ARTIGO

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Where is the symbol of Brazilian Ornithology? The geographic distribution of the Golden Parakeet (*Guarouba guarouba* – Psittacidae)

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RESUMO: Onde está o símbolo da Ornitologia Brasileira? A distribuição geográfica da ararajuba (*Guarouba guarouba* – Psittacidae). Neste artigo nós analisamos registros de ocorrência da ararajuba (*Guarouba guarouba*) – um emblemático psitacídeo endêmico da Amazônia Brasileira e ameaçado de extinção – para identificar possíveis modificações temporais em sua ocorrência e para modelar sua distribuição potencial. A espécie é conhecida de quase 70 localidades. Após 1987, novos registros estenderam a distribuição conhecida consideravelmente para sudoeste, enquanto regiões no extremo leste da distribuição não apresentaram registros recentes. Nós interpretamos o primeiro caso como um aumento do conhecimento da distribuição histórica através do aumento de pesquisas, e o último caso como uma verdadeira retração na distribuição, melhor explicada pelo desmatamento naquela região. Para os últimos anos, nós estimamos a atual área de ocorrência em 340.000 km^2, o que compreende menos de 65% da distribuição original. A modelagem sugere uma distribuição potencial da ararajuba em uma região menos úmida da Amazônia, numa interface de Floresta Ombrófila Sub-montana e Floresta Ombrófila de Terras Baixas, na borda do Planalto Central. Esta distribuição coincide com o arco do desmatamento, o que coloca em sérios riscos a sobrevivência futura da espécie. Unidades de conservação na região do rio Tapajós parecem ser a maior esperança para proteção das populações conhecidas. Além disso, esperamos que nosso modelo de distribuição potencial direcione buscas por populações previamente desconhecidas e auxilie o entendimento do habitat desse emblemático psitacídeo.

PALAVRAS-CHAVE: espécie ameaçada, distribuição potencial, registros de ocorrência, desmatamento.

ABSTRACT: The Golden Parakeet (*Guarouba guarouba*) is a poorly known, endangered psittacid endemic to the Brazilian Amazon. We examined point records of the species to identify possible temporal changes in its occurrence and to model its potential distribution. It is known from roughly 70 localities. After 1987, new records extend the known distribution considerably to the southwest, whereas regions at the eastern end of the range do not contain recent records. We interpret the former as improved knowledge of the true historical distribution based on increased sampling, and the latter as a genuine range retraction, best explained by deforestation in that region. We estimate the species' current area of occurrence at 340,000 km^2, embracing less than 65% of its original range. Distribution models predict a potential distribution of the Golden Parakeet throughout a region of relatively low humidity, at the interface between lowland and submontane rainforest at the border of the Brazilian Shield. This distribution coincides with the colonization frontier ("arc of deforestation") in the Amazon, which places the species' future in serious risk. Existing and planned parks and reserves in the Tapajos River region appear to offer the best hope for protection of currently known populations. Furthermore, we hope that our distribution model leads to intensive searches and discovery of populations previously unknown and to improved understanding of habitat preference and niche.

KEY-WORDS: endangered species, records of occurrence, potential distribution, deforestation.

The geographic distribution of a species is a complex interaction between the environment and the biology of the organism throughout its history (Brown 1996). This interaction determines the necessary resources for the species' survival. Thus, to know where a species occurs is a basic step for biogeographical and ecological studies (Rushton *et al.* 2004), and is especially important in conservation planning for endangered species.

The Golden Parakeet (*Guarouba guarouba*) is a spectacular, large, macaw-like psittacid, endemic to the Brazilian Amazon. Its unusual plumage is entirely yellow and green, the national colors of Brazil. For these reasons, the species is a natural candidate for the Brazilian national bird (Sick 1997) and is the symbol of the Brazilian Ornithological Society. However, it is also the object of active illegal trade and is officially listed as a threatened

species (BirdLife International 2007). Ironically, despite its cultural importance and endangered status, the species remains poorly known. No two authors map its distributional limits similarly (see Oren and Novas 1986, Collar 1997, Juniper e Parr 1998, BirdLife International 2007), and the environmental conditions that determine its presence are unknown (Oren and Novaes 1986). Moreover, new records (Yamashita and França 1991, Lo 1995), extending its distribution considerably, created a seemingly inexplicable lacuna (Collar 1997).

Mapping and analysis of point records are important tools for understanding the true geographic distribution of a species (Peterson *et al.* 2001, Engler *et al.* 2004, Nunes *et al.* 2007). Recently, geographical approaches, such as ecological niche modeling, have been developed that offer new possibilities for understanding species distributions and patterns of biodiversity (Jones *et al.* 1997, Peterson 2001, Salem 2003). Ecological niche is a critical determinant of distribution, and its modeling gives more visibility to the complex interaction between species and environmental characteristics on a geographical scale (Peterson *et al.* 1999, Rushton *et al.* 2004). Modeling enables prediction of where a species may occur, directing searches for unknown populations and identifying potential areas for colonization or reintroduction (Engler *et al.* 2004, Rushton *et al.* 2004), which in turn is useful for management and conservation, especially for rare and threatened species (Rushton *et al.* 2004, Guisan and Thuiller 2005, Phillips *et al.* 2006).

In this article, we aim to define the historical and current geographic distribution of the Golden Parakeet and to model its potential distribution. The last compilation of this species' records was published over twenty years ago (Oren and Novaes 1986), so an update should incorporate new data and identify any range retraction or expansion (*e.g.,* Nunes 2003, Nunes *et al.* 2007). Compilation of known records, along with the results of the modeling of potential distribution, should provide an improved notion of the habitat and ecological niche of the species and help orient conservation of this emblematic species.

METHODS

Point records and area of occurrence

We reviewed all records of occurrence of the Golden Parakeet (published or not) from literature, specimens in museums and consultations with experienced ornithologists, and we treat all these as "confirmed" records. These include our own records made during field research on behavior and ecology of the species (Laranjeiras 2008). Those records extracted from interviews with locals were considered "uncertain" records. In addition, information on possible absences were derived from research, expeditions and inventories that did not detect the Golden Parakeet in a particular region.

The records were mapped using ArcMap software (ESRI 2004) for subsequent spatial analyses. Adjacent records (separated by less than 10 km) were grouped together and treated as one. This is justified based on probable lack of independence among adjacent records, lack of precise coordinates for historical records, equivalent resolution in the vegetation data, and the impact of densely packed points on the calculation of α-hull polygons (SPWG-IUCN 2006, see below). We determined the limits of the area of occurrence using the α-hull technique, which permits the degree of detail and contiguity of the area to be determined by a user-selected constant, α (see Burgman and Fox 2003). Values of α range from zero, at which point records are treated as disjunct areas of occurrence, to infinity (least convex polygon). We adopted an α value of two, as suggested by SPWG-IUCN (2006), which permits a reasonably high degree of concavity in described polygons and range disjunction between clusters of points separated by relatively long distances. We further adapted this technique to avoid the existence of any isolated single points or lines (whose areas are incalculable and which represent a biological situation that we believe unlikely in this species), by connecting these isolated features to the nearest polygon or other isolated feature by the two shortest possible straight lines.

We subdivided all the confirmed records into "historical" (pre-1987) and "recent" (since 1987), because the first publications synthesizing the distribution of the Golden Parakeet (Oren and Willis 1981, Oren and Novaes 1986) date to this period. By this time, deforestation in eastern Amazonia had begun in earnest (Fearnside 2005), roughly marking the recent period as one in which anthropogenic changes could be responsible for range modifications. In addition, it is reasonable to consider a period of 20 years to define the current distribution of a psittacid (IUCN 2001, Nunes 2003, Tobias and Brightsmith 2007). To calculate current area of occurrence, we subtracted the area deforested (INPE 2007) from the total area of polygons derived from locality data.

Field searches for the Golden Parakeet

In July 2006, we spent ten days traversing the "transamazônica" highway (BR-230) between the Madeira (Humaitá, Amazonas) and Tapajós rivers (Jacareacanga, Pará) in active search of Golden Parakeets. This transect cuts through a large lacuna in the species' known distribution, in which confirmation of presence or absence is highly desirable (BirdLife International 2007, see Introduction). In addition to direct searching, we interviewed locals to determine their familiarity with the species.

Modeling of potential geographic distribution

We used MaxEnt 3 software (Phillips *et al.* 2006) for modeling. MaxEnt has demonstrated good performance compared to alternative methods (Elith *et al.* 2006, Phillips *et al.* 2006, Pearson *et al.* 2007), with the following positive features: it can incorporate categorical variables; it does not require absence data (instead it uses environmental background data), it quantifies alternative thresholds, it computes model validation statistics, and it can show which environmental variables contribute most to the model.

Modeling was conducted using default MaxEnt parameters. For model validation, MaxEnt calculates an AUC value (area under the curve) based on the predicted area of occurrence compared to the point localities used to generate and test the model (training and testing data, respectively; see Phillips *et al.* [2006] for detailed description of AUC). The higher the AUC value (range 0-1), the better the model. We ran three models with different combinations of confirmed and uncertain locality records. Our "basic" model used 60% of confirmed records (chosen randomly) as training data and then was tested both using the remaining 40% of confirmed records and the uncertain records. Our "robust" model used all confirmed records as training data and all the uncertain records as test data. Finally, an "extrapolated" model was generated, based on 60% of total records (confirmed and uncertain combined) for training and 40% for testing. Five specific historical records were exluded from the modeling, because they occurred in localities currently classed as "anthropic" in the vegetation database, but that were probably under natural cover at the time of the observations (see below and Appendix A). To delimit the potential distribution, we chose a threshold based on the maximum training sensitivity (inclusion of records) and specificity (exclusion of areas of "absence"), thus covering as many known localities as possible without extrapolating too far into areas without records.

