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Habitat Loss on Rondon's Marmoset Potential Distribution

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Abstract: The Amazon basin is one of the most biologically diverse places on earth. However, agricultural expansion and infrastructure development have led to widespread deforestation that threatens the survival of many taxa. Conservation strategies to contest these threats include protected areas and environmental legislation. Nevertheless, the basic biology of many taxa is largely unknown, which poses an immense challenge when devising effective strategies to safeguard such species in the long-term. This is particularly true for primates. Monkeys from the genus *Mico* are poorly studied with half of the currently known species being described after 1976, and their distribution and threats remain poorly understood. Using the model Maxent, we re-evaluated the distribution range for Rondon's marmoset, one of the most threatened species in this genus. Our results estimated a distribution that is 15,500 km^2 smaller than previously described for this species (68,649 km^2). Furthermore, much of its modeled distribution (71%) lies outside of protected areas. Agriculture expansion and infrastructure development have converted/destroyed 20,532 km^2 of forest within its range (38%) mainly in areas without protection. Another 10,316 km^2 of forest is projected to be cleared by 2040 under current deforestation patterns. The expected cumulative loss of over 50% of its range size in the coming 15 years raise awareness about the threaten category of this species. In the absence of new protected areas, it remains to be seen whether Rondon's marmoset can be effectively conserved in remaining fragments of forest in farmlands.

Keywords: Amazon basin; Callitrichidae; IUCN's threatened categories; Maxent; Rondônia; species distribution models

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1. Introduction

Decades of biological inventories in the Brazilian Amazon basin have revealed its extraordinary diversity for well-studied species groups, such as trees, birds and mammals [1–4]. Much of this diversity has, and will continue to be, threatened by ongoing agriculture and infrastructure expansion and forest disturbance from logging, fire and non-timber resource extraction [5–8]. Predictive deforestation models estimated a reduction of 40% forest cover in the Amazonian range of a group of 95 non-flying mammals by 2050 as a result of agricultural expansion [9]. To help overcome this threat, countries such as Brazil have created an extensive network of protected areas [10,11] and have established environmental legislation, such as the forest code to regulate land use outside protected areas [12]. This law stipulates that 80% of the native vegetation in private properties in the Amazon region should be set aside for retaining native vegetation and associated biodiversity. Although these two strategies have dramatically reduced deforestation during the past six years in Brazil [13], the recent changes in the forest code and the continued clearance of about 4000 km^2 between 2011 and 2012 [14], as well as other forest disturbances such as fire and unsustainable logging, are still a subject of considerable concern. It is increasingly accepted that the interacting effects of agricultural expansion and forest fragmentation with an increase in fire events and more severe droughts due to climate change may combine to shift the Amazon towards a disturbance-dominated ecosystem [15,16].

Set against these threats, our understanding of the biodiversity of the Amazon basin remains very rudimentary. For example, 1200 species were described during the last decade [4] and theoretical models indicate that large numbers of species still await discovery [17,18]. Moreover, even for those species that are identified, we often lack even the most basic knowledge regarding their ecology and natural history, particularly so for species that are threatened by extinction. Understanding the distribution of threatened species is one of the key factors for their conservation, as this information allows identifying the extent of potential habitat and proximate threats, clarifying the degree of protection afforded in the form of protected areas [19] and to know population trends based on repeated surveys [20]. Species distribution models have been developed for the identification of suitable habitat when information about the presence of a species is limited [21,22]—a common problem when studying recently discovered or poorly known species.

Marmosets from the genus *Mico*, (family Callitrichidae) are restricted to the Neotropics [23], nonetheless information about these species, largely restricted to the Amazon basin, is limited. Eight out of the 14 known species in this group, were described after 1976 [23,24] and the IUCN Red List of Threatened Species (IUCN, 2012) categorizes two species as Vulnerable (*M. rondoni* and *M. leucippe*), six as Least Concern, and six as Data Deficient [25].

We developed a species distribution model to evaluate the distribution of the Rondon's marmoset (*Mico rondoni*), which is classify as Vulnerable according to the IUCN [24]. This species is threatened because of forest loss associated to infrastructure development such as the highway BR-364, and has a patchy distribution and low densities [24]. Although some information about the distribution of this species at the confluence of the Ji-Parana and Madeira rivers has been known since 1985 [26], a fuller description of the species range was only published in 2010 [24]. The occurrence and distribution of this species is confined to northern Rôndonia state [26] where *M. rondoni* has a sympatric distribution with *Sanguinus fuscicollis wedelli*. These two species form mixed groups [27] and *S. f. wedelli* parasite gum tree resources from *M. rondoni* [27]. This part of the Amazon basin is affected by human activities that are significantly reducing and fragmenting native vegetation, and although there are protected areas there, they are also threatened by continued deforestation and unsustainable exploitation [11,14,28]. We aimed here to (i) re-evaluate the distribution of this marmoset based on new records obtained in the field; (ii) assess the extent of its estimated range that occurs within existing protected areas and (iii) based on current patterns of forest clearance, estimate possible changes in the range size of this species.

