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## Taxonomy, natural history, and conservation of *Paroaria baeri* (Aves: Thraupidae)

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*Paroaria baeri* (Crimson-fronted Cardinal) is a poorly known and uncommon species, inhabiting low vegetation growing along the edges of water bodies in central Brazil. Having collected new specimens along the Rio Araguaia, we revised the taxonomy of this species by examining plumage coloration and morphometric data of 36 specimens housed in Brazilian, European, and North American museums. This sample encompasses all known specimens available. Measurements of the two currently recognized subspecies overlap widely, but their plumage coloration is clearly diagnostic. Furthermore, they are distinct in the absence (*Paroaria baeri baeri*) and presence (*Paroaria baeri xinguensis*) of sexual dichromatism, and are separated by a sharp geographic barrier. These observations are consistent with the lack of gene flow between both taxa, and we propose to consider them as independent species, *P. baeri*, found on the Rio Araguaia, and *P. xinguensis*, found on the Rio Xingu. Both taxa inhabit shrubbery formations and low riparian forests along river-created habitats, *P. baeri* being endemic to the Cerrado and *P. xinguensis* being endemic to the Amazon. New information on the range, habitat, breeding, and conservation status of *P. baeri* is presented. We also present the first records of *P. xinguensis* since the collection of its type series in the 1940s.

**Keywords:** breeding; Cerrado; diet; neotropical birds; Rio Araguaia; Rio Xingu

### Introduction

The genus *Paroaria* Bonaparte, 1832 has recently been the subject of systematic analyses based on molecular and morphological data (Yuri and Mindell 2002; Burns and Naoki 2004; Nodari 2008; Dávalos and Porzecanski 2009), resulting in marked changes on its taxonomy. The first change proposed was the allocation of this genus, traditionally included in the family Emberizidae, in the family Thraupidae (Yuri and Mindell 2002; Burns and Naoki 2004). The second proposed change was that *Paroaria*, thought to comprise five species (Clements 2007), might have eight species (Dávalos and Porzecanski 2009), a treatment not fully followed by Hilty (2011) who recognized only six biological species. The taxonomic revision conducted by Dávalos and Porzecanski (2009), based on morphological and molecular data, suggested the split of *Paroaria baeri* Hellmayr 1907, elevating its two subspecies to species level. Nevertheless, given the lack of a consistent sample for the uncommon *P. baeri* (only five specimens were examined and no molecular data were available for *Paroaria baeri xinguensis* Sick 1950), the authors emphasized that more research on this species “is needed to clarify its distribution, taxonomy, and conservation status” (Dávalos and Porzecanski 2009, p. 247). Their

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proposition was analyzed by the “South American Classification Committee,” which concluded that it seems “very premature to separate *P. b. xinguensis* from *P. baeri* at this point” (Remsen et al. 2011). In this paper, we present a taxonomic revision of *P. baeri* (Crimson-fronted Cardinal) in light of recently collected specimens, including a summary of the range, natural history, and conservation status of each taxon studied.

### ***Taxonomic history***

*Paroaria baeri* is restricted to central Brazil, where its members inhabit shrubby areas and low riparian forests along lakes and sluggish rivers (Ridgely and Tudor 1989; Sick 1997). Members of this species are restricted to isolated areas with difficult access until quite recently, and they were only described in the twentieth century. Consequently, there is no junior synonym for its two currently recognized subspecies (Hellmayr 1938; Pinto 1944; Paynter and Mayr 1970; Clements 2007), and its taxonomic history is relatively simple, as summarized below.

*Paroaria baeri baeri* Hellmayr 1907 was described from three specimens collected on the Rio Araguaia, state of Goiás (Hellmayr 1907), nearby Leopoldina (now Aruanã) (Hellmayr 1908). This taxon is restricted to the Rio Araguaia valley (Hellmayr 1908, 1938) and two of its tributaries in eastern state of Mato Grosso, namely Rio Cristalino (Pinto 1938) and Rio das Mortes (Pinto and Camargo 1952). The holotype and two paratypes, formerly at the Rothschild Collection, Tring, UK, are now housed at the American Museum of Natural History, New York, USA (LeCroy 2012).

*Paroaria baeri xinguensis* Sick 1950 was described from eight specimens collected on the Rio Xingu, Mato Grosso (Sick 1950). The holotype, collected at “Acampamento Iauarun [= Diauarum], alto [Rio] Xingu,” and five paratypes were deposited at the Museu Nacional, Rio de Janeiro, Brazil (Gonzaga 1989). Two additional paratypes, which have been considered lost (Gonzaga 1989), are now housed at the American Museum of Natural History (L.E. Lopes, pers. obs.), but have not been recognized as such by LeCroy (2012).

