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ORIGINAL ARTICLE

Common opossum population density in an agroforestry system in Bolivia

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ABSTRACT

The common opossum, *Didelphis marsupialis* thrives near human settlements. Understanding its ecology could help planning management decisions about this species, especially in anthropogenic landscapes. Yet, there are no density estimations for this species throughout its distribution range in Bolivia. We estimated the density of *D. marsupialis* in a rural agricultural community, where agroforestry plantations and fallows cover most of the land. We counted individuals in line transects and used DISTANCE software to calculate density. We covered a total of 70.21 km in 143 night counts, obtaining 38 records of *D. marsupialis.* We estimated a density of 0.30 individuals ha^{-1} (SE = 0.062; range: 0.20 - 0.45 individuals ha^{-1}), with a mean encounter rate of 0.54 individuals km^{-1}. Encounter rate varied between habitats, with mean values of 0.20 in secondary forests and 0.64 in agroforestry plantations. Our density estimate is near the lower range of previously reported values for the common opossum in other countries. We argue that our results may reflect the response to the availability of food resources and predation pressure in agroforestry plantations.

KEYWORDS: *Didelphis marsupialis*, tropical agroecosystems, line transect, DISTANCE sampling

Densidad de carachupas en un sistema agroforestal de Bolivia

RESUMEN

La carachupa, *Didelphis marsupialis* prospera cerca de asentamientos humanos. Entender la ecología de una población puede ayudar a tomar decisiones de manejo de esta especie, especialmente en paisajes antropogénicos. Sin embargo, no existen estimaciones de la densidad de esta especie en todo su rango de distribución en Bolivia. Este estudio estimó la densidad de *D. marsupialis* en una comunidad agrícola, donde los sistemas agroforestales y barbechos cubren la mayoría de la tierra. Empleamos conteos en transectos lineales y usamos el programa DISTANCE para calcular la densidad. En total recorrimos 70.21 km en 143 noches de conteo y obtuvimos 38 registros de *D. marsupialis*. Estimamos una densidad de 0.30 individuos ha^{-1} (SE = 0.062; rango: 0.20 - 0.45 individuos ha^{-1}) y una tasa de encuentro promedio de 0.54 individuos km^{-1}. La tasa de encuentro varió entre hábitats, con valores promedio de 0.2 para bosque secundario y 0.64 para sistemas agroforestales. Nuestra estimación de densidad se encuentra cerca de los valores más bajos antes reportados para la especie en otros países. Creemos que nuestros resultados reflejan la respuesta a la disponibilidad de recursos en sistemas agroforestales y la presión de depredación en nuestro sitio de estudio.

PALABRAS-CLAVE: *Didelphis marsupialis*, agroecosistema tropical, transecto lineal, muestreo con DISTANCE

INTRODUCTION

The common opossum, *Didelphis marsupialis* Linnaeus 1798, is a medium-sized nocturnal mammal that occurs from Mexico to northeastern Argentina, as well as Trinidad and the Lesser Antilles, from sea level to about 2000 m (Rocha and Rumiz 2010). It is a common species across its distribution range, and thrives well near human settlements and croplands (Rocha and Rumiz 2010). It feeds mainly on insects, fruits, small vertebrates, and occasionally on pollen and nectar (Julien-Laferriere and Atramentowicz 1990; Cáceres 2002; Ceotto *et al.* 2009). The common opossum is used in some regions as game meat, but it can also be considered as a harmful species by farmers, because it preys on poultry (Bezerra-Barros and de Aguiar-Acevedo 2014; Astua de Moraes *et al.* 2016).