Elevation, vegetation, lowest monthly mean temperature, and a dry season intensity and duration index (Walsh [1996] Index, based on the monthly rainfall data) were the environmental layers used in the modeling. These environmental layers used are commonly associated with bird habitat descriptions and were chosen based on their apparent relevance to the biology of the species and empirical tests including other variables that produced far less useful predictions. The Walsh Index is a combination of precipitation and seasonality, each of which alone did not contribute significantly to the results of the modeling. All layers except vegetation came from the World Clim database (Hijmans *et al.* 2005) in raster format at a resolution of 30 arc-seconds (about 1km at the equator). The vegetation layer is a shapefile (scale 1:2,500,000) available from Brazil's Ministério do Meio Ambiente (www.mma.gov.br). We recognized 86 vegetation types, including all but the finest (sixth) level of Veloso's (1992) hierarchical classification, for which no clear biological significance is known (Nelson e Oliveira 1999). We transformed the shape file in raster format and defined resolution as 30 arc-seconds. All layers were cut to the limits of the Brazilian Legal Amazon.

RESULTS

The Golden Parakeet is known from approximately 70 localities in five Brazilian states (Figure 1, Appendix A). Most localities are in the state of Pará, but records are distributed across east-central Amazonia, from northern Rondônia to western Maranhão, always south of the Amazon River and east of the Madeira.

Total, historical, and current area of occurrence

The total area of occurrence is 515,000 km^2 (polygon α-hull). Until the mid-1980s, the species was known only from Maranhão and Pará, in 26 localities (Figure 2; Oren and Willis 1981, Oren and Novaes 1986), with an area of occurrence of 160,000 km^2. In the early 1990s, two records in northern Rondônia (Yamashita and França 1991) and Mato Grosso (Lo 1995) expanded the species' known distribution. In 2007, one new record finally included the state of Amazonas within the area of occurrence (L. Parry *in litt.* 2007). On the other hand, no records have been made in the extreme eastern part of the distribution since the mid-'80s (Figure 2).

Since 1987, then, the Golden Parakeet's known area of occurrence increased by 355,000 km^2, principally toward the west and southwest, and diminished by 100,000 km^2, mostly in the east. Recent records (within the last 20 years) are distributed in an area of 410,000 km^2 (Figure 2). Not including deforested areas (INPE 2007), the current distribution amounts to roughly 340,000 km^2, or 65% of the total area known to have been occupied at one time or another.

The Golden Parakeet in southeastern Amazonas, uncertain records and related absences

We did not find the Golden Parakeet in the southeastern part of the state of Amazonas, despite its regular occurrence just across the state line in extreme western Pará. The majority of locals in this part of Amazonas do not know the species, but six uncertain records suggest the Golden Parakeet's presence along tributaries of the Madeira River and other localities in extreme eastern Amazonas (Figure 1, Appendix B).

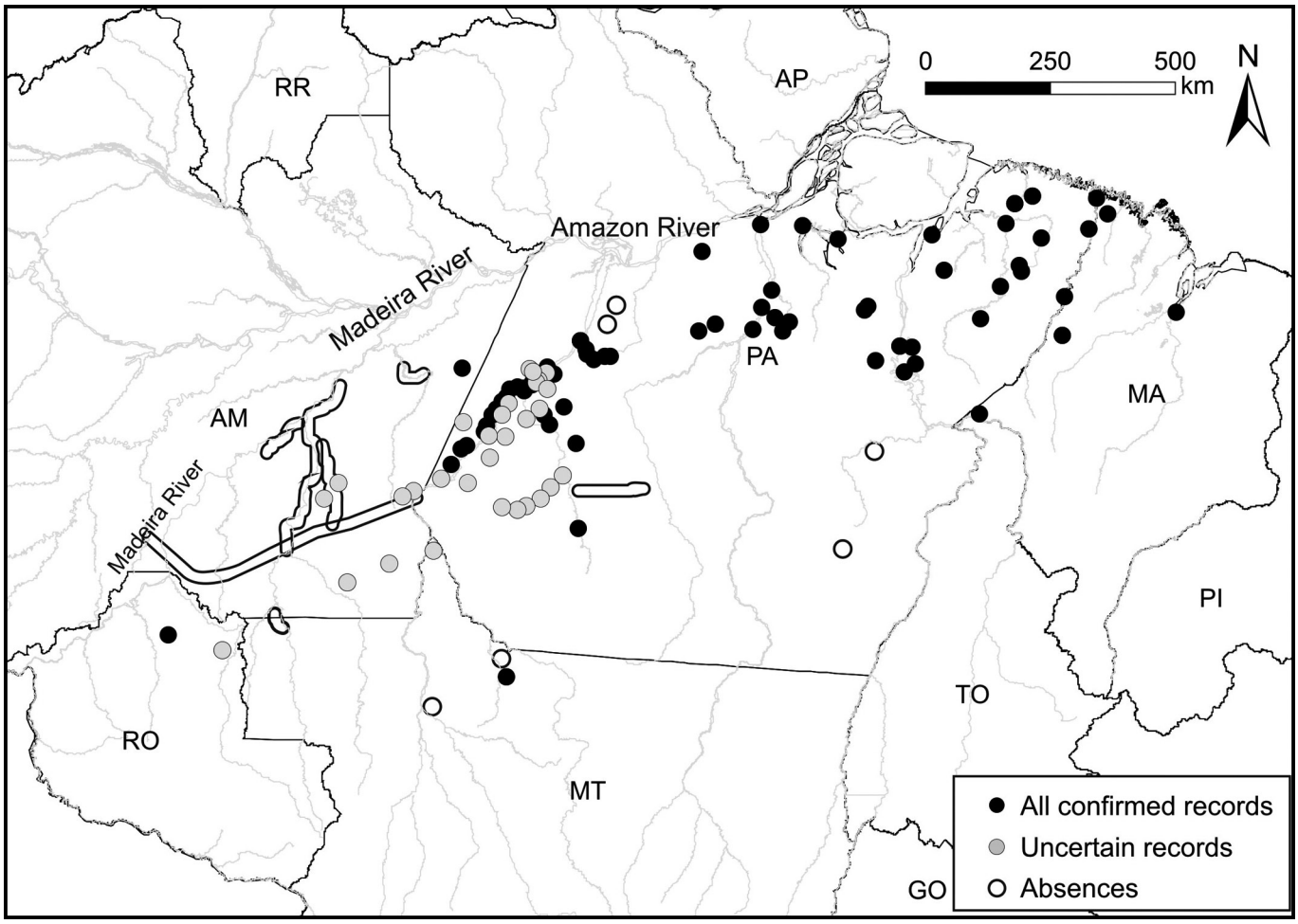

FIGURE 1: All records (confirmed and uncertain) and reported absences of the Golden Parakeet.

Other uncertain records suggest the species' presence in several communities and tributaries of the Tapajós River in western Pará (Figure 1, Appendix B). Especially high abundance of Golden Parakeets was reported along the "transgarimpeira" highway (secondary road of BR-163 highway). In general, most of the uncertain records are located within areas also containing confirmed records. On the other hand, absences have also been reported from the same general region (see Discussion; Figure 1, Appendix C).

Modeling of potential distribution

The models forecasted correctly that the greatest concentration of areas with good conditions for occurrence of the Golden Parakeet is south of the Amazon River (Figure 3, Appendix D). Some areas north of this river, where the species is not known to occur, were also indicated, although most are separated by long distances. All models had high AUC values, indicating their good fit to the data (Table 1). Vegetation was the variable that most contributed to results, but with less than half of total (Table 1).

The three models generated are extremely similar to one another, differing only slightly in their extent or inclusiveness (Figure 3, Appendix D). All show the potential distribution of Golden Parakeet along a roughly east-west axis south of the Amazon River. None includes the western or most of the northern parts of the Amazon, nor peripheral areas in the southeast (Serra do Cachimbo and Serra do Carajás), where the species also does not occur.

TABLE 1: AUC values, thresholds and layers' relative contribution for each model. *Values when including uncertain records in model (see Methods). ** Maximum training sensitivity plus specificity. *** Minimum annual temperature.

Model		Basic	Robust	Extrapolated
AUC	Training	0.936	0.940	0.919
	Test	0.936 (0.841)*	0.845	0.922
Number of points used	Training	38	64	56
	Test	26 (28)*	28	35
Threshold	MTSPS**	0.265	0.229	0.222
Layers	Vegetation	47.2	42.1	34.1
	M.A.T.***	31	29.4	20.1
	Walsh Index	19	25.7	32
	Elevation	2.8	2.9	13.8