The main diagnostic character between both subspecies is the extent of the dark crimson throat patch. The nominate subspecies has the entire upper throat dark crimson and *P. b. xinguensis* has a throat that is mostly black in color, only the malar streak being dark crimson (Sick 1950; Ridgely and Tudor 1989).

### **Materials and methods**

Fieldwork was conducted in several localities along the Rio Araguaia from 2007 to 2009, when we visited the municipalities of Aragarças, Montes Claros de Goiás, Araguaína, Caseara, Araguacema, Cocalinho, Muricilândia, and Xinguara, among others. During these expeditions, we explored the complete range of habitats found in the region (from grasslands to evergreen forests, including several types of riparian habitats). We found *P. baeri* in three occasions and collected six specimens that were deposited in the Universidade Federal de Minas Gerais, Belo Horizonte, Brazil (DZUFMG) and in the Museu de Zoologia da Universidade de São Paulo, São Paulo, Brazil (MZUSP). We also examined additional specimens housed in the above-mentioned institutions as well as in the following institutions: American Museum of Natural History, New York, USA (AMNH); Field Museum, Chicago, USA (FMNH); Louisiana State University Museum of Natural Science, Baton Rouge, USA (LSUMZ); Museu Nacional, Rio de Janeiro, Brazil (MNRJ); Museu Paraense Emílio Goeldi, Belém, Brazil (MPEG); Reserva Ecológica do Instituto Brasileiro de Geografia e Estatística, Brasília, Brazil (RECOR); and Museum für

Naturkunde, Berlin, Germany (ZMB). These collections house 36 specimens of *P. baeri*, including the holotype and the two paratypes of *P. b. baeri* and the holotype and all paratypes of *P. b. xinguensis* (see Appendix). To our knowledge, we examined all specimens of *P. baeri* available in ornithological collections. We also examined the digital pictures of two individuals of *P. b. xinguensis* recently photographed in nature (see below for additional detail).

Taxonomic decisions were based on plumage coloration and morphometric characters. We closely inspected each specimen to check if the diagnostic characters proposed (Hellmayr 1908; Sick 1950) were observable and if any intermediate color pattern could be found. A dial caliper was used to measure the length of the total culmen, closed wing (chord), tail, and tarsus, following Baldwin et al. (1931). All measurements were taken to the nearest 0.1 mm. The mean and the standard deviation were calculated for each morphometric variable.

We conducted a principal component analysis (PCA), a technique that summarizes the patterns of correlations among observed variables, reducing a large number of variables to a smaller number of components (Tabachnick and Fidell 2007). All four morphometric variables measured were used in the PCA.

Given the small sample size available, especially for *P. b. xinguensis*, we pooled together data for both sexes before conducting the PCA. This procedure was decided after preliminary analysis revealed no significant differences between measurements of males and females of *P. b. baeri* using Student's *t*-test (Zar 2010), with a significance level adopted of 5%. We validated this decision after comparing the mean measurements of males and females of *Paroaria gularis* (Linnaeus, 1766), the sister taxon of *P. baeri*. This was based on the measurements of 20 males and 20 females of Brazilian specimens referable to the nominate subspecies and deposited in MPEG. No significant differences were observed for wing, tail, and tarsus length, but culmen length differed significantly and slightly with a mean difference of about 0.4 mm between sexes (data not shown) of *P. gularis*.

## Results and discussion

### *History of collection*

Although *P. baeri* was described from the specimens collected by G.A. Baer on August 1906 (Hellmayr 1907, 1908), our searches for this species in museum collections revealed one overlooked specimen (ZMB 28827) which had been collected 18 years before. This specimen was collected on 15 August 1888 by Dr P. Ehrenreich, a German ethnographer and anthropologist who, accompanied by Prof. Von den Steinen, briefly visited the type locality of this species (Brogiato 2005). The bulk of the bird collection amassed during this trip was deposited in the ZMB and never reported upon (Hellmayr 1908), exception made to some specimens received in exchange by other museums (e.g., Hellmayr 1906; Berlepsch 1907).

