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Authors: Raboy, Becky E., Neves, Leonardo G., Zeigler, Sara L., and Oliveira, Leonardo C.

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Occurrences of the Golden-headed Lion Tamarin (*Leontopithecus chrysomelas*) above 500 Meters in Southern Bahia, Brazil and Implications for Conservation Planning

Becky E. Raboy^{1,2,3}, Leonardo G. Neves², Sara L. Zeigler⁴ and Leonardo C. Oliveira^{2,5,6,7,8}

¹Smithsonian Conservation Biology Institute, National Zoological Park, Washington DC, USA

²Instituto de Estudos Socioambientais do Sul da Bahia, Ilhéus, BA, Brazil

³Centre for Research and Conservation, Royal Zoological Society of Antwerp, Antwerp, Belgium

⁴Department of Geography, University of Maryland, College Park, MD, USA

⁵Department of Biology, University of Maryland, College Park, USA

⁶Programa de Pós-graduação em Ecologia, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brazil

⁷Programa de Pós-graduação em Ecologia e Conservação da Biodiversidade, Universidade Estadual de Santa Cruz, Ilhéus, BA, Brazil

⁸Bicho do Mato Instituto de Pesquisa, Belo Horizonte, MG, Brazil

Abstract: The golden-headed lion tamarin, *Leontopithecus chrysomelas*, was formerly thought to range below 300–400 m above sea level, because of changes in forest physiognomy and lack of resources at higher elevations. We document four cases (from two studies) of *L. chrysomelas* ranging above 500 m, and investigate the behavior of two groups that ranged from 100 to 700 m. We discuss the possibilities that 1) resources may be more abundant at higher elevations than previously thought, 2) a shift may have occurred in the species elevation-use patterns in response to forest loss and degradation at lower elevations, and that 3) golden-headed lion tamarins require low elevations for access to resources but use higher altitudes to travel between lower lying areas. Understanding exactly how *L. chrysomelas* uses higher elevations and the limits of its upper ranging patterns has significant conservation implications for this endangered species. Even without being able to definitively ascertain that golden-headed lion tamarins are able to settle in stable home ranges at higher elevations with adequate resources for breeding and survival, they certainly move through these habitats. We suggest, therefore, that slopes and ridge-tops should be taken into account as corridors to be preserved for gene flow in the otherwise highly fragmented *L. chrysomelas* metapopulation.

Key words: Altitudinal limit, golden-headed lion tamarin, *Leontopithecus chrysomelas*, Callitrichidae, forest connectivity, habitat suitability, Neotropics, resource limitation

Introduction

The golden-headed lion tamarin (*Leontopithecus chrysomelas*) inhabits wet coastal and inland semi-deciduous forests in the northern Atlantic forest, extending through southern Bahia and, in the past, northwest Minas Gerais (Pinto and Rylands 1997; Raboy *et al.* 2010). It is classified as Endangered on the IUCN Red List due to habitat loss and fragmentation resulting from conversion of forest and shade-cocoa agroforest to cattle pasture or other agricultural crops. It was believed that *L. chrysomelas* inhabited altitudes mostly below 300 m above sea level (Coimbra-Filho 1969; Hershkovitz 1977; Rylands *et al.* 1993). Pinto

and Rylands (1997) found *L. chrysomelas* as high as 400 m but supposed it improbable that *L. chrysomelas* would use elevations higher than 500–550 m because of changes in climate, floral communities and forest physiognomy. Areas in the *L. chrysomelas* geographic distribution include elevations up to 1,100 m (Fig. 1). The question thus remains, to what extent (altitudinal limit, frequency and type of use) do *L. chrysomelas* use the higher elevation habitats? The golden lion tamarin (*L. rosalia*), another coastal, but more southerly species, has now been found at elevations of up to 550 m (Kierulff and Rylands 2003). The black lion tamarin (*L. chrysopygus*), occurring on the inland plateau of the

state of São Paulo, has been recorded at elevations of 700 m (Coimbra-Filho 1970) and 900 m (C. Knogge pers. comm.).

Here we report on the occurrence of *L. chrysomelas* in areas above 500 m on four occasions in different areas of their distribution. We also present a frequency histogram of elevation use from two study groups followed at higher elevations. We discuss reasons why *L. chrysomelas* might be seen at higher elevations and the conceptual implications of higher-elevation use for the development of habitat and landscape models implemented to assist in conservation planning for this species.

