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Original contribution

RELATIVE ABUNDANCE OF MAMMALIAN SPECIES IN A CENTRAL PANAMANIAN RAINFOREST

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Abstract
Mammals are understudied in the Neotropics with very little baseline distribution and abundance data available for many species. We quantified relative abundance of mammal species in central Panama during December 2005-April 2006. A total of 221 images of 16 mammal species (13 prey species and three predator species) were recorded. The Agouti (*Dasyprocta punctata*) had the highest relative abundance at 38.0% followed by the Coati (*Nasua narica*) at 22.2% and the White-tailed Deer (*Odocoileus virginianus*) at 16.3%. Relative abundance of predators was 1.8%, 1.4%, and 0.5% for Coyote (*Canis latrans*), Ocelot (*Leopardus pardalis*), and Jaguarundi (*Puma yagouaroundi*), respectively. Predator:prey ratios were 59.5 kg prey/kg felid and 25.1 kg prey/kg Coyote. The capture rate and number of species detected were comparable to other studies conducted in similar tropical habitats outside of the study region. These data provide useful baseline information for wildlife conservation activities in Panama.
Key words: camera-traps, mammalian diversity, Panama, wildlife populations

Abundancia relativa de mamíferos en una selva tropical del centro de Panamá
Resumen
Los mamíferos han sido escasamente estudiados en el Neotrópico, existiendo escasos datos de distribución y abundancia para muchas especies. Este estudio cuantifica la abundancia relativa para distintas especies de mamíferos en Panamá central, en el período comprendido entre diciembre de 2005 y abril de 2006. Fueron registrados un total de 221 fotos de 16 especies de mamíferos (13 especies de presas y tres especies de predadores). El Agoutí (*Dasyprocta punctata*) presentó la abundancia relativa más alta con 38,0%, seguido por el Coatí (*Nasua narica*) con 22,2% y el Venado de cola blanca (*Odocoileus virginianus*) con 16,3%. La abundancia relativa de las especies de predadores fueron 1,8%, 1,4% y 0,5% para el Coyote (*Canis latrans*), el Ocelote (*Leopardus pardalis*) y el Jaguarundí (*Puma yagouaroundi*), respectivamente. La relación predador:presa fue de 59,5 kg presa/kg felino y 25.1 kg presa/kg Coyote. La tasa de captura y el número de especies detectadas fue comparable con otros estudios realizados en otros hábitats tropicales fuera de Panamá. Estos datos proveen una buena línea de base para la conservación de la vida silvestre de Panamá.
Palabras Clave: cámaras-trampa, diversidad de mamíferos, Panamá, poblaciones de fauna silvestre

Introduction

Mammals play an important role in tropical ecosystems as seed dispersers, herbivores, and prey (Redford 1992, Terborgh & Wright 1994, Asquith *et al.* 1997). Even with these important roles, mammals are understudied in the Neotropics with very little baseline distribution and abundance data available for many species (Urquiza-Hass *et al.* 2009). Studies have occurred in South America to determine the presence and relative abundance of mammalian species (Medellin 1994, Trolle & Kery 2005, Martins *et al.* 2007, Urquiza-Hass *et al.* 2009) but such studies are rare for Central America. Having species inventories for specific geographical areas in the tropics has been cited as an urgent research priority in

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order to adequately protect areas with high biodiversity, endemism, or areas of imminent destruction (Soule & Kohm 1989). In addition, assessing protected areas to determine if they are meeting conservation goals requires monitoring population trends of species present, and changes in trends should be documented (Carrillo *et al*. 2000).

