Monitoring species of mammals using track collection by rangers in the Tilarán mountain range, Costa Rica

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ABSTRACT: Although monitoring of animal populations for informed decision making is fundamental for the conservation and management of biodiversity, monitoring programs are not widely implemented. In addition, monitoring plans often represent an economic burden for many conservation organizations. Here we report on the monitoring of five focal species of mammals in the Tilarán mountain range, Costa Rica. We used a participatory approach in which trained rangers of four institutions conducted trail surveys in an area of *ca* 50,000ha to determine the presence/absence of the paca (*Cuniculus paca*), collared peccary (*Pecari tajacu*), tapir (*Tapirus bairdii*), jaguar (*Panthera onca*) and puma (*Puma concolor*) using track collections. Permanent transects of 3 km were sampled on the same day every month in 2000-01 (141 km) and 2009-10 (303 km). Four of the five focal species were registered in our sampling. One of the most valuable outcomes of the study was the initiative of the rangers to train community members to participate in the monitoring plan. We believe that this participatory approach not only has great potential for the integration of rangers in long term monitoring, but also the incorporation of citizen science-based programs. Multi-institutional collaboration for species monitoring could reduce costs and increase the sampling effort.

Key words: *Citizen-science, Cuniculus paca*, endangered species, environmental education, Monteverde, *Panthera onca*, reserve management.

RESUMEN: A pesar de que el monitoreo de poblaciones animales para la toma de decisiones es fundamental para la conservación, los planes de monitoreo no son ampliamente implementados. Además, los planes de monitoreo a menudo representan una carga económica para muchas organizaciones. Este estudio presenta resultados del monitoreo de cinco especies de mamíferos de la Cordillera de Tilarán, Costa Rica. Guardabosques de cuatro instituciones realizaron muestreos de senderos en un área de aproximadamente 50.000 hectáreas para determinar la presencia/ausencia de tepezcuintle (*Cuniculus paca*), sahino (*Pecari tajacu*), tapir (*Tapirus bairdii*), jaguar (*Panthera onca*) y puma (*Puma concolor*) mediante la búsqueda de huellas. Usamos transectos permanentes de 3 kilómetros en 2000-01 y 2009-10. Cuatro de las cinco especies focales se registraron en nuestro muestreo. Creemos que este enfoque participativo no sólo tiene un gran potencial para la integración de los guardabosques en el monitoreo a largo plazo, sino también la incorporación de programas de ciencia-ciudadana.

Palabras clave: Ciencia-ciudadana, *Cuniculus paca*, especies amenazadas, educación ambiental, Manejo de reservas, Monteverde, *Panthera onca*.

The ongoing habitat degradation and the rapid loss of biological diversity in recent decades (Butchart et al., 2010) have prompted immediate conservation actions through the establishment of protected areas in various countries. This reactive strategy has resulted in the setting aside of 12,2% of the area of the terrestrial world for protection under different conservation categories (Chape et al., 2005). Some basic conservation actions often include delimitation of the areas and their direct surveillance. Casual or systematic inventories as well as long-term monitoring of species have been used to determine demographic parameters and to estimate temporal and spatial tends in population size (Pusey et al., 2007; Sinclair et al., 2007; Stoner et al., 2007). Although monitoring of animal populations for informed decision making is fundamental for the conservation and management of biodiversity (Kremer et al., 1994; Vaughan et al., 2003; Green et al., 2005; Lovett et al., 2007; Teder et al., 2007; Henle et al., 2013), monitoring programs are not widely implemented or are poorly executed (Lindenmayer &

Likens 2009; but see Schmeller et al., 2009). Also, monitoring plans often represent an economic burden for many conservation organizations, particularly in developing countries (Sheil, 2001; Bruner et al., 2004).