Study Area

Rondon's marmoset is restricted to the southwest of the Brazilian Amazon basin (Figure 1) at the interfluvium of the Ji-Parana (or Machado) and Madeira rivers [24]. The mean temperature of this region varies between 26 and 28 °C, with a rainy season usually from October to May, and precipitation ranging from 1600 to 2400 mm/year [29]. This region is located within the Rondônia center of endemism [30], a highly relevant area given the number of endemic species when compared with other regions in the southern Amazon [31]. Most of this area was originally covered by tropical forest (Tropical Rainy zone according to Köppen's classification) with small patches of savannah [32]. Importantly, the vegetation profile has changed from tropical forest to pasturelands due to increased deforestation since the end of 1960s [33] and recent infrastructure expansion including urbanization and road development [34].

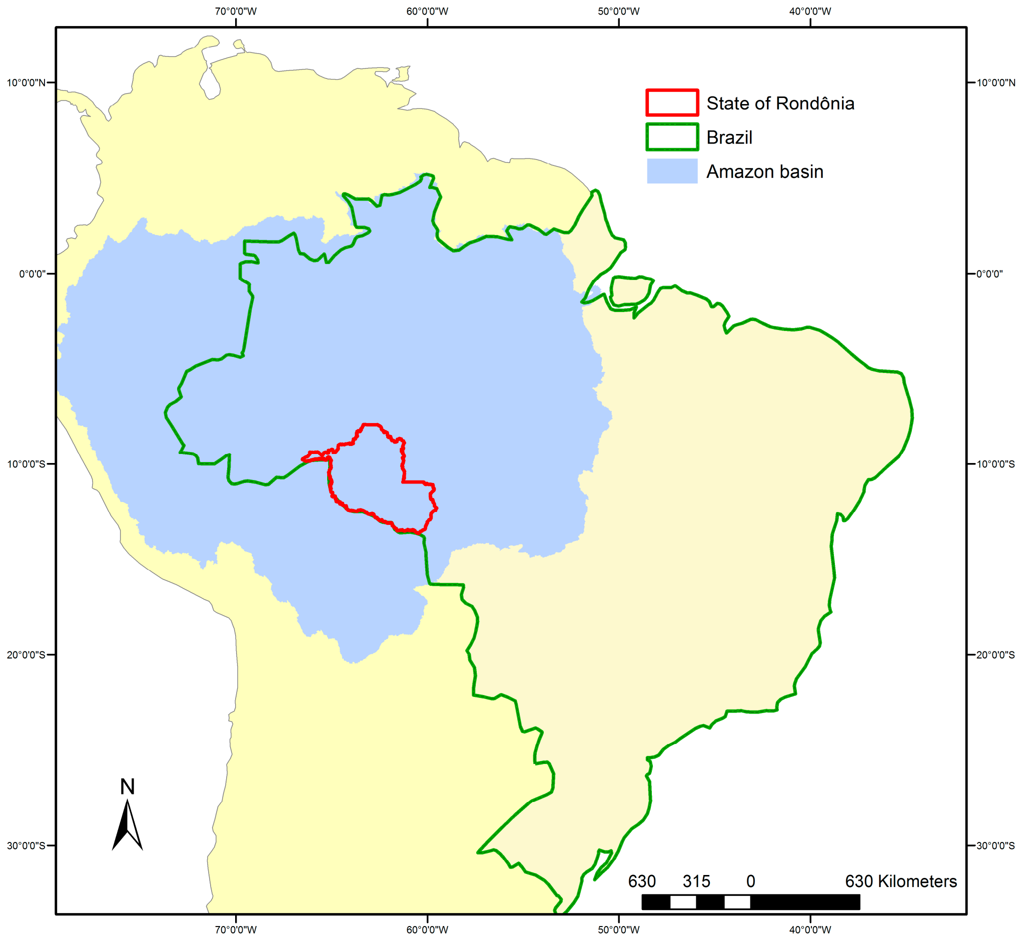

Figure 1. The Amazon basin, Brazil and Rondônia state.

2. Materials and Methods

2.1. Species Distribution Model

In order to model the distribution of this species we obtained records from the literature concerning the presence of Rondon's Marmoset. Those records have been obtained by S. Ferrari and co-workers from the species description [24]. In addition, we compiled all observations from a separate survey in the northern portion of Rondônia (M. Messias 2001, 2002, and M. Messias 2012, unpublished data). During the dry season of 2011 J.M. Ochoa-Quintero performed additional surveys for this species in the central portion of its estimated distribution using direct observation in transects of 1 km across 100 forest fragments in an estimated area of 3100 km^2 visited (Table A1). Visited forest fragments ranged from 400 to 9000 ha, and were embedded across an environmental gradient going from 9% to 98% forest cover in landscapes of 10,000 ha (but see detailed methods in [35]). Although, sampling effort from above mentioned surveys have different effort, the fact that the modelling approach only requires presence/absence data allowed the use of information from different sources.