One of the most cost-effective methods for monitoring secretive mammalian species is the use of camera traps. Cameras traps are less invasive, time consuming, and cheaper than other methods, thus providing an advantage over other research techniques (Cutler & Swann 1999). Camera traps have been used to quantify presence and relative abundance of rainforest mammals (Sadighi *et al*. 1995, Brooks 1996, Martins *et al*. 2007). Cameras also have been used by researchers to estimate population density and relative abundance of wildlife species (Jacobson *et al*. 1997, Karanth & Nichols 1998, Nielsen & McCollough 2009). In addition to population parameters and presence of species, cameras have been used to assess feeding ecology and activity patterns of wildlife (Grundel 1990, Moreno *et al*. 1995, Pierce *et al*. 1998, Springer *et al*. 2011).

The Republic of Panama requires information on status of mammalian populations to forward conservation initiatives. Currently 35 terrestrial mammals defined as endangered or threatened occur in Panama with little data existing on their abundance and distribution (CITES 2010). Specifically, local biologists are interested in quantitative assessments of relative abundance for: (1) deer [e.g., White-tailed Deer (*Odocoileus virginianus*) and Red-brocket Deer (*Mazama americana*)], (2) felids [e.g., Ocelot (*Leopardus pardalis*)] and (3) Coyote (*Canis latrans*). Deer and felid species represent important native prey and predator species, respectively, in Panama and throughout the Americas.

Ocelot studies have been conducted in other portions of the Neotropics with density estimates ranging from 0.12/km^2 (Dillon & Kelly 2008) in Central America to 0.56/km^2 in South America (Trolle & Kery 2005). Currently, Coyote populations appear to be growing and expanding in distribution in Panama, but the actual distribution and abundance of the Coyote is unknown. Coyotes have been known to outcompete other carnivore species (Litvaitis & Harrison 1989, Moruzzi *et al*. 2002, Livaitis *et al*. 2006) and may pose a new challenge to the conservation of native species in Panama.

We conducted a brief camera trapping survey during 2005-2006 to provide baseline information on the relative abundance of mammals in central Panama. Our first objective was to determine relative abundance and density of mammalian species captured by camera traps, focusing on deer, felids, and coyotes as species of special concern. Our second objective was to calculate predator:prey ratios (Shaller 1972, Emmons 1987) using these data to assess availability of prey items to predators on the study area.

Materials and methods

Study area

This study occurred at the 404-ha Ecoparque Panama protected area, located in central Panama, 16 km west of Panama City (Weaver 2009; Figure 1). The general area consists of the former Howard Air Force Base, Rodman Naval Station, and the Kobe Army Base. The study area receives 260 cm of rainfall annually with 90% occurring during the wet season (May-December; Robinson *et al*. 2000). Average temperatures range between 25o C and 27o C. The area consists of 77% tropical forest and 23% is a mixture of nonnative grasses, shrubland, marsh, and Department of Defense facilities (Asociación Nacional para la Conservación de la Naturaleza [ANCON] 1996). Forested portions consist primarily of semideciduous seasonal forest with three sub-classes: tall forest, mixed forest, and low forest. The dominant tree species include Spanish Elm (*Cordia alliodora*), Yellow Plum (*Spondias mombin*), Trumpet Tree (*Cecropia peltata),* and Cuipo (*Cavanillesia platanifolia*).

Methods

Relative abundance of mammalian species was assessed using remote cameras during 1 December 2005 – 30 April 2006. Two types of digital remote cameras (n = 20) were used, the Cuddeback 3 mega pixel NF4300 no-flash and the Moultrie 1.3 mega pixel NFH-DGS-100 infrared trail camera. Cameras were set to operate 24 hours a day, with a picture interval of 1 minute, and were checked on a weekly basis to remove memory cards and replace batteries when necessary. Cameras were placed 1 m off the ground on trees and all vegetation and debris were cleared from the field of view (Nielsen & McCullough 2009). Cameras were unbaited and placed on game trails.

