SPECTACLED BEAR (*Tremarctos ornatus*) HABITAT PREFERENCES IN THE NORTHWESTERN BOLIVIAN ANDES

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**Key Words**: Spectacled bear, *Tremarctos ornatus*, landscape species, habitat preferences, tropical Andes, Bolivia

**Running Head**: Spectacled bear habitat use

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Abstract

Spectacled bear (*Tremarctos ornatus*) habitat preferences was studied within two adjacent protected areas in the northwestern Bolivian Andes. Standard transects measuring habitat variables and bear sign frequency were employed at 33 sample sites spanning seven different vegetation types. Spectacled bears actively preferred high elevation elfin forest and upper montane humid forests, and used high elevation humid ‘páramo’ grasslands and middle montane humid forests according to their availability. Bears were absent from dry montane and Andean foothill forests and relative abundance was low in lower montane humid forests.
INTRODUCTION
The first step in determining the relationship between the distribution and abundance of a species and the characteristics of its habitat is to document whether species exhibit preferential habitat use and establish the different scales of selection. Subsequently, associated geographical or ecological variables can be used to help predict the presence or abundance of a given species (Guisan & Zimmermann, 2000). This multi-scale and nested approach acknowledges the influence of spatial variation of habitat related variables on species behavior, recognizes that there is no such thing as an "appropriate scale" (Luck, 2002), and allows the modeling of species distributions across wide ranges (Gómez, 2004). In this light the selection of different scales of analysis might help us take more rigorous decisions regarding the conservation of key elements of a given landscape.

The spectacled bear (*Tremarctos ornatus*) is an endemic species of the Tropical Andes, and the only representative of the Ursidae family in South America. The spectacled bear range occupies around 26,000 km² spanning five countries, Venezuela, Colombia, Ecuador, Peru and Bolivia, with the latter two countries representing over 60% of their range (Peyton, 1999). In Bolivia the spectacled bear inhabits a broad altitudinal swathe (450m a.s.l. to 4000m a.s.l.) to the east of the eastern mountain range of the Andes, mainly in montane humid grasslands, montane forests and Andean foothill forests (Rumiz & Salazar, 1990). Nevertheless, field data regarding *Tremarctos* is scarce in Bolivia and even theoretical distribution maps are in need of revision (Salazar & Anderson, 1990; Eulert, 1995; PAHS, 1995; Rumiz & Salazar, 1999; Rivadeneira, 2000; Velez & Azurduy, 2000; Rechberger et al., 2001; Paisley, 2002).
Although spectacled bears are considered principally vegetarian (Peyton, 1980; Suarez, 1984; Castellanos, 1997; Rivadeneira, 2000; Velez & Azurduy, 2000; Paisley, 2002), they are known to make large-scale movements (Rechberger et al., 2001) and are thought to move altitudinally across several types of vegetation (Peyton, 1980; Suarez, 1985; Rodriguez & Cadena, 1992). This hypothesis is based on the seasonal use of Andean grasslands and of adjacent humid montane forest (Suarez, 1985; Rodriguez & Cadena, 1992).

Spectacled bears are also considered a flagship species for the conservation of the Tropical Andes (Cuesta et al., 2001). However, across their range spectacled bears are also the source of considerable farming and livestock based conflict with rural human communities, because of crop or livestock associated losses (Goldstein, 1991; Morales, 2003; Goldstein et al., in press). Using the landscape species selection criteria (Coppolillo et al., 2004) spectacled bears were chosen as a "landscape species" (Sanderson et al., 2002) for the humid tropical Andes and subsequently used to determine areas and actions for biodiversity conservation in the Apolobamba protected area (Gómez, 2004) in the Northwestern Bolivian Andes Conservation Landscape.

There have been several attempts to describe spectacled bear habitat (Peyton, 1980; 1983; Suarez, 1985; Eulert, 1995; Velez & Azurduy, 2000; Cuesta et al., 2000), however only Peyton (1980; 1983) and Cuesta et al. (2000) linked *Tremarctos* presence or relative abundance to clearly defined habitat and vegetation variables. In this article we present an evaluation of habitat use across two scales, the
landscape and habitat scales in the Northwestern Bolivian Andes, using the relationship between some ecological and geographical variables and the relative abundance of spectacled bear sign.

**METHODS**

**Study area**

The study was conducted across two adjacent Bolivian protected areas; Madidi National Park and Natural Area of Integrated Management and Apolobamba Natural Area of Integrated Management. These protected areas are found in the northern portions of the Department of La Paz in Bolivia (69°02'- 69°50' W and 14°12'- 15°10' S) and the study area ranged altitudinally between 500 m a.s.l. and 3700 m a.s.l. (Fig. 1) and covered 9068 km².