Population density is one of the most important ecological parameters to understand ecosystems and to apply management strategies (Ojasti and Dallmeier 2000; Pramod *et al.* 2012). Despite the common occurrence of *D. marsupialis* in human-influenced tropical habitats, there are no recently published density estimates of this species in Bolivia (Rocha

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and Rumiz 2010). Most estimates were carried out in Central America during the 1980s and 1990s, using trap grid methods (e.g. Atramentowicz 1986; Sunquist *et al*. 1987; Julien-Laferriere 1991). Trap capture (live-trapping) is the most used method for studying marsupials because they are supposedly less prone to under-estimating density and abundance, as compared to other methods such as transect counts. The latter method depends on the probability of detection (i.e. the capacity of detecting an animal), which decreases with the distance between the observer and the animals (Thomas *et al.* 2013; Fauteux *et al*. 2018). Line transect counts are mainly used for estimating the density of large animals (Thomas *et al*. 2013; Hoffmann *et al*. 2010). Yet, comparative studies suggest that line-transect counts may be as reliable as grids for evaluating *Didelphis marsupialis* populations (Emmons 1984), and have been used in other studies on mammals (e.g. Chiarello 2000).

The highest density values of the common opossum were reported for the *llanos* of Venezuela (0.25 – 2.75 individuals ha^{-1}; O'Connell 1979 in Sunquist *et al*. 1987), whereas lower estimates were reported in selectively logged forests in Peru (0.13 – 0.30; Emmons 1984). Densities in primary and secondary forests of French Guiana, Panamá and Brazil ranged from 0.07 to 1.32 individuals ha^{-1} (Charles-Dominique *et al*. 1981; Atramentowicz 1986; Malcolm 1990; Julien-Laferrier 1991). Somewhat higher figures, between 0.8 – 2.2 and 0.9 – 2.0 individuals ha^{-1}, were found in human-influenced savannas and gallery forest of Brazil and Venezuela, respectively (Cáceres and Monteiro-Filho 1998; Sunquist *et al*. 1987; O'Connell 1989).

Density estimations for *D. marsupialis* in agroecosystems are absent in the literature. Agroecosystems in the lowland tropics are highly diverse, varying from monocultures (simplified crops) to diversified agroforests. Agroforests are a common type of agriculture in the Alto Beni region of Bolivia (Benavides *et al*. 2017). It has been suggested that these crop systems offer suitable foraging and dispersing habitats for several mammalian species, likely due to their structural complexity, which resembles a forest more than conventional crops, and provide food resources throughout the year (Gallina *et al.* 1996; Nyhus and Tilson 2004; Perfecto and Vandermeer 2008; Altieri 2009; Cassano *et al*. 2012). If resources for the common opossum are abundant within agroforestry plantations, it is reasonable to expect high population densities. We report the first density estimate of the common opossum in an agroforest at the piedmont area of the Bolivian Amazonian region. As information on our study area is very scarce, we also provide encounter rates for other mammalian species for which a density estimate was not possible.

MATERIAL AND METHODS

The study was conducted at Remolinos (15°41' – 15°42´S, 67°04' – 67°06'W), a rural agricultural community within the Palos Blancos municipality, La Paz department, Bolivia. The community encompasses about 2000 ha of mountainous terrain, at a mean elevation of 450 m. Undisturbed vegetation and secondary forest patches are representative of Amazonian and sub-Andean forests, with species such as *Brosimum* sp. (Moraceae), *Hura crepitans* (Euphorbiaceae), *Otoba parvifolia* (Myristicaceae), among others (Quintana and Vargas 1995). Trees are younger in the secondary forest, around 20 – 30 years old (C. Benavides, pers. obs). However, agroforestry plantations and fallows cover most of the community's lands. Fallows are dominated by various families of shrubs and pioneer tree species, such as *Cecropia* spp., *Ochroma pyramidale,* and various species of *Inga* (PIAF-El CEIBO 2002). Crops are varied and mainly under successional agroforestry systems, combining rice, corn, watermelon, banana, squash, manioc, peanuts, papaya and different species of *Citrus.* Cacao (*Theobroma cacao*) is the most common commercial crop, and 40% of its production is organic (Jacobi *et al*. 2014). Trees such as *Swietenia macrophylla*, *Amburana cearensis*, and *Cedrela odorata* (Quintana and Vargas 1995) are being regrown within crop areas with trees up to around 20 years old. Several species of palms and fruit trees (e.g. *Attalea phalerata*, *Averrhoa carambola*) are kept and planted in home orchards for local consumption (Benavides *et al*. 2017).