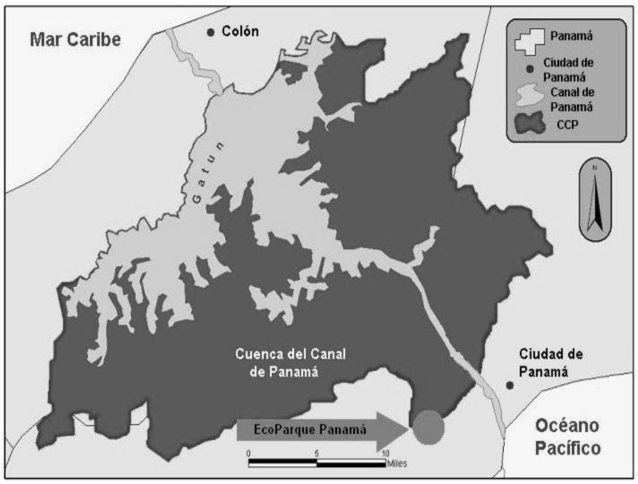

Figure 1. Location of study area in central Panama, 2005-06

To reduce the likelihood of sampling the same individuals repeatedly, it was assumed only one individual per species could be captured at each camera-trap location during any 24-hour period. The exception to this was if there was more than one individual captured during a capture event or if individuals could be identified by pelage patterns (Martins *et al.* 2007). This count was referred to as the 24-hour count. To get an understanding of capture rates for each species we divided the sum of the 24-hour count for each species by the total number of 24-hour periods sampled. Relative abundance was calculated by taking the total number of pictures of a given species during the 24-hour periods divided by the total number of pictures during the 24-hour periods for all species and multiplied by 100 to turn this value into a percentage for easier interpretation. To determine the density of each species on the study area, we used the calculated abundances for all species and divided them by the total sampling area (404 ha; Karanth & Nichols 1998). We recognize that using this area for all calculations may result in biased estimates of density, specifically overestimating density by using an area that is likely smaller than the coverage of the study.

We calculated the kg prey/kg predator ratio (Schaller 1972, Emmons 1987) for animals observed at Ecoparque Panama; prey was considered those species potentially depredated by the predators we observed. We classified the Ocelot, Jaguarondi (*Puma yagouaroundi*), and Coyote as predators and assigned prey using diets of the predators (Emmons 1987, de Oliveira 1998, Hidalgo-Mihart *et al.* 2001, Bianchi *et al.* 2011). We considered the Agouti (*Dasyprocta punctata*), Coati (*Nasua narica*), Collared Peccary (*Tayassu tajacu*), Common Opossum (*Didelphis marsupialis*), Tapeti (*Sylvilagus brasiliensis*), Nine-banded Armadillo (*Dasypus novemcinctus*), Northern Tamadua (*Tamandua mexicana*), Paca (*Agouti paca*), Raccoon (*Procyon lotor*), Red-brocket Deer, Red-tailed Squirrel (*Sciurus granatensis*), Tome's Spiny Rat (*Proechimys semispinosus*), and White-tailed Deer as potential prey items. We calculated prey weight in two ways. For one calculation we limited prey items to that of small prey items (< 24 kg); White-tailed Deer and Red-Brocket dDeer were excluded from these calculations. We removed potential large prey items (> 24 kg) because we did not believe the predators would target prey items this large on a consistent basis. To calculate the kg of small prey available, the average weight of each prey species (Emmons 1997) was multiplied by the total number of captures of each species in the 24-hour trapping intervals, then all weights of prey species were combined (Schaller 1972). The same method was used to estimate the weight of large prey and the predators. We calculated two separate kg prey/kg predator ratios; a felid ratio which excluded the Coyote and an overall predator ratio that included the Coyote. This was done to gain insight into the potential impact of the newly colonizing Coyote into the area. The total for small prey species then was divided by predator species (small prey kg/kg predator) and compared to suggested ratio boundaries for felids (Schaller 1972, Emmons 1987). Since the cited method for calculation of kg prey/kg predator used all potential prey items, a separate ratio including both deer species were calculated to understand the potential impact on the ratio with the inclusion of these larger herbivores which may be taken by predators we observed, especially as fawns (Litvatius & Bartush 1980, Vreeland *et al.* 2004, Rohm *et al.* 2007).