In general, the study area belongs to the biogeographical province of the Bolivian Yungas (Mueller et al., 2002; Navarro, 2002). Vegetation types in the study area began at high elevations with Andean open grasslands (páramo yungueño; 9% of the study area) changing into elfin forest (6%) at the tree line, and then upper montane humid forest (10%), middle montane humid forest (26%), low montane humid forest (32%), and foothill humid forest (15%), with dry montane forest (3%) also present in one valley within the study area (Zenteno et al., in press).
Sample collection

Using a randomly stratified design according to the proportion of vegetation type 60 points were selected across the study area. A sub-sample of 33 points was then chosen based on logistical accessibility. Thus points that were considered more than 2 days from the nearest access route (road or established trail) were excluded from the sample. Evaluations were conducted between December 2000 and October 2003 and the majority of transects (28) were evaluated during the dry season (May to October).

Evaluations at each selected site consisted of one strip transect with a total length of 2.5 km and a width of 3 m (1.5 m either side of the trail). Initially a one kilometer strip transect was established and subsequently five randomly selected 300 m perpendicular strips were added. Along transects the number of different types of spectacled bear sign was recorded; scat, tree nests, hairs, scratch marks, feeding sites, beds, and paths. In order to reflect the relative abundance of spectacled bears by vegetation type we used sign encounter rates, expressed as the number of signs/km of transect.

Information on the habitat was also recorded along each transect, including the height and diameter at breast height (DBH) of all the trees with a DBH greater than 5cm. This data provided a detailed analysis of different tree communities across vegetation types (Zenteno et al., in press), and also allowed the calculation of basal areas for each transect. Additional variables were recorded in plots of 9 m² at 50 m intervals along the transects; elevation, aspect, slope, canopy cover, visibility at ground level, tree density, palm density, shrub density, bromeliad density, potential
bear resource tree density, leaf litter depth, mean tree height, mean emergent tree height, and distance to water (modified from Sandoval, 2000, and Gentry, 2001).

**Statistical analysis**

Normality assumptions were tested for all habitat variables and encounter rates using the W Shapiro – Wilks test. When variables were not normally distributed they were transformed accordingly (Sokal & Rohlf, 1995). In order to select the most appropriate relative abundance index we performed a Spearman’s coefficient correlation matrix using the different types of bear sign and their respective encounter rates. We then examined spectacled bear sign encounter rate variation between vegetation types using the Kruskal- Wallis test. Vegetation type selection was evaluated using a $X^2$ test and the Bonferroni confidence intervals on bear sign frequencies. To examine possible relationships between spectacled bear relative abundance and habitat variables we used stepwise regression. Multicolinearity between variables was analyzed using the Pearson correlation coefficient, and $r \leq 0.80$ was considered a suitable criterion for omitting a variable from the multivariate analysis (Luck, 2002).

**RESULTS**

**Relative abundance index across the landscape**

Spectacled bear sign encounter rates were highly variable between different vegetation types (Table 1). Spectacled bear path encounter rate (PER = number of paths/1 km of transect) was significantly related to encounter rates of all other types of bear sign ($r = 0.49, p = 0.004$ with feeding sites; $r = 0.389, p = 0.025$ with scats; $r =$
0.407, p = 0.019 with scratch marks; r = 0.405, p = 0.02 with hairs; r = 0.347, p = 0.048 with beds). A test was not possible for tree nests due to an extremely small sample size (n=1). We therefore decided to use Path Encounter Rate (PER) as an indicator of spectacled bear relative abundance across different vegetation types in the landscape, and in the sample site based evaluation of the influence of various habitat variables on the relative abundance of the species. No significant differences in PER were encountered between sample years (KW test, $X_i^2 = 1.730$, p = 0.421), and so years were amalgamated for posterior evaluations.

**Landscape selection**

Spectacled bear relative abundance was significantly different across vegetation types (KW test, $X_i^2 = 15.336$, p = 0.018), with PER highest in elfin forest, upper montane humid forest, and middle montane humid forest; lower in lower montane humid forest and high Andean humid grasslands, and absent during the study in dry montane forest and foothill humid forest.