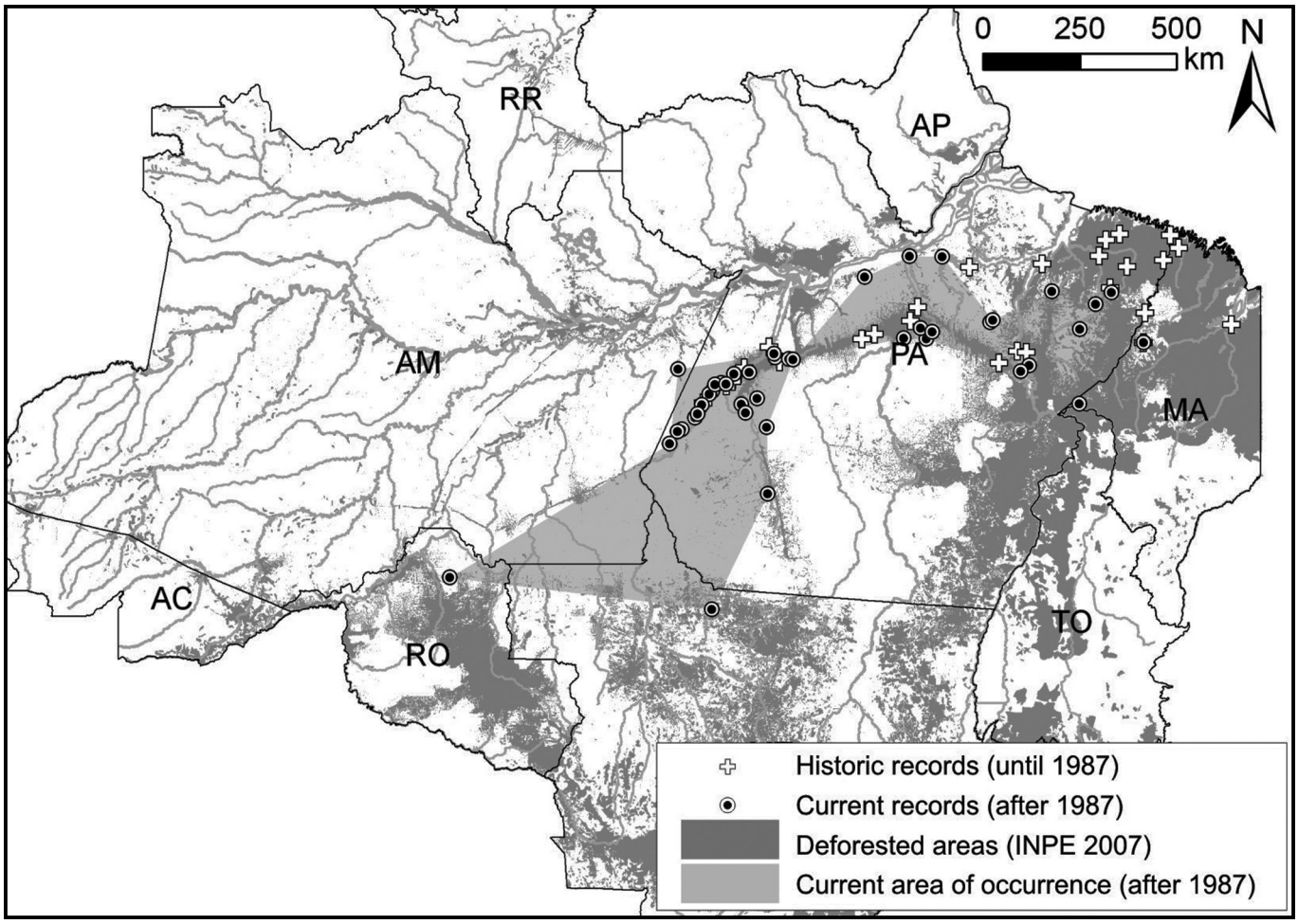

FIGURE 2: Current geographic distribution of Golden Parakeet, showing arc of deforestation in the Amazon.

DISCUSSION

We present in this article the most up-to-date and complete compilation of records of the Golden Parakeet. Potential localities of occurrence are indicated by uncertain records and are reinforced by modeling. Thus, we offer directions for the search for new populations and for understanding the species' geographic distribution, ecological requirements, and conservation status.

Historical and current area of occurrence

We believe the range retraction observed after 1987 is best explained by the increased deforestation in Maranhão and eastern Pará in the 1970s and '80s (see Fearnside 2005). During that period, there were no records of the species in numerous localities within this region, which led Oren and Novaes (1986) to consider the species rare, endangered, and locally extinct. Since then, very little research has been conducted in that region. However, although the Golden Parakeet still survives in localities with some degree of deforestation, such as Tucuruí and the Reserva Florestal Agropalma (see Appendix A), it seems to require mostly intact forest and disappears from places fully deforested (BirdLife International 2007; Laranjeiras 2008). Hence, this range retraction should be considered valid until proven otherwise.

In the case of the expansion to the west (Rondônia) and south (Mato Grosso), a better explanation is the increase in research after 1987. These areas had received very little study previously. This combined with the species' apparently low overall population density (Laranjeiras 2008) leads to low probability of detection in much of its range. Thus, we suspect that these populations always existed, but had been overlooked. Nevertheless, these two records continue to lack a full connection to the rest of the species' distribution, and large areas appear not to contain the birds (see below).

In the last twenty years, then, records have been concentrated in central and western Pará. Recent records in Maranhão and eastern Pará demonstrate the survival of the species in those parts of the distribution where deforestation is not yet complete. We cannot rule out the possibility that the distribution is moving west, pushed by deforestation. However, if we consider the total area of occurrence as including recent and historical records, then there has been a reduction of 30-40% in the last

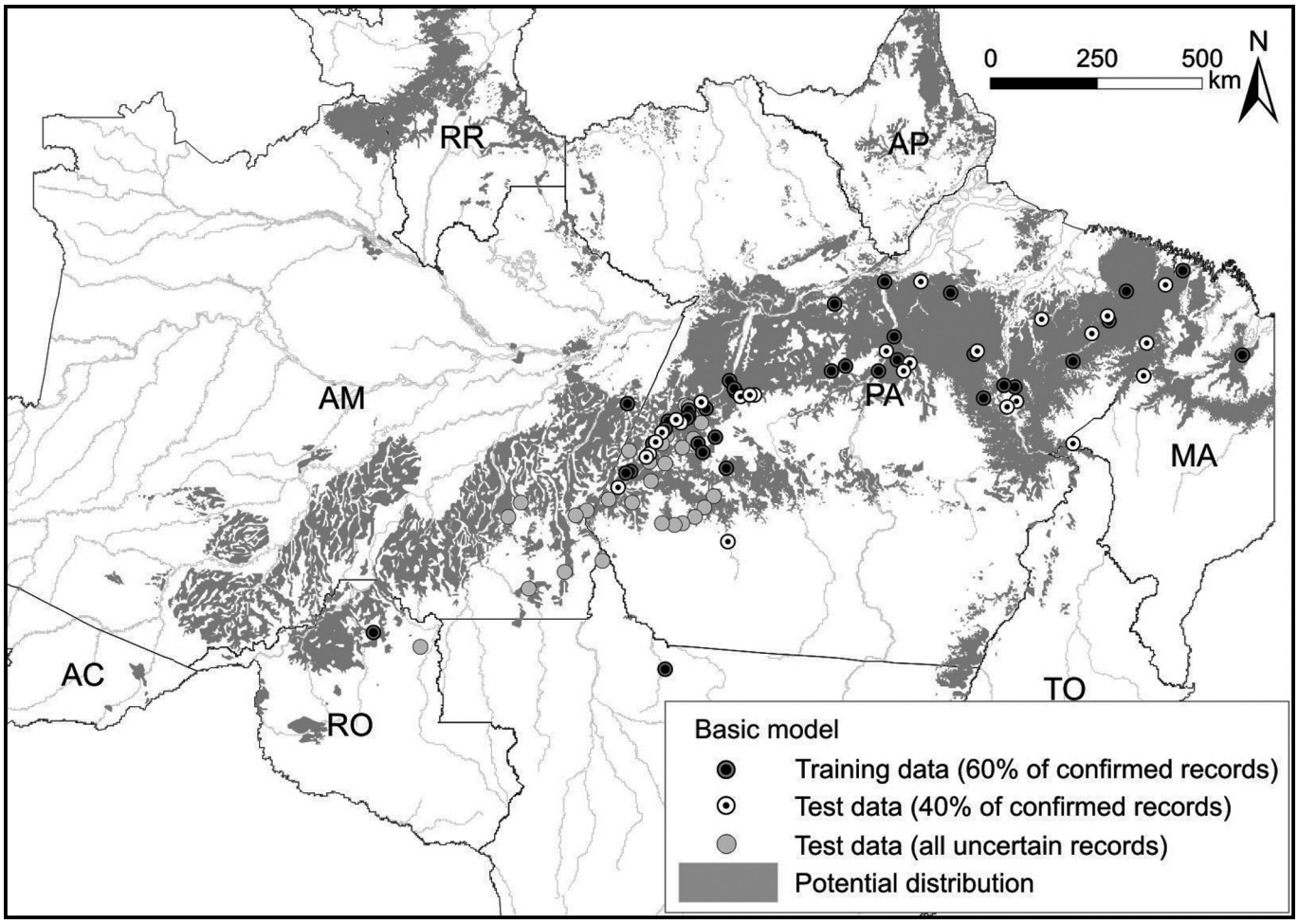

FIGURE 3: Potential distribution of Golden Parakeet (Basic Model; see text). Note that a few outlying records were not included the area predicted by the model (omission, see text).

years. Furthermore, considering the lack of records in vast areas in the western part of the range (Figure 1) as indicative of a genuinely patchy distribution, then the current area of occurrence of the Golden Parakeet probably should not include more than 340,000 km^2.

Uncertain records, absence of evidence and evidence of absence

The uncertain records (not confirmed by experienced ornithologists) are located in regions between confirmed records, which make them very probable. Nevertheless, inventories and expeditions in many cases have not detected the Golden Parakeet in the same regions. For example, in the Tapajós National Forest, the species has not been recorded at numerous points (Henriques *et al.* 2003), but it occurs in considerable abundance along the Cupari River, which forms the western limit of this reserve (Kyle 2005). This suggests a non-uniform or clumped distribution in space, and perhaps also in time, possibly associated with the distribution of certain food or nesting resources (Laranjeiras 2008). This sort of patchiness is known for other threatened parrots, such as the Lear's Macaw (*Anodorhynchus leari;* Collar 1997).

On the other hand, other lacunas, such as along the lower and middle Madeira the lower Aripuanã River (right bank tributary of the middle Madeira; see Figure 1), appear to be genuinely outside the species' area of occurrence. Confirmation of these absences and comparison of nearby localities with and without the species may be the key to understanding the occurrence of the Golden Parakeet.

