The Roosevelt – Rondon Expedition Marmoset (*Mico marcai*): Unveiling a Data Deficient Species

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Abstract

The Roosevelt-Rondon Expedition marmoset, *Mico marcai,* was collected in 1914 and to date, all information on this species comes from three skins brought back by the Expedition and two additional skins collected in the 1990s. It is no surprise then that *M. marcai* has been classified as Data Deficient (DD). Given that *Mico marcai*'s suspected range sits on the path of the advancing Brazilian "Arc-of-Deforestation", it is urgent that relevant data be collected to assess this taxon. Here we present the first comprehensive field data on the distribution, population size and threats on *M. marcai* with the goal of removing the species from the DD category. From 2012 to 2015, we surveyed for the species in 11 localities, in and around the Marmelos-Aripuanã interfluve, and estimated density using distance sampling on 10 transects. We also used spatial predictive modelling to project the amount of habitat that will be lost within its range in 18 years under different deforestation scenarios. We found marmosets in 14 localities and calculated its Extent of Occurrence to be 31,073 km². We walked 271 km and detected 30 marmoset groups, allowing us to estimate their density to be 8.31 individuals/km² and a total population of 258,217.71 individuals. By a "Business as usual" scenario, 20,181 km² of habitat will be lost in three marmoset generations (~18 years), compromising 33% of the species' range. Accordingly, *M. marcai* should be classified as globally Vulnerable under category A3c. Following our study, we propose the Amazonian marmosets, genus *Mico*, should undergo similar re-assessment as their ranges all fall in the path of the Arc-of-Deforestation.

Keywords: Amazonian marmosets, Conservation Status, Data Deficient, Habitat Loss, Southern Amazonia

INTRODUCTION

The assessment of a species threat status is the first step towards its conservation. Non-assessed species remain outside the conservation 'radar' whereas species for which important ecological and population data are lacking remain as Data Deficient (DD) (IUCN, 2012), a highly undesirable status as DD species can be seriously threatened but remain overlooked by conservationists. One such species is the Roosevelt-Rondon Expedition *Mico marcai*) from the Southern Amazon, an area heavily impacted by the advancing Brazilian agricultural frontier. In the latest Brazilian National Threat Assessment of Primates, *Mico marcai* was the only marmoset classified as DD, the same classification as it has on the latest IUCN Red List (Rylands & Silva Jr, 2008, Silva 2015). This primate was first observed and collected by the Roosevelt-Rondon Expedition in 1914 but remained overlooked in the National Museum of Rio de Janeiro mammal collection for 79 years until Alperin (1993), while revising all marmosets of the *argentata* group, described it as a new taxon and named it *Callithrix argentata marcai*. This taxon was later elevated to full species status and included in the genus *Mico* (Rylands et al., 2000).

Marca's marmoset type specimen was apparently collected at the confluence of Roosevelt and Aripuanã Rivers (information on the specimens' museum tag) (Alperin, 2002) (Figure 1). In 2000, van Roosmalen et al. described a new species of marmoset, *M. manicorensis* and its type locality was considered as the confluence of the Manicoré and Madeira Rivers (Figure 1). However, the hypothesized distribution of *M. manicorensis* encompassed the Manicoré-Aripuanã interfluve, including the type locality of *M. marcai*. Based on an examination of the few available specimens,

74 Garbino (2014) proposed that van Roosmalen et al. (2000) *manicorensis* was a junior
75 synonym of Alperin (1993) *marcai*, a taxonomic proposition held to date.

76 In this study, we present the first comprehensive data analysis on *M. marcai*
77 distribution and population size from field surveys and literature records. Our goal is to
78 fulfil an important knowledge gap on the species' occurrence, density, and threats that
79 will enable us to carry out its first conservation status assessment. Finally, using spatial
80 predictive modelling, we predicted the amount of Marca's marmosets' habitat that will
81 be lost by 2036 under a more conservative 'Governance' scenario and a more realistic
82 'Business as Usual" scenario. To the best of our knowledge, this is the first study
83 specifically aimed at removing an Amazonian primate species from its DD status by
84 gathering relevant *in situ* information through a series of surveys and systematic
85 transect sampling and using the latest available remote sensing data to model current
86 and future habitat loss.