Results

During the five-month period we recorded 221 24-hour photos of 16 mammalian species (Table 1). A total of a 175 images of 11 different small prey species and eight images of three predator species (four coyotes, three ocelots, and one jaguarundi) were documented. White-tailed Deer had a much higher relative abundance (16.9%) than the Red-brocket Deer (0.9%). The density of White-tailed Deer was estimated at 8.9 individuals/km^2 and Red-brocket Deer at 0.5 deer/km^2. Relative abundance for the predator species was 1.8%, 1.4%, and 0.5% for the Coyote, Ocelot, and Jaguarundi, respectively. The Coyote had the highest density estimate at 1 coyote/km^2, with Ocelot being second highest at 0.7 ocelots/km^2, and the Jaguarundi having the lowest density estimate at 0.3 jaguarundi/km^2. The ratio of felid predator: small prey was estimated to be 23.6 kg small prey/kg felid predator. When the Coyote was added to the estimate, the result was 9.9 kg small prey/kg predator, showing a decrease of 13.7 kg small prey/kg predator. When the two deer species were included in the calculations, ratios were 60.9 kg prey/kg felid and 25.7 kg prey/kg predator respectively.

Table1. Totals of mammal species and their respective relative abundance and capture rates via remote camera survey in central Panama, 2005-06.

Species	Common name	Total	24 h*	Pics/day	% Rel.ab.
Nasua narica	Coati	51	49	0.0213	22.17
Didelphis marsupialis	Common Opossum	9	4	0.0017	1.81
Leopardus pardalis	Ocelot	3	3	0.0013	1.36
Procyon lotor	Raccoon	1	1	0.0004	0.45
Dasyprocta punctata	Agouti	125	84	0.0351	38.01
Tamandua mexicana	Northern Tamandua	3	3	0.0013	1.36
Odocoileus virginianus	White-tailed Deer	65	36	0.015	16.29
Mazama americana	Red-brocket Deer	3	2	0.0008	0.90
Tayassu tajacu	Collared Pecary	24	21	0.0087	9.50
Agouti paca	Paca	9	7	0.0029	3.17
Sciurus granatensis	Red-tailed Squirrel	1	1	0.0004	0.45
Dasypus novemcinctus	Nine-banded Armadillo	1	1	0.0004	0.45
Proechimys semispinosus	Tome's Spiny Rat	4	3	0.0013	1.36
Canis latrans	Coyote	5	4	0.0017	1.81
Sylvilagus brasiliensis	Tepati	1	1	0.0004	0.45
Puma yagouarundi	Jaguarundi	1	1	0.0004	0.45
TOTAL		**306**	**221**	**0.981**	**1.00**

* Number of photos of the total that were uniquely identifiable during any 24-hour period

Discussion

The 16 mammalian species (13 predator species and three prey species) documented during this camera study is similar to other studies in the Neotropics (Trolle 2003, Martins *et al.* 2007). The capture rate (0.10 pictures/day) and predator abundance (3.6%) was also similar to Martins *et al.* (2007), who reported a capture rate of 0.08 pictures/day. They also found a high prey to predator abundance ratio, with a cumulative relative abundance of Puma (*Puma concolor*), Jaguar (*Panthera onca*), and ocelots of 5%.

Relatively few studies have assessed densities of White-tailed Deer in the Neotropics. Estimated ranges of 1.6 - 27.6 deer/km^2 have been found in tropical dry forests in Mexico (Mandujano & Gallina 1995, Conception Lopez-Tellez *et al.* 2007). Our estimate of deer density in central Panama (8.9 individuals/km^2) is within this range, and intermediate when compared to the 3-37 deer/km^2 in rural areas of North America (Woolf & Roseberry 1998, Rooney 2001, Winchcombe & Ostfeld 2001).