Since 1970 a handful of protected areas with similar conservation objectives but with different management strategies have been founded in the Tilarán mountain range, Costa Rica (Burlingame, 2000). Since their establishment, dozens of scientific studies have been conducted in these protected areas (Nadkarni & Wheelwright, 2000), and some attempts to implement monitoring programs have been launched (J. E. Arévalo, pers. obs.). Studies indicate that while deforestation and hunting pressures around the protected areas have decreased in the last three decades, poaching (G. Céspedes, pers. comm., Director of the surveillance program), habitat fragmentation and isolation continue to be a threat to some species (Wheelwright, 2000). The extent of these threats and their impacts on mammal populations is largely unknown, hindering the managers' ability to take effective conservation actions.

The objective of this study is twofold: 1) to determine the presence or absence of five threatened species of mammals and estimate their relative abundance and 2) to promote multi-institution collaboration as an important starting point for making informed conservation decisions. Through this approach, we build human capacity for the monitoring of wildlife in the protected areas and generate baseline information for informed conservation and management actions.

MATERIAL AND METHODS

Study site: Tilarán mountain range, located in northwest Costa Rica, comprises a complex system of protected areas and private landholdings (Fig. 1). Four protected areas are included in this study: Arenal Volcano National Park (AVNP: 12,124 ha), Alberto Manuel Brenes Biological Reserve (AMBBR: 7794 ha), Monteverde Cloud Forest Reserve (MCFR: 4025 ha) and Children's Eternal Rainforest operated by the Monteverde Conservation League (MCL: 22,500 ha). These protected areas account for ca 50,000 ha of continuous forest, with some other private properties with forest remnants embedded in them. Over half of the study area is administered by two private NGOs, the Tropical Science Center (Monteverde Cloud Forest Reserve) and the Monteverde Conservation League (Children's Eternal Rainforest) (Fig. 1). The rugged topography of the area and its elevational gradient contain a variety of plant associations within seven life zones (Holdridge, 1966; Haber, 2000). Elevation in the study area ranges from 474m to 1850m asl. Rainfall varies from moderate precipitation in the seasonal tropical moist forest on the Pacific slope (1950-3000 mm) to high precipitation in the lower montane rain forest on the Atlantic slope (3600-8000 mm) (Haber, 2000). The area hosts more than 121 species of mammals of which at least 58 are bats (Timm & LaVal, 2000).

Focal species: We used three criteria for the selection of the focal species: 1) species with variable home range size, 2) species that interact among themselves in ecological processes such as predator-prey dynamics, and 3) species that are known to be hunted by humans. The selected species from the smallest to the largest home range are: paca (*Cuniculus paca*), collared peccary (*Pecari tajacu*), tapir (*Tapirus bairdii*), puma (*Puma concolor*), and jaguar (*Panthera onca*) (Beck-King & Von Helversen, 1999; Sáenz et al., 1999; Rabinowitz & Nottingham, 1986). Pacas, collared peccary and tapirs are preyed by pumas and jaguars; and are traditionally pursued by poachers for their meet (Redford & Robinson, 1987; Carrillo et al., 2000; Wainwright, 2007). Likewise, jaguars and pumas are subject to predation by humans in retaliatory killings because these predators occasionally attack domestic animals (Quigley & Crawshaw, 1992; Carrillo et al., 2000; Daily et al. 2003; Treves & Karanth 2003; Wainwright, 2007).

Training workshops: We created a collection reference of plaster tracks of the five focal species using live animals at "La Marina" zoo to be used for training workshops and for future identification. Two workshops to train surveillance rangers and maintenance personnel in mammal monitoring techniques were designed. The first workshop covered the fundamentals of research procedures and monitoring protocols. The second workshop included the collection of plaster samples of the animal tracks, the identification of mammal tracks and the protocols to register and process the information collected. These were offered in 1999 and again in 2009 to the personnel of the four aforementioned protected areas. In 1999 a total of 21 people were trained, utilizing two stations located within the study area (Pocosol Field Station and San Gerardo Field Station). In 2009 we implemented the same workshop strategy to train 27 personnel members and local guides using the facilities and trails of the MCFR.