87

88 **STUDY AREA**

89 This study was carried out in the Marmelos-Aripuanã interfluve, two right bank
90 tributaries of the Madeira River in Brazil (Figure 1). The climate is tropical, with a short
91 dry season from July to September, a mean annual temperature of 28°C and a mean
92 annual precipitation of 2,500 to 3,000 mm/year (Hayakawa & Rossetti, 2015). The
93 vegetation is comprised mostly of upland forest, seasonally flooded forests, and patches
94 of white sand *campinaranas* (Anderson, 1981). The study area is within the "Arc-of-
95 Deforestation" region of Amazonia, which is under severe threat from the rapidly
96 expanding Brazilian agricultural frontier, urban encroachment, logging and
97 infrastructure projects (Nepstad et al., 2001; Vieira et al., 2008). Our study area is
98 located inside the Manicoré municipality, which together with Apuí municipality, are

the two main municipalities in livestock production in Amazonas State, forming the 'Arc of Cattle Ranching' (Carrero et al., 2015). Additionally, the study area has been recently considered a deforestation hotspot due to the Transamazônica Highway (Fearnside et al., 2009; Carrero & Fearnside, 2011).

METHODS

Surveys and Transect Sampling

Between 2012 and 2014, we carried out six expeditions to the Marmelos–Aripuanã interfluve to survey for marmosets and other primates, totalling 63 days of fieldwork. Our surveys included, (1) the confluence of the Roosevelt and Aripuanã rivers, (2) the upper and lower Manicoré River, and (3) the mid Aripuanã River (Fig. 1). Surveys were conducted on the ground using existing trails and roads, and on board of small boats along the rivers searching for the species presence (National Research Council, 1981). We recorded all sightings with a Global Position System (GPS) device and, using these locality records along with data from the literature (Ferrari, 1993; van Roosmalen et al., 2000; Alperin, 2002; Röhe, 2007, Garbino 2014), we defined the species' Extent of Occurrence (EOO, *sensu* IUCN, 2012). To do that, we followed IUCN's guideline to calculate a species EOO where a minimum convex polygon (MCP) containing all of the species records is produced (IUCN, 2012). Assuming rivers are effective barriers to primate dispersal (see Ayres & Clutton-Brock,1992), we subsequently adjusted our EOO by linking our calculated MCP to the nearest large rivers to produce a more accurate map and measurement of the total area potentially occupied by the species, *i.e.,* its geographical range.

In order to estimate the species abundance and population density, we carried out systematic transect sampling in two sites from January to February 2015. The first

124 set of transects was placed near the species' type locality (7°31'17.86" S;
125 60°40'24.65"W). The second set was placed in the lower Manicoré River (6°1'19.56" S;
126 61°37'54.81"W). In total, we opened six transects in the first site and four in the second,
127 averaging 3.07 ± 0,63 km in length each (Figure 1). The exact distribution of transects
128 within the area was done by randomization of each trail starting point and direction
129 using ArcGIS. We followed standardized field protocols for data collection using the
130 distance sampling method (Burnham et al., 1980; Buckland et al., 1993; Peres, 1999) to
131 estimate marmoset densities where two observers would walk the length of the transects
132 at a speed of 1.5 km/h recording, when detected, the number of individuals sighted and
133 the perpendicular distance between the transect and the center of the group. Transect
134 surveys were carried out from 7 am to 11 am in one direction, and from 2 pm to 5 pm in
135 the reverse direction. We gave transects a two-day rest in between sampling to reduce
136 the impact of the observers' presence on the detection rate. We estimated the density of
137 marmosets using the software DISTANCE 7.1 (REF). This analysis fits several
138 detection functions to provide the probability of detecting groups and estimate the
139 possible number of individuals missed by the observers. The encounter rate (groups/km)
140 obtained and the average number of individuals per group was used as parameters to
141 estimate density.