We modeled the distribution of Rondon's Marmoset using the model Maxent [36]. This model has been widely applied to species-distribution projects [37] and is reasonably robust to the problem of small sample sizes [38]. We used 19 bioclimatic variables and altitude obtained from WorldClim at one kilometer resolution [39]. We extracted climatic values from all variables where Rondon's marmoset and Weddell's Saddle-back Tamarin (*Saguinus fuscicollis weddelli*) have been recorded (Table A1) and checked for autocorrelation among them. We included the records of the sympatric Weddell's Saddle-back Tamarin [24] for additional climatic values, as the number of records of Rondon's marmoset are limited.

We finally included four variables (total rainfall, altitude, temperature and precipitation during the coldest months) with low correlation $r^2 < 0.7$ to model the distribution of *M. rondoni*. To obtain the distribution we ran 10 models using only the records of Rondon's marmoset, and the four previously mentioned climatic variables, using a cross validation technique. We calculated the standard deviation of all generated models, and selected the mean model as the final one. Presence and absence at individual sites were determined in a probabilistic maximum entropy framework using as a threshold the maximum training sensitivity plus specificity (implemented in Maxent 3.3 [36]). With the obtained results, we compared the generated potential distribution area of this species with the one proposed by [40].

2.2. Current Levels of Protection and Threats

We calculated the extent of protected area coverage in the distribution of Rondon's marmoset by overlapping the potential distribution with protected areas in this region. Information about protected areas was obtained from the World Database on Protected Areas [41]. Based on this information and using a forest cover map generated by Prodes we estimated a forest cover loss within the potential range of Rondon's marmoset from 1997 to 2011 inside and outside protected areas at the north of Rondônia. The Prodes program monitors deforestation in the Brazilian Amazon Forest annually since 1997 [14] which allowed us to estimate the trend of this threat in the region.

2.3. Re-Assessing the IUCN Threat Status of Rondon's Marmoset

We estimated the forest loss in the projected range of Rondon's marmoset by dividing the area into 100 km^2 grids (landscape). From each landscape, we obtained the forest loss rate between 2008 and 2011 and the remaining forest cover in 2011. We selected this time frame as a proxy of current patterns of forest loss using a similar methodology to that used to define deforestation patterns at the municipality scale [42]. The deforestation rate (re-scaled to $\log_2$) based on patch area fit a 2nd degree polynomial, such that an intermediate level of forest coverage was associated with the highest level of forest clearance. We then constructed a bootstrap simulation of projected deforestation to estimate the uncertainty in forest clearance levels for landscapes differing in forest cover. We re-sampled the data (B = 1000) to estimate the 95% confidence band for the trend in future deforestation. This method constitutes a simple approach to estimate future deforestation impact based on the current pattern of forest loss, including uncertainty in the evaluation. Although this method did not consider forest recovery, studies about land use cover change stated that agriculture expansion make forest regrowth less frequent in the region [43,44]. We subsequently used the deforestation estimates to iteratively estimate forest coverage in northern Rondônia over a 30-year time span. Using both the data in observed forest loss and the estimated future forest loss we re-evaluated the threat category for this species using the IUCN criteria [25].

3. Results

3.1. Species Distribution Model

In total we collected 19 sightings for Rondon's Marmoset: five from Ferrari et al. (2010) [24], five records from M. R. Rezende Messias and nine records J.M. Ochoa-Quintero obtained from field observations (Table A2). All records are within the range proposed by the IUCN [40], apart from one collected in the south of the Serra of Pacáas Novos. The range of this species appears to be delimited in the north and west by the interfluvial area bounded by the Mamore-Madeira and Ji-Parana rivers but the southern limit is unclear. Nonetheless, based on observations carried out just to the south of its modeled distribution without sightings of this species, we expect that Rondon's marmoset may be displaced by the Black-tailed marmoset (*M. melanurus*) in this region.

According to the climatic variables modeled in this analysis this species is predicted to occur in an area of 53,149 km^2. This range is 15,500 km^2 smaller than that proposed by Oliveira et al. [40]. The results of the species distribution model based on a 10-fold cross-validation technique and the high AUC score of the averaged model (0.83 $\pm$ 0.086, mean $\pm$ S.D.) give us some confidence about the accuracy of our predictions. In addition, all but one of the locality records for Rondon's are located within the area predicted to support the species under the distributional model (Figure 2). Furthermore, the standard deviation among the different models was low across the entire study area. The most important factor influencing the modeled distribution of this species was the difference between the mean maximum and minimum temperature during the year. The most important variable with independent contribution to the model was altitude. The remaining variables only make minor contributions to improving model fit.