Sampling design: To facilitate the adoption of the monitoring protocol, and to avoid unwanted alterations in dense vegetation in the steep topography of the study area, we used for the basis of our study the many existing routes that are walked regularly or occasionally by the personnel of the protected areas. To determine the presence of the mammals along the existing routes, we used the indirect method of the passive collection of tracks. As a starting point, we carried out a general inventory of the potential presence of the focal species in the whole study area by surveying the routes and trails of field stations from November 1999 to May 2000. This inventory effort included 44 sampling events (6,3 ±3,9 per month) in 38 locations within 12 management sectors. This general inventory further enhanced the ability of the rangers to find and collect tracks and allowed us to obtain general information on species presence in the whole area.

From June 2000 to January 2001 (series 2000-01) we conducted the first systematic sampling that consisted of one permanent transect of 3 km on each of six trails for a total of 18km. The rangers searched for tracks in all transects in a single day once per month for a total of eight months (except on two occasions with one day of difference and one missing sample). The 47 surveys accounted for 141 km of effective systematic sampling in the first series. In 2009 (series 2009-10) we selected nine routes (four of the original plus five new ones) and established one permanent transect of 3 km on each trail. To obtain a more representative sampling of the heterogeneous forest types and geomorphology, we included transects that traversed overgrown vegetation, secondary and primary forest that varied in altitude from 539 m to 1661 m and covered five life zones (Holdridge, 1966). We sampled each of the nine transects in a single day once per month for a complete year (except for March 2010 when only two transects were sampled). We conducted 101 trail surveys accounting for 303 km of effective sampling.

To estimate the relative abundances of the focal species, we also used the indirect method of animal presence-absence through the passive collection of tracks along permanent transects (Sutherland, 2006). While this method may underestimate animal numbers in terms of population size (Beck-King & von Helversen, 1999), it is one that does yield good relative abundance figures (Carrillo et al., 2000). Since we could not know the number of individuals from multiple tracks along trails, we used the presence of the species as a record of at least one individual for each date of collection. The exception is for the collared peccary, which is a gregarious species, so one record represents a group. We calculated the relative abundance for each focal species as the average number of tracks per km using data from the systematic transects sampled, excluding the data from the general inventory.

Track collection: All the systematic surveys were conducted early in the morning and lasted for two to three hours. The rangers walked the trails with a slow pace looking for tracks on the trail and within approximately one meter on either side of the trail. Upon the sighting of a track, the rangers encircled the track with a plastic ring cut from any flexible plastic container or by placing twigs around it, mixed the dental plaster powder with water in a container till it reached a semiliquid consistency and poured the mix on the circled track. Once the plaster was dry the track was cleaned to allow the ranger to write the name of transect, species name (when known), date of collection and names of the collectors on the back of the plaster. Whenever possible, the rangers collected two or three plasters per species at each location to increase the chances of good quality samples for the species identification. All the tracks were cataloged with a consecutive number and stored. After the planned project time was completed, one of the authors (J. E. Arévalo) verified the species identification of track models, comparing each to the witness plaster sample of the known species reference and also following Reid (1997).

RESULTS

A total of 155 plaster track samples were collected during the general inventory, of which 101 belonged to four of the five focal species. The presence of pumas was recorded in all the 12 sectors, peccaries in nine, pacas in seven and tapirs in four. We identified at least 14 species of mammals during the general inventory (list in Appendix 1).

In the first systematic 2000-01 series we collected 160 plasters of which 131 represented the focal species. Peccaries and pumas were found in all the six permanent transects, pacas in five transects and tapirs only in two transects. For the latter, there were four records in transect Leonel Hernández and three in transect Bekom (Fig. 1). In the 2009-10 series, we collected 183 sample tracks, of which 153 belonged to the focal species. The presence of peccaries was recorded in all the nine transects, followed by the pumas in eight, the pacas in five and the tapirs in three.