142 For these calculations, we first used a Chi-Square Goodness-of-Fit Test (GOF)
143 to determine the appropriate truncations and perpendicular distances intervals to adjust
144 the detection functions, considering $p > 0.6$. We compared the adjustments of the
145 detection functions using Akaike Information Criterion values (AIC). Two models were
146 considered distinct when they presented differences greater than two points between
147 AIC values; those with smaller AIC values were considered more parsimonious. If more
148 than one function was considered a good fit to the data, we would then select the model

149 where the density estimate had the lowest coefficient of variation. We then used the
150 density value to estimate the average abundance of marmosets in the region by the
151 formula $A = D * a$, where A means abundance, D is the density value and a is the
152 species' distribution area predicted in this study. Mean estimates are shown followed by
153 the 95% confidence intervals (CI) and the coefficient of variation (CV).
154
155 *Species Threatened Status Evaluation*
156 As recommended by the IUCN, we multiplied the lower confidence interval of
157 the species' density by the predicted distribution area to obtain a conservative
158 population size of Marca's marmoset. We also calculated total habitat lost to date within
159 our newly calculated *M. marcai*'s range and constructed predictive models to assess
160 how much of the species range will be lost by 2036 (in 18 years). This period represent
161 three generation time estimated for *Mico* (Mittermeier & Rylands 2008; Nishijima et al.
162 2012). To meet the first level of a treat category, Vulnerable (VU), we should observe,
163 estimate, inferred or suspect population size reduction of ≥50% over the last 10 years or
164 three generations (IUCN 2012). Since data on generation time or lifespan for *M. marcai*
165 is not available, we used information provided by Mittermeier & Rylands (2008) for *M.*
166 *leucippe* (see also Nishijima et al., 2012).
167 Data on current forest loss was obtained from PRODES (2015) for the years
168 between 1997 and 2015. For the construction of our predictive models of habitat loss,
169 we considered two scenarios (after Soares-Filho et al., 2006):
170 (i) "Governance" scenario, *i.e.*, assuming 1) current deforestation trends, but
171 with a 50% cap in forest loss due to current laws that prohibit farmers to clear more than
172 50% of forest in their properties, and 2) that existing and proposed protected areas are
173 effectively managed.

(ii) "Business-as-usual" scenario, *i.e.*, considering current deforestation trends across the Amazon basin plus the effect of infrastructure development and low management effectiveness of protected areas. We calculated the amount of forest loss in each scenario and the percentage of it that lies within *M. marcai* distribution to estimate the species' habitat loss.

Using all the data generated in this study, we then adopted IUCN criteria and sub-criteria to evaluate if *M. marcai* belongs in an IUCN Redlist threat category, *i.e.,* Vulnerable, Endangered or Critically Endangered (IUCN, 2012).

RESULTS

Species Geographical Range

During our initial survey work, we observed *M. marcai* groups in 14 different localities: 1) along the left bank of the Aripuanã and Roosevelt Rivers, 2) on both banks of the Manicoré River, and 3) on the left bank of Branco River, a small tributary of the Marmelos River (Figure 1; Table 1). Based on these data and data from the literature, we calculated our adjusted EOO or the species geographical range to be 31,073.13 km², limited to the east by the Aripuanã River, to the west by the Marmelos River, to the north by the Madeira River and to the south by the open savannah vegetation of the Campos Amazônicos National Park, an unsuitable habitat for Amazonian marmosets (Figure 1).