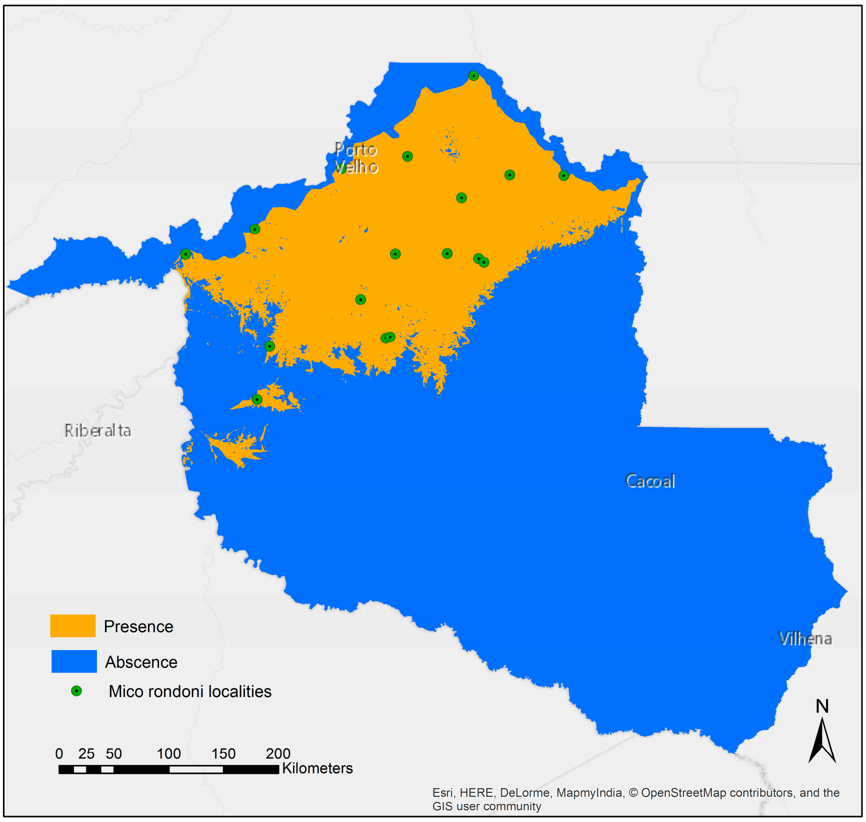

Figure 2. Records of *M. rondoni* and modelled distribution area obtained from Maxent. The area of presence and absence was defined using the median value of the maximum training sensitivity plus specificity obtained from the 10th fold validation technique.

3.2. Protected Area Coverage of the Predicted Distribution

For the 53,149 km^2 where this species occurs, 29% falls within protected areas, covering 23 protected areas and four indigenous reserves (Figure 3). However, Rondon's marmoset has only been observed in four of these protected areas (Samuel Ecological Station, Jamari National Forest, Environmental Protection Area Rio Pardo and Extractivist Reserve Ouro Preto) (Table A2). Moreover, the majority of its range (71% according to the model) is not protected.

This species has lost 20,532 km^2 (38%) of forest cover within its range, mainly from 1997 to 2011 (11,663 km^2). Most of the loss has occurred outside protected areas (18,783 km^2), with only 1689 km^2 of protected forest being lost (Figure 3). For comparison, 50% of the forest area where Rondon's Marmoset is expected to occur outside of protected areas has already been cleared, while only 11% has been lost inside protected areas. The deforestation trend, although larger outside protected areas, keep a similar pattern inside and outside of protected areas (Kendall tau = 0.49, p = 0.041) (Figure 4). It means that years with larger deforestation outside protected areas coincide with larger deforestation inside protected area but at a lower deforestation rate.

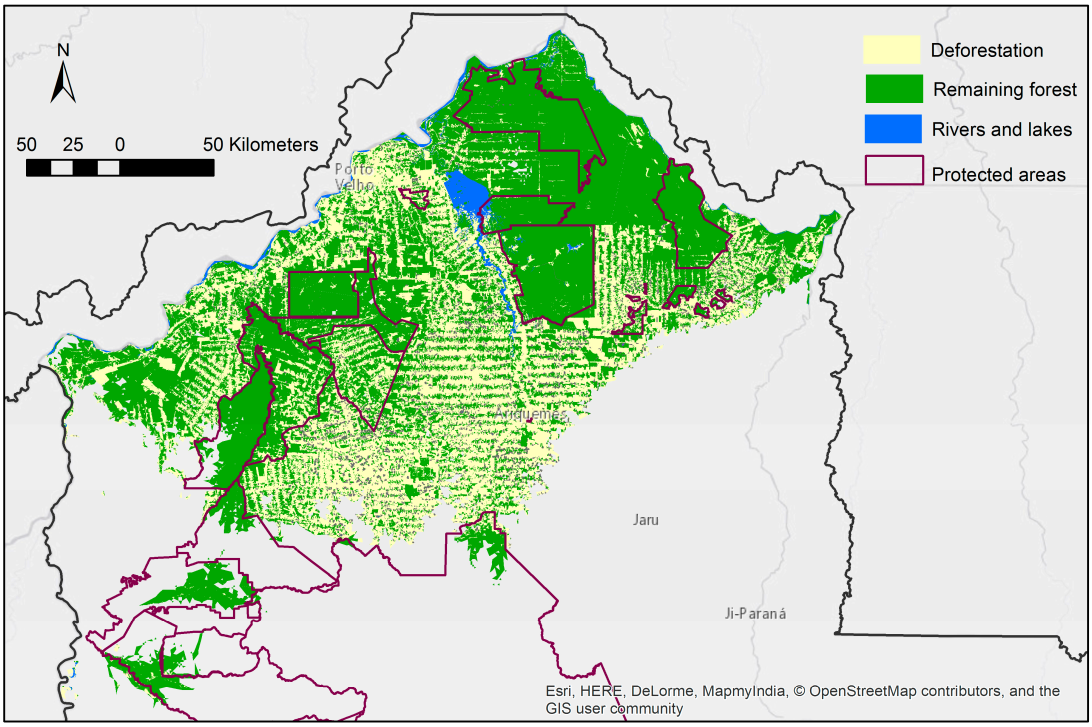

Figure 3. Forested and cleared areas within the modelled range of *M. rondoni*. Information about deforestation was obtained from Prodes (Deforestation monitoring of the Brazilian Amazon project) (INPE, 2012).