Methods

We compiled results from two different studies conducted by the authors in southern Bahia: the “GHLT Connection” and the “Cabruca Project.” Researchers in the GHLT Connection conducted a survey of *L. chrysomelas* throughout the species’ known historic distribution. The area, shown as the polygon outlined in black in Figure 1, included forests between the Rio de Contas and the Rio Jequitinhonha, from the coast westward toward the region of the rios Gongoji, Acará, Catolé Grande and Ribeirão do Salto. Researchers in the Cabruca Project studied the behavior and ecology of *L. chrysomelas* groups in shade-cocoa (“cabruca”) agroforest. The Cabruca Project was carried out in two phases. The first was a survey of the shade-cocoa region in the east of the range of *L. chrysomelas* to select study sites, and the second involved the study of radio-collared groups of *L. chrysomelas* in the study locations chosen. *L. chrysomelas* groups were followed on multiple days in the municipalities of Camacã, Una, Ilhéus, Jussari and Arataca.

The two projects implemented varying overall experimental designs. The GHLT Connection surveyed forest patches selected by stratified random sampling between November 2005 and November 2007 using playback methods outlined in Raboy *et al.* (2010). When *L. chrysomelas* were sighted, a GPS point was taken. For the most part, elevations higher than 400 m were not sampled, presuming *L. chrysomelas* would not be found in these areas, but occasionally points along transects reached these elevations and higher. The Cabruca Project first surveyed for possible long-term monitoring sites between June and August of 2006 and 2007 based on results from the GHLT Connection, word of mouth regarding possible locations of *L. chrysomelas*, and additional playback work. Following that, selected *L. chrysomelas* groups were monitored with radio-telemetry between April 2008 and September 2009. Two of the seven study groups ranged in areas with elevations above 500 m. At 20-min intervals, a group’s geographic position and altitude were recorded using a GPS device. UTM coordinates were collected using Corrégo Alegre datum (UTM Zone 24L) for both projects. The altitude of observations was determined by measuring elevation at the location of observation with the GPS altimeter and by cross referencing UTM coordinates (re-projected from the Corrégo Alegre datum to South American 69) with a Shuttle

Radar Topography Mission (SRTM) elevation map of the study region (South American 69; data courtesy of NASA/NGA/USGS at <http://www2.jpl.nasa.gov/srtm/>).

For the first part of our investigation, we noted all observations from each of the two studies documenting *L. chrysomelas* above 500 m. We subsequently used the results of the Cabruca Project to determine histograms of elevation use for the two high-elevation study groups of *L. chrysomelas*. For this we determined the number of 20-minute observations that occurred in each 100 m altitude class to ≥ 700 m.

Results

We registered *L. chrysomelas* above 500 m at four different localities in three different municipalities of Bahia (Fig. 1):

1) *Floresta Azul (from GHLT Connection)*. Two individuals were seen at 633 m (cross referenced at 600–700 m), responding to playback calls at the border between shade-cocoa and secondary forest. The group later moved to even higher altitude, although it was not possible to register a GPS point. 426166 E 8345747 N at maximum altitude measurable.

2) *Arataca (from Cabruca project - site selection phase)*. A group of four individuals was recorded at 515 m (cross referenced at 400–500 m but <80 m Euclidean distance from the 500 m contour) in primary forest. 463817 E 8319996 N.

3) *Arataca (from Cabruca Project - monitoring phase)*. A group of eight individuals including two infants (approximately one month old) were observed using a maximum altitude of 551 m (cross referenced at 500–600 m) in primary forest. 455530 E 8323006 N at maximum altitude observed.

4) *Camacã (from Cabruca Project - monitoring phase)*. Two males were observed at a maximum altitude of 650 m (cross referenced at 600–700 m) in primary forest. 439756 E 8302606 N at maximum altitude observed.

The majority of the 20-minute observations for the Cabruca Project for one reproductive group (“Bem Te Vi”) were in the 300–400 m elevation category (Fig. 2). On two of 14 days of observation, the group used altitudes above 500 m. For another group (two males; “São José”), the majority of observations were also in the 300–400 m elevation category, although the two males used five elevation classes (from 200 m to 600 m; Fig. 2). On three of seven days of observation they ranged to altitudes above 500 m. On one of those days, individuals in the São José group spent the entire day above 400 m in cabruca and primary forest, using a sleeping hole also above 400 m. Both groups of *L. chrysomelas* used slopes spanning at least four elevation classes or 400 m differential from highest to lowest observations.