Density and abundance

In total, we walked 271.6 km on the 10 transects. We registered groups of *M. marcai* on 30 occasions, resulting in an encounter rate of 0.11 individuals/km (CV: 21.80). The best distribution of perpendicular distances was obtained through five

intervals of 10 meters each (GOF $\chi^2 = 0.52$; df = 4; p = 0.91) (Figure 2). The detection function that furnished the best fit was Uniform with one cosine adjustment term (AIC 82.22; n=29). The number of individuals detected per group tended to decrease with the increase in perpendicular distances (r = -0.22; p = 0.13). Therefore, we performed an estimate of the average group size using a linear regression, yielding a value of 4.09 individuals/group (CI: 3.23-5.16; CV: 11.41). The density of marmosets was estimated at 8.31 individuals/km² (CI: 4.85-14.22; CV: 25.94) while the density of groups corresponded to 2.03 groups/km² (CI: 1.23-3.36; CV: 23.29). The average abundance of Marca's marmosets within the species' range was estimated at 258,217.71 individuals (CI: 150,704.70 - 441,859.91).

Species conservation status

Our conservative population size estimate for *M. marcai* was 150,704.70 individuals. In terms of forest cover, we calculated a loss of 635.49 km² of habitat within the species range to date, or 2% of the species' total range area. In our predictive models, the species' future habitat loss in the next 33 years will amount to 5,800.18 km² (19%) under the Governance scenario, and to 20,181.29 km² (33%) under the Business as Usual scenario. Such levels of habitat loss translate into a loss of 49,732.6 *M. marcai* individuals in the near future if we consider our conservative population size estimate..

DISCUSSION

This study presents, for the first time, data on the geographic distribution and population size of *Mico marcai*. Such data were collected with the specific goal of gathering sufficient information to remove this species from its IUCN Data Deficient status (DD). IUCN Red List guidelines (IUCN, 2012) recommend that species should

224 be assessed using all available evidence (published and/ or unpublished) to avoid as
225 much as possible placing a species in the Data Deficient category (IUCN 2012). DD
226 status does not mean the species is not under threat, it means it becomes a priority for
227 future research. In fact, there are examples where a DD species turned out to be eligible
228 to a threatened category as soon as relevant data **became** available (Bland et al., 2015).
229 This is the case of our study species. *M. marcai* was considered DD in the last IUCN
230 Red List assessment with the justification of lack of information on its occurrence,
231 distribution and potential threats that could affect its population. With the new data
232 provided by our study, we can safely place it in the Vulnerable (VU) category under
233 criteria A3c; a 30% population reduction projected for the next 18 years (three
234 generations) due to a decline in its Extent of Occurrence (EOO).

235 The results of our field study show that *M. marcai* currently has a large
236 estimated population of 150,704.70 individuals occupying a sizeable range of 31,073.13
237 km² (minus 635.49 km² lost to agriculture). Nevertheless, the accelerating rate of
238 deforestation in this region caused by the ever-expanding Brazilian agriculture frontier
239 and infrastructure development (roads and hydroelectric power plants) poses a serious
240 threat to the future survival of this marmoset. Under a 'Business as Usual' scenario, our
241 predictive model projected a total loss of 33% of the species total range by 2036, thus a
242 bleak future for this marmoset.

243 Although part of the current species geographic range is theoretically protected
244 by Indigenous Lands (ILs) and by Protected Areas (PAs), these units are under strong
245 pressure by the current trend in PA downgrading, downsizing, and degazettement
246 (PADDD) in the Brazilian Amazon (Bernard et al., 2014; Ferreira et al., 2014; Pack et
247 al., 2016). Three main factors drive the PADDD which we think directly decrease the
248 effectiveness of PAs within *M. marcai*'s range: 1) The political instability and the