Red-brocket Deer is distributed from southern Mexico to northern Argentina with densities commonly estimated at 1/km^2 (Branan & Marchinton 1985, Ojasti 1996). Abundances of the Red-brocket Deer in Bolivia have been cited between 0-7.2 individuals/km^2 but are likely on the lower end of this estimate (Rivero *et al*. 2004). Densities in Peru were 1.1 deer/km^2 in a hunted area and slightly lower in an unhunted area (Hurtado-Gonzales & Bodmer 2004). Our density estimate of 0.49 deer/km^2 corresponds to the lower end of these ranges.

We detected two felid species in our survey, which is slightly fewer than other pertinent camera surveys (Trolle 2003, Martins *et al*. 2007). Our estimate of Ocelot density in central Panama was 0.7 ocelots/km^2, which is slightly higher than the estimates of Trolle & Kery (2005) who estimated 0.56 ocelots/km^2 in Brazil. Our estimate is also higher than Lundlow & Sunquist (1987) telemetry study estimate of 0.38 ocelots/km^2 and the estimates of 0.12/ km^2 - 0.25/km^2 of Dillon & Kelly (2008) for Belize. However, our estimate is lower than González-Maya & Cardenal-Porras (2011) estimates of 0.64/ km^2 - 1.02/ km^2 in Costa Rica. Our estimate of 0.3 jaguarundi/km^2 is the only density estimate for the species we could find in the literature; however this estimate is likely high because of previous work suggesting this species has a very large home range (Konecny 1989, Caso 1994).

The use of predator/prey ratios allows for insight into the health of an ecosystem. Schaller (1972) suggested that a healthy ecosystem will have a 94-301 kg prey/kg predator ratio. Although these ratios were created for lions in Africa, the ratios have proved to be equally useful for studies of ocelots, pumas, and jaguars (Emmons 1987). The ratio that we calculated for only felid predators on our study area was 23.6 kg prey/kg felid. When the coyotes were added, the ratio decreased to 9.9 kg prey/kg predator and indicated that our study area had a vastly lower prey biomass than the suggested boundaries. When the two deer species were included in the prey calculations, the ratios were 60.9 kg prey/kg felid and 25.7 kg prey/kg predator, respectively. Even with the inclusion of much larger prey items, these estimates are still below the suggested range for a healthy ecosystem by Schaller (1972). A shortfall exists in the sampling method used because potential small prey items for the predators in central Panama (i.e., rodents and birds; Emmons 1987) were likely not detected by remote cameras, causing an underestimate in the number of prey available.

The Coyote's presence doubles the number of predators competing for prey in the region and more than doubles the prey:predator ratio. Since the Coyote competes for the same prey base as the felids, and may in fact outcompete them in some instances (Litvaitis & Harrison 1989, Moruzzi *et al*. 2002, Livaitis *et al*. 2006), the newly colonizing Coyote adds another ecosystem dynamic that will affect predator and prey populations. Their extreme adaptability to man given increasing human development may be a possible cause of the expansion of the coyote into Panama (Vaughan 1983, Sosa-Escalante *et al*. 1997). This expansion is likely to continue as development continues throughout Central America. Implications of Coyote presence in the region may be interesting to researchers in the future especially since coyotes are known to prey heavily upon fawns (Litvatius & Bartush 1980, Vreeland *et al*. 2004, and Rohm *et al*. 2007) and therefore may affect deer populations.

Conclusions

We provide preliminary estimates of relative abundance of mammalian wildlife in central Panama. We report a species composition similar to other Neotropical regions, but note the increasing presence of the coyote, which may have profound effects on the ecosystem given the reduction of larger carnivore populations (e.g., puma and jaguar) during the past century (Cougar Management Guidelines Working Group 2005, Paviolo *et al*. 2008). Other researchers may use these initial analyses to focus more intensive studies of predators and prey in Central America.

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