An association with submontane rainforest has been proposed as a determining factor (Oren and Novaes 1986, Yamashita and França 1991, Lo 1995), but many records are not located in this kind of vegetation (Appendix E1). Consequently, the vegetation, as mapped by the available sources, does not seem to be the only indicator for the Golden Parakeet.

Points of occurrence also show an ill-defined association with rivers (Figure 1). Although the species appears to prefer terra firme forest and not to occur regularly in seasonally flooded forest along rivers, records are usually within several kilometers of rivers and not in the regions farthest from them. On the one hand, this is just the

pattern one might expect for any terra firme species where most points of access to the forest for surveys are along rivers, the main route of transportation. Also, the entire Amazon basin is densely penetrated by rivers, so virtually any locality will lie within several kilometers of some river. However, a transect across an interfluve should permit an analysis of the importance of proximity to rivers of different sizes and types. The "transamazônica" highway is just that sort of transect, crossing the Tapajós and the vast interfluve to its west until the Madeira River. The absence of records from anywhere along the "transamazônica" within the state of Amazonas coincides with the departure of the highway from the vicinity of the Tapajós River and its long traverse across terra firme cut only by streams and small rivers. If this indirect association with larger rivers proves to be real, it is still not clear what specific features of this association are important to the birds.

The Golden Parakeet thus appears to have a complex relationship to its environment at any scale, reflected both in its points of occurrence and its geographic distribution (see below), which remains to be convincingly explained. Long-term studies at permanent sites will also help evaluate whether small or large-scale movements and social interactions, on a seasonal or longer time frame, play a role in the patchiness of the species' occurrence.

Modeling of potential distribution

The approaches to modeling used in this study were all validated (see Table 1), indicating good predictive power, and led to very similar predictions. The three models included almost all records as well as including regions between confirmed records and some marginal areas and localities with only uncertain records. Hence, the potential distribution presented in the models fits well the original data, helping us to understand the occurrence of Golden Parakeet.

Omission of known localities from the potential distribution and inclusion of areas without occurrence were both acceptably limited in the results of the modeling. However, specific cases warrant attention. The exclusion of the area near Alta Floresta, from which there is a single observation, from the potential distribution suggests that the area does not contain ideal habitat and is unlikely to maintain a resident population. On the other hand, the area identified by the models on the Mato Grosso – Tocantins state line near the Araguaia river is far from any known records of the species and is disjunct with respect to other areas of appropriate habitat; thus, it appears at a glance to be unlikely to have a population as yet undetected. Nevertheless, these presumed anomalies can and should be tested in the field.

In addition to delimiting reasonably well the region of actual occurrence of the Golden Parakeet and suggesting areas for future searches, the niche models also indicated several areas in the northern Amazon, where the species apparently does not and never has occurred. These areas were identified as having the same characteristics (from among those included in the modeling) associated with the presence of the species. The absence of the birds from these regions is not necessarily an error in the models, but rather a result of physical or biological barriers, or other historical factors, that prevent the species from occupying more distant localities with seemingly appropriate conditions (Pulliam 2000). In the case of the Golden Parakeet, there are no records from north of the Amazon or west of the Madeira, despite the presence of apparently appropriate habitat there. These rivers are well known distributional limits for hundreds of taxa of Amazonian birds (Haffer 1978). They are enormously wide and are flanked by broad expanses of a mosaic of várzea vegetation types, none of which the parakeet occupies. They are also the only "whitewater" (muddy-water) rivers in this part of the Amazon, providing the first barrier of this sort that would be encountered by a species attempting to disperse out of southeastern Amazonia into the rest of the Amazon basin. Thus, it's reasonable to assume that the Golden Parakeet's distribution was well modeled in the region where the species occurs, and that it simply does not cross the Amazon or Madeira rivers to occupy other potentially habitable regions (see *Conclusions*).

If we examine the relationship between point records and each of the environmental layers individually, it is possible to explore habitat requirements more intuitively (Appendix E). The records are limited to an intermediate zone of minimum annual temperature (Appendix E2) and of the Walsh Index (Appendix E3). As for vegetation (Appendix E1) and elevation (Appendix E4), the records are located in zones of contact between submontane and lowland forests, at the interface between lowland Amazonia and the Brazilian Shield. Perhaps these variables have some direct relevance to the occurrence of the species.

Like many parrots, the Golden Parakeet sleeps in tree cavities (Oren and Novaes 1986; Laranjeiras 2008). In other species, temperature control is one of the explanations for this behavior (Collar 1997). If this is correct, then cold nighttime temperatures may limit the species' distribution to the south. But why not occur more extensively in warmer climates further north and throughout the lowlands? The Walsh index (linked to dry season intensity and duration) may provide a clue. The species may require reasonably warm temperatures at all times, but not be able to tolerate the constantly high humidity of the more aseasonal parts of the Amazon. It is tempting to speculate that under more humid conditions its cavities might house pathogenic fungi or molds that harm adults or nestlings, for example. Or perhaps these relatively restricted climatic conditions are important determinants of one or a few plant species of particular importance to

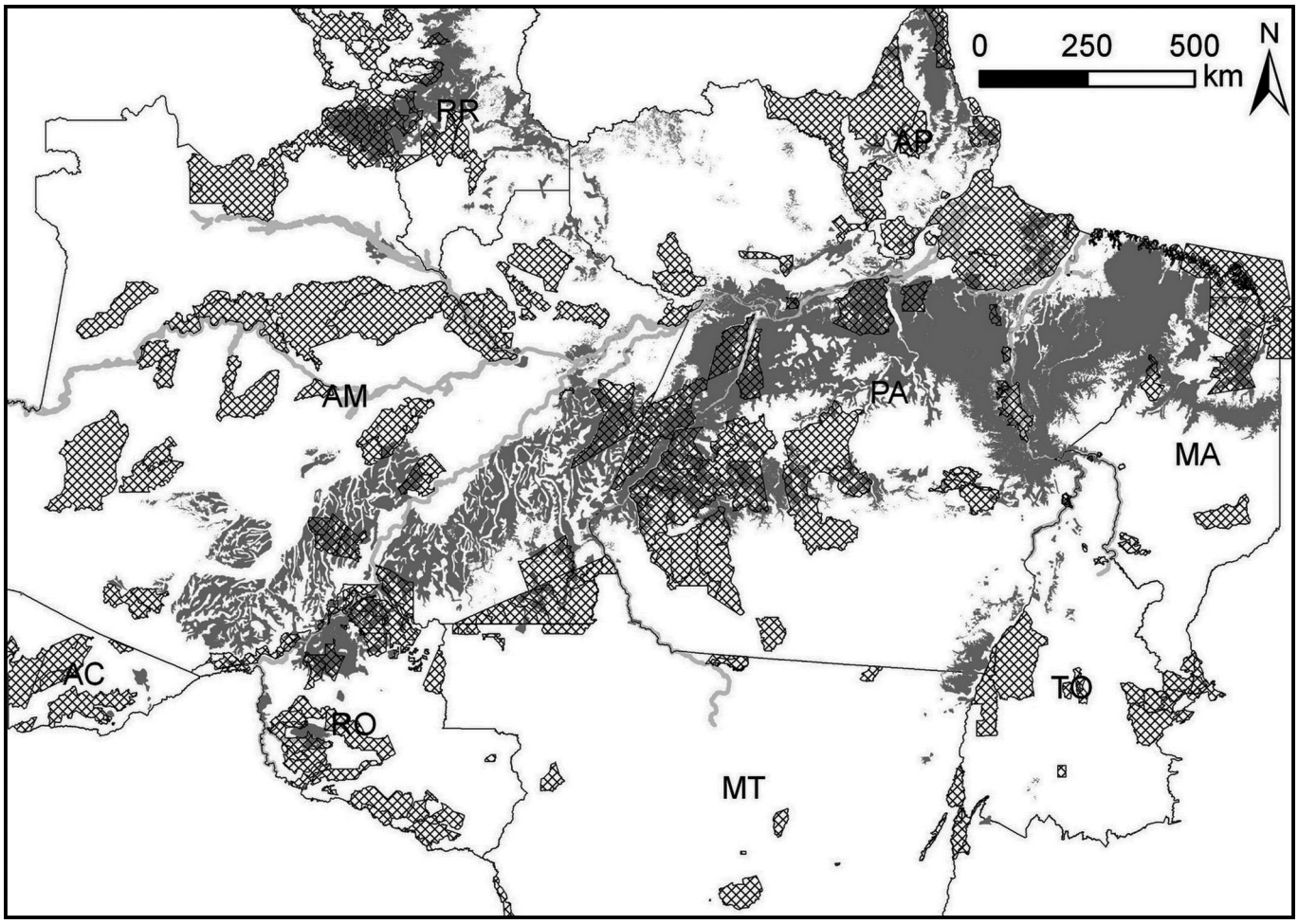

FIGURE 4: Coverage of the Golden Parakeet's potential distribution by parks and reserves, including both sustainable development and integral protection categories at the federal and state levels. Note concentration of reserves in the Tapajós River region – the species' best hope – and the shortage of protected areas in the east.

the parakeet as nesting sites or food sources. These possibilities suggested by the modeling offer directions for future research.

Conservation and future scenarios

The distribution of the Golden Parakeet partially overlaps the "arc of deforestation" in the Amazon, and in the last years the species has lost at least 35% of its area of occurrence. In the next 25 years, the eastern and northern portions of its range are expected to be devastated (Soares-Filho *et al.* 2006). In a more pessimistic scenario (Soares-Filho *et al.* 2006), the south and west will also be completely deforested. Hence, the central portion of the distribution (along the Tapajós River and possibly toward the Xingu River as well), where there is a high concentration of protected areas (Figure 4) represents the species' best hope for survival.

