Waterhouse, 1841)	Derby's woolly Opossum		X*	X	VU	LC
	Didelphis marsupialis Linnaeus, 1758	Common Opossum	X	X*	X		LC
	Marmosa sp.	Marmosa		X*			
Erethizontidae	*Coendou* sp.	Porcupine		X*	X*		
Felidae	*Leopardus pardalis* (Linnaeus, 1758)	Ocelot	X	X	X*	NT	LC
	Leopardus wiedii (Schinz, 1821)	Margay	X	X		VU	NT
	Leopardus tigrinus (Schreber, 1775)	Tigrillo			X*	VU	VU
	Panthera onca (Linnaeus, 1758)	Jaguar		X*	X*	CR	NT
	Puma yagouaroundi (Saint-Hilaire, 1803)	Jaguarundi	X		X	NT	LC
Leporidae	*Sylvilagus brasiliensis* (Linnaeus, 1758)	Tapeti	X	X*	X		LC
Megalony-chidae	*Choloepus hoffmanni* (Peters, 1858)	Hoffmann's Two-toed Sloth		X	X	VU	LC
Mustelidae	*Eira Barbara* (Linnaeus, 1758)	Tayra	X	X	X		LC
Myrmecophagidae	*Tamandua mexicana* (Saussure, 1860)	Northern Tamandua	X	X	X	VU	LC
Procyonidae	*Nasua narica* (Linnaeus, 1766)	White-nosed Coati	X	X	X*	DD	LC
	Potos flavus (Schreber, 1774)	Kinkajou		X	X		LC
	Procyon cancrivorus (Cuvier, 1798)	Crab-eating Raccoon	X	X	X	DD	LC
Sciuridae	*Notosciurus granatensis* (Humboldt, 1811)	Red-tailed Squirrel		X	X		LC
	Simosciurus stramineus (Humboldt, 1811)	Guayaquil Squirrel	X	X	X		LC
Tayassuidae	*Pecari tajacu* (Linnaeus, 1758)	Collared Peccary	X	X*	X	NT	LC
	Tayassu pecari (Link, 1795)	White-lipped Peccary		X*		EN	VU
Species richness			**18**	**27**	**25**		

stramineus), White-tailed Deer (*O. virginianus*), Lowland Paca (*Cuniculus paca*), Collared Peccary (*Pecari tajacu*), and Tayra (*Eira barbara*). Between 10 and 30 events were recorded for four species: Nine-banded Armadillo (*Dasypus novemcinctus*), Northern Tamandua (*Tamandua mexicana*), Tapeti (*Sylvilagus brasiliensis*), and Margay (*L. wiedii*). Less than 10 independent events were recorded for the remaining six species, including White-nosed Coati (*Nasua narica*) and Jaguarundi (*Puma yagouaroundi*), which were each recorded less than five times.

DISCUSSION

Accurate information on species presence-absence is a critical first step to understanding the status of mammal populations and developing strategies to ensure their protection (Antos and Yuen 2014). This is especially important in the case of MNP, the largest protected area in southwestern Ecuador and an important refuge for the region's fauna. As the first study to use camera traps in MNP, this work provides updated information on the mammals present in the park and establishes a baseline for further research and development of effective wildlife management in a tropical dry forest ecosystem.

Our survey failed to detect four of the arboreal and seven of the terrestrial mammal species reported in previous studies (Parker and Carr 1992; Albuja 1997; Table 1). The arboreal species not detected in our study were Derby's Woolly Opossum (*Caluromys derbianus*), Kinkajou (*Potos flavus*), Hoffmann's Two-toed Sloth (*Choloepus hoffmanni*), and Red-tailed Squirrel (*Sciurus granatensis*), likely due to the low probability of detecting arboreal species with ground-based camera traps. In the case of terrestrial species, detection failure could be due to: (i) the inability of our methods to detect rare and elusive species; (ii) incorrect reporting of species' presence in the previous studies, which relied heavily on local testimonies; or (iii) extinction of these species from MNP. Despite conducting a robust survey covering 70% of the park and using camera traps with a demonstrated capacity to detect cryptic species (Carbone et al. 2001), we concede that rare species like the Sechuran Fox (*Lycalopex sechurae*), Oncilla (*Leopardus tigrinus*) and Northern Naked-tailed Armadillo (*Cabassous centralis)* may have escaped detection.

Endemic to the Tumbesian ecoregion and listed as Vulnerable by the *Red Book of Mammals of Ecuador* (Tirira et al. 2011), the Sechuran Fox (*L. sechurae*) has previously been reported in MNP (Albuja 1997; Tirira 2007) but is rarely seen due to its elusive behavior. Its population may have been extirpated in MNP due to habitat loss and increasing intrusion by human settlements (Buffman 2011). Less is known about the impacts of human disturbance on the Northern Naked-tailed Armadillo (*C. centralis*), which is listed as Data Deficient by the *IUCN Red List* and Nearly Threatened in Ecuador (Tirira et al. 2011). Another poorly known species is the Oncilla (*L. tigrinus*), which occurs at very low densities throughout its distribution and is listed as Vulnerable by the *IUCN Red List* (de Oliveira et al. 2008; Tirira 2011). The abundance of Oncilla is reported to decrease with the presence of other medium-sized cats (Oliveira-Santos et al. 2012), which were fairly common in the park (see below). Continued monitoring is necessary to confirm whether these species have indeed gone extinct from MNP.