A total of 487 paths were recorded at 27 of the 33 sample sites. Spectacled bear path sign frequency differed significantly across vegetation types from the expected frequency according to availability across the landscape ($X_i^2 = 471.08$, g.l. = 6; p < 0.001). Bonferroni confidence limits revealed that elfin and upper montane forests are clearly preferred by spectacled bears, whilst lower montane humid forest is not actively selected by bears, and foothill forest and dry montane forest forest do not
appear to be viable habitat for spectacled bears. High Andean humid grasslands and middle montane humid forest were used according to their availability.

**Ecological and geographical variables related to the Andean bear relative abundance in the landscape**

Table 2 summarizes values for each habitat variable at sample sites where spectacled bears were present. The majority of these variables were significantly correlated with elevation (mean emergent tree height: \( R = -0.929, p < 0.001 \); mean tree height: \( R = -0.892, p < 0.001 \); potential bear resource tree density: \( R = -0.475, p = 0.005 \); shrub density: \( R = -0.693, p < 0.001 \); canopy cover: \( R = -0.477, p = 0.005 \); visibility at ground level: \( R = -0.465, p = 0.006 \); slope: \( R = -0.418, p = 0.016 \); palm density: \( R = -0.475, p = 0.005 \); basal area: \( R = -0.574, p < 0.001 \); distance to water: \( R = -0.255, p = 0.151 \); bromeliad density: \( R = -0.113, p = 0.532 \); leaf litter depth: \( R = -0.063, p = 0.729 \); aspect: \( R = -0.067, p = 0.713 \)). Thus mean emergent tree height and mean tree height were excluded from the analysis and a total of 10 variables were used in the stepwise regression to determine the most parsimonious model. The final model (Table 3) was highly significant (\( F_{4,28} = 4.2411, p < 0.008 \)), and explained 61% of PER variance (coefficient of regression \( R \)). Habitat selection by spectacled bears was positively related to elevation and basal area of potential food items, and to a lesser degree, slope and distance to water, but only the first two variables had a significant (\( p < 0.05 \)) beta coefficient.

**INSERT TABLE 2**

**INSERT TABLE 3**
DISCUSSION

Spectacled Bear Habitat Use

Spectacled bears in the northwestern Bolivian Andes showed clear preferences for higher elevation forest vegetation types (elfin and upper montane humid forests). However, it is important to emphasize the relative scarcity of these vegetation types in the landscape (see Figure 1). Middle montane forest was also an important habitat and was used in proportion to its availability. Previous multiple sign type studies of spectacled bear habitat use also identify higher elevation forests as preferred habitat (Peyton, 1980; Paisley, 2001), mainly related to food resources within these forest types.

Recent studies have suggested that high elevation Andean humid grasslands and immediately adjacent montane forests are preferred habitats for spectacled bears (Paisley, 2001). In this study, spectacled bears used ‘páramo’ grasslands according to their availability. Páramo grasslands offer a limited diversity of food types such as large bromeliad plants (*Tilia* spp.), and some Ericaceae fruits near the forest border. We suggest that the visibility and accessibility of more open grassland habitats has lead some previous studies to overestimate the importance of this habitat, although a radio-telemetry study of two animals revealed seasonal use of grasslands in the wet season (Paisley, 2001), and it is important to emphasize the dry season nature of the present study. In addition, local people report bears more frequently from open habitats precisely because they are more visible and because livestock conflicts with spectacled bears are almost entirely confined to this habitat (Goldstein et al, in press). Thus, we would like to stress that the seasonal use of open-forested areas remains a hypothesis.
Lower montane humid forest was also registered as bear habitat, but bears were not recorded in the immediately adjacent vegetation types of dry montane forest (ranging between 700 and 1200m elevation) and foothill forests at the base of the Andes. Additional information from interviews with park guards and several local community members suggests that true dry forest is not a suitable habitat for the spectacled bear, although occasional records in transitional areas with lower montane humid forest exist (Rios et al., 2001). It is also worth mentioning that occasional records from foothill forest occur across the region, for example, a photograph of an adult on a beach of the river Tuichi at 450 m.a.s.l (Chalalan Ecolodge, pers. comm. to B. Rios), but so far we have been unable to demonstrate that foothill forest is a viable habitat for the spectacled bear in the northwestern Bolivian Andes landscape.