Between March and November 2012, we used line transect counts to estimate the density of pacas (*Cunniculus paca*) for another project (Benavides *et al*. 2017), following the DISTANCE sampling approach (Laake *et al*. 1996; Ruette *et al*. 2003; Thomas *et al*. 2013). During the counts, we also spotted other mammalian species, including the common opossum, which was the most frequently observed animal. This species was easily detected and individuals were less wary than other animals (e.g. *Dasypus novemcinctus*).

We established transects based on the participation of farmers in the project. We set nine different transects, ranging from 0.25 to 1.5 km in length (Table 1). Six transects were placed in agroforestry systems, one traversed a small portion of a grassland (with patches of trees) and a secondary forest, and the last two were placed through secondary forest patches. The overall size of the sampling area was ~650 ha. Agroforestry plantations represented 70% of the sampling area and the other 30% was considered as secondary forest, including the transect that traversed the grassland (Figure 1.). The total transect lengths were 2.5 km in agroforestry plantations and 2.3 km in secondary forests. The survey effort in agroforestry plantations totaled 54 km (112 surveys), whereas the effort in secondary forests amounted to 15.4 km (31 surveys) (Table 1). Transects were separated at least 250 m from each other; based on the home-range size of *C. paca* (i.e. ± 4 ha, Beck-King

Table 1. Transect length and sampling effort in each habitat type surveyed for common opossum, *Didelphis marsupialis* in Remolinos, Bolivia. C = cropland (agroforestry plantations), G = grassland, SF = secondary forest.

Trail	Length (km)	N surveys per transect	Effort (km)	N animals observed	Habitat type	Encounter rate
1	0.36	8	2.88	5	C	1.74
2	0.25	30	7.50	6	C	0.80
3	0.36	8	2.88	4	C	1.39
5	0.46	2	0.92	1	C	1.09
6	0.79	45	35.55	11	C	0.31
8	0.27	19	5.13	8	C	1.56
Sub-total	**2.49**	**112**	54.86	35		**0.64**
4	0.55	17	9.35	2	G-SF	0.21
7	1.50	2	3.00	1	SF	0.33
9	0.25	12	3.00	0	SF	0.00
Sub-total	**2.30**	**31**	**15.35**	**3**		0.20
TOTAL	4.79	143	70.21	38		0.54

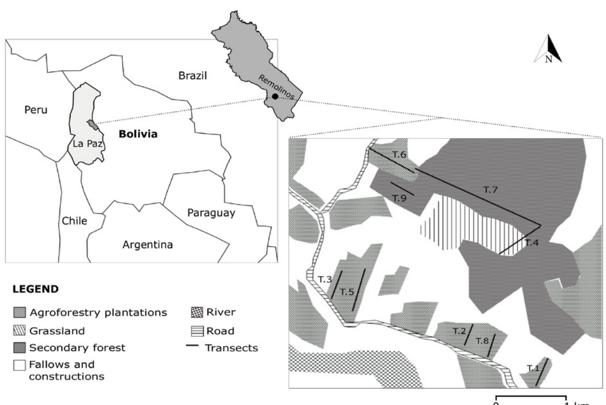

Figure 1. Location of the study area in Bolivia, and distribution map of the sampling-line transects (T.1-T.9) for common opossum, *Didelphis marsupialis* and main land-cover types within the study area in the community of 'Remolinos' in the East of the department of La Paz-Bolivia..

et al. 1999). Considering that the home range for common opossums varies between 0.2 and 16.3 ha (Sunquist *et al.* 1987; O'Connell 1989; Cáceres and Monteiro-Filho 2001; Sanches *et al.* 2012), the distance between transects allowed for the possibility of recording the same individual twice in the same transect. However, only four or five transects were surveyed each night, following a different sequence each time. Additionally, we used data from transects on our way back to the camp only when no observations were made on the first passage and, as pointed above, common opossums usually walked away slowly when detected.