### *Plumage coloration*

Although both subspecies look similar, they can be easily diagnosed both by the extent of the throat patch, and by the extent of barring on the underparts. All examined specimens of *P. b. baeri* exhibited a well-marked dark crimson throat patch, chest and breast white, and the sides of breast indistinctly barred with black. This effect is due to a subterminal dark grayish bar present on the feathers of the sides of chest, which is concealed by the white tip of adjacent feathers (Figure 1). A slight variation is observed in the width and intensity of

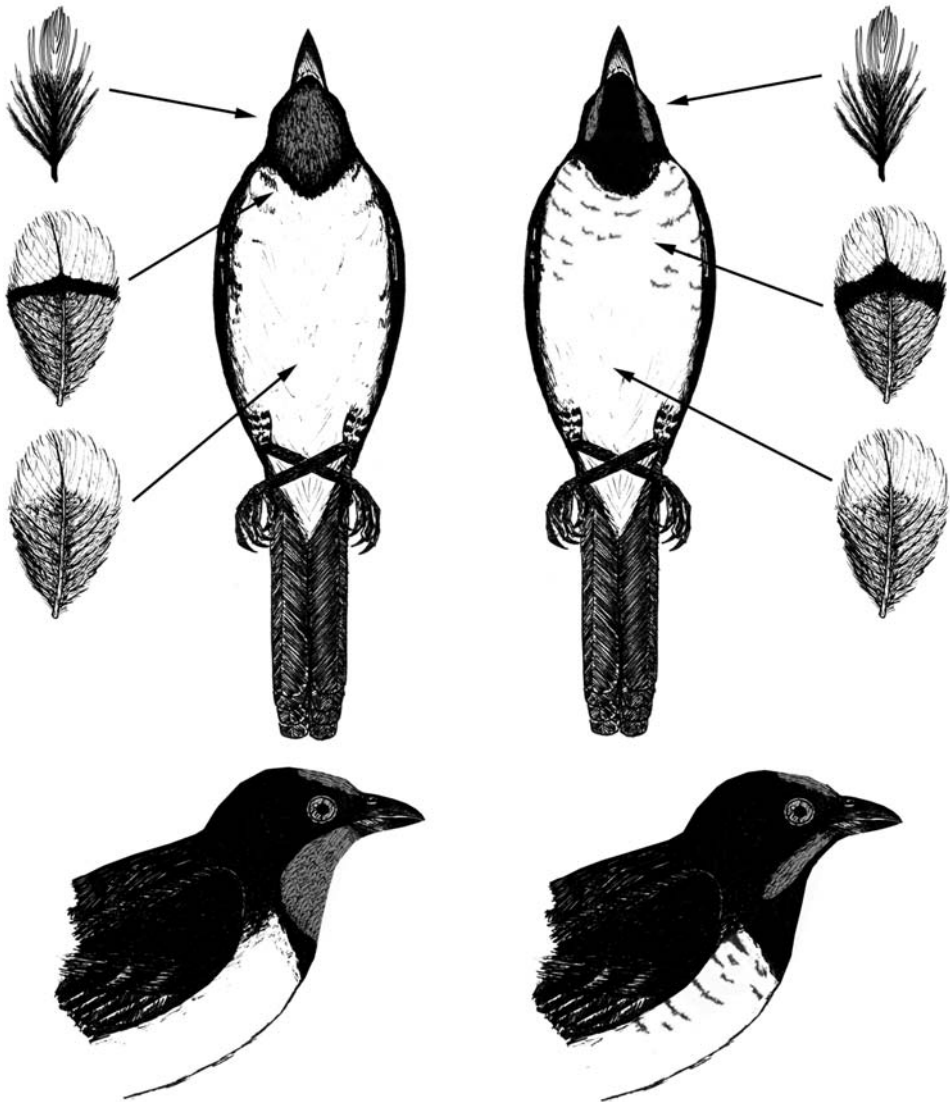


Figure 1. Diagnostic character patterns observed in *Paroaria baeri baeri* (left) and *Paroaria baeri xinguensis* (right), females depicted. From an India Ink drawing by L.E. Lopes.

the dark grayish bar of chest feathers, as well as in the extent of the throat and crown crimson patch. Poorly prepared specimens with badly arranged breast feathers, or which lost some of those feathers, generally exhibit indistinct breast barring, but never attain the barring intensity that can be observed in the females of *P. b. xinguensis* (see below). This taxon is not sexually dimorphic, and the adults of both sexes present the under wing-coverts variegated with black, not only the male, as alleged by Hellmayr (1908).

In contrast, *P. b. xinguensis* shows a marked sexual dichromatism. Females have a throat that is mostly black in color and a dark crimson malar streak. On males, some of the black feathers of the throat are tipped dark crimson. Breast barring is more conspicuous in *P. b. xinguensis* than in *P. b. baeri*. This difference is due to the dark subterminal band of the breast feathers of *P. b. xinguensis*, which is wider and blacker than that of *P. b. baeri*.

Furthermore, such feathers cover the entire chest of the males, rather than just its sides as in *P. b. baeri*, extending down to the breast and sides in the females (Figure 1).