changes in governmental policies on land use and conservation in the Amazon; 2) The planned hydroelectric plants for the biome, especially on the south margin tributaries of the Amazon river.; 3) The increase in human settlements surrounding the PAs and ILs. Four hydroelectric dams will be constructed within *M. marcai*'s range flooding an area of 1,118.42km² (ANEEL, 2012). The reservoirs of "Prainha" (7º13'41''S, 60º39'08''W) and "Samaúma" (7º54'44''S, 60º11'48''W) on the Aripuanã River, and the reservoirs "Inferninho" (8°25'17"S, 60°57'35"W) and "Cachoeira Galinha" (7°42'19"S, 60°54'51"W) on the Roosevelt River, will directly affect the area of occurrence of *M. marcai* and two other marmosets: its sympatric *Callibella humilis* and the marmoset found in the right bank of Aripuanã River, *M. chrysoleucos*. In addition to that, the Transamazônia Highway bisects *M. marcai's* range. This road is notorious for the negative impact it has brought to the conservation of Southern Amazonia (Ayres et al., 1991). Finally, the municipalities of Apuí and Manicoré have been considered the two top municipalities in livestock production in Amazon State, forming the 'Arc of Cattle Ranching' (see above).

Following the same parameters of the IUCN and providing a baseline for the global assessment, the Brazilian government – through Chico Mendes Institute for Biodiversity Conservation (ICMBio) led the assessment of the conservation status of the Brazilian primates in 2013 (http://www.icmbio.gov.br/portal/faunabrasileira), where 9 *Mico* species were classified as "Least Concern", 2 as "Near Threatened", and one as "Vulnerable". *Mico marcai* was the only one considered "Data Deficient. However, the threats for Amazonian marmosets are known from less than a handful studies (Gonçalves et al., 2003; Ochoa-Quintero et al., 2017) and the distribution of many of these species are estimated based on few occasional records (Ferrari, 1993; Silva Jr & Noronha, 1995; van Roosmalen et al., 2000; Noronha et al., 2007;Fialho, 2010; Garbino

2011). Most *Mico* species, however, also inhabit the "Arc-of-Deforestation" region where threats and habitat loss trends are similar to or higher than those estimated in this study for *M. marcai*. For instance, Ochoa-Quintero et al. (2017) recently estimated a decline of more than 50% of the potential distribution of *M. rondoni* due to habitat loss. Thus, we advocate that the conservation status of all marmosets should be re-examined following the same steps used in this study. The data set presented here provide a baseline to both national and global assessment lists of endangered species. As a consequence of our fieldwork and data analysis, we recommend the change of status of *M. marcai* to a VU species. These findings shed light on the need for reliable and complete population and distribution data to properly assess threats to other Amazonian primates and build plans for its effective conservation in a changing scenario.

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AUTHOR CONTRIBUTIONS

FES, HEB, JRG, LPL, RCA, IJL, CLBF, ATS and MIS designed the study. FES, JRG, LPL, RCA, IJL, ATS and MIS collected the data. FES, HEB, JRG, CLBF and JPB

298 conducted data analysis. All authors contributed to results interpretation and assisted
299 with manuscript writing and revision.
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BIOGRAPHICAL SKETCHES

Felipe E. Silva has been contributing to the taxonomy, distribution, and conservation of Amazonian primates. Hani El Bizri is interested in wildlife conservation and hunting impacts in the tropics. Jonas R. Gonçalves' research is focused on primate conservation and spatial analysis. Lísley P. Lemos has been involved with research on primate conservation and wildlife use in rural Amazonia. Rodrigo C. Araújo research includes Ecology and Conservation of Primates. Ivan J. Lima research is focused on the diversity, biogeography and evolution of small mammals in the Amazon Rainforest. Aline S. Tavares is interested in ecology and conservation of Neotropical vertebrates, especially chelonians. Marcelo I. Santana is interested in mammal morphology and wildlife photography. Caetano L.B. Franco's research is focused on conservation and sustainable use of natural resources, and territorial planning. Jean P. Boubli research scope includes biogeography, ecology and conservation with a focus on Amazonian primates.

TABLES

Table 1. Occurrence records of *Mico marcai* obtained from published data and on-the-ground surveys in the Ariupanã-Marmelos interfluve.