Discussion

We documented four *L. chrysomelas* groups in different geographic regions using forests at 500–700 m altitude, the highest altitudes yet published for the species. Our findings imply several possibilities in relation to the previous suggestion that lion tamarins use only lower elevations. First, the

hypothesis that resources are inadequate at higher elevations may be incorrect for the levels at which *L. chrysomelas* were found. In a study focusing on the avifauna of southern Bahia, Silveira *et al.* (2005) indicated that the vegetation became markedly stunted at approximately 800 m across their study sites in the Serra dos Lontras and Javi ranges. Up to this point, the forest still comprised tall trees and bromeliads (Silveira *et al.* 2005) and, at least in physiognomic terms, might be favorable to lion tamarins from what we know of their needs. In a botanical inventory of three montane areas in southern

Bahia, Amorim *et al.* (2009) recorded 1,129 plants species at altitudes 300 to 1080 m above sea level. Seventeen species on this list were also present and classified as “extremely valuable” on a list of key resource species for *L. chrysomelas* by Oliveira *et al.* (2010) from a lower-lying forest (<100 m altitude). An additional 25 species were listed as “key” (useful but to a lesser degree than the “extremely valuable”; Oliveira *et al.* 2010). Amorim *et al.* (2009) also recorded high bromeliad diversity above 400 m. Golden-headed lion tamarins forage for animal prey most commonly in bromeliads (Oliveira *et al.*