The results of the stepwise regression confirm that existing habitat preferences are related to high densities of spectacled bear potential resource trees, as well as shrub stems in general. This points to a corresponding increase in resource availability, both in terms of food and shelter, and as such greater bear importance. Literature reviews confirm that most identified spectacled bear food species are concentrated in these two habitats (Zenteno et al., in press). Available dietary information suggests that spectacled bears primarily consume bromeliad hearts, berries, palm hearts and fleshy fruits (Cabrera & Yepes, 1960; Peyton, 1980; Suarez, 1985; Goldstein, 1986; Lozada, 1989; Castellanos, 1997; Velez & Azurduy, 2000; Paisley 2001; Rivadeneira, 2001). However, very little information on spectacled bear diet has been collected at lower elevations, and given that these dietary items remain abundant in lower elevation forests (Flores et al., 2002; Zenteno et al., in press), we suggest that
greater spectacled bear abundance in higher elevation forests might also be partially
due to a relative dearth of potential vegetarian competitors. In the lower elevation
montane forests of northern La Paz, several Amazonian taxa are present in
significant numbers; Tapirus, Tayassu, Pecari, Mazama, Lagothrix, Ateles, Alouatta,
Cebus, Cuniculus, Dasypocta, Nasua, Eira, Mutu, Penelope, Pipile. Many of these
taxa begin to disappear in middle montane humid forests and are entirely absent
from the highest elevation forest types (Rios, 2001; Rios et al, 2001) leaving the
spectacled bear as the main mammalian fruit and berry consumer in these forests.

Altitude is obviously strongly related to vegetation type and is a major factor in
differentiating the various forms across the northwestern Bolivian Andes (Zenteno et
al., in press). Slope was not expected to be a major factor as spectacled bears are
known to be excellent climbers, although vegetation type and tree size might be
expected to be stunted on extreme inclines. Distance to water is also of limited use
given that most of the Andean landscape is relatively close to streams, however,
vegetation immediately adjacent to streams and rivers is specific and this might
influence bear presence. This might be most relevant in elfin forests that climb further
in fingers alongside highland streams.

**Encounter rate as relative abundance index**

Given that any spectacled bear sign is related to bear movements, it is not surprising
that spectacled bear path encounter rates were significantly related to encounter
rates for all other sign types. The Path Encounter Rate (PER) represents a promising
measure of spectacled bear relative abundance given the ease with which bear paths
are identified and their overall frequency compared to other types of bear sign.
Indeed, we recommend that future studies use path encounter rates as a standard measure of spectacled bear relative abundance, particularly as scat, bed and nest decomposition rates are unknown and are likely to vary more considerably across habitats than the detectability of bear paths. Feeding sign encounter rates may also be problematic if bear diet varies significantly across vegetation types implying variation in feeding sign type and as a result decomposition rates. Studies assessing variations in detectability over time for all types of bear sign across different types of habitat should be a priority for further evaluating the robustness of relative abundance measures.

A possible criticism of PER as a relative abundance measure is that the detectability of spectacled bear paths may be related to ground level vegetation density, a variable that varies across vegetation types. However, this situation was recognized at the beginning of the study and care was taken in the field to reduce this potential bias. Additionally large mammal communities diversify as altitude decreases, and future studies should be aware that the possibility of misidentifying bear paths and feeding signs increases as the larger mammals species begin to appear.

Reliable estimates of spectacled bear relative abundance are critical in order to evaluate the overall conservation potential for this threatened species of different regions across the Tropical Andes. It is important to emphasize that as yet across the entire spectacled bear range there is not a single density estimation carried out by direct methods (Peyton, 1999). The operational budget for the surveys presented in the paper was approximately 200 US dollars per sample site and the results have allowed the construction of reliable distributional and biological models for spectacled
bears. These models in combination with information concerning human activities across the landscape has permitted the development of a landscape scale action plan for the conservation of spectacled bear and the biodiversity they represent in the northwestern Bolivian Andes. This action plan includes the identification of critical connectivity issues and priority conservation and management interventions (Gómez, 2004).

Nevertheless, for the conservation and management of spectacled bear populations many critical data deficiencies remain including robust estimates of population density. Similarly, little is known regarding spectacled bear movements, either from a seasonal or life history perspective (Paisley, 2001; Castellanos, 2003). For example, are bears found continually in lower montane forest or is this a seasonal use in times of relative resource scarcity in higher elevation montane forests, as has been proposed for spectacled bear use of the high Andean grasslands?

Acknowledgements

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Table 1. Spectacled bear sign encounter rates by vegetation type. FHHF = foothill humid forest, LMHF = low montane humid forest, MMHF = middle montane humid forest, UMHF = upper montane humid forest, EF = elfin forest, DMF = dry montane forest; OHG = open highland grasslands.