### *Color of soft parts*

The iris color of *P. b. baeri* varies from reddish-orange to red; maxilla is black, mandible is light gray, with black tip; and tarsus and toes are black. Juvenile birds have brown iris; maxilla and mandible are black, and tarsus and toes are dark grayish (data from labels of specimens housed in DZUFMG). This same color pattern can be observed from the color pictures of this subspecies (see Alves 2005; Buzzetti and Silva 2005; Hilty 2011). It is noteworthy that Hellmayr (1907, 1908, 1938) described the basal half of mandible of this species as “dull reddish.” Given that the holotype’s label does not give any information on soft parts color, obviously there has been some wrong information obtained from the examination of dried specimens, which sometimes exhibit grayish brown basal mandibles. The soft part colors of *P. b. xinguensis* are not distinct (Sick 1950).

### *Measurements*

Data on body weight of *P. b. baeri* (Table 1) are based on the specimens housed in DZUFMG and MZUSP, and are the first to be published for the members of this species (Dunning 2008). *Paroaria baeri baeri* showed slightly longer wing, tail, and tarsus length than *P. b. xinguensis* (Table 1), but the significance of such differences was not tested given the small sample size available. Nevertheless, although differences in body size between these taxa may prove to be significant when more specimens are available, body measurements are not consistently diagnostic.

The PCA (Figure 2) demonstrated that, although there is a general tendency for the formation of two groups, there is no clear-cut separation between the specimens from the Rio Araguaia basin and those from the Xingu basin. The contribution ratios of the first principal component (PC1) were 43.2%, whereas the second principal component (PC2) contributed to 28.9%, accounting for a total of 72.1% for the two components represented in Figure 3.

### *Geographic distribution*

The two subspecies of *P. baeri* are allopatric, occurring in a transition zone between the Cerrado savannas and the Amazon forest, and use a similar habitat (see below). For this reason, the members of this group have been referred in the literature as endemic either to

Table 1. Morphometric values of *Paroaria baeri baeri* and *Paroaria baeri xinguensis*.

Characters	Taxa	
	<i>Paroaria baeri baeri</i>	<i>Paroaria baeri xinguensis</i>
Total culmen	16.4 ± 0.63 (22) 15.6–17.8	16.5 ± 0.47 (6) 15.5–17.1
Closed wing	81.9 ± 1.48 (24) 79.1–85.1	79.2 ± 1.50 (7) 77.5–81.7
Tail	76.4 ± 1.77 (24) 73.0–80.2	74.5 ± 1.80 (7) 72.2–77.2
Tarsus	22.2 ± 0.87 (24) 20.9–23.6	20.9 ± 1.10 (7) 19.2–22.3
Weight	25.9 ± 1.05 (9) 24.5–27.0	Not available

Notes: Data from both sexes were pooled together, excluding young specimens. All linear measurements in mm, weight in g, presented as means ± SD, followed by sample size (between parenthesis) and minimum–maximum values.