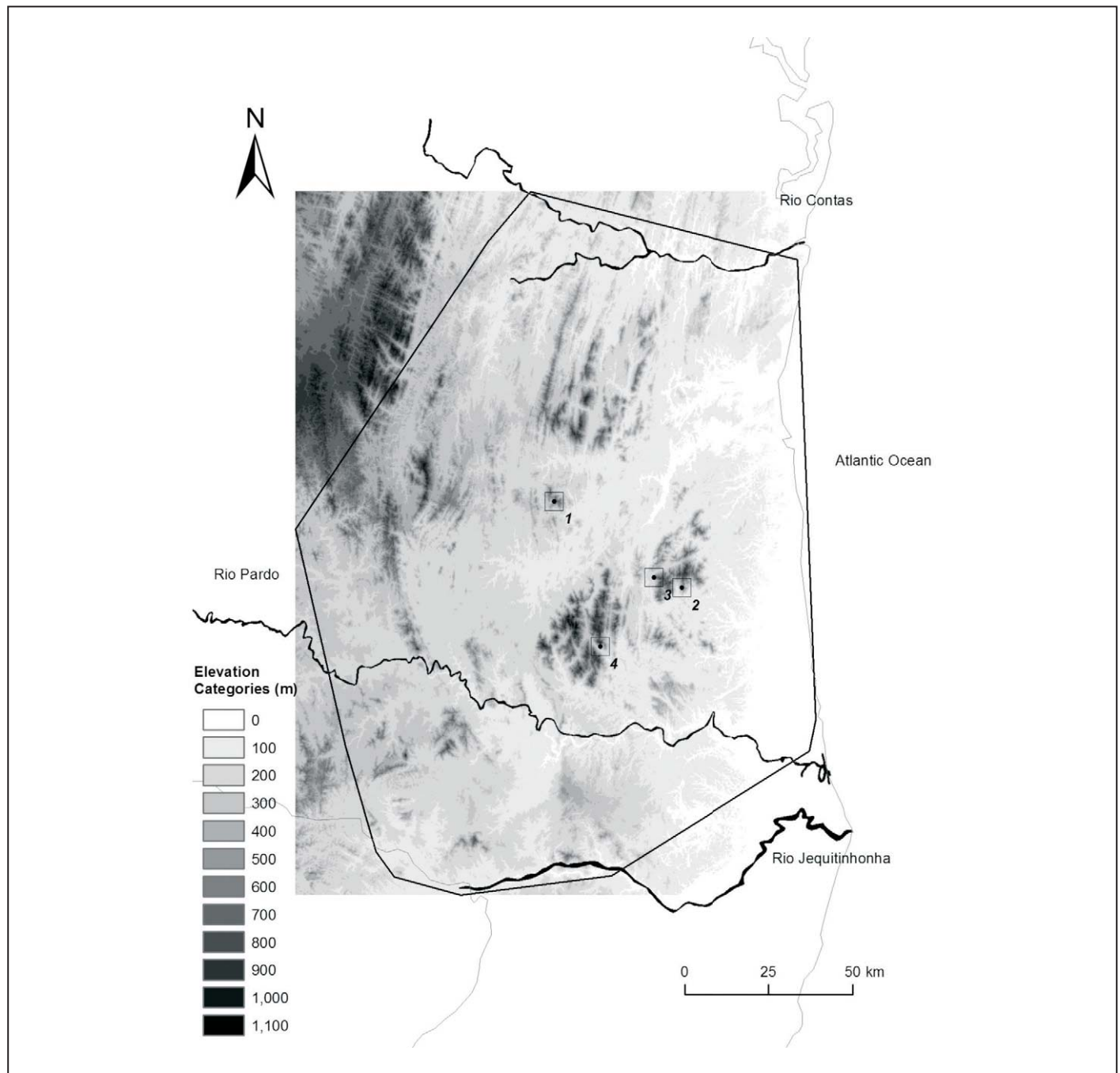


Figure 1. Elevation map of southern Bahia. A light grey line delineates the boundary of Bahia state. The black polygon represents the former distribution of *L. chrysomelas* and the area sampled for the GHLT Connection Project (Raboy *et al.* 2010). The four *L. chrysomelas* sightings above 500 m are shown by the points outlined in squares.

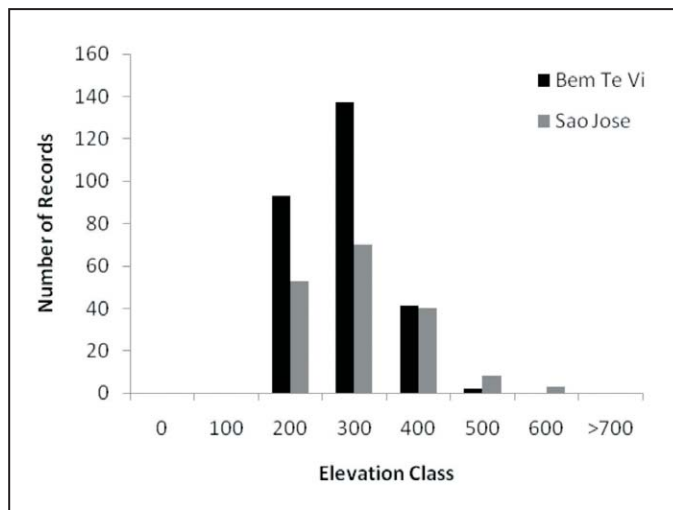


Figure 2. Elevational distribution of observations from two groups of *L. chrysomelas* in the Cabruca Project.

2011; Raboy and Dietz 2004). We documented *L. chrysomelas* above 500 m at two locations of the Amorim study. The results from Silveira *et al.* (2005), Amorim *et al.* (2009), and the Cabruca Project documenting golden-headed lion tamarin groups eating and sleeping above 400 m are suggestive that *L. chrysomelas* might have adequate resources at these and higher elevations.

Second, a shift may have occurred in the species elevation-use patterns in response to anthropogenic change in the region, and *L. chrysomelas* could be using higher elevations despite their poorer resources. Kierulff and Rylands (2003) suggested that the presence of *L. chrysomelas* above 500 m in the Serra do Mar in the state of Rio de Janeiro was the result of deforestation at lower levels that had pushed populations into more mountainous areas. Groups were seen at these higher elevations but near to houses where they had access to cultivated fruits such as bananas. Silveira *et al.* (2005) believed that extensive deforestation at lower elevations also explained the presence of some bird species found in Bahia at altitudes higher than documented in other locations. Historical evidence of the absence of lion tamarins in higher elevations currently used by them would indicate a shift towards higher elevation, but this information does not exist. Comparative studies of foraging and reproductive success of *L. chrysomelas* ranging exclusively at higher and at lower elevations along with corresponding phenological studies to estimate food availability would help elucidate the patterns in elevation use seen in this species.