The Golden Parakeet should be considered a flagship species and could help in more generalized conservation causes in this most endangered part of the Amazon. The easternmost portion of its distribution is in the so-called "Belém area of endemism", noted for the presence of numerous endemic taxa and for its critical state of endangerment (Silva *et al.* 2005). As an emblematic and charismatic species, the Golden Parakeet could prove an important tool for the conservation of this region. Put another way, not only is it risky for this already endangered species to lose yet another major part or its distribution, but the effort to save it there can have positive repercussions for conservation in general. On the other hand, in the middle of its range, where most recent records were made, conservation of the species should insure its perpetuation in the wild (Kyle 2005). Recently, numerous reserves have been created in this region. Much of this area is currently zoned for sustainable timber extraction; thus, careful attention to the preservation of the Golden Parakeet must be given in reserve management plans. Furthermore, the search for populations in the west is a conservation priority defined by BirdLife International (2007), reinforced by the results of our models. Some parks and reserves offer good chances for discovery of populations (Figure 4), such as the Pau-Rosa and

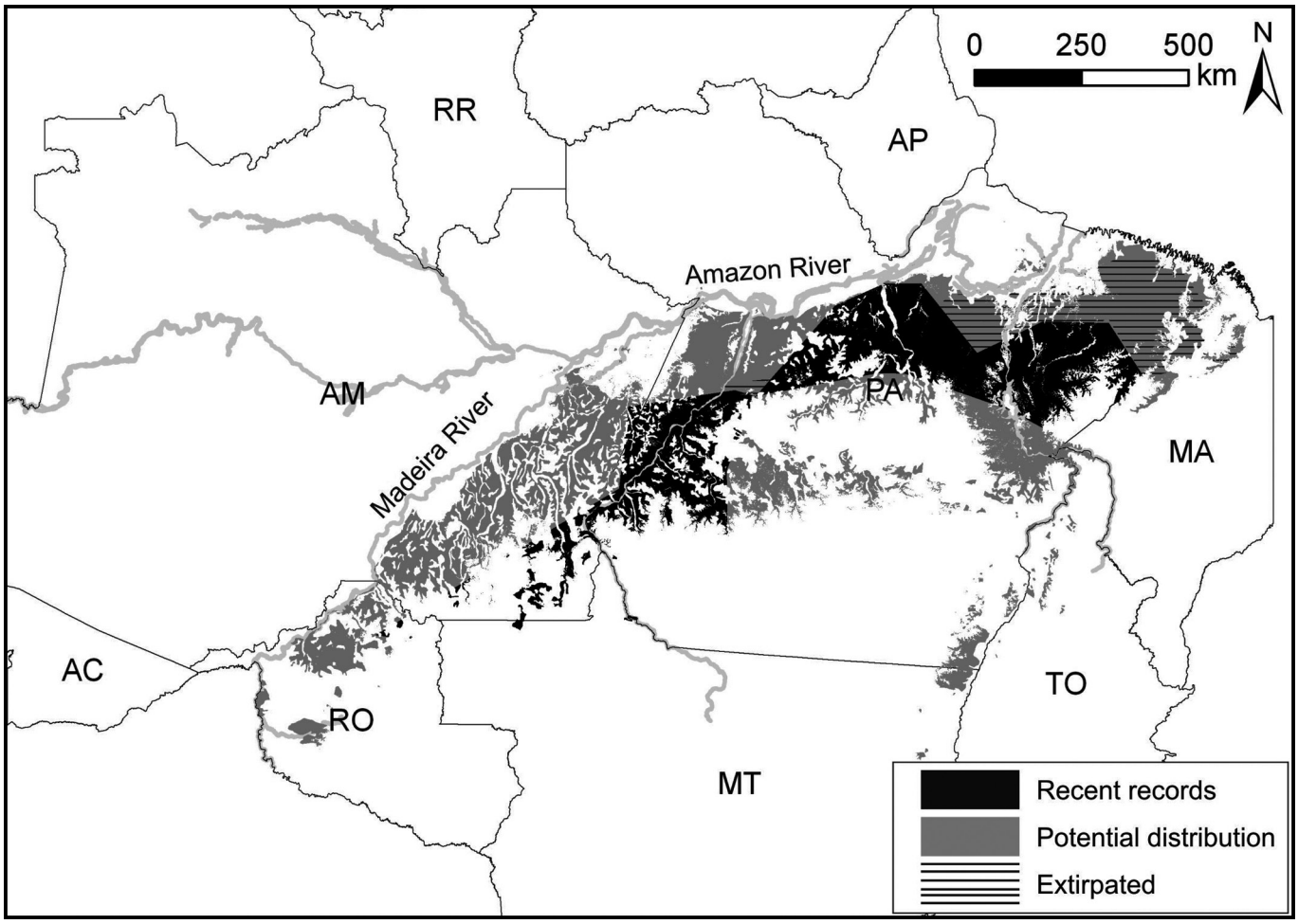

FIGURE 5: Best estimate of the geographic distribution of the Golden Parakeet based on current data. Medium gray indicates the overall potential distribution (basic model), cropped by the Amazon and Madeira rivers. Black indicates where the potential distribution overlaps known records (alpha-hull polygon; see text). The hatched region is that part of the potential distribution from which the species has not been reported since 1987. Rivers shown in pale gray.

Jatuarana National Forests and Sucunduri State Park (all in southeastern Amazonas).

CONCLUSIONS

We believe that the best depiction of the true distribution of the Golden Parakeet, based on current information, is that area within the Madeira-Amazon interfluve shown by modeling to contain the conditions associated with likely occurrence (Figure 5). Restriction to this interfluve is common in Amazonian birds. However, the details of this geographic distribution are peculiar compared to other Amazonian bird species. Our results show that Golden Parakeet should survive in an oddly delimited area south of Amazon River, along the border of Brazilian Shield, from extreme western Maranhão to northern Rondonia. We hope that the current study represents a useful step in depicting this distribution, in helping focus future research efforts to better understand it, and in calling attention to the strong influence of deforestation on the occurrence of the species. Additional information on the natural history of Golden Parakeet (see Laranjeiras 2008) will be presented elsewhere. This beautiful bird is not only symbolic of Brazilian ornithology, but also of the plight of bird conservation in the Amazon.

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APPENDIX A

All 69 localities of Golden Parakeet records. List organized by state, from east to west, and within states in chronological order. Original reference cited for published records (see References). *Approximate date. ** Not used in the modeling.

Maranhão

1. 1909 – Serra do Pirocaua (1°31'S, 45°55'W). Three specimens MPEG (#06838, #06839, #06840). Collector: Lima, F.
2. 1980 – Drainage of Pindaré River (3°16'S, 44°41'W). Sight record (Silva 1993).
3. 1983 – Gurupi area (3°42'S, 46°45'W). Sight record (Silva 1993).
4. 1999 – Primavera Farm of Celulose Maranhão Group (4°66'S, 48°14'W). Sight records (Fabio Röhe pers. comm. 2008).
5. 2001* – Reserva Biológica do Gurupi (3°42'S, 46°44'W). Sight records (Carlos Yamashita *in litt.* 2008).

Pará

6. 1903** – Maracanã River, Santo Antônio da Prata (1°19'S, 47°36'W). Specimen MPEG (#02646). Collectors: Schönmann, J./Rodrigues, R. S.
7. 1906 – Gurupi River (3°00'S, 46°42'W). Sight record (Hidasi 1973).
8. 1908** – Estação experimental do Peixe-Boi (1°11'S, 47°17'W). Specimen MPEG (#05886). Collector: Martins, O.
9. 1909 – Xingu River, Vitória (2°52'S, 52°00'W). Specimen MPEG (#06614). Collector: Snethlage, E.
10. 1912 – Left bank of Tocantins River, Arumatheua (3°53'S, 49°41'W). Two specimens Museu Nacional do Rio de Janeiro (#3443, #3444) and one speciemen MPEG (#10273). Collector: Lima, F.
11. 1920** – Tocantins River (1°53'S, 49°06'W). Two specimens MZUSP (#11057, #11058). Collector: Lima, F.
12. 1932** – Vizeu (1°13'S, 46°07'W). Specimen MPEG (#13938). Collector: Lima, F.
13. 1939 – Pracupi River, right bank of lower Amazonas River, Portel (1°57'S, 50°47'W). Specimen MPEG (#28129). Collector: Lasso.
14. 1955 – Córrego Murucutum, Gurupi River, Camiranga (1°48'S, 46°16'W). Four specimens Museu Nacional do Rio de Janeiro (#1461, #1462, #1482, #1487). Collector: no data. Also in Aguierre and Aldrigui (1983).
15. 1959** – Capim River near Belém-Brasília Highway (BR-163) (1°41'S, 47°46'W). Eight specimens MZUSP (#43976, #43977, #43978, #43979, #43980, #43981, #43982, #43983). Collector: Dente.
16. 1959 – Km-92 of Belém-Brasilia Highway (BR-163) (2°26'S, 47°31'W). Two specimens MPEG: one at 1959 (#15586) and other at 1962 (#28130). Collector: José Hidasi.
17. 1962 – Fordlândia, right bank of Tapajós River (3°48'S, 55°27'W). Three specimens MZUSP, collected at 1964 (#56313) and at 1971 (#64772, #64771). Collector: Olalla.
18. 1974 – Km-186 of Transamazônica Highway (BR-230), to southwest of Itaituba (5°05'S, 56°59'W). Sight record mentioned by Oren and Willis (1981). Also, personal observations (TOL) at 2007.
19. 1974 – Transamazônica Highway (BR-230) between Itaituba and Altamira (east of Tapajós River) (4°08'S, 55°12'W). Sight record mentioned by Oren and Willis (1981).
20. 1974 – Transamazônica Highway (BR-230) at 85km to west of Altamira (3°30'S, 53°00'W). Sight record (Oren and Willis 1981).
21. 1974 – Transamazônica Highway (BR-230) at 120km to west of Altamira (3°36'S, 53°18'W). Sight record (Oren and Willis 1981).
22. 1974 – Transamazônica Highway (BR-230) between Altamira and Marabá (west of Tocantins River) (4°10'S, 50°06'W).Sight record (Oren and Willis 1981).
23. 1974 – Itaituba (4°16'S, 56°02'W). Sight record (Silva 1993).
24. 1974 – Altamira (3°11'S, 52°10'W). Sight record (Silva 1993).
25. 1977 – Sítio Fé em Deus, Igarapé Pedral, (a tributary of Guamá River), Ourém (1°56'S, 47°07'W). Specimen MPEG (#32083). Collector: Moreira, M.
26. 1978 – Km-95 of the Transamazônica Highway (BR-230) to southwest of Itaituba, Parque Nacional da Amazônia (4°41'S, 56°27'W). Sight record (Oren and Willis 1981).
27. 1978 – Km-60 of the Transamazônica Highwat (BR-230) to southwest of Itaituba, Uruá. Parque Nacional da Amazônia. (4°32'S, 56°18'W). Sight record (Oren and Willis 1981). Also, personal observations (TOL) at 2007.
28. 1980 – Tucuruí, 18 km toward east of Tocantins River. (3°55'S, 48°28'W). Sight record (Oren and Willis 1981).