In total, 70.21 km were covered in 143 night counts between sunset and 5:00 a.m., which includes the activity period of *D. marsupialis* (Sunquist *et al.* 1987). Surveys were done walking at a speed of <1 km h^{-1}, avoiding making noise, while searching for individuals on both sides of the trail, stopping from time to time to listen. When an animal was spotted, we identified the exact site where it was when first observed and then measured the perpendicular distance to the line transect using a measuring tape. All night counts were carried out by two of the authors (C. Benavides and A. Arce), after about two months of training. Density and total encounter rate were estimated using the DISTANCE software (v.6.2) (Laake *et al.* 1996). We allowed DISTANCE to choose the best model under the Akaike Information Criteria (AIC). Although we also provide encounter rates for other mammalian species, we do not discuss those in detail because of small sample sizes, but we consider those data of scientific value since they are the only data available for mammals within this region in Bolivia.

For means of comparison of our results, we searched the open access literature on *D. marsupialis* density on Google Scholar®. We considered information on density estimation methods, as well as the country and habitat where the study was carried out (Table 3).

RESULTS

Overall we obtained 38 sightings of *D. marsupialis* and an encounter rate of 0.54 (95% CI 0.20 – 0.45) individuals per km. Animals were spotted at a mean distance of 7.3 m from the transect. Relative density (encounter rate) of *D. marsupialis* was 3.6 times higher in agroforestry plantations (0.64 individuals km^{-1}) than in secondary forests (0.20 individuals km^{-1}) (see Table 1). The mean distance of observation was 7.28 m in agroforestry plantations and 0.33 m in secondary forest. DISTANCE chose the Half-normal key detection function model, with $k(y) = \exp(-y^2/2\sigma^2)$, where "y" is distance and "σ" is the model parameter, and estimated a global density of 0.30 individuals ha^{-1} [Standard Error (SE) = 0.062), 95% CI = 0.20 – 0.45 individuals ha^{-1}]. The encounter rates for opossums and other four medium-sized mammals ranged from 0.05 for *Dasypus novemcinctus* to 0.41 individuals km^{-1} for *Cuniculus paca* (Table 2).

DISCUSSION

Our estimate of 0.30 individuals per ha for *D. marsupialis* is within the values already reported in the literature for the species (see Table 3 for details), but below the mean value from all the previous studies (0.9 individuals ha^{-1}). Our density estimate is similar to those found in a mature tropical forest disturbed by natural and selective logging in Peru by Emmons (1984). Agroforests can be similar in vegetation richness and structure to undisturbed forest, and several mammal species have been observed to use this human-influenced habitat as foraging sites and migration routes (e.g. Cassano *et al.* 2012). For a generalist species like the common opossum, we expected higher densities in a habitat that may offer rich and stable resources due to the high diversity of fruiting species with year-round production (Harvey *et al.* 2006; Harvey and González Villalobos 2007; Pardini *et al.* 2009; Cassano *et al.* 2012; Caudill *et al.* 2015).

It has been suggested that density estimates based on line transects may be biased when the species studied are easily frightened and difficult to be detected (e.g. when vegetation cover is dense) (Chiarello 2000), affecting the detection function of line-transect counts (Thomas *et al.* 2013; Fauteaux *et al.* 2018). In general, trap captures (live-trapping) have been preferred over line transects to study marsupials such as *Didelphis* (e.g. Sunquist *et al.* 1987; Malcolm 1990; Julien-Laferrier 1991; Table 3). However, Emmons (1984) showed that night counts and live trapping result in similar abundance estimates for *D. marsupialis*. Also, the common opossum is a conspicuous species, and was rarely frightened by human presence at our study site, suggesting they may be somewhat used to human presence and are not usually hunted locally. It is notable that our encounter rate was much higher in agroforestry plantations than in secondary forests. Visibility of animals was lower in secondary forest, and our survey effort was mainly concentrated in agroforestry plantations, owing to the higher access difficulty to the secondary forest patches. Both circumstances likely decreased the probability of observing common opossums in secondary forest, and may have led to the underestimation of density estimates in these habitats. Nonetheless, the apparent selection and higher frequency of use of agroforests over secondary forests by common opossums in our study area deserves further investigation. We propose that opossums may be more

Table 2. Encounter rates of common opossum (*Didelphis marsupialis*) and other medium-sized mammals in line transect counts at Remolinos, Bolivia.

Species	Common name	Local name	Encounter rates (ind km^{-1})
Dasypus novemcinctus	Nine banded armadillo	Tatú	0.05
Mazama americana	Red Brocket deer	Huaso	0.09
Sylvilagus brasiliensis	Brazilian cottontail rabbit	Tapití	0.28
Cuniculus paca	Paca	Jochi Pintado	0.41
Didelphis marsupialis	Common opossum	Carachupa	0.54

Table 3. Density estimates (D) for *Didelphis marsupialis*, including information on habitat types, country, survey method and estimation methods used for recording opossums. DE= Data extrapolation (crude counts/surface), CR= capture-recapture, DS= distance sampling.

Country	D (ind ha^{-1})	Habitat	Survey method	Estimation method	Reference
French Guiana	0.22 – 0.50	Secondary forest	Line transect census	DE	Charles-Dominique *et al.* 1981
	0.45	Secondary forest	Live-trapping	CR	Atramentowicz 1986
	0.22	Mainly primary forest	Live-trapping	CR*	Julien-Laferrier 1991
Panamá	0.09 – 1.32	Secondary forest, primary forest	Live-trapping	CR	Fleming 1972
Venezuela	0.25 – 2.75	Open grasslands with scattered palms, low stature forest (in a ranch)	Live- trapping	CR	O'Connell 1979[a,b]
	0.25 – 2.50	*id* O'connell 1979	Live- trapping	CR	August 1984[a]
	1.00 – 2.00	*id* O'connell 1979	Live-trapping	CR	Sunquist *et al.* 1987
	0.90	Fallow, savanna, gallery forest (in a ranch)	Live-trapping	CR	O'Connell 1989
Brazil	0.07	Continuous forest	Live-trapping	CR	Malcolm 1990
	0.80 – 2.20	Anthropized forest	Live-trapping	CR	Cáceres and Monteiro-Filho 1998
Costa Rica	0.43	-	-	-	Glanz 1982[c]
Peru	0.13 – 0.30	Mature ever green tropical forest, disturbed by natural and selective logging	Line transect counts	DE	Emmons 1984
Bolivia	0.30	Agroforestry plantations, secondary forest	Line transect counts	DS	this study

*Complemented with nocturnal surveys, [a]Cited from Sunquist *et al.* (1987), [b]IUCN (2016) (http://www.iucnredlist.org/details/40501/0), accessed on 11 Sept 2018; [c]Cited from Emmons (1984).

abundant in agroforestry plantations as a function of higher resource availability (food) and suitable vegetation cover as compared to forest patches.

The relatively low overall density of *D. marsupialis* estimated for our study site may be also affected by the presence of domestic dogs (*Canis familiaris*) and other less common predators, such as ocelots, *Leopardus pardalis* (Moreno *et al.* 2006; Foster *et al.* 2010; Cassano *et al.* 2012; Cassano *et al.* 2014). Local residents in Remolinos commonly employ domestic dogs for hunting, but only occasionally kill common opossums for medicinal purposes (C. Benavides, pers. obs). However, when dogs are left alone in crops, they hunt to eat, and we confirmed that their prey include the common opossum by observing hunting events. Common opossums are also killed by farmers when found near their homes, because they occasionally prey on poultry. However, they are not considered as a great problem by farmers (C. Benavides, pers. obs.). Future research should also be focused on the effect of predation on the common opossum populations.

CONCLUSIONS

We estimated the density of the common opossum, *Didelphis marsupialis* using line transects and distance sampling in agroforestry plantations in the Amazonian piedmont in Bolivia as 0.30 individuals ha^{-1}. The estimate lies below the average of the values already reported in literature. The density of *D. marsupialis* may be responding to a combination of resource availability (food and vegetation cover) and predation pressure at our study site.

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REFERENCES

Altieri, M. 2009. Agroecology, small farms and food sovereignty. *Monthly Review,* 61: 102–111.

Astua de Moraes, D.; Lew, D.; Costa, L.P.; Pérez-Hernandez, R. 2016. *Didelphis marsupialis*. The IUCN Red List of Threatened Species 2016: e.T40501A22176071, (https://www.iucnredlist.org/species/40501/22176071#habitat-ecology). Accessed on 11 Sep 2018.

Atramentowicz, M. 1986. Dynamique de population chez trois marsupiaux Didelphides de Guyane. *Biotropica,* 18: 136–149.

August, P. V. 1984. Population ecology of small mammals in the llanos of Venezuela. *Special publications - The Museum, Texas Tech University*, 22: 71-104.

Beck-King, H.; von Helversen, O.; Beck-King, R. 1999. Home range, population density, and food resources of *Agouti paca* (Rodentia: Agoutidae) in Costa Rica: A study using alternative methods. *Biotropica,* 31: 675–685.

Benavides, C.; Arce, A.; Pacheco, L.F. 2017. Home range and habitat use by pacas in a montane tropical forest in Bolivia. *Acta Amazonica*, 47: 227–236.

Bezerra-Barros, F.; de Aguiar-Azevedo, P. 2014. Common opossum (*Didelphis marsupialis* Linnaeus, 1758): food and medicine for people in the Amazon. *Journal of Ethnobiology and Ethnomedicine*, 10: 65–78.

Cáceres, N.C.; Monteiro-Filho, L.A. 1998. Population dynamics of the Common opossum, *Didelphis marsupialis* (Mammalia, Marsupialia), in southern Brazil. *International Journal of Mammalian Biology*, 63: 169–172.

Cáceres, N.C.; Monteiro-Filho, E.L.A. 2001. Food habits, home range and activity of *Didelphis aur*ita (Mammalia, Marsupialia) in a forest fragment of southern Brazil. *Studies on Neotropical Fauna and Environment*, 36: 85–92.

Cáceres, N.C. 2002. Food habits and seed dispersal by the white-eared opossum, *Didelphis albiventris*, in southern Brazil. *Studies on Neotropical Fauna and Environment,* 37: 97–104.

Cassano, C.R.; Barlow, J.; Pardini, R. 2012. Large mammals in an agroforestry mosaic in the Brazilian Atlantic Forest. *Biotropica,* 44: 818–825.

Cassano, C.R.; Barlow, J.; Pardini, R. 2014. Forest loss or management intensification? Identifying causes of mammal decline in cacao agroforests. *Biological Conservation*, 169: 14–22.

Caudill, S.A.; DeClerck, F.J.A.; Husband, T.P. 2015. Connecting sustainable agriculture and wildlife conservation: Does shade coffee provide habitat for mammals? *Agriculture, Ecosystems & Environment,* 199: 85–93.

Ceotto, P.; Finotti, R.; Santori, R.; Cerqueira, R. 2009. Diet variation of the marsupials *Didelphis aurita* and *Philander frenatus* (Didelphimorphia, Didelphidae) in a rural area of Rio de Janeiro state, Brazil. *Mastozoología Neotropical,* 16: 49–58.

Charles-Dominique, P.; Atramentowicz, M.; Charles-Dominique, M.; Gérard, H.; Hladik, A.; Hladik, C.M.; *et al*. 1981. Les mammifères frugivores arboricoles nocturnes d'une forêt guyanaise: interrelations plantes-animaux. *Revue d'Écologie – la Terre et la Vie*, 35: 342–435.

Chiarello, A. 2000. Density and population size of mammals in remnants of Brazilian Atlantic Forest. *Conservation Biology,* 14: 1649–1657.

Emmons, L. 1984. Geographic variation in densities and diversities of non-flying mammals in Amazonia. *Biotropica,* 16: 210–222.

Fauteux, D.; Gauthier, G.; Mazerolle, M.J.; Coallier, N.; Bêty, J.; Berteaux, D. 2018. Evaluation of invasive and non-invasive methods to monitor rodent abundance in the Arctic. *Ecosphere*, 9: e02124.

Fleming, T. 1972. Aspects of the population dynamics of three species of opossums in the Panama Canal Zone. *Journal of Mammalogy*, 53: 619–623.

Foster, R.J.; Harmsen, B.J.; Valdes, B.; Pomilla, C.; Doncaster, C.P. 2010. Food habits of sympatric jaguars and pumas across a gradient of human disturbance. *Journal of Zoology,* 280: 309–318.

Gallina, S.; Mandujano, S.; Gonzales-Romero, A. 1996. Conservation of mammalian biodiversity in coffee plantations of central Veracruz, Mexico. *Agroforestry Systems,* 33: 13–27.

Glanz, W. E. 1982. The terrestrial mammal fauna of Barro Colorado Island: censuses and long-term changes, In: Leigh, E. G.; Rand, A. S.; Windsor, D. M. (Ed.). *The Ecology of a tropical forest*. Smithsonian Institution Press, Washington, p. 455-468.

Harvey, C.A.; González, J.; Somarriba, E. 2006. Dung beetle and terrestrial mammal diversity in forests, indigenous agroforestry systems and plantain monocultures in Talamanca, Costa Rica. *Biodiversity and Conservation,* 15: 555–585.

Harvey, C.A.; González Villalobos, J.A. 2007. Agroforestry systems conserve species-rich but modified assemblages of tropical birds and bats. *Biodiversity and Conservation,* 16: 2257–2292.

Hoffmann, A.; Decher, J.; Rovero, F.; Voigt, C.; Schaer, J. 2010. Field methods and techniques for monitoring mammals. In: Eymann, J.; Degreef, J.; Häuser, C.; Monje, J.C.; Samyn, Y.; Van den Spiegel, D. (Ed.). *Manual on Field Recording Techniques and Protocols for All Taxa Biodiversity Inventories and Monitoring*. ABC Taxa, United Kingdom, p.482–529.

Jacobi, J.; Schneider, M.; Pillco, M. I.; Huber, S.; Weidmann, S.; Rist, S. 2014. La contribución de la producción del cacao orgánico a la resiliencia socio-ecológica en el contexto del cambio climático en el Alto Beni – La Paz. *Acta Nova,* 6: 1–33.

Julien-Laferriere, D.; Atramentowicz, M. 1900. Feeding and reproduction of three Didelphid marsupials in two Neotropical forests (French Guiana). *Biotropica,* 22: 404–415.

Julien-Laferriere, D. 1991. Organisation du peuplement de marsupiaux en Guyane française. *Revue d'Écologie – la Terre et la Vie,* 46: 125–144.

Laake, J.L.; Buckland, S.T.; Anderson, D.R.; Burnham, K.P. 1996. *DISTANCE User's Guide* V2.2. Colorado Cooperative Fish & Wildlife Research Unit, Colorado State University, Fort Collins, 87p.

Malcolm, J.R. 1990. Estimation of mammalian densities in continuous forest of Manaus. In: Gentry, A.H. (Ed.). *Four Neotropical Rainforests.* Yale University Press, New Heaven, p.339–357.

Moreno, R.S.; Kays, R.W.; Samudio, R. 2006. Competitive release in diets of ocelot (*Leopardus pardalis*) and puma (*Puma concolor*) after jaguar (*Panthera onca*) decline. *Journal of Mammalogy,* 87: 808–816.

Nyhus, P.; Tilson, R. 2004. Agroforestry, elephants, and tigers: balancing conservation theory and practice in human-dominated landscapes of Southeast Asia. *Agriculture, Ecosystems & Environment,* 104: 87–97.

O'Connell, M.A. 1979. Ecology of didelphid marsupials from northern Venezuela. In: Eisenberg, J.F. (Ed.), *Vertebrate Ecology in the Northern Neotropics*, Smithsonian Press, Washington D.C., p.73–87.

O'Connell, M.A. 1989. Population dynamics of neotropical small mammals in seasonal habitats. *Journal of Mammalogy,* 70: 532–548.

Ojasti, J.; Dallmeier, F. 2000. *Manejo de Fauna Silvestre Neotropical.* SI/MAB Series #5. Smithsonian Institution/MAB Biodiversity Program, Washington D.C., 233p.

Pardini, R.; Faria, D.; Accacio, G.M.; Laps, R.R.; Mariano-Neto, E.; Paciencia, M.L.B.; *et al.* 2009. The challenge of maintaining Atlantic forest biodiversity: A multi-taxa conservation assessment of specialist and generalist species in an agro-forestry mosaic in southern Bahia. *Biological Conservation,* 142: 1178–1190.

Perfecto, I.; Vandermeer, J. 2008. Biodiversity conservation in tropical agroecosystems. *Annals of the New York Academy of Sciences,* 1134: 173–200.

PIAF-El CEIBO. 2002. Vegetación de Alto Beni. In: Sub-Programa Aprovechamiento Forestal (Ed.). *Guía de Especies Forestales de Alto Beni*. El Ceibo LTDA, Sapecho-Bolivia, p.3–4.

Pramod, A.F.; Kumara, V; Gowda, R.H. T. 2012. Encounter rate of large mammals in Thanigebyle range Bhadra wildlife sanctuary, Karnataka. *International Multidisciplinary Research Journal,* 2: 9–11.

Quintana, G.; Vargas, L. 1995. *Guía Popular de Plantas Utilizadas por los Mosetenes de Covendo, Santa Ana y Muchanes (Alto Beni, Bolivia)*. Fondo Nacional Para el Medio Ambiente (FONAMA), La Paz, 186p.

Rocha, N.; Rumiz, D. 2010. Didelphidae. In: Wallace, R.B.; Gómez, H.; Porcel, Z.; Rumiz, D. (Ed.). *Distribución, Ecología y Conservación de los Mamíferos Medianos y Grandes de Bolivia*. Fundación Simón I. Patiño, Santa Cruz-Bolivia, p.147–159.

Ruette, S.; Stahl, P.; Albaret, M. 2003. Applying distance-sampling methods to spotlight counts of red foxes. *Journal of Applied Ecology*, 40: 32–43.

Sanches, V.Q.A.; Gomes, M.M. de A.; Passos, F. de C.; Graciolli, G.; Ribas, A.C. de A. 2012. Home-range and space use by *Didelphis albiventris* (Lund 1840) (Marsupialia, Didelphidae) in Mutum Island, Paraná river, Brazil. *Biota Neotropica,* 12: 50–55.

Sunquist, M.E.; Austad, S.N.; Sunquist, F. 1987. Movement patterns and home range in the common opossum (*Didelphis marsupialis*). *Journal of Mammalogy,* 68: 173–176.

Thomas, L.; Buckland, S.T.; Burnham, K.P.; Anderson, D.R.; Laake, J.L.; Borchers, D.L.; *et al.* 2013. Distance sampling. In: El-Shaarawi, A.H.; Piegorsch, W.W. (Ed.). *Encyclopedia of Environmetrics.* John Wiley & Sons, Ltd, Chichester, p. 544–552.

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