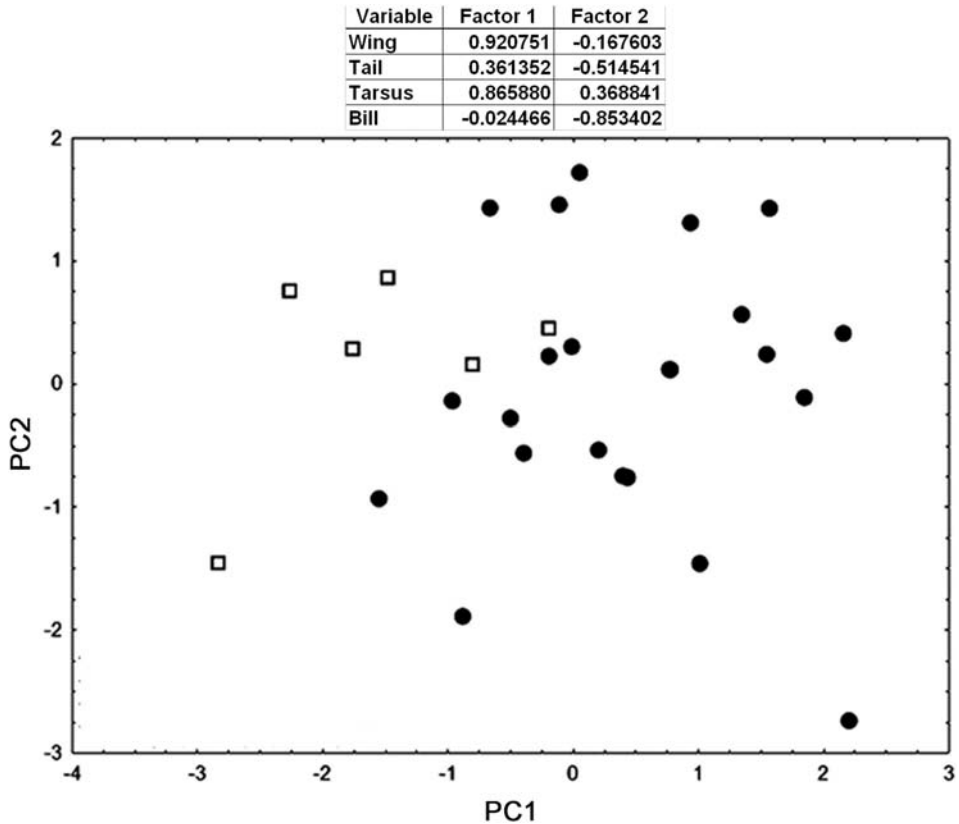


Figure 2. Scatterplots of PC1 versus PC2 scores of a PCA of the morphometric variables measured from the specimens of *Paroaria baeri baeri* (circles) and *Paroaria baeri xinguensis* (squares). Data for males and females were pooled together. Factor loadings are presented as a table in the upper part of the figure.

the Amazon (Stotz et al. 1996) or to the Cerrado (Silva 1997; Silva and Bates 2002). A close look on its distribution indicates that *P. b. baeri* is endemic to the Cerrado, being restricted to the Rio Araguaia and its tributaries (Figure 3). It is a lowland taxon, with localities of occurrence situated between 160 and 270 m asl. This taxon is stated by Dávalos and Porzecanski (2009) as occurring “occasionally from the Rio Xingu and its tributary the Rio Culuene in Mato Grosso,” which is an error (see below).

*Paroaria baeri xinguensis* is endemic to the Amazon, being restricted to the “Mato Grosso seasonal forests” ecoregion (Olson et al. 2001), an area dominated by seasonal evergreen forest that harbors a floristically distinct flora (Kunz et al. 2009). Enclaves of savanna vegetation found in the type locality of this taxon are small and isolated (Villas Bôas and Villas Bôas 1994). This taxon is endemic to the Rio Xingu valley (Figure 3) and was until presently known from only two sites where the type series was collected. A brief description of the habitat of *P. b. xinguensis* as well as a report of some other bird species recorded in the area can be found in Sick (1960).

Here, we present two additional sites where this taxon was observed and photographed by Moysés Lourenço Bossi Lima and Lourenço Davi (pers. com.), who rediscovered this taxon after more than 60 years without records since its description. The first record was