29. 1985 – Porto do Buburé, Tapajós River, Parque Nacional da Amazônia (4°36'S, 56°19'W). Sight record (Oren and Parker 1997).
30. 1992 – Vilarinho do Monte. (1°43'S, 52°12'W). Sight record (Collar *et al.* 1992).
31. 1998 – Fazenda Cauaxí, near 100km to southwest of Paragominas (3°23'S, 48°14'W). Sight record (Alexandre Aleixo *in litt.* 2007).
32. 2002 – Capim River (2°49'S, 47°51'W). Sight record (Toa Kyle *in litt.* 2007).
33. 2002 – Cuiabá-Santarém Highway (BR-163), 239 km to North of Novo Progresso, Trairão (5°07'S, 56°06'W). Sight record (Pacheco and Olmos 2005).
34. 2004 – Cupari River, Floresta Nacional do Tapajós. (4°03'S, 55°19'W). Sight records (Kyle 2005).
35. 2004 – Cachoeira do Grim-Rurópolis, Rurópolis. (4°05'S, 55°00'W). Sight records (André Ravetta *in litt.* 2008).
36. 2004 – Rurópolis. (4°54'S, 54°54'W). Sight records (André Ravetta *in litt.* 2008).
37. 2005 – Reserva Florestal Cia Pará Pigmentos, Ipixuna (2°33'S, 47°29'W). Sight record (Luís Fábio Silveira *in litt.* 2007).
38. 2005 – Reserva Florestal Agropalma, Tailândia (2°31'S, 48°52'W). Sight records (Silveira and Belmonte 2005).
39. 2005 – 20 km toward west of Novo Progresso (7°11'S, 55°29'W). Sight record (Alexandre Aleixo *in litt.* 2007).
40. 2005 – Km-145 of Transamazônica Highway (BR-230), to south of Itaituba, Parque Nacional da Amazônia (4°49'S, 56°47'W). Sight records (Kyle 2005).
41. 2005 – Km-160 of Transamazônica Highway (BR-230), to south of Itaituba, Parque Nacional da Amazônia (4°53'S, 56°51'W). Sight records (Kyle 2005).
42. 2005 – Km-250 of Transamazônica Highway (BR-230), to north of Jacareacanga (5°25'S, 57°11'W). Sight records (Kyle 2005).
43. 2005 – Km-305 of Transamazônica Highway (BR-230), to north of Jacareacanga (5°42'S, 57°30'W). Sight record (Kyle 2005).
44. 2005 – Vicinity of Cupari River (3°57'S, 55°20'W). Sight record (André Ravetta and Toa Kyle *in litt.* 2008).
45. 2006 – Monte Carmelo, Prainha (2°11'S, 53°14'W). Sight record mentioned (Ivo Rohling *in litt.* 2006).
46. 2006 – Floresta Nacional de Caxiuanã (1°43'S, 51°26'W). Sight records (Renata de Melo Valente and Alexandre Aleixo *in litt.* 2007).
47. 2006 – Km-350 of Transamazônica Highway (BR-230), to north of Jacareacanga (6°02'S, 57°46'W). Personal observations (TOL).
48. 2006 – Right bank of Tucuruí Dam (4°13'S, 49°24'W). Sight records (Sidnei de Melo Dantas *in litt.* 2007).
49. 2006 – Left bank of Tucuruí Dam (4°22'S, 49°36'W). Sight records (Sidnei de Melo Dantas *in litt.* 2007).
50. 2007 – Jamanxim River (5°19'S, 56°00'W). Sight records mentioned by Wandler Camargo (*in litt.* 2007).
51. 2007 – Km-330 of the Transamazônica Highway (BR-230), to north of Jacareacanga (5°45'S, 57°36'W). Personal observations (TOL).
52. 2007 – Right bank of the "Volta Grande" of the Xingu River, Belo Monte (3°36'S, 51°47'W). Sight record (Sidnei de Melo Dantas *in litt.* 2008).
53. 2007 – Vicinity of Pacajás River, Portel, near 100 km to north of Tucuruí (3°14'S, 50°19'W). Sight record (Sidnei de Melo Dantas *in litt.* 2008).
54. 2007 – Vicinity of Pacajás River, Portel, near 120 km to north of Tucuruí (3°11'S, 50°15'W). Sight record (Sidnei de Melo Dantas *in litt.* 2008).
55. 2007 – Km-48 of the Transamazônica Highway (BR-230), to south of Itaituba (4°25'S, 56°17'W). Personal Observations (TOL).
56. 2007 – Km-110 of the Transamazônica Highway (BR-230), to south of Itaituba, Parque Nacional da Amazônia (4°38'S, 56°34'W). Personal Observations (TOL).
57. 2007 – Km-130 of the Transamazônica Highway (BR-230), to south of Itaituba, Parque Nacional da Amazônia (4°40'S, 56°43'W). Personal Observations (TOL).
58. 2007 – Km-200 of the Transamazônica Highway (BR-230), to south of Itaituba (5°08'S, 57°02'W). Personal Observations (TOL).
59. 2007 – Km-245 of the Transamazônica Highway (BR-230), to north of Jacareacaga (5°20'S, 57°08'W). Personal Observations (TOL).
60. 2007 – Parque Nacional do Jamanxim (5°39'S, 55°31'W). Sight record (Alexandre Aleixo *in litt.* 2008).
61. 2007 – Parque Nacional da Amazônia. 5 km to west of the km-90 of the Transamazônica Highway (BR-230) (4°39'S, 56°28'W). Sight record (André Ravetta *in litt.* 2008).
62. 2008 – Left bank of the Xingu River ("Volta Grande"), Eletronorte Camping, Altamira. (3°22'S, 51°56'W). Personal observations (TOL).

63. 2008 – Transamazônica Highway, at 12 km to east of Miriticuba (4°23'S, 55°55'W). Personal observations (MCH).
64. 2008 – West boundary of the Floresta Nacional do Trairão (4°59'S, 55°44'W). Sight record (André Ravetta *in litt.* 2008).
65. 2008 – Right bank of Xingu River, Tapuama, 50 km to north of Altamira (3°36'S, 52°20'W). Sight record (André Ravetta *in litt.* 2008)
66. 2008 – Right bank of the "Volta Grande" of the Xingu River, Comunidade Caracol, Belo Monte (3°27'S, 51°40'W). Sight record (André Ravetta *in litt.* 2008).

Mato Grosso

67. 1991 – Alta Floresta (9°51'S, 56°34'W). Sight record (Lo 1995). Also, in 1995, personal observation (MCH, B. M. Whitney).

Amazonas

68. 2007 – Comunidade Laranjal, Maués/Amaná Rivers – Maués (4°18'S, 57°35'W). Sight records (Luke Parry *in litt.* 2007).

Rondônia

69. 1989 – Floresta Nacional do Jamari (9°07'S, 62°54'W). Sight records (Yamashita and França 1991).

APPENDIX B

Uncertain records of Golden Parakeet from interviews with local people in the western portion of the distribution in 2006 and 2007.

Southeastern state of Amazonas:

1. Maracanã river, 120km to south of Apuí (8°10'S, 59°39'W)
2. Cachoeira Monte Cristo, Sucunduri river, to south of Terra Preta village (7°49'S, 58°53'W)
3. Transamazônica highway (BR-230), ramal to Vila Nova village, to east of Sucunduri (6°31'S, 58°27'W)
4. Rio Acari, to east of AM-360 (6°22'S, 59°49'W)
5. AM-360 highway, km-60, Igarapé Canadá (6°39'S, 60°04'W)
6. Transamazônica highway (BR-230) to west of Jacareacanga, Pará (6°17'S, 57°57'W)

North of Itaituba, Pará:

7. Pote village (not mapped)
8. Mãe Maria village (4°31'S, 56°12'W)
9. Boa Esperança village (4°34'S, 56°14'W)
10. Nova Arixi village (4°19'S, 56°21'W)
11. Nova Conquista village (4°21'S, 56°18'W)
12. Nova Fronteira village (not mapped)
13. Nova Integração village (not mapped)

South of Itaituba:

14. Montanha's island in the Tapajós river (4°56'S, 56°45'W)
15. Amaná river, affluent of Maués river (5°16'S, 57°33'W)
16. Jatobal village in the Tapajós river (5°08'S, 56°52'W)
17. Penedo village in the Tapajós river (5°30'S, 57°06'W)

East of Itaituba (east bank of Tapajós river):

18. Pimental village (not mapped)
19. Igarapé do Rato (5°32'S, 56°48'W)
20. Rapids of Jamanxim river (5°13'S, 56°26'W)
21. Crepori river (5°54'S, 57°04'W)
22. River of the Tropas (6°22'S, 57°29'W)
23. Trairão (4°41'S, 56°02'W)
24. Caracol village (5°02'S, 56°11'W)
25. Jardim do Ouro village ("transgarimpeira highway), Jamanxim river (6°13'S, 55°46'W)
26. São Chico village ("transgarimpeira" highway) (6°27'S, 55°59'W)
27. Km-100 village ("transgarimpeira" highway) (6°38'S, 56°10'W)
28. Km-140 village ("transgarimpeira" highway) (6°47'S, 56°25'W)
29. Creporizinho village ("transagarimpeira" highway) (5°50'S, 56°34'W)
30. Creporizão village ("transgarimpeira" highway) (6°48'S, 56°51'W)

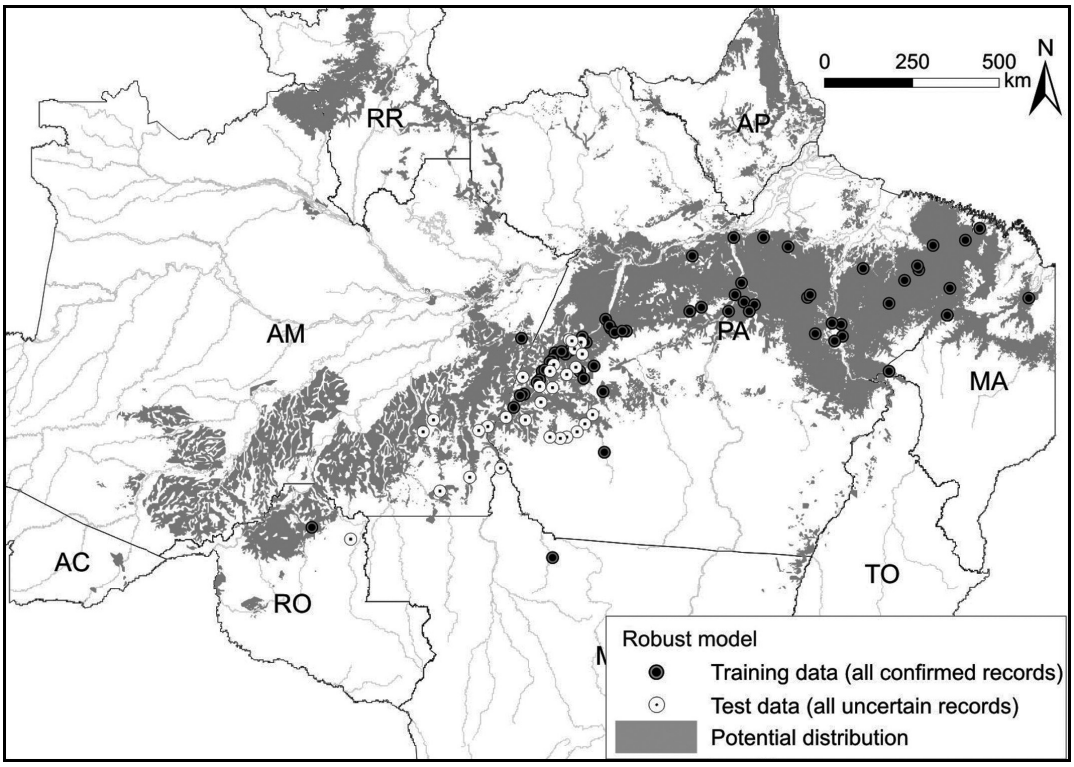
APPENDIX C

Absences reported from field work within the region of distribution of the Golden Parakeet (see References).

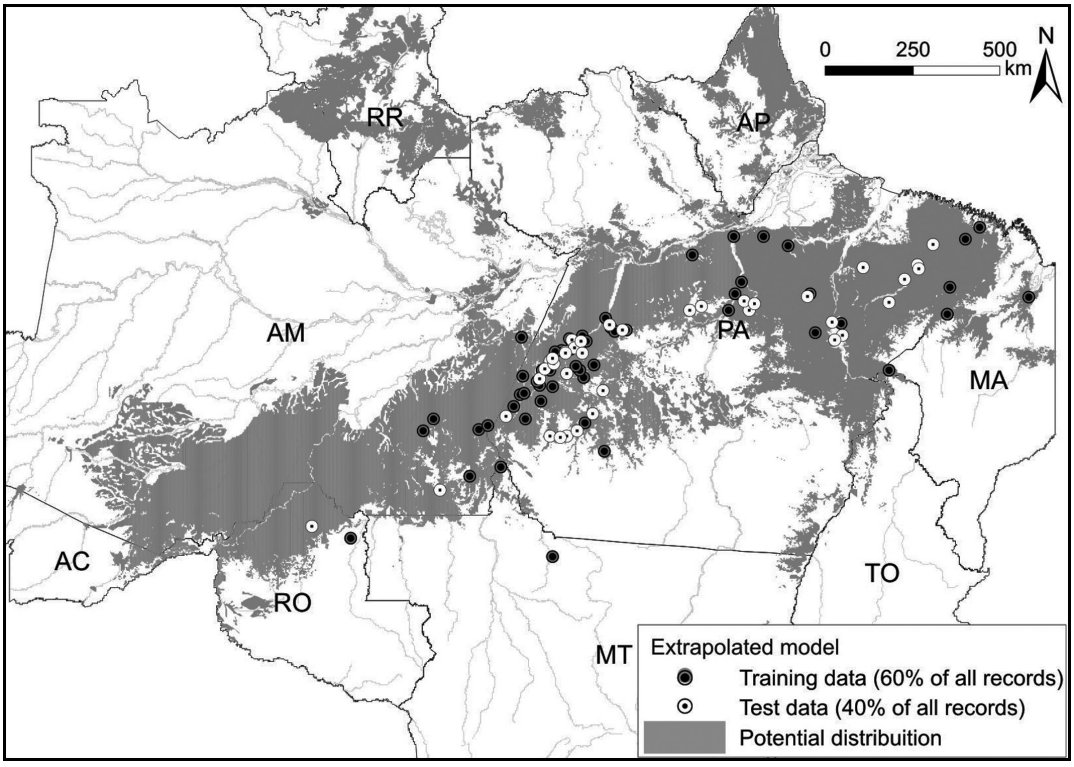
1. 1909 – A region between the upper Tapajós and Iriri rivers. A several-day expedition for zoological collection (Oren and Willis 1981).
2. 1980 – Serra do Carajás (Pará). A several-week expedition for ornithological inventories and search for the species. Oren and Novaes (1986).
3. 1980 – Gorotire (west of Pará). A several-week expedition for ornithological inventories and search for the species. Oren and Novaes (1986).
4. 1984 – Airipuanã (north of Mato Grosso). Several years expended to research of parrot's community in this region. Roth (1984).
5. 1997 – Alta Floresta (north of Mato Grosso). Several years of ornithological inventories and research and bird watching in several localities of this region (Zimmer *et al.* 1997)
6. 2003 – Central region of Tapajós National Forest. Several years of systematic research of bird community in this conservation reserve (Henriques *et al.* 2003).
7. 2004 – Lower and middle Aripuanã River (southeast of the state of Amazonas). More than 15 days of ornithological inventories over several years. Personal observations (MCH; Cohn-Haft *et al.* 2007).
8. 2006 – Transamazônica Highway (BR-230) between Humaitá (Amazonas) and Jacareacanga (Pará). A ten-day expedition for direct observation of the species. Personal observations (TOL)
9. 2006 – AM-360 Highway between Apuí and Novo Aripuanã (State of Amazonas), one-day car survey. Personal observations (TOL).
10. 2006 – Sucunduri river (southeast of the state of Amazonas). A ten-day ornithological survey. Personal observations (MCH)
11. 2007 – Roosevelt River (southeast of Amazonas). Twenty-day ornithological survey (Luis Fábio Silveira and Vitor Piacentine, pers. comm. 2008).
12. 2007 – Abacaxis river. Ten-day ornithological survey (Luís Fábio Silveira, pers. comm. 2008).

APPENDIX D

Potential distribution of Golden Parakeet from complementary data sets: Robust and Extrapolated models.