Both Parker and Carr (1992) and Albuja (1997) reported three different deer taxa in MNP, while we only detected White-tailed Deer (*O. virginianus*) and Red Brocket (*M. americana*) (Figure 2). Locally named "venado encerado", the third deer species could be the subspecies *M. a. fuscata*, which is endemic to western Ecuador (Parker and Carr 1992). Local residents attested that hunting of White-tailed Deer occurs within the park, which was corroborated by our observation of a family hunting the species for subsistence. While this species is currently considered one of the most endangered mammals in Ecuador (Tirira 2011), it was detected at 35% of the sampling points and was the third most photographed species in the survey, which suggests that the population of MNP is resilient to current levels of hunting (Reyna-Hurtado and Tanner 2005). Loss of top predators like Puma (*Puma concolor*) and Jaguar (*Panthera onca*) may contribute to White-tailed Deer's high abundance in in the park (Ripple et al. 2014). In contrast, Red Brocket was photographed less than five times and may be threatened by overhunting and habitat degradation both within and outside the park. Further study is needed to clarify whether different subspecies

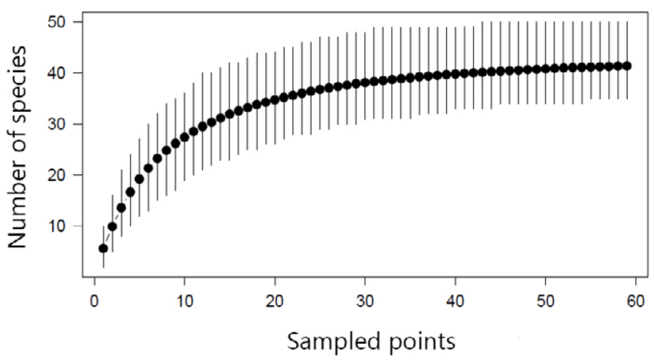

Figure 2. Accumulative species curve for PN Machalilla, data collected during 2015

of *M. americana* occur in MNP and to understand the factors affecting the population viability of this species.

Jaguar (*P. onca*) and White-lipped Peccary (*T. pecari*) have likely been eradicated not only from the park but the surrounding region, as the last report of either species in MNP was 18 years ago (Albuja 1997). MNP was probably their last available refuge in Manabí province. Local residents' opinions are mixed about the continued presence of Jaguars in MNP, with some arguing that they disappeared 20 years ago, while others suggest they still inhabit isolated areas of the park. However, we failed to capture any photographs or encounter tracks of the species even in remote areas. It is estimated that the available habitat for Jaguar has been reduced by 80% in western Ecuador due to deforestation (MAE and WCS 2014). Recent studies have confirmed its presence far to the north in Cotocachi-Cayapas Reserve of Esmeraldas province (Zapata-Ríos and Araguillin 2013) and to the south in Cerro Blanco Protected Forest of Guayas province (Saavedra 2009). But the species has not been confirmed to exist in the enormous expanse between these two areas for years. Loss of Jaguar may have significant cascading trophic effects such as diminished regulation of prey populations and secondary consequences on community structure and function (Jorge et al 2013; Ripple et al. 2014).

In the case of White-lipped Peccary, the three main areas of western Ecuador where the species was believed to remain were Cotocachi-Cayapas Reserve, Mache-Chindul Reserve, and MNP (Zapata-Ríos and Tirira 2011). However, as with Jaguar, the fact that no individuals of White-lipped Peccary were detected in the most remote areas of MNP, and considering the species normally appears in high densities, suggests it is now locally extinct. Loss of these species has important implications for seed dispersal and forest regeneration (Keuroghlian and Eaton 2008).

Although reported to occur throughout Ecuador's protected areas (Tirira 2007), the Puma (*P. concolor*) was neither detected in our survey nor in the previous studies of MNP. Some local residents maintain that Puma still occurs in the park, but it probably went extinct approximately 50 years ago due to habitat loss and hunting (MAE and WCS 2014). Even if Jaguar, Puma, and White-lipped Peccary persist in MNP, their numbers appear to be extremely low and are likely close to local extinction thresholds (Ochoa-Quintero et al. 2015).

Medium-sized wild cats like Ocelot (*L. pardalis*), Jaguarundi (*P. yagouaroundi*), and Margay (*L. wiedii*) seem to be abundant inside the park (Figure 2). Together these species were detected at more than 20% of the sampling points, which suggests occupancy rates comparable to those in other protected areas (Ahumada et al. 2013). However, during the five months of fieldwork

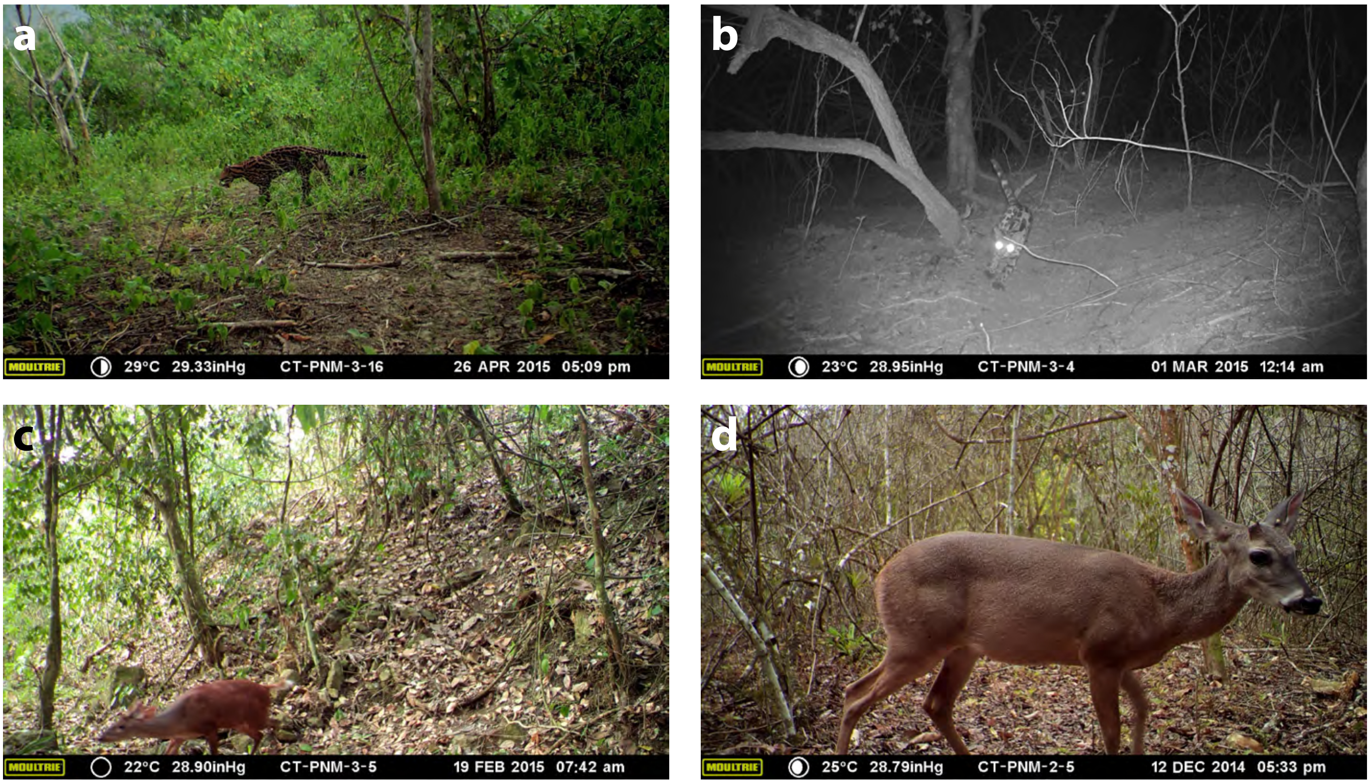

Figure 3. Photographs of 4 species identified in Machalilla NP: (**a**) Ocelot (*Leopardus pardalis*), (**b**) Margay (*Leopardus wiedii*), (**c**) Red Brocket (*Mazama americana*) and (**d**) White-tailed Deer (*Odocoileus virginianus*).

we encountered two fresh carcasses of Jaguarundi on the road located along the border of the park. Given the increased probability of road kills as tourism and urbanization increase along the Ecuadorian coast, we need further information on population dynamics and drivers of mortality for these species (Barthelmess et al. 2010; Freitas et al. 2015).

To ensure the role of Machalilla National Park as a refuge and source habitat for the biodiversity of the Tumbes-Chocó-Magdalena hotspot, collaboration between local communities, local governments, the Ministry of environment, researchers, and other stakeholders is needed for management planning and implementation. Management should be developed within an adaptive framework, in which stakeholders collaborate in an ongoing, systematic process of strategy creation and adjustment as circumstances change (Chazdon et al. 2009). Specifically, strategies promoting sustainable resource extraction, livestock management, and community monitoring and enforcement are needed (MAE-SNAP-GEF 2007). Moreover, the fate of Machalilla's wildlife is not independent from the surrounding landscape. Park management should be integrated with conservation, agricultural production, and sustainable rural livelihoods at a regional scale (Harvey et al. 2008). If these approaches are not taken, it will be difficult to ensure the health and continued presence of certain wildlife populations in the park. Promotion of environmental awareness and involvement of local communities in park management will go a long way toward mitigating the recent impacts of habitat degradation on the wildlife of MNP and ensuring biodiversity conservation in this important dry forest hotspot (Fiallo and Jacobson 1995).

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