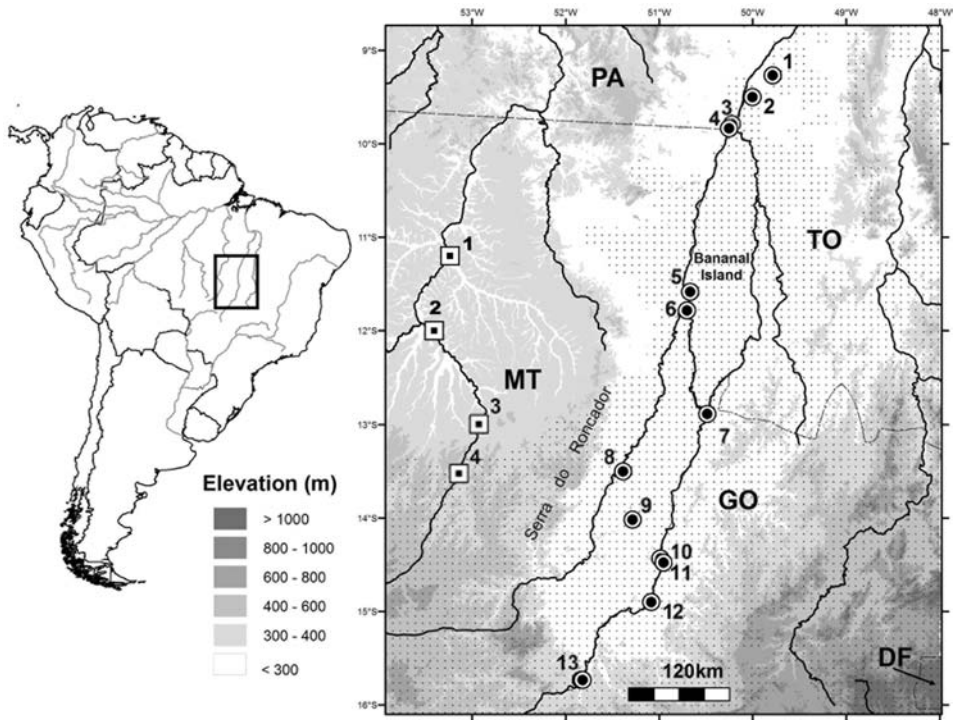


Figure 3. Geographical distribution of *Paroaria baeri baeri* (circles) and *Paroaria baeri xinguensis* (squares). Stippled area depicts the Cerrado region according to Olson et al. (2001). *P. b. baeri*: 1, Rio do Coco, Caseara; 2, Cantão State Park; 3, Fazenda Barra das Princesas, Santana do Araguaia; 4, Fazenda Fartura, Santana do Araguaia; 5, Praia em frente da Ilha do Bananal; 6, Pousada Kuryala, São Felix do Araguaia; 7, Fio Velasco, São Miguel do Araguaia; 8, São Domingos, Rio das Mortes; 9, Rio Cristalino; 10, Fazenda Mirante do Araguaia, Cocalinho; 11, Ilha acima de Cocalinho; 12, Aruanã, Rio Araguaia (type locality); 13, Barra do córrego Ponte Alta, Registro do Araguaia. *P. b. xinguensis*: 1, Diauarúm, alto Xingu (type locality); 2, Jacaré, baixo Culuene; 3, Rio Culuene, 6.5 km by river upstream from its junction with Rio Sete de Setembro, Canarana; 4, Rio Culuene, 15 km by river upstream from the bridge of MT-020 road, Gaúcha do Norte. Sources: Hellmayr (1908), Pinto (1938), Sick (1950), Pinto and Camargo (1952), Pinheiro and Dornas (2009), Amaro Alves (pers. com.), Moysés Lourenço Bossi Lima and Lourenço Davi (pers. com.), and material examined at the ornithological collections visited. Brazilian states are indicated as follows: PA, Pará; MT, Mato Grosso; TO, Tocantins; GO, Goiás; and DF, Distrito Federal.

obtained on 20 June 2012 in Rio Culuene, 6.5 km by river upstream from its junction with Rio Sete de Setembro (12°56'18"S, 52°50'55"W), municipality of Canarana. The second record was obtained on 22 June 2012 also in Rio Culuene, 15 km by river upstream from the bridge of MT-020 road (13°34'34"S, 53°05'00"W), municipality of Gaúcha do Norte. The two new records presented here represent a remarkable range extension of 180 km southward. The altitudinal range of this subspecies is 270–320 m asl.

Drainages of the upper Rio Xingu and the Rio das Mortes (a western tributary of the Rio Araguaia) are separated by the Serra do Roncador (Almeida and Hennies 1969), a ridge of elevated land with gently sloped sides, running NNE-SSW from 12°00'S to 14°30'S (Eiten 1975). For most of its length, the flat crest of this range has an altitude of slightly over 450 m, rising gently to about 630 m at the latitude of 13°30'S (Eiten 1975). Sick (1950) pointed out that the Serra do Roncador was mainly responsible for isolating

both subspecies. In fact, dry savanna vegetation occupies the uplands, especially along the crest, where no suitable habitat can be found (Eiten 1975). Riparian habitats are only found down the valleys (Eiten 1975). An intensive bird survey conducted in Serra do Roncador failed to find any *Paroaria* species in the area (Fry 1970), but other birds associated with river-created habitats (Remsen and Parker 1983), such as *Cranioleuca vulpina* (Pelzeln, 1856), *Sakesphorus luctuosus* (Lichtenstein, 1823), and *Hypocnemoides maculicauda* (Pelzeln, 1868), were detected along the valley of the Rio Suiá Missu, indicating that the appropriate habitat for Crimson-fronted Cardinals was sampled to some extent.

The adjoining lowlands in the headwaters of some of the tributaries of Xingu and Araguaia rivers are poorly sampled for birds, and it is possible that a more extensive collecting effort might reveal the presence of *P. b. xinguensis* along the Rio Sete de Setembro, one of the main tributaries of the Xingu river, and of *P. b. baeri* along many of the left bank tributaries of the Araguaia river. Nevertheless, given that these taxa are closely associated with river-created habitats (see below), it seems unlikely that they will meet at the headwaters of any river, where habitat seems to be unsuitable. The possibility that these taxa might come into contact somewhere downstream (i.e., near the Rio Amazonas, like what occurs with *Sakesphorus luctuosus*; Lopes and Gonzaga 2012) is highly unlikely, because these regions are well sampled for birds (Oren and Albuquerque 1991), and no Crimson-fronted Cardinal has ever been collected there.

There are two extra-limital records of *P. b. baeri* for the Distrito Federal, central Brazil (Bagno and Marinho-Filho 2001) that we do not accept here. The first one is a female collected in “Brasília” on 12 June 1968 by Irene de O. Lima (RECOR 629). This specimen is the only one in this institution which was collected by Irene de O. Lima who apparently never got involved with ornithological studies in Brazil. This specimen also brings on its label the inscription “cardeal-da-Venezuela” (“Venezuelan Cardinal”), which makes us believe that it was a cage bird, reared by someone not familiar with the range of South American cardinals.