Locality	Latitude	Longitude	Reference
BR 230 - Matá Matá	-7.5212	-60.6733	This study
Acampamento BR 230	-7.6052	-60.7512	This study
Igarapé do Acampamento	-7.5443	-60.6783	This study
Vicinity BR 230	-7.4932	-60.6868	This study
Manicoré River (Right Bank), Comunidade Mocambo	-5.9841	-61.5374	This study
Manicoré River (Right Bank), Comunidade Lago dos Remédios	-5.9327	-61.4449	This study
Manicoré River (Left Bank), Comunidade do Bom Fim	-6.0224	-61.6492	This study
Manicoré River (Left Bank), Comunidade Três Estrelas	-6.0221	-61.6319	This study
Manicoré River (Right Bank), Comunidade Terra Preta	-5.9948	-61.5812	This study
Linha Nova Esperança between Branco River (Right Bank) and Santo Antônio do Matupi)	-7.9411	-61.6427	This study
Estrada do Estanho, PARNA Campos Amazonicos	-8.1049	-61.8560	This study
Type locality (Rio Castanho=Roosevelt River)	-7.55	-60.7167	Alperin 2002
Humaitá-Apuí Road (BR-230), km 292, left margin of Rio Aripuanã	-7.5333	-60.6667	Garbino 2014

FIGURES

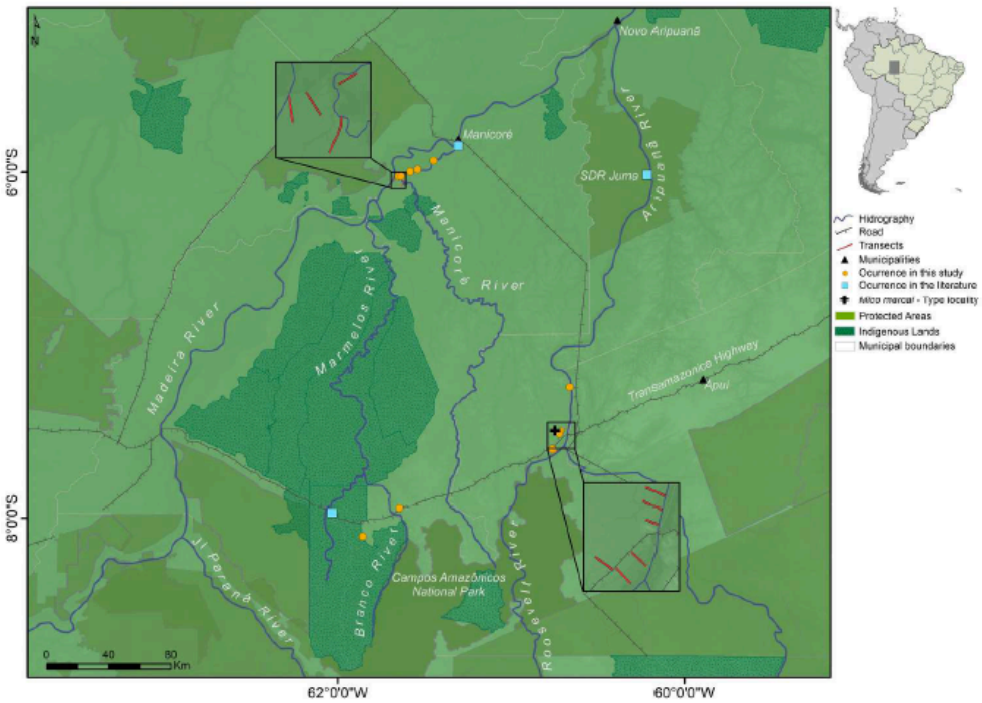


Figure 1. Sites sampled by survey and distance sampling method within the Aripuanã-Marmelos interfluve – area of occurrence of *Mico marcai* in southern Brazilian Amazonia