With the exception of the studies we have mentioned, little information exists indicating the effect of altitudinal gradient on potential *L. chrysomelas* resources in southern Bahia. Other callitrichid genera have been documented using higher elevations in the Atlantic forest. *Callithrix geoffroyi*, also thought to be a lowland species (500 m; Passamani and Rylands 2000; Rylands and Faria 1993) with a similar diet to lion tamarins (except, principally, its exploitation of

plant exudates when fruits are scarce), has been found in the Estação Biológica de Santa Lúcia, a reserve ranging from 550–950 m in Espírito Santo (Passamani *et al.* 2000) and at 1274 m in the Serra do Cipó National Park, Minas Gerais (Oliveira *et al.* 2003). Pinto *et al.* (2009) found that elevation was one of the five most important predictors of species density for three (*Brachyteles*, *Cebus* and *Callithrix*) of five focal species in a study of primates (including *Alouatta*, and *Callicebus*) throughout four Brazilian states: São Paulo, Rio de Janeiro, Minas Gerais and Espírito Santo. For *Brachyteles*, *Cebus* and *Callithrix*, the relationship between species density and elevation was negative, but elevation was less consistent as a predictor of density for all five species as compared to precipitation and temperature (Pinto *et al.* 2009).

Sightings of *L. chrysomelas* groups in higher altitudes do not necessarily mean that they use resources or reproduce in these areas. A third explanation is that they continue to be low-elevation species and only use higher-altitude forests for travel or dispersal, traversing slopes and peaks with limited or absent resources for the same reasons they cross open fields (B. Raboy pers. obs.). In the GHLT Connection, we observed that higher elevation forests tended to be better preserved than many of those in lower elevations. Summits at higher elevation in the west often stood as forest islands surrounded by cattle pasture. The steeper terrain and rise in elevation decreases its accessibility or suitability for certain forms of agriculture. Moreover, Brazilian legislation (Forestry Code/Federal law 4771/65 and CONAMA resolution 303/02) considered areas of steep terrain slopes (>45 degrees), hill and mountain tops (above 2/3 height in relation to the base) and high altitude (>1800 m) as Areas of Permanent Protection (APP; CONAMA 2002). APPs must preserve the original native vegetation and may not be used for production (Sparovek *et al.* 2010). Although *L. chrysomelas* resource quality has not been quantified in these areas, forested hilltops certainly provide *L. chrysomelas* with cover and protection from predators.

Increasing the known upper elevational limit to which *L. chrysomelas* finds resources, reproduces or travels within has implications for conservation planning in that it increases the available habitat. Assuming the higher-elevation habitat is suitable for finding resources and breeding, it provides refugia from the degradation and fragmentation of the lowland forests. If high elevation forests serve only as a conduit—a corridor—for dispersal and gene flow between lower-lying populations, this still has strong conservation implications, increasing the potential functional connectivity of existing fragments. Increased connectivity facilitates gene flow in the metapopulation, which is at present extremely fragmented (Raboy *et al.* 2010; Zeigler *et al.* 2010).

Prior conservation modeling predicting future *L. chrysomelas* abundance excluded the possibility that *L. chrysomelas* used forest above 400 m. Holst *et al.* (2006) conducted a Population and Habitat Viability Analysis (PHVA) for populations of *L. chrysomelas* in two areas containing high elevations—the Serra do Baixo and Serra das Lontras.

While the estimated overall areas were 32,089 ha for Serra do Baixão and 8,015 ha for Serra das Lontras, the areas deemed suitable for *L. chrysomelas* were only 13,782 ha and 1,668 ha respectively, principally due to the large amount of forest above 400 m elevation in these locations. If *L. chrysomelas* uses elevations greater than the upper limit of 400 m for maintaining territories and breeding, the predicted outcomes for population size and probability of maintaining genetic diversity in those locations could be considerably underestimated. Recent work with howler monkeys (*Alouatta pigra*) in cloud forest of Guatemala indicated use of much higher altitude

than previously thought. The authors suggest these regions will become important for species conservation and must be included in updated estimates of the species range (Baumgarten and Williamson 2007).

Superimposing a reclassified elevation map (0–300 m, 300–500 m, 500–700 m and >700 m) on a forest cover map of the *L. chrysomelas* range elaborated by Zeigler *et al.* (2010), we determined that forested areas under 500 m in the *L. chrysomelas* range (880,179 ha) represented 91.2% of the total forest cover including all elevations (965,861 ha; Fig. 3). Forested areas between 500 m and 700 m were 6.2% and those

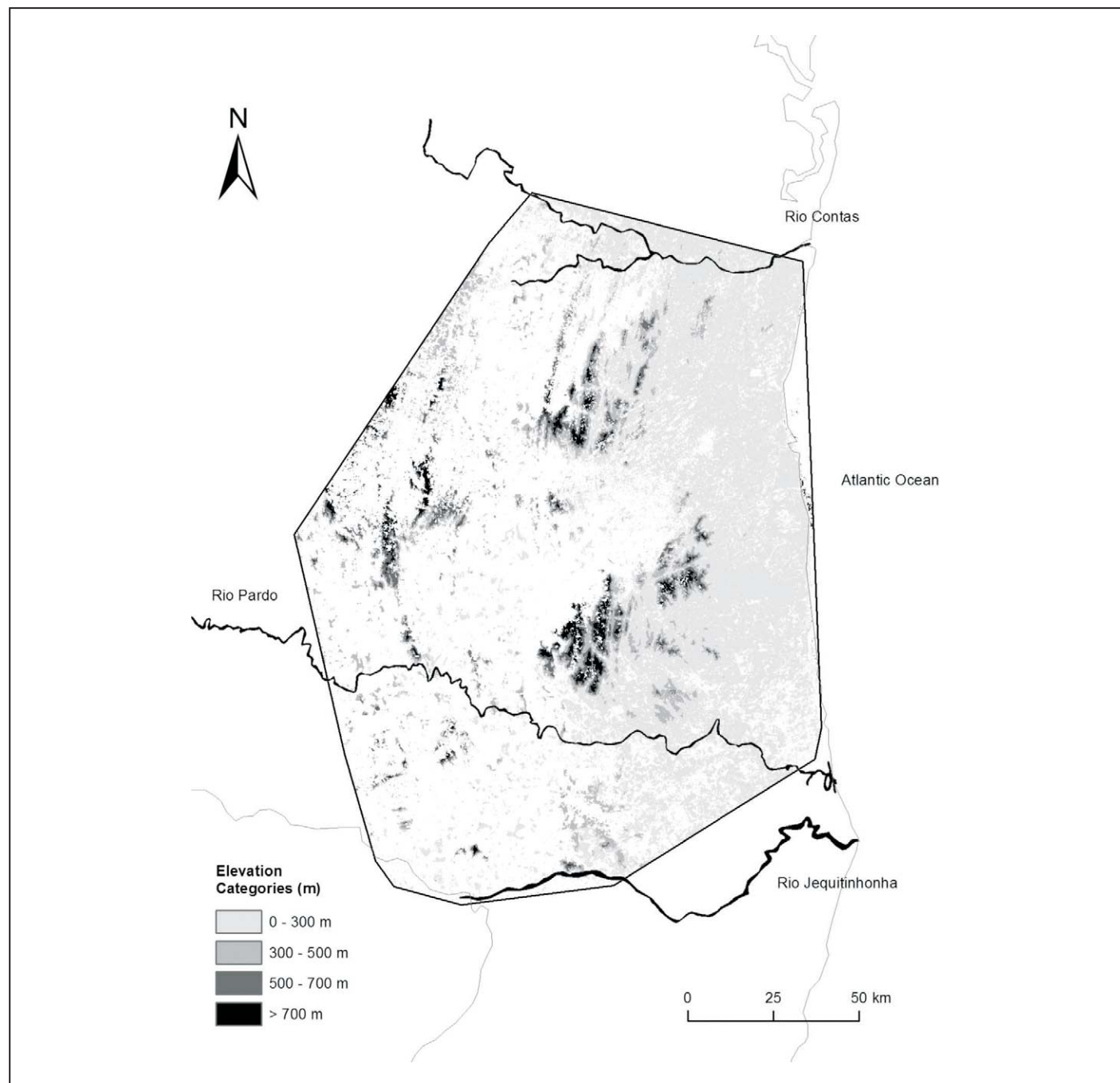


Figure 3. Map showing the remaining forest in the *L. chrysomelas* distribution by four elevation classes. Forest cover was determined by Sara Zeigler, based on interpretation of 2007 Landsat images (see Zeigler *et al.*, 2010 for more details).

at elevations above 700 m were 2.6% of the total forest cover. Thus, the additional area gained, considering all forest up to 700 m as suitable for *L. chrysomelas* (rather than the <500 m model), increases potential forest for the species by 6.8%.