The second one is an undocumented record from Águas Emendadas Ecological Station, in which this species was said to be “rare,” inhabiting “cerrado sensu stricto” (Bagno 1998), a woodland 3–6 m tall with closed scrub and scattered trees. This kind of habitat is not used by this species, which is closely tied to riparian vegetation in elevations below about 300 m asl. Records of this species for the Distrito Federal, which is above 1000 m asl, were not obtained during 1 year and a half spent by the senior author studying the bird fauna of the Águas Emendadas Ecological Station (Lopes et al. 2005). We suggest that the record presented by Bagno (1998) originated from a cage bird released in the area by someone, or from a misidentification of *Paroaria dominicana* (Red-cowled Cardinal), which was introduced in the Distrito Federal (L.E. Lopes, pers. obs.).

A third extra-limital record was presented by Hidasi (1973) who supposedly collected a specimen of *P. b. baeri* in Araguatins, northern state of Tocantins. This specimen, and an additional one included in the accession book of the Museu de Ornitologia de Goiânia, where this specimen was supposed to be deposited, was not found by Dornas and Pinheiro (2011) in that institution. These authors believed that these specimens represented misidentified *P. gularis*, which is the only cardinal usually found in the area.

### ***Taxonomic conclusions***

The diagnosis between both subspecies, as pointed out by Sick (1950), is fully corroborated here. All specimens examined could be easily referred to either *P. b. baeri* or *P. b. xinguensis*, and the diagnostic characters are stable along the entire known range of

the subspecies studied. Individual variation is subtle, with a single exception that can be attributed to hybridization (see below), being more noticed in *P. b. baeri*, probably due to the larger sample size available for this taxon.

Meyer de Schauensee (1966) hypothesized that *P. baeri* is conspecific with *P. gularis*, a species that shows obvious differences in plumage color patterns, in addition to other marked morphological differences, such as the shape of the feathers on the foreneck and the shape of bill (Hellmayr 1938). A phylogeny of the genus *Paroaria* demonstrates that *P. gularis* is not the sister taxon of *P. baeri* sensu lato (Dávalos and Porzecanski 2009).

Sympatry between *P. gularis* and *P. baeri* was unknown until quite recently, but their occurrence has been recorded in the Cantão State Park (Buzzetti 2000; Dornas 2008; Pinheiro and Dornas 2009), north of the Bananal Island, where they can be seen foraging together in mixed-species flocks (L.E. Lopes, pers. obs.). Hilty (2011) presented the evidence of hybridization between *P. b. baeri* and *P. gularis*, reporting a bird photographed in Barreira do Campo, municipality of Santana do Araguaia, state of Pará (ca. 09°17'S, 50°03'W), which showed a plumage coloration that looked intermediate between these species. Areta et al. (2011) presented additional records of hybrids between *P. b. baeri* and *P. gularis* from four localities along their narrow area of overlap (ca. 160 km). Hybridization might in fact explain a distinct specimen (DZUFMG 6216) collected in this area, which presented a crimson crown extending down to the nape, as well as a larger throat patch, almost entirely crimson. Slight differences on the hue of the crimson patches of this specimen are also observable, mainly due to the large extension of the crimson tips in the barbs of the throat and crown feathers when compared with typical specimens.

Records presented by Areta et al. (2011) are not the first cases of hybridization between different *Paroaria* species. McCarthy (2006) reports captive hybrids between *Paroaria coronata* (Miller, 1776) and the distantly related *P. dominicana* (Linnaeus, 1758) (Dávalos and Porzecanski 2009) that were fertile. *Paroaria coronata* is also known to interbreed in captivity with *Paroaria nigrogenis* (Lafresnaye, 1846) and with at least five other species belonging to different genera or even families [*Sicalis flaveola* (Linnaeus, 1766), *Gubernatrix cristata* (Vieillot, 1817), *Cardinalis cardinalis* (Linnaeus, 1758), *Chrysomus ruficapillus* (Vieillot, 1819), and *Molothrus bonariensis* (Gmelin, 1789)] (McCarthy 2006). This just corroborates the early proposition of Rosen (1979) that the ability to interbreed is an ancestral condition and thus, according to the principles of the phylogenetic systematics, cannot be used as a valid argument to delimit taxa (Zink 2006).

An incomplete molecular phylogeny of the genus *Paroaria* (Nodari 2008), which estimated the time of divergence between clades using a molecular clock, indicated that the divergence between *P. baeri* and the clade composed by *P. gularis* and *Paroaria capitata* (d'Orbigny and Lafresnaye, 1837) dates back to the beginning of the Pleistocene (ca. 2.26–1.78 Ma). The logical consequence of this analysis is that the sister taxa *P. baeri* and *P. xinguensis* must have diverged more recently than that.