The relative abundances of the species estimated in the 2000-01 and 2009-10 series place the peccary as the most abundant species, followed by the puma, the paca and the tapir as lowest (Fig. 2). Although the relative abundance for all species was lower 2009-10 compared

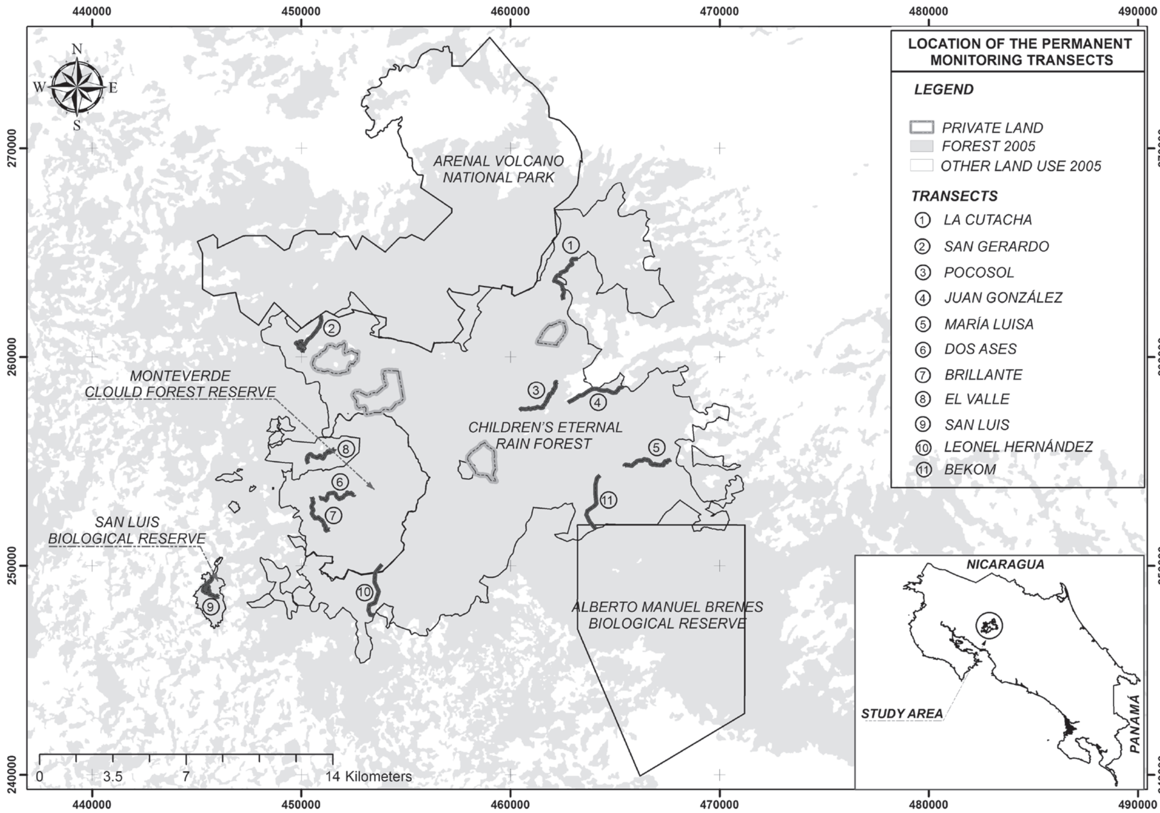

Fig. 1. Location of the protected areas and distribution of the permanent monitoring transects in the study area, Tilarán mountain range, Costa Rica.

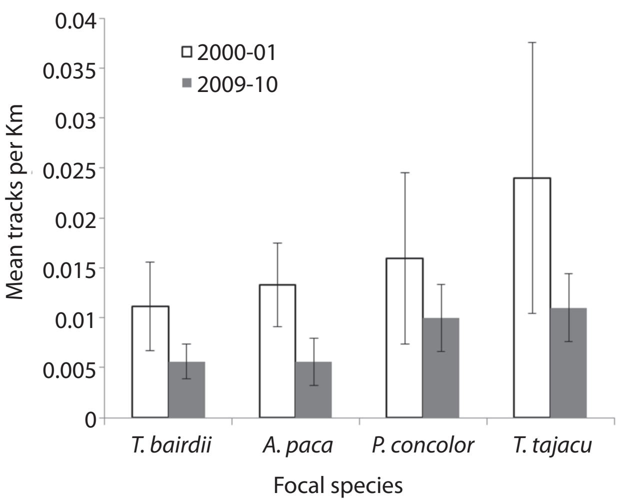

Fig. 2. Relative abundance of four focal species of mammal assessed by the average tracks per kilometer in permanent transects sampled over two time series in the Tilarán mountain range, Costa Rica. Vertical lines represent the standard deviation.

to 2000-01; the general trend in species abundances was similar.

During the 2009-10 series, changes in the relative abundance of the focal species varied by month showing defined peaks in all the species (Fig. 3).The abundance of the puma, peccary and paca tended to follow similar trends between October and January and between April and May, and the tapir shows a more variable pattern (Fig. 3).

DISCUSSION

We confirmed the presence of four of the five focal species in our study area (Appendix 1). The lack of jaguar records was unexpected, since the species has been documented for the study area (Hayes et al. 1983; Wilson 1983, Sáenz et al. 1999; Timm and LaVal 2000) and the rangers have previously heard about occasional sightings by locals (though not confirmed). However, recent

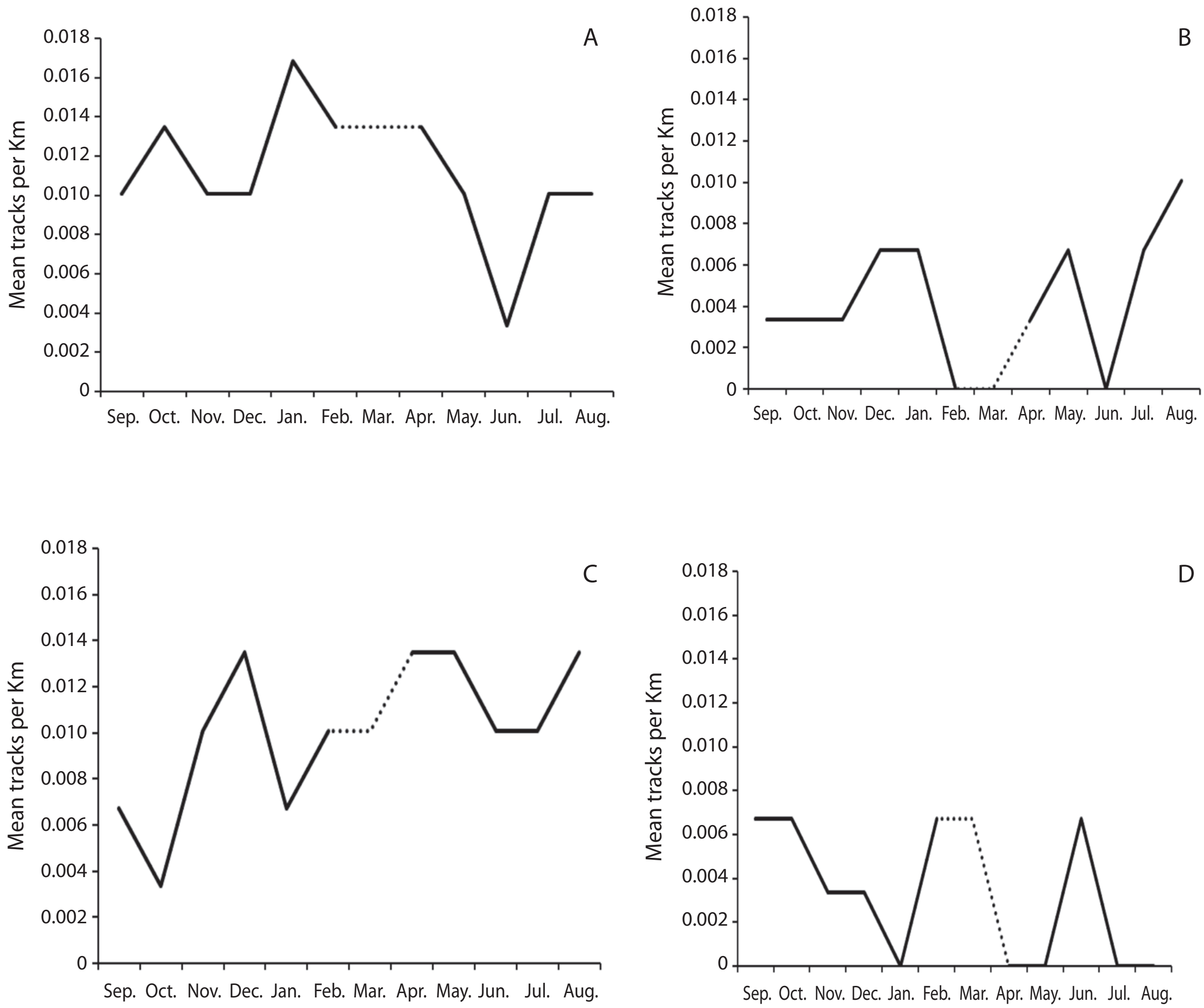

Fig. 3. Monthly relative abundance of the four focal species recorded in the Tilarán mountain range during 2009-2010. (A) Collared peccary (*T. tajacu*), (B) paca (*A. paca*), (C) puma (*P. concolor*) and (D) tapir (*T. bairdii*). Data for March (dotted line) is not presented because only two transects were surveyed in that month.

evidence has confirmed the presence of the jaguar in the area. A video and a series of photographs on February 8, 2012 and September 8, 2013 respectively, were obtained from camera traps (Stealth Cam) in Pocosol in the Children's Eternal Rainforest (Fig. 1). In addition, one of our trained rangers who co-authors this article (S. Vargas) found a track of a jaguar on December 14, 2013; and another video on January 11, 2015 within the Monteverde Cloud Forest Reserve recorded another individual (Fig. 1). All these recent findings prove that this species has not yet been extirpated from the protected area. As top predators, jaguars require large home ranges to search and find prey successfully. For instance, the size of home ranges for this species in Belize was estimated between 2800 and 4000 ha (Rabinowitz and Nottingham 1986), whereas in Pantanal Brazil it could be up to 9000 ha (Schaller & Crawshaw, 1980). Furthermore, Salom-Pérez et al. (2007) estimated a density of 7 jaguars per 10,000 ha in Corcovado National Park, Costa Rica. Based on this density and home range estimates, our study area of ca 50,000 ha of continuous forest could potentially support several individuals. Based on the recent jaguar records, we believe that some individual may still reach the relatively isolated area coming from other mountain ranges thus maintaining a low population density. In contrast, the puma was recorded in every month and in all but one of the surveyed transects during our study (Fig. 1 and Fig. 3). Pumas and jaguars are sympatric species that overlap throughout their tropical distribution range where they have similar habits and habitat area requirements (Schaller & Crawshaw, 1980; Rabinowitz & Nottingham, 1986; Reid, 1997). Evidence from elsewhere indicates that pumas are more tolerant to landscape changes and human intervention compared to jaguar (Timm & LaVal, 2000; De Angelo et al., 2011; Sollmann et al., 2012). For example, pumas have been recorded in areas subject to intense land use change with heavy forest fragmentation and where jaguars have been extirpated (Pacheco et al., 2006).

Of the three other focal species, the collared peccary was the most frequently registered species of potential prey for the pumas (Fig. 2 and Fig. 3). Peccaries are gregarious and have a widespread distribution that ranges from lowlands to 3000 m above sea level (Sáenz et al., 1999). In addition, peccaries take a great variety of food types and occupy both altered and pristine habitats (Sowls, 1983). The flexible condition of habitat use and diet may favor the permanence and relative high abundance of this species in the study area. In contrast, the abundance of pacas and tapirs was relatively low. Pacas have small home range and have been reported to be locally common. For instance, Beck-King & Von Helversen (1999) reported densities of up to 70 individuals per 100 ha in the pacific lowland of Costa Rica. Pacas in Costa Rica can occur from sea level to 3000 m, but their abundance may be influenced by freshwater bodies and food availability (Wainwright, 2007). The terrain in the higher elevation in the study area is very abrupt and with small creeks, whereas in lower elevations there are small valleys with wider rivers and some lagoons. Juan Gonzalez (Fig. 1) was the only site located in the tropical wet forest transition to premontane life zone, and is a site where most of the records were obtained. This site has a great portion of regenerating areas with guava trees (*Psidium guajava*) whose fallen fruits are consumed by pacas. Tracks of tapirs were found in only two life zones, the premontane wet forest and the lower montane rain forest. The specific sites, Bekom, Brillantes, Dos ases, El valle and Leonel Hernández range from 1260 to 1621 m of elevation (Fig. 1). The apparent association of this species to highland crests of the Tilarán mountain range was previously documented (Lawton, 2000). However, tapirs can potentially occupy habitats from sea level to the highest mountain range in Costa Rica, and usually near water (Wainwright, 2007).

Conservation implications: Our two systematic surveys yielded valuable information on the presence of four focal species and their relative abundances. However, even when the samplings covered several months and relatively extensive area, the surveys were not enough to detect the presence of the jaguar. This species was only detected afterwards product of the persistent track reports by the rangers. We believe that reliable information on specie presence and abundance can be obtained through long term monitoring plans with the direct involvement of the rangers. Our multi-institution approach derived in human capacity building over the years, allowing continues records of mammal tracks within the protected areas.

Data of relative abundance of mammals in only two time series such in this study is not sufficient to verify population trends. Thus, it is important to maintain periodic systematic surveys to produce good species abundance estimates. For instance, we cannot attribute the apparent decrease in the abundance of the species to any particular threat – like poaching - as estimates of abundance are highly variable and short in time. During our study, rangers reported pacas and peccaries as the most common mammals killed by poachers (unpublished information). However, poaching has significantly decreased in the Monteverde area and most of the poaching activities take place in the periphery rather than in the core protected areas (G. Alvarado, pers. obs.).

Strengthens and shortcomings: We acknowledge that the random selection of transects for the surveys is advised though not always feasible (Gibbs 2000). However, we present the following advantages of using pre-existing trails, for monitoring terrestrial mammals: (1) the rangers are very familiar with the trail routes facilitating the adoption of the practice; (2) the monitoring activities actually enhance the surveillance of the area by rangers while sampling is conducted; (3) when the terrain is very steep, tracks are not well marked for good identification; and (4) many mammal species use the human-made trails leaving tracks on mud (this is not usually the case in the forest floor that is covered by thick leaf litter).

The accuracy of the indirect method of assessing mammal abundance by track could be influenced by the weight of the animal or prolonged dry conditions that may reduce print detection. Thus, we propose to combine track surveys with camera traps in order to increase the accuracy of abundance estimates. In addition, the participation of multiple observers in the study could influence detectability in different areas. Thus, we propose to maintain the standard protocol we used in our study along with regular training workshops of the rangers and management personnel. The incorporation of volunteers aids to reduce costs and enhances educational outreach. Successful monitoring programs through volunteers have been conducted in other countries (Harris & Yalden, 2004; Kindberg et al., 2009). In our case, the rangers also trained eight volunteers and two naturalist guides that helped with the track collection thus minimizing cost and promoting conservation actions. In addition, the accumulated plasters of the species are being used in many schools as material to promote the conservation of endangered species.

We believe that multi-institutional collaboration involving citizens, rangers and scientists, generates synergism in conservation and environmental education efforts. The approach presented here can improve and promote conservation and management tasks in three main ways: 1) Reduction of direct costs, 2) Increase sampling efforts thus covering more area, and 3) enhance education with the active participation of local citizens.

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APPENDIX 1

List of identified species using track plaster samples collected by maintenance and protection personnel of the different conservation institution during 1999-2001 in the Tilarán mountain range, Costa Rica

Scientific name	Common name	Focal species
Cuniculus paca	Paca	Yes
Canis latrans	Coyote	No
Didelphis sp	Opossum	No
Dasyprocta punctata	Agouti	No
Dasypus novemcinctus	Armadillo	No
Eira barbara	Tayra	No
Leopardus pardalis	Ocelot	No
Leopardus wiedii	Margay	No
Mazama americana	Red Brocket Deer	No
Nasua narica	Coati	No
Procyon lotor	Raccoon	No
Puma concolor	Puma	Yes
Tapirus bairdii	Tapir	Yes
Pecari tajacu	Collared Peccary	Yes