Functional connectivity also increased slightly, particularly north of the Rio Pardo, when forest at elevations above 500 m could serve as corridors for dispersing *L. chrysomelas* (S. Zeigler unpubl.). While high elevation areas make up only a small portion of the *L. chrysomelas* range, the location of these areas is significant. Many of them are located centrally in the *L. chrysomelas* distribution (Fig. 3) in areas that currently harbor *L. chrysomelas* and other threatened biodiversity (SAVE Brasil *et al.* 2009), such as those analyzed in the PHVA. These regions are regarded as having significant conservation potential as part of a network of reserves recently created or proposed (SAVE Brasil *et al.* 2009). Floresta Azul (Sighting 1) is within the Serra dos Barbados range that rises to approximately 800 m, with cabruca forest occurring up to 700 m. The region of Arataca where *L. chrysomelas* was found (Sightings 2 and 3), is part a chain of mountains that includes the Serra das Lontras, the Serra dos Quatis and the Serra Javi where the maximum altitude is nearly 1,000 m. Cabruca is prevalent up to altitudes of 600 m. The region of Camacã where *L. chrysomelas* was found (Sighting 4) is located in the Serra do Baixo chain (west of Lontras) that rises up to 900 m and is composed of a mosaic of vegetation ranging from open pasture to mature forest. Cabruca is a habitat known to be used by *L. chrysomelas* and provides suitable resources throughout the species' range (Oliveira *et al.* 2010, 2011; Raboy *et al.* 2010).

It is evident that *L. chrysomelas* can be found in higher elevations than previously thought, though exactly how they use these areas is still unclear. While observations of *L. chrysomelas* above 500 m are still seemingly rare, it is important to note that the two projects assessed in this paper for the most part avoided sampling for *L. chrysomelas* in higher altitude areas presuming the species would not be present. We predict that future systematic sampling for *L. chrysomelas* in elevations of 500 m to 700 m will yield a greater number of sightings than was documented from our *ad libitum* visitation of this elevation. Forested slopes and ridges serving as corridors (at least up to about 600–700 m) may greatly contribute to increasing the connectivity of the *L. chrysomelas* metapopulation and should be investigated further. Specifically, future studies are necessary to evaluate what limits the use of higher elevations by *L. chrysomelas*, what is truly “too high” for lion tamarins, and how ecological parameters (home range size, habitat use, sleeping site use and dispersal patterns) and social and demographic characteristics (group size, composition and biomass) of *L. chrysomelas* vary by elevation.

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18444-1 for the capture of *L. chrysomelas*. The owners and employees of the Fazendas Almada, Santa Rita, Riachuelo and São José and the private reserves of Ararauna and Serra do Teimoso permitted us to conduct our study on their properties and provided support to our field team. We thank Jiomário dos Santos Souza, Edimalvan da Purificação and Paula Roberta Pedreira dos Reis for field assistance. Financial support was provided by University of Maryland (UM) Biology Department, Seeds of Change, the Lion Tamarins of Brazil Fund, the Wildlife Conservation Society, International Foundation of Science, The Rufford Small Grants Foundation and Idea Wild, the University of Maryland (College of Chemical and Life Sciences Board of Visitors, Ann G. Wylie Dissertation Fund, Drs. Wayne T. and Mary T. Hockmeyer Doctoral Fellowship), and CAPES/Fulbright. We are grateful to Leticia Bastos for taking us to her field site in the Serra das Lontras where we were able to record *L. chrysomelas* above 500 m.

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Authors' addresses:

Becky E. Raboy, Smithsonian Conservation Biology Institute, National Zoological Park, 3001 Connecticut Ave, NW, Washington, DC, 20008 USA, **Leonardo G. Neves**, Instituto de Estudos Socioambientais do Sul da Bahia, BA, 45653-145 Brazil, **Sara L. Zeigler**, Department of Biological Sciences, Virginia Tech. Blacksburg, VA 24060 USA, and **Leonardo C. Oliveira**, Pós-graduação em Ecologia, Universidade Federal do Rio de Janeiro, RJ, 21941-590 Brazil. E-mail of first author: <raboyb@si.edu>.

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