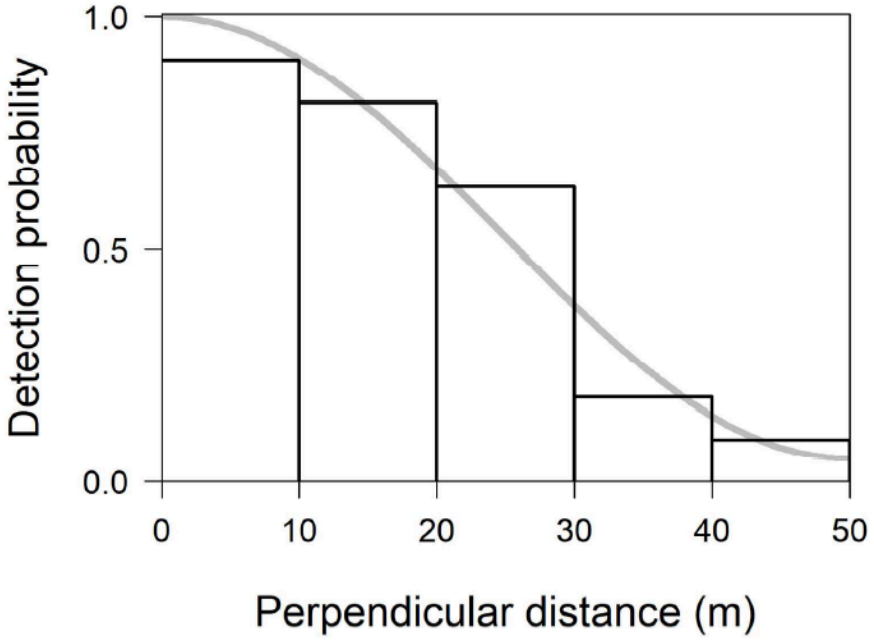
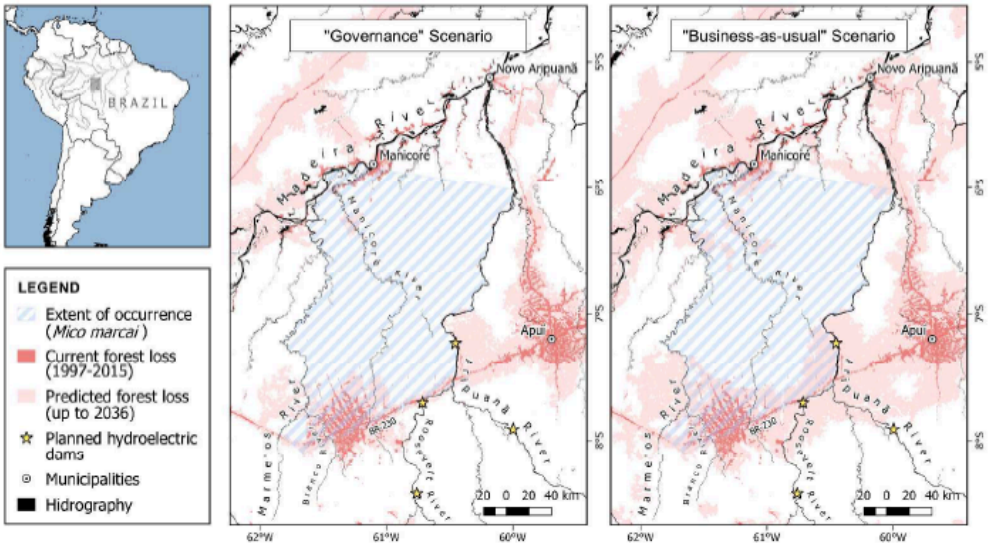


Figure 2. Distribution of perpendicular distances of *Mico marcai* sightings on transects in the Marmelos-Aripuanã interfluve. The trend line represents the best detection function fitted to the distance classes.



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462 **Figure 3.** Extent-of-occurrence for *Mico marcai* in the Aripuanã-Marmelos interfluve,

463 and the current and predicted species habitat loss by deforestation until 2036 under

464 "Governance" and "Business as Usual" scenarios.

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