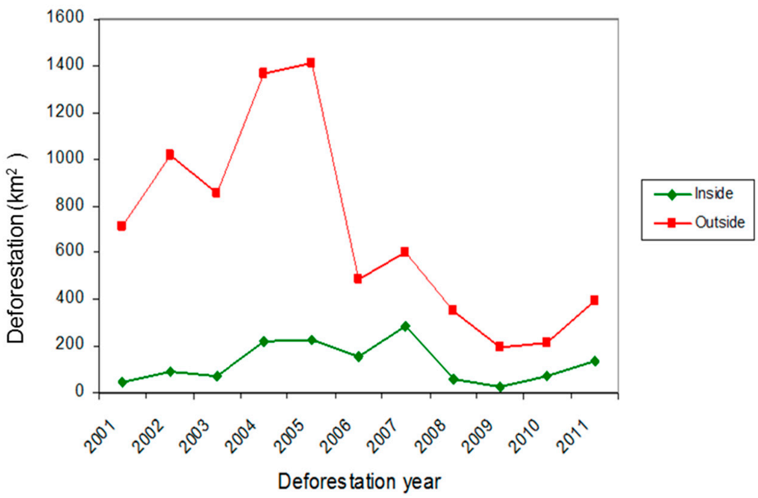

Figure 4. Area (square kilometres) deforested inside and outside protected areas in the modelled distribution of *M. rondoni*.

3.3. Current Pattern of Forest Loss, Expected Deforestation and Re-Evaluation of the IUCN Threat Status of Rondon's Marmoset

The current pattern of deforestation is significantly different from the null expectation of consistent rate of deforestation across all fragment sizes ($F_{\_2,\,566}$ = 84.45, $p < 2.2 \times 10^{-16}$, r^2 = *0.23*) (Figure 5). Generally, landscapes with a forest cover below 60% exhibited greater levels of variability in forest clearance rates (Figures 5 and 6). Overall, after a 30-year projection we expect that only 22,301 km^2 of forest will remain in the modeled distribution of Rondon's marmoset under a business-as-usual scenario (95% confidence range bounded by 21,228 and 23,561 km^2). These figures suggest that between 39.9% and 44.3% of existing forest in northern Rondônia is at risk of being cleared due to agricultural expansion or infrastructure development and another 10,316 km^2 (19.4%) of forest is expected to be lost in the next 30 years (Figure 7).

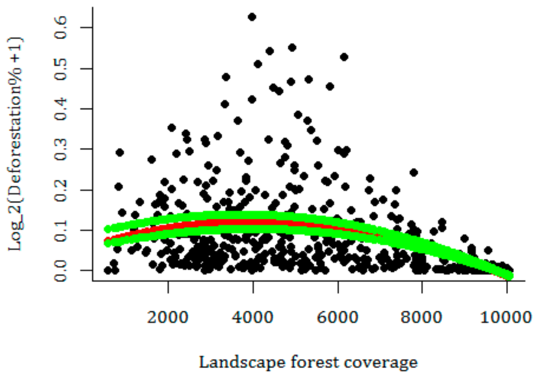

Figure 5. Current pattern of deforestation in landscapes with different forest cover.

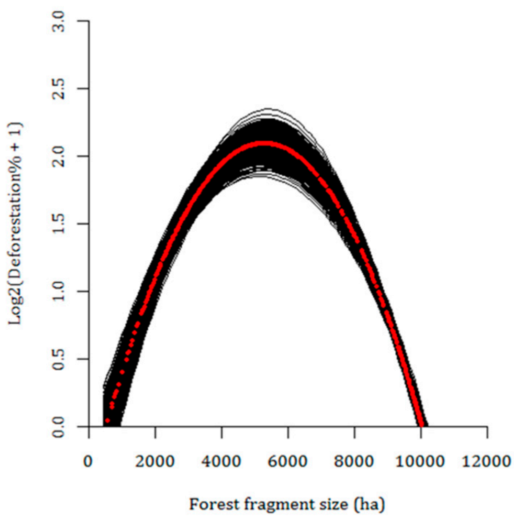

Figure 6. Estimated forest loss according to forest cover in the landscape within *M. rondoni* modelled distribution area.