We demonstrated that the taxa *P. b. baeri* and *P. b. xinguensis* are clearly diagnosable by plumage, distinct, respectively, in the absence and presence of sexual dimorphism, and are separated by a sharp geographic barrier. These observations are consistent with the lack of gene flow between the two taxa, which is given by an apparent geographic mechanism and, consequently, they represent separately evolving metapopulation lineages (de Queiroz 1998, 2005). Considering these taxa as subspecies or as independent species is just a matter of philosophical belief. Followers of the Biological Species Concept (Mayr 1969; Johnson et al. 1999) will probably consider these taxa as conspecific, because there is a good chance that they would interbreed successfully (which is speculative and not particularly informative from the taxonomic point of view expressed

above). Followers of the Phylogenetic Species Concept (Cracraft 1983) or the General Lineage Concept of Species lineages (de Queiroz 1998, 2005) will consider them as distinct species, as proposed by Dávalos and Porzecanski (2009).

Here, we support the view of two species, namely *P. baeri* Hellmayr 1907 and *P. xinguensis* Sick 1950, hereafter considered as distinct species. This taxonomic arrangement results in the need of modification of the vernacular names of these taxa. As English names, we propose Araguaia Cardinal for *P. baeri* and Xingu Cardinal for *P. xinguensis*. As Portuguese names, we suggest “cardeal-do-Araguaia” for *P. baeri* and “cardeal-do-Xingu” for *P. xinguensis*.

### *Natural history*

Given that both species inhabit particularly poorly studied areas (see Oren and Albuquerque 1991; Silva 1995), little is known about them, and a review of their natural history is necessary. *Paroaria baeri* is a fairly common to uncommon species, usually found in small flocks along the margins of lakes and sluggish rivers, generally associated with shrubs of *Sapium haematospermum* (Euphorbiaceae), locally known as “sarã,” and shrubs of *Psidium riparium* (Myrtaceae), “goiabinha-da-praia” (Dornas 2008; Pinheiro and Dornas 2009, notes on the labels of Sneathlague’s specimens, L.E. Lopes, pers. obs.). Pinto and Camargo (1952) also observed that *P. baeri* preferentially inhabits shrubby formations near water.

The “sarã” is a pioneer species that colonizes sandbanks deposited along the Rio Araguaia (Richter 2000). These shrubs reach the height of 4–5 m, forming dense stands 30–50 m wide, locally known as “saranzal” (Richter 2000). Two distinct strata may be recognized in this formation. Lower stratum is open, because it is seasonally flooded, with water level reaching up to 1.5 m. Upper stratum is closed, corresponding to the shrub crown, which is dense and often tangled with vines (Richter 2000). Further information on the riparian vegetation of the Rio Araguaia can be found in Ratter (1987).

Almost nothing is known about the reproduction of *P. baeri*. The only known dated nest was found on 22 December (Dornas 2008). Indirect evidence of breeding season is obtained from gonadal condition of collected specimens. One female collected on 9 July 2007 in Registro do Araguaia (DZUFMG 5438) presented inactive gonads. The same was observed for two adult females (DZUFMG 6214 and 6216) and one male (DZUFMG 6215) collected on 9 July 2008 in Caseara. These data suggest that the breeding season of *P. baeri* starts with the onset of rainy season, possibly extending from October to January, a pattern commonly found among central-southern Brazilian passerines (Marini and Durães 2001; Lopes and Marini 2005).

The nest of *P. baeri* is an open cup, made of roots and dry twigs, firmly attached to the foliage with spider web (Buzzetti and Silva 2005). It is constructed in bushes overhanging the water in the seasonally flooded vegetation of fluvial islands of the Rio Araguaia (Buzzetti and Silva 2005; Dornas 2008).

Eggs of *P. baeri* were described as whitish (Dornas 2008), but this goes against the egg color pattern observed in some other species of the genus. Eggs of *P. gularis* are said to be “smooth almost glossless greenish white, covered with blotches and small patches of greenish brown, with a few underlying mauve spots, the markings being more frequent about the thick end” (Cherrie 1916). A similar color pattern was described for the eggs of *P. coronata*, *P. capitata*, and *P. dominicana* (de la Peña 1987; Hartert and Venturi 1909; Ihering 1914). Strikingly, a color picture of the nest of *P. baeri* (Buzzetti and Silva 2005) also depicts a color pattern similar to that observed for the remaining species of the genus.

The nest studied by Dornas (2008) was allegedly parasitized by the Shiny Cowbird *Molothrus bonariensis* because it contained two types of eggs. Nevