Ecología en Bolivia 51(1): 4-14. Abril 2016. ISSN 1605-2528.

Probability of presence of terrestrial mammals in the buffer zone of a protected area in southeast Peru

Probabilidad de presencia de mamíferos terrestres en la zona de amortiguamiento de un área protegida en el sureste de Perú

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Abstract

Buffer zones adjacent to protected areas can have a high conservation value for wildlife species but are usually neglected by authorities in charge of conservation areas. We used 13 camera traps in an equal number of sample stations during 1,730 trap days in the southern portion of Manu National Park buffer zone in southeastern Peru, to measure variations in the probability of presence of six terrestrial mammal species and a diversity index (Shannon-Wiener Index) with distance to the limit of the park and elevation. Relative Abundance Index (number of pictures per species/100 camera trap days) varied between 0.06 (South American coati-*Nasua nasua*) and 1.5 (mountain paca-*Cunniculus taczanowskii*). Results indicate that species responded differently to distance to the park and elevation. However for the Peruvian brocket deer (*Mazama chunyi*), a little known species, and for the oncilla (*Leopardus tigrinus*), probability of presence diminished with increased distance from the park, and for the deer, it increased with elevation. On average, diversity and abundance of terrestrial mammal species diminished with distance from the park and elevation. Our results highlight the importance of buffer zones adjacent to protected area for the conservation of threatened and restricted range species. They also call for the atention to conservation initiatives outside protected areas to increase their conservation value and maintain conectivity between conservation units.

Key Words: Camera traps, Cloud forest, Manu National Park, Peru, Terrestrial mammals.

Resumen

Las áreas de amortiguamiento que rodean las áreas protegidas pueden tener un alto valor de conservación para las especies silvestres, pero son usualmente ignoradas por las autoridades encargadas de la gestión de las áreas protegidas. Empleamos 13 cámaras trampa en igual número de estaciones de muestreo durante 1.730 días trampa en la porción sur de la zona de amortiguamiento del Parque Nacional del Manu, en el sureste de Perú para evaluar variaciones en las probabilidades de presencia de seis especies de mamíferos terrestres y en el valor de un indice de diversidad (Indice de Shannon-Wiener) con la distancia al límite del parque y la elevación. El Indice de Abundancia Relativa (numero de fotos por especie/100 cámaras trampa día) varió entre 0.06 (coatí –*Nasua nasua*) y1.5 (paca de montaña –*Cunniculus taczanowskii*). Los resultados sugieren que las especies respondieron en forma diferente con respecto a la distancia al límite del parque y la elevación. Para el venado peruano (*Mazama chunyi*), una especie muy poco conocida y con un rango de distribución restringido y para la oncilla (*Leopardus tigrinus*), la probabilidad de presencia disminuyó a mayores distancia del límite del parque y aumentó con la elevación para el venado. La diversidad y abundancia de las especies de mamíferos terrestres evaluados en general disminuyó con la distancia al límite del parque y con la elevación. Nuestros resultados destacan la importancia de las zonas de amortiguamiento cercanas a las áreas naturales protegidas para la conservación de especies amenazadas y de rangos de distribución restringidos; también llaman la atención hacia enfoques de conservación fuera de las áreas protegidas para expandir su impacto de conservación e incrementar la conectividad entre unidades de conservación.

Palabras clave: Bosques nublados, Cámaras trampa, Mamíferos terrestres, Parque Nacional del Manu, Perú.

Introduction

Although creation of protected areas is still one of the main strategies to protect biodiversity, buffer zones that surround them may play an increasingly important role for the conservation of species (Naughton-Treves *et al.* 2005, Wittemyer *et al.* 2008, Laurance *et al.* 2012). Buffer zones are usually established around protected areas to reduce direct impacts of extractive activities on biodiversity (UNESCO 1996, Neumann 1997). Although perceived by some as a way of land alienation, buffer zones around protected areas can extend the protection of species and habitats beyond their limits, reducing their isolation and extinction probabilities (Neumann 1997). Depending on habitat structure and width, buffer zones can also act as conservation corridors between protected areas or can help connect them with areas that are important for species but are under other land use regimes (Noss 1987) .

Importance of buffer zones might be particularly relevant under climate change scenarios that predict migration of plant and animal species in the tropical Andes following alterations in precipitation and temperature and thus influencing species distribution and abundance that might drive them outside protected areas (Feeley *et al.* 2011, Forero-Medina *et al*. 2011) or under increased land use changes and fragmentation following human migration and encroachment around protected areas that tend to alter habitat structure and composition and increase human-wildlife conflicts (Laurance 2000, Kintz *et al.* 2006, Wittemyer *et al.* 2008).

In Peru, buffer zones are declared together with the creation of protected areas and activities that are conducted here must be in accordance with the objectives of the protected area itself. Extractive activities and establishment of new settlements are limited in buffer zones, yet this is poorly implemented by protected area managers given restricted personnel and funds (Kintz *et al.* 2006, Piana & Marsden 2012). Due to the limitations in the creation of protected areas, it is important to asses the role of remaining habitat outside them for species conservation and look into innovative ways that might help reduce loss of biodiversity (Knight 1999).

Camera trapping is a non-invasive method used for wildlife studies and are particullarly well suited for species that are shy, secretive and/or nocturnal. Camera traps allow remote and continuous collection of data for single and multiple species and have been intensively used to obtain data on habitat use, abundance and distribution of several terrestrial wildlife species, incluiding those that inhabit tropical forests (Karanth 1995, Pettorelli *et al.* 2010, Rovero *et al.* 2013) .

In this study we use photographs taken by camera traps as a means to detect wide-ranging species, such as carnivores and ungulates outside Manu National Park (MNP). The main objectives of this study were to model the probability of presence of a set of terrestrial mammal species, as well as to estimate species diversity and abundance (Shannon–Wiener Index) in areas bordering Manu National Park and to measure how these changed with distance from the park boundaries and elevation. Additionally we make recommendations on the protection of particular areas inside and outside the park in order to maintain these restricted range and threatened wildlife species.

Study area

Our research was conducted in Wayqecha Cloud Forest Research Station (Wayqecha) and surrounding areas in Cusco department in the buffer area of Manu National Park (MNP) in southeastern Peru, an area known for its high biodiversity (Patterson *et al.* 2006). Being a strictly protected area, activities inside MNP are limited to tourism and research in areas close to its buffer zone. MNP buffer zone width along the Kosñipata valley ranges from 15 km to less than one km. Activities conducted here include forest burning and conversion into pasturelands, cattle grazing, hunting, agriculture and tourism. These activities are weakly regulated by MNP authorities, while cattle grazing also occur inside MNP particularly below Acjanacco pass and Wayqecha.

With 587 hectares, Wayqecha is located in the upper portion of the Kosñipata valley (2,900 m) in Cusco. The road that connects Cusco with the town of Pilcopata, at the bottom of the valley, separates the park from its buffer zone (Fig. 1). Average precipitation in Wayqecha is 1,700 mm and average temperature is 12.5°C. Elevation within the research station ranges from 2,300 to 3,500 m. Forest habitats include montane forest with abundant tree ferns at low elevations, bamboo (*Chusquea* sp.) forests and moss-covered dwarf forest under the tree line (ACCA 2015).

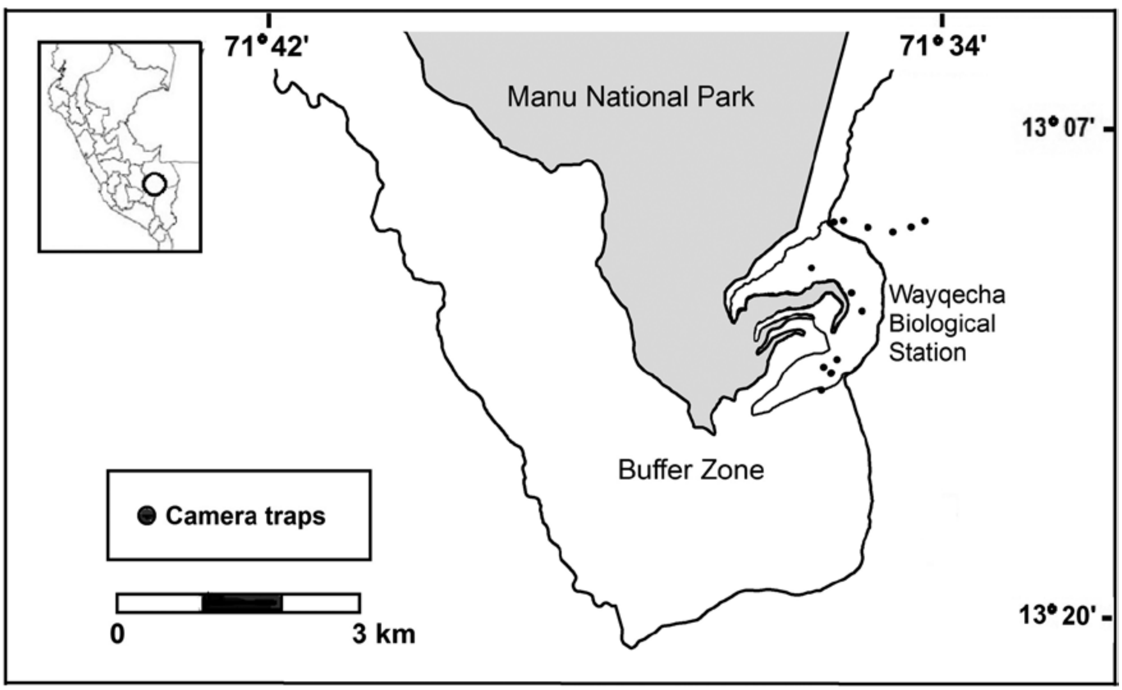

Figure 1. Map of the study area and camera traps lay out.

Methods

Camera trap deployment and settings

We used 13 camera traps (seven Reconyx PC 850 and six Bushnell MP Trophy Cam) that were located along trails in Wayqecha Research Station (seven cameras) and nearby trails adjacent to the station but outside Manu National Park (six cameras). Sampling stations were selected because of evidence of the presence of mammal species such as tracks. Cameras were fixed 20 cm above ground, usually tied to a tree trunk with nylon webbings and pointing towards the trails; and were programmed to take three pictures per trigger using a one-second lapse between photos and with high sensibility. All cameras were active 24 hours per day and each photo registered the time and date when the photo was taken; and were checked once a month to replace batteries and memory cards.

To calculate Relative Abundance index (RAI) of species (number of pictures per species/100 camera trap days), we selected the total number of pictures for each species taken by all cameras during the whole survey period, divided it by the total number of camera trap days and multiplied by 100. Pictures of the same species taken by the same camera with at least 30 minutes intervals were considered as different individuals (O'Brien *et al.* 2003).

Statistic analysis

We used principal component analysis (PCA) to identify autocorrelations among the predictor variables. PCA collapses multivariate datasets onto a small number of composite axes that represent important environmental gradients that can be interpreted according to the factor loadings of individual variables that contribute to them (Ter Braak 1986). The variables included in the PCA were Euclidean distance from sampling station to the border of Manu National Park (distance), elevation at which the station was located (elevation), and the longitude and latitude where each camera trap was located. The value of Shannon–Wiener Index at each station was calculated for all mammal species and number of individuals photographed here. Elevation of each sampling station was obtained with a GPS, and distance from each stations to the limit of Manu National Park was obtained with ArcMap 10.1 (ESRI 2012).

We then used Generalized Additive models (GAMs) to measure the probability of presence of each species (and response of Shannon-Wiener Index) in the two main axes of PCA. GAMs are extensions of generalized linear models that replace the linear regression coefficients with semi-parametric smoothing functions and additively calculate the component response (Hastie & Tibirishani 1986, Guisan *et al.* 2002). GAMs allow for the probability distribution of the response variable and the link between predictors and the probability distribution to be more general/flexible, and are better suited to deal with highly non-linear and complex relationships or thresholds between the response and predictive variables predictors (Granadeiro *et al.* 2004, Vilchis *et al.* 2006).

We ran Gaussian or Poisson GAMs with the number of individuals per species of six terrestrial mammal species detected at each sampling station (only those species with more than eleven detections –Wisz *et al.* 2008), and for the Shannon-Wiener index using the 'mgcv' package in R (R Core Team 2015) version 3.2.1. Predictor variables for each model were the two most important PCA axis scores. Model selection was based on Akaike's Information Criterion (AIC; Burnham & Anderson 2004).

Results

Thirteen sampling stations totaling 1,730 (108 ± 32.4) (mean ± 95% C. I.) trap days were positioned in Wayqecha and outside the limits of the research station. Elevation of sampling stations ranged from 2,373 to 3,055 m (0.2812 ± 100.8) and distance of stations to the limit of the park ranged from 139 to 2,380 m (1.047 ± 344.6).

In total we registered 125 encounters (photos) of nine especies of terrestrial mammals. Higher number of detections were obtained for mountain paca (27), followed by Peruvian brocket-deer and puma (23 and 21 respectively), while white-tailed deer (*Odocoileus virginianus*) and South American coati (*Nasua nasua*) were the species with the less number of records (1 and 2 respectively). RAI per species (number of pictures per species/100 camera trap days) varied, with mountain paca having the highest value (1.5) followed by puma and Peruvian brocket-deer with 1.33 and 1.27 respectively. Lower RAI values were obtained by South American coati (0.06) and white-tailed deer (0.12).

Shannon-Wienner index at sampling stations increased with sample effort (Fig. 2), however correlation between these variables was low (r_s = 0.58; P = 0.04). Shannon-Wiener Index was not correlated with distance to Manu National Park (r_s = -0.40; P = 0.19), nor with elevation (r_s = -0.26; P = 0.39).

Autocorrelation and representation of environmental gradients

PCA reduced habitat variables to three axes that accounted for 97.6% of overall variability (see table 1). Sampling stations with high scores on axis 1 are located further away from the parks' limits and north of the study area, while those with high scores on Axis 2 are located at high elevation and at the west side of the study area. PCA scores of habitat variables on Axis 3 where not particularly high, yet might represent sampling stations at mid distances from the park limit.

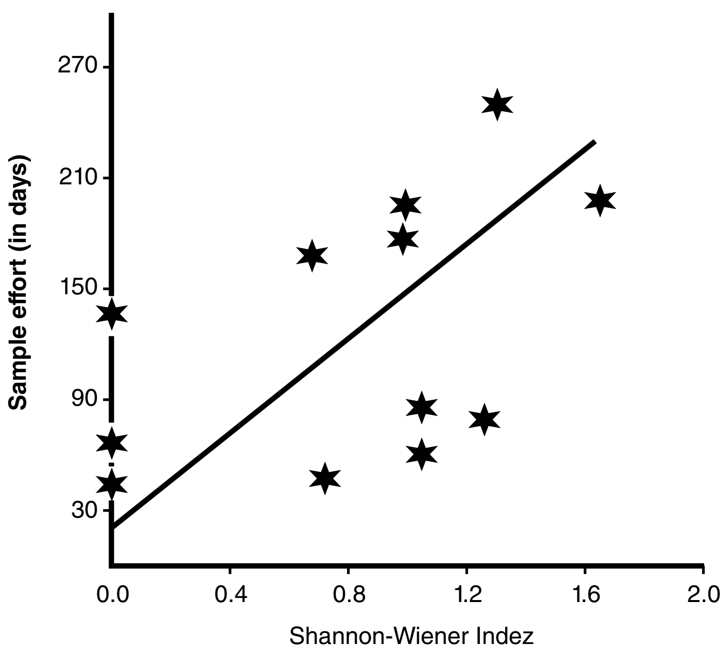

Figure 2. Scatterplot of Shannon – Wienner Index vs sampling effort (in days) per sampling station in Wayqecha Biological Station and Manu National Park buffer zone.

Table 1. Eigen values, percentage of variance explained by PCA axis and PCA values of response variables per axis. Values below 0.20 are not shown; + and – signs arethat of the PCA loadings on each axis of PCA.

	Axis 1	**Axis 2**	**Axis 3**
Eigen value	2.15	1.49	0.27
% Variance	53.8	37.2	6.6
Distance	0.85	0.36	-0.38
Elevation	(-)	0.97	(+)
Latitude	0.94	(+)	0.23
Longitude	0.74	-0.62	(+)

Species distribution models

Species responded differently to distance from MNP and to elevation. Probability of presence of Peruvian brocket-deer and oncilla outside the park decreased with distance to the park's limit, while that of mountain paca increased at mid distances. For Molina's hog-nosed skunk probability of presence sharply increased close to the park (and to the road that separates it from Wayqecha). However, in general, number of individuals and species of mammals, represented by Shannon-Wiener Index, decreased with increased distance from the park.

Probability of presence of brocket deer increased with elevation, while for oncilla, and the skunk it increased at mid elevations. For the paca it remained constant. Shannon-Wiener Index decreased with elevation (Fig. 3).

Discussion

In our study area, camera traps proved to be a very useful method to evidence the presence of elusive and little known species that are difficult to detect or are active at night, such as mountain paca (*Cunniculus taczanowskii*) and Peruvian brocket deer (*Mazama chunyi*), or species that rare and wide ranging such as oncilla (*Leopardus tigrinus*) or spectacled bear (*Tremarctos ornatus*). Our results are similar to those obtained by Rodriguez & Amanzo (2001) at 1,710 m in the Vilcabamba Cordillera in Cusco, where, mountain paca, puma and spectacled bear were the most frequently detected medium to large mammal species, while South American coati (*Nasua nasua*) was among the less detected. Although "imperfect detection" is a common problem related to monitoring wildlife with camera traps than can lead to erroneous interpretation of data in this study we minimized such bias by placing cameras in the field during a long sampling season and by operating sampling stations within the season for long periods to maximize species probability of detection (McKenzie 2005, Webb *et al.* 2014). Additionally, the use of Poisson GAMs to model species probability of presence reduced the weights of possible absences in our models. However, the study area was limited to a narrow elevational band in the buffer area of MNP where cloud forest dominated and was less than five kilometers from the park. Because of this, results obtained here might better represent variations in the activity patterns of species with large territory requirements such as puma (*Puma concolor*) and spectacled bear.

Mountain paca is a rare and near threatened species that inhabits in montane forest along the Andes from Venezuela to Bolivia (Tirira *et al.* 2008). Before this study, the species was reported less than 5 km from our study area, between 1,920 and 3,450 m in habitats that included a transition from grassland to mossy elfin forest and shrubland (Solari *et al.* 2006). Probability of presence of mountain paca increased at mid distances from MNP, and might reflect the species reduced tolerance to edge forests. In contrast, probability of presence of Molina´s hog-nosed skunk, a nocturnal species that forages in open habitat (Donadio *et al.* 2001) was positively influenced by cleared areas along the road separating MNP from the park's buffer areas.

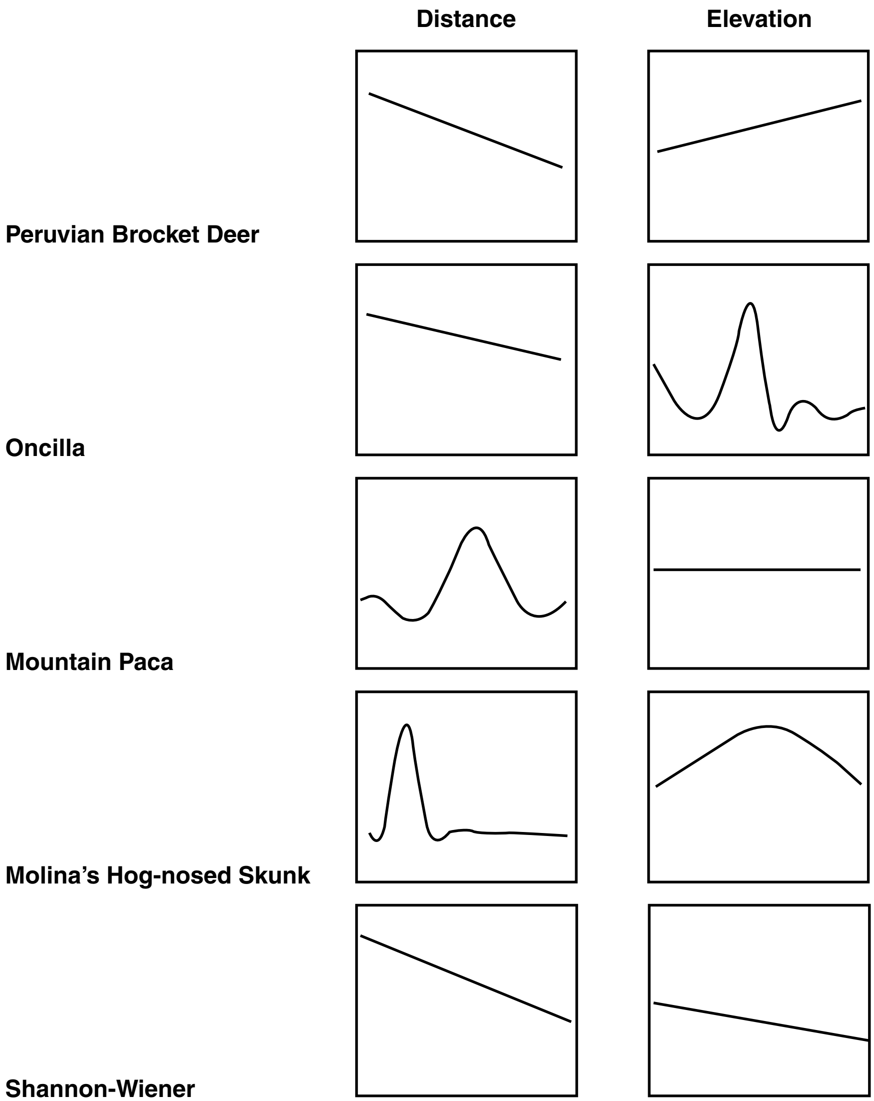

Figure 3. GAM plots of the probability of species presence and Shannon-Wiener along two main Axes of PCA.

Peruvian brocket deer (*Mazama chunyi*) is a species with a decreasing population that in Peru is restricted to an altitudinal belt of between 1,000 to 4,000 m in the Yungas forest of Cusco, Puno and Madre de Dios departments (Rumíz & Barrio 2008, Rumíz & Pardo 2010). The species has been reported in MNP and buffer areas at elevations between 2,450-3,300 m (Solari *et al.* 2006). We photographed the species between 2,750 and 3,050 m, with most records below 3,000 m. The species probability of presence diminished with distance from MNP, yet in its buffer zone, high-elevation forests close to the park might provide suitable habitat for the species. In Bolivia, Peruvian brocket deer has been registered in humid Yungas forests where human activities such as cattle grazing, agriculture and tourism is conducted, thus indicating a certain degree of tolerance to habitat modification (Tirira *et al.* 2008).

The spectacled bear is categorized as vulnerable due to habitat loss and prosecution by humans (Peyton 1999). In Peru, as elsewhere along its range, it occupies a wide variety of habitats including montane and cloud forest and puna grassland along both side of the Andes. In recent years, human encroachment and associated habitat fragmentation and hunting has decimated the species population, particularly in the northern coast and west of the Andes (Peyton 1999). In this study, spectacled bear was the fourth most detected species, with most records occurring between 2,600-2,900 m. Its presence in Wayqecha and surrounding areas might highlight the importance of buffer areas south of MNP to increase connectivity between patches of suitable habitat used by this species.

Conservation recommendations

We registered mammal species of varied sizes, habits and activity patterns in MNP buffer area that are close to Wayqecha. Land acquisition and conservation of communal lands such as forested areas inside peasant/indigenous communities that are protected by community members, have been used as a strategy to protect species and their habitats globally, and can help reduce direct pressures against wildlife species if extractive activities such as hunting are regulated (Nepstad *et al*. 2005, Peres & Nascimento 2006). In buffer areas of MNP, hunting of protected species, forest conversion into pastures and road construction are common and contribute to habitat fragmentation and wildlife species prosecution. Our study area included one privately owned biological station that is mainly used for research and where original habitats are maintained and preserved. Probability of presence of at least one threatened mammal species (mountain paca) outside MNP increased here, highlighting the importance of buffer areas conservation for threatened and restricted range species with diminishing populations and small territories such as the paca. However, for wide ranging-species severely threatened by human prosecution and habitat loss such as the spectacled bear, habitat protection schemes beyond protected areas should incorporate larger areas that those we studied in order to create conservation corridors to maintain connectivity between protected areas such as those occurring in south east Peru (Peyton 1999, Kattan *et al*. 2004).

Conclusions

In the cloud forest of south-eastern Peru, particularly in MNP buffer areas that are close to Wayqecha Research Station, camera traps were a good tool to register threatened and restricted range terrestrial mammal species.

The probability of presence of Peruvian brocket deer, oncilla and Shannon-Wiener Index diminished with increased distance from the park, while that of mountain paca was the highest at mid distances from MNP. Probability of presence of the deer and mountain paca increased with elevation, while that of Shannon-Wiener Index decreased, as expected, while that of oncilla and Molina hog-nosed skunk in MNP buffer area increased at mid elevations.

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Artículo recibido en: 5 de septiembre de 2015.
Manejado por: Lilian Painter.
Aceptado en: 12 de noviembre de 2015.