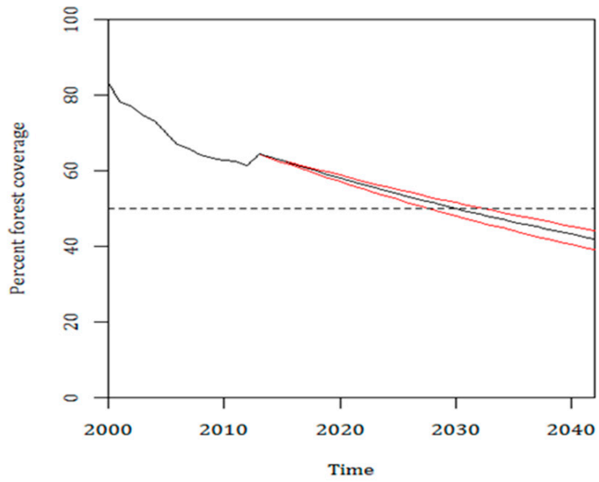

Figure 7. Previous forest clearance as observed by the monitoring of forest loss in the Brazilian Amazon (2000–2012) and expected forest loss using the modelled pattern of deforestation according to the remaining forest cover at the landscape scale in the modelled distribution area. Red lines represent the 95% confidence bound and the dashed horizontal line corresponds to 50% forest coverage relative to the pre-1997 baseline. Forest loss was calculated for the whole estimated distribution area.

As mentioned, 38% of the forest cover in the potential range of this species has already been lost by 2011. Under the current pattern of deforestation this species will lose a further 20% of forest cover in its remaining potential distribution area by 2030. This implies a decline exceeding 50% of its potential distribution in the coming years which nearly aligns with the IUCN criteria for the Endangered category [25].

4. Discussion

Rondon's marmoset is facing a growing risk of extinction that exceeds the previous estimated assessment for this species [40]. Similar to many other tropical forest-dependent taxa the primary threat facing this species is agricultural expansion and associated infrastructure development [45,46]. Extra care is needed to evaluate the distribution and threats faced by these newly discovered and poorly known species to ensure that they can be successfully protected.

The overall geographic concordance between the IUCN's expected species distribution for Rondon's marmoset [40] and our model gives us confidence in this prediction. However, our modeled distribution is 15,500 km^2 smaller than previously estimated for this species. The most relevant variables influencing the presence of this species are characteristic of the northern part of the Amazon basin. This is a region with relatively low seasonal variation, which is represented by the small difference between the maximum and minimum temperatures during the year. The low seasonal variability also coincides with lowland topography, a key feature of the core Amazon basin. Other historical and ecological aspects are not incorporated in this model, such as competition with other syntopic species or potential exclusion by closely related species, such as Weddell's Saddle-back Tamarin or Black-tailed marmoset [27].

Protected areas, despite their legal status, mirror the changes occurring in neighboring farmlands. In years with high deforestation rates outside of protected areas, forest clearance inside them also increased which evidences the link between these areas [47]. Deforestation events may coincide with periods of limited control of forest clearing and higher anthropogenic pressure at these sites. Although researchers have identified that protected areas are critical to minimizing deforestation in the Amazon basin [13], the correlation between the rate of deforestation inside and outside of parks strongly suggests that protected areas are not isolated entities that are unaffected by prevailing deforestation drivers. Laurence et al. [47] found a link between the performance of protected areas to sustain populations of several taxonomic groups and processes happening in surrounding areas. Additionally, other activities, such as forest degradation from fire in Rondônia [48] and unsustainable logging across the Amazon basin [49], for which we have little information and reduced ability to quantitatively map, may also have serious consequences for species survival as has been evidenced in other Amazon regions.

Protected areas are, without question, the cornerstone of any protection effort for the Rondon's marmoset and many other species occurring in the Amazon basin and elsewhere [50]. Nonetheless, their maintenance in the long term is not sufficient to assure the continued existence of this species. Protected areas, such as Bom Futuro Federal Park and the Extractivist reserve Jaci Parana, are suffering extensive deforestation [14] because of human colonization. To mitigate the effects of human settlement within Bom Futuro, and to compensate for the building of several Madeira river dams, a new protected area was created in the north of Rondônia, an area where Rondon's marmoset is not predicted to occur because of the Madeira river distribution barrier. The same mismatch between mitigation and suitable habitat for this species may also take place in the Rio Pardo protected area, which is undergoing a new delimitation assessment.

Given that most of the remaining distribution of Rondon's marmoset is outside of protected areas and that most of those lands are dedicated to farming, we recommend using a landscape perspective to target the protection of this species. Recent studies in human-modified landscapes have demonstrated the importance of the context in which forest fragments are located to define the way a species is expected to respond to changes in forest cover and configuration [51,52]. Individual landscapes can be targeted for the implementation of tools such as payments for environmental services or environmental legislation to regulate vegetation loss within individual farms. Rondon's marmoset could become a flagship species for the protection of biodiversity in the northern part of the study area where deforestation and new infrastructure development are causing extensive forest loss.

The deforestation pattern found in our results has been shown by other researchers in the Amazon basin at both landscape and municipality scales [35,42]. These analyses are based on relating the probability of deforestation to the location of nearby deforestation events [53–55]. According to these findings, the main landscapes to be targeted for protection are ones in which deforestation is close to 20% and have not yet undergone any substantial increases in clearance rate. Those areas are in the north east of *M. rondoni*' distribution and close to the Machadinho do Oeste river. Second in the list of priorities are landscapes that may increase the connectivity among protected areas where Rondon's Marmoset is still present.

Two new dams will exacerbate the already detrimental effects of deforestation. The construction of Samuel's dam inundated an area of approximately 570 km^2 [56]. Although some compensation took place with the creation of the Samuel Ecological Station, unforeseen consequences have already occurred. The flood of the Jamari River increased its width to such an extent that it now forms a barrier as formidable as the Madeira and Ji-Parana river confluence, a known cutoff to the northern distributional limit of Rondon's Marmoset. Clearly these new flood areas, plus the paved road BR-364, have effectively bisected the remaining range of Rondon's Marmoset, potentially forming two isolated populations (Figure 3). Although the two new dams (Jirau and Santo Antonio) may not produce the same effect as they are located in the limit of the distribution, the Rondon's marmoset's range will be reduced by an estimated 529 km^2 in a short period of time. In addition, the area required for these dams and any human settlement compensation and associated infrastructure developments will push deforestation into new frontiers in northern Rondônia.

5. Conclusions

Here we have identified the main threats and their possible impacts on the remaining populations of this marmoset, but more basic ecological information is needed to make a more targeted assessment. Rondon's marmoset, like other species in this genus, shows a clear association with the distribution of other monkeys [24]. It is important, therefore, to evaluate the impact of the Weddell's Saddle-back

Tamarin on Rondon's marmoset. Field survey observations indicate that surveying tree holes for gum extraction can provide some signal of competition between these two species [24,47], but this assumption needs to be further studied. It is necessary to evaluate if Rondon's marmoset occurs in the other 23 protected areas in its range where it has not yet been found and to increase the sampling size to perform further species distribution models for this species. The suitability of farmlands with different levels of forest cover as refugia should be quantified. Based on such studies, clearer and more accurate measures can be taken to maintain this flagship species in northern Rondônia.

More broadly, we have shown that recently described and poorly known species may need an urgent re-evaluation of its status as current threats may affect its populations in a few years. Although limited information on these species is available, a re-evaluation using available data may elucidate both gaps in information or even define where urgent actions are required to reduce their extinction risk.

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Author Contributions: J.M.O.-Q., W.J.S., and T.A.G. conceived and designed the project. J.M.O.-Q. collected the data in the field. J.M.O.-Q. and C.H.C. performed the analyses. M.R.M. collaborate with records of the species. J.M.O.-Q., T.A.G., and C.H.C. wrote the paper. F.A.C.D. reviewed and edited the manuscript.

Conflicts of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

Appendix

Table A1. Species and records obtained from the literature, unpublished data of Messias, M. R. and field work carried out during the dry season of 2011.

Number	Species	*X*	*Y*	Source
1	*Mico rondoni*	−64.72666	−10.76028	Ferrari et al. 2010 [24]
2	*Mico rondoni*	−64.61778	−10.32111	Ferrari et al. 2010
3	*Mico rondoni*	−63.46666	−8.75000	Ferrari et al. 2010
4	*Mico rondoni*	−62.91667	−8.08333	Ferrari et al. 2010
5	*Mico rondoni*	−62.16833	−8.90750	Ferrari et al. 2010
6	*Mico rondoni*	−65.31261	−9.55228	Mariluce Rezende Messias unp. Data
7	*Mico rondoni*	−64.73684	−9.34888	Mariluce Rezende Messias unp. Data
8	*Mico rondoni*	−64.01567	−8.84924	Mariluce Rezende Messias unp. Data
9	*Mico rondoni*	−63.01840	−9.09545	Mariluce Rezende Messias unp. Data
10	*Mico rondoni*	−62.61887	−8.90285	Mariluce Rezende Messias unp. Data
11	*Mico rondoni*	−63.85925	−9.93685	Ochoa-Quintero JM
12	*Mico rondoni*	−63.74462	−9.62525	Ochoa-Quintero JM
13	*Mico rondoni*	−63.64947	−10.25626	Ochoa-Quintero JM
14	*Mico rondoni*	−63.61388	−10.24537	Ochoa-Quintero JM
15	*Mico rondoni*	−63.56884	−9.55847	Ochoa-Quintero JM
16	*Mico rondoni*	−63.13775	−9.55532	Ochoa-Quintero JM
17	*Mico rondoni*	−62.87828	−9.59665	Ochoa-Quintero JM
18	*Mico rondoni*	−62.83247	−9.62761	Ochoa-Quintero JM
19	*Mico rondoni*	−62.11989	−9.55746	Ochoa-Quintero JM
20	*Sanguinus weddelli*	−64.91000	−10.83278	Ferrari et al. 2010

Table A1. *Cont.*

Number	Species	*X*	*Y*	Source
21	*Sanguinus weddelli*	−64.80277	−10.40334	Ferrari et al. 2010
22	*Sanguinus weddelli*	−64.72666	−10.76028	Ferrari et al. 2010
23	*Sanguinus weddelli*	−64.65834	−10.59111	Ferrari et al. 2010
24	*Sanguinus weddelli*	−64.61778	−10.32111	Ferrari et al. 2010
25	*Sanguinus weddelli*	−64.57389	−10.31861	Ferrari et al. 2010
26	*Sanguinus weddelli*	−64.54194	−10.31833	Ferrari et al. 2010
27	*Sanguinus weddelli*	−64.42944	−10.82750	Ferrari et al. 2010
28	*Sanguinus weddelli*	−64.13056	−10.42500	Ferrari et al. 2010
29	*Sanguinus weddelli*	−64.10722	−10.42361	Ferrari et al. 2010
30	*Sanguinus weddelli*	−63.78417	−10.51250	Ferrari et al. 2010
31	*Sanguinus weddelli*	−63.46666	−8.75000	Ferrari et al. 2010
32	*Sanguinus weddelli*	−63.31167	−12.02694	Ferrari et al. 2010
33	*Sanguinus weddelli*	−62.91667	−8.08333	Ferrari et al. 2010
34	*Sanguinus weddelli*	−62.79250	−11.69861	Ferrari et al. 2010
35	*Sanguinus weddelli*	−62.73250	−10.21611	Ferrari et al. 2010
36	*Sanguinus weddelli*	−62.03250	−9.02139	Ferrari et al. 2010
37	*Sanguinus weddelli*	−61.43306	−12.20083	Ferrari et al. 2010
38	*Sanguinus weddelli*	−64.85093	−11.39505	Mariluce Rezende Messias unp. Data
39	*Sanguinus weddelli*	−64.66525	−10.92667	Mariluce Rezende Messias unp. Data
40	*Sanguinus weddelli*	−64.57185	−10.41757	Mariluce Rezende Messias unp. Data
41	*Sanguinus weddelli*	−64.40190	−11.60116	Mariluce Rezende Messias unp. Data
42	*Sanguinus weddelli*	−63.75452	−9.63040	Ochoa-Quintero JM
43	*Sanguinus weddelli*	−63.68235	−9.72496	Ochoa-Quintero JM
44	*Sanguinus weddelli*	−63.64947	−10.25626	Ochoa-Quintero JM
45	*Sanguinus weddelli*	−63.61388	−10.24537	Ochoa-Quintero JM
46	*Sanguinus weddelli*	−63.56832	−10.23835	Ochoa-Quintero JM
47	*Sanguinus weddelli*	−63.21380	−10.05134	Ochoa-Quintero JM
48	*Sanguinus weddelli*	−62.91580	−10.38790	Ochoa-Quintero JM
49	*Sanguinus weddelli*	−62.87795	−10.30455	Ochoa-Quintero JM
50	*Sanguinus weddelli*	−62.87411	−10.28550	Ochoa-Quintero JM
51	*Sanguinus weddelli*	−62.72091	−9.75068	Ochoa-Quintero JM
52	*Sanguinus weddelli*	−62.24402	−9.54754	Ochoa-Quintero JM
53	*Sanguinus weddelli*	−61.97526	−9.86657	Ochoa-Quintero JM
54	*Sanguinus weddelli*	−61.91976	−9.52122	Ochoa-Quintero JM

Table A2. List of the 27 protected areas and their categories within the estimated distribution of *M. rondoni*. Protected areas where this species has been recorded are highlighted in bold.

Name of Protected Area	National Category
Resex Rio Preto Jacunda	Reserva Extrativista (Extractivist reserve)
Resex Jaci Parana	Reserva Extrativista (Extractivist reserve)
Resex Pacaas Novos	Reserva Extrativista (Extractivist reserve)
Flona Jacunda	Floresta Nacional (National florest)
Resex Mogno	Reserva Extrativista (Extractivist reserve)
Resex Ipe	Reserva Extrativista (Extractivist reserve)
Resex Cedro	Reserva Extrativista (Extractivist reserve)
Resex Angelim	Reserva Extrativista (Extractivist reserve)
Resex Sucupira	Reserva Extrativista (Extractivist reserve)
Fers Gaviao	Florestas Estaduais de Rendimento Sustentado (State Forest of Sustainability)
Fers Periqutos	Florestas Estaduais de Rendimento Sustentado (State Forest of Sustainability)

Table A2. *Cont.*

Name of Protected Area	National Category
Fers Mutum	Florestas Estaduais de Rendimento Sustentado (State Forest of Sustainability)
Fers Tucano	Florestas Estaduais de Rendimento Sustentado (State Forest of Sustainability)
Fers Araras	Florestas Estaduais de Rendimento Sustentado (State Forest of Sustainability)
Esec Samuel	**Estação Ecológica (Ecological Station)**
Flona Jamari	**Floresta Nacional (National Forest)**
P.E. Guajara-Mirim	Parque Estadual (Estate Park)
Resex Ouro Preto	**Reserva Extrativista (Extractivist reserve)**
Apa/Fes Rio Pardo	**Area de Proteção Ambiental/Floresta Estadual (Area of environmental protection/ State Forest)**
P.M. Ariquemes	Parque Municipal (Municipal park)
P.M. Cana-Ariquiemes	Parque Municipal (Municipal park)
Flona Bom Futuro	Parque Federal (Federal Park)
Karipuna	Indigenous reserve
Karitiana	Indigenous reserve
Rio Negro Ocaia	Indigenous reserve
Uru-Eu-Wau-Wau	Indigenous reserve
Parque Estadual de Candeias	Parque Estadual (State Park)

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