<table>
<thead>
<tr>
<th>Vegetation type</th>
<th>Feeding sites</th>
<th>Paths</th>
<th>Beds</th>
<th>Scratch marks</th>
<th>Scats</th>
<th>Tree nests</th>
<th>Hairs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ER</td>
<td>sd</td>
<td>ER</td>
<td>sd</td>
<td>ER</td>
<td>sd</td>
<td>ER</td>
<td>sd</td>
</tr>
<tr>
<td>FHHF</td>
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<td>0.0</td>
<td>0.0</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<td>LMHF</td>
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<td>1.3</td>
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<td>1.7</td>
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<td>0.2</td>
<td>0.2</td>
<td>0.0</td>
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<td>MMHF</td>
<td>0.8</td>
<td>1.3</td>
<td>6.3</td>
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<td>0.1</td>
<td>0.7</td>
<td>0.9</td>
<td>0.0</td>
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<td>UMHF</td>
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<td>1.1</td>
<td>8.4</td>
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<td>EF</td>
<td>4.0</td>
<td>1.6</td>
<td>16.7</td>
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<td>0.7</td>
<td>0.8</td>
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<td>DMF</td>
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<td>0.0</td>
<td>0.0</td>
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<td>0.0</td>
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<tr>
<td>OHG</td>
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<td>6.0</td>
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<td>5.2</td>
<td>0.1</td>
<td>0.3</td>
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Table 2. Values for each habitat variable at sample sites where spectacled bears were present

<table>
<thead>
<tr>
<th>Variable</th>
<th>Units</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
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<tr>
<td>Aspect</td>
<td></td>
<td>1</td>
<td>8</td>
<td>5.07</td>
<td>2.20</td>
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<tr>
<td>Basal area</td>
<td>m²/m²</td>
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<td>4.11</td>
<td>1.80</td>
<td>1.31</td>
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<td>Bromeliad density</td>
<td></td>
<td>0</td>
<td>111</td>
<td>23.96</td>
<td>23.02</td>
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<tr>
<td>Canopy cover</td>
<td></td>
<td>0</td>
<td>5</td>
<td>2.74</td>
<td>1.85</td>
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<tr>
<td>Distance to water</td>
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<td>4</td>
<td>6</td>
<td>5.81</td>
<td>.48</td>
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<tr>
<td>Elevation</td>
<td>m a.s.l.</td>
<td>958.10</td>
<td>3699.60</td>
<td>2419.36</td>
<td>880.97</td>
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<td>Emergent tree height</td>
<td>m</td>
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<td>30.00</td>
<td>13.99</td>
<td>9.97</td>
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<td>Leaf litter depth</td>
<td>cm</td>
<td>0</td>
<td>64.68</td>
<td>22.18</td>
<td>18.37</td>
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<tr>
<td>Mean tree height</td>
<td>m</td>
<td>0</td>
<td>22.50</td>
<td>8.5496</td>
<td>6.36</td>
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<tr>
<td>Palm density</td>
<td>Ind/km²</td>
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<td>211.00</td>
<td>27.30</td>
<td>47.06</td>
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<tr>
<td>Slope</td>
<td>degree</td>
<td>7.5</td>
<td>33.9</td>
<td>19.77</td>
<td>7.22</td>
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<tr>
<td>Visibility</td>
<td></td>
<td>0</td>
<td>4</td>
<td>2.11</td>
<td>1.311</td>
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Table 3. Habitat variables included in the final model showing the values of the beta statistic, levels of significance (Sig.) and proportion of the variance explained (R).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients</th>
<th>S.E.</th>
<th>Sig.</th>
<th>R</th>
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<tr>
<td>Constant</td>
<td>-38.138</td>
<td>16.327</td>
<td>0.027</td>
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</tr>
<tr>
<td>Elevation</td>
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<td>0.001</td>
<td>&lt;0.001</td>
<td>0.296</td>
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<tr>
<td>Basal area(^a)</td>
<td>5.879</td>
<td>1.692</td>
<td>0.001</td>
<td>0.544</td>
</tr>
<tr>
<td>Distance to water</td>
<td>3.832</td>
<td>2.227</td>
<td>0.096</td>
<td>0.587</td>
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<tr>
<td>Slope(^b)</td>
<td>46.961</td>
<td>38.639</td>
<td>0.234</td>
<td>0.614</td>
</tr>
</tbody>
</table>

\(^a\) Transformed into square root  
\(^b\) Transformed into its inverse
Figure 1. Study area and sample sites within the Madidi and Apolobamba protected areas of northern La Paz Department, Bolivia.