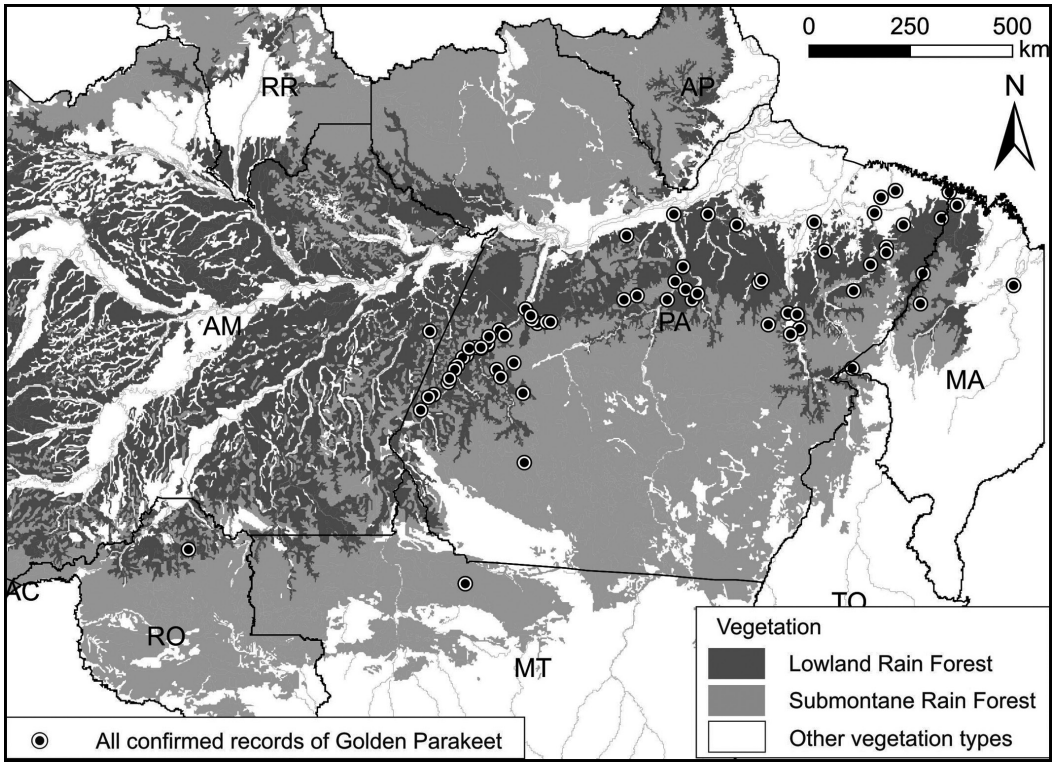
1. Potential distribution of Golden Parakeet in accordance with Robust Model.



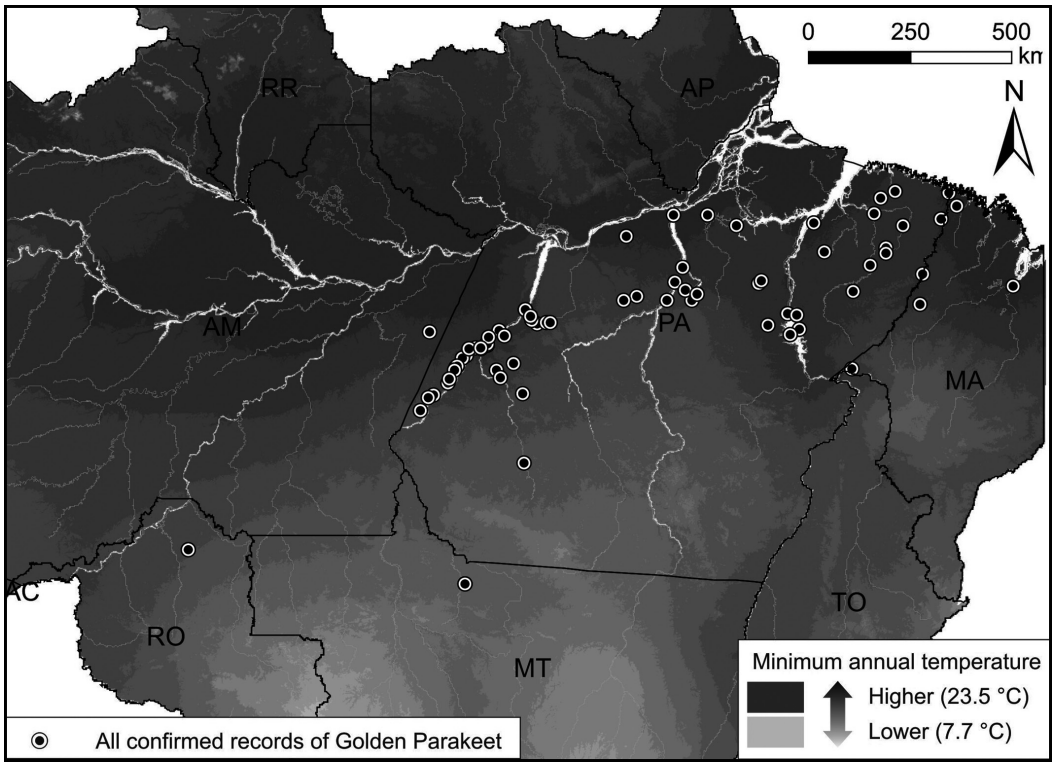
2. Potential distribution of Golden Parakeet in accordance with Extrapolated Model.

APPENDIX E

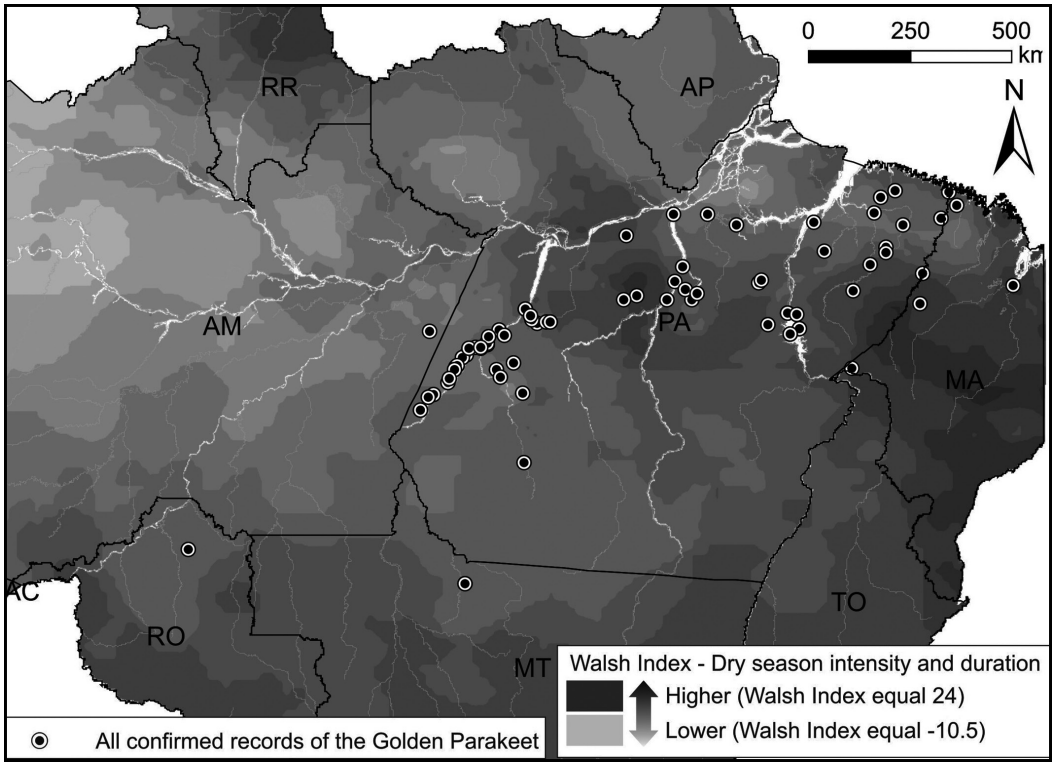
All records of Golden Parakeet overlapped on different environmental layers utilized in the models.



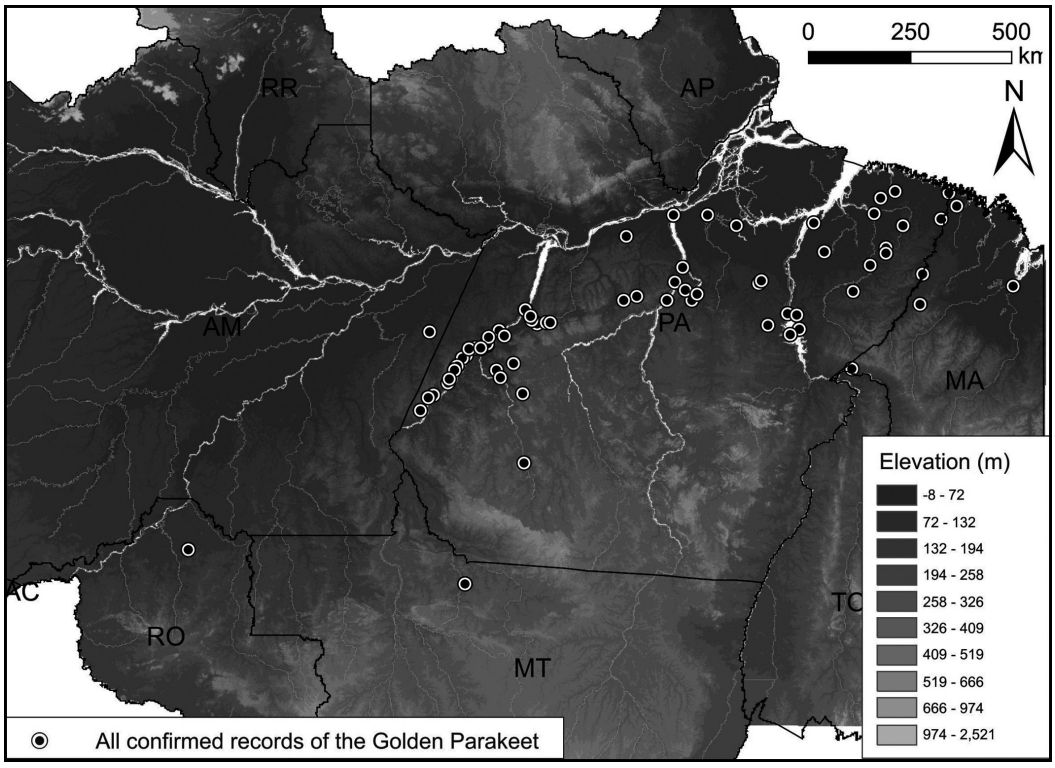
1. All records of Golden Parakeet overlapped on vegetation, considering specifically lowland and submontane rain forest.



2. All records of Golden Parakeet overlapped on Minimum annual temperature.



3. All records of Golden Parakeet overlapped on Walsh Index.



4. All records of Golden Parakeet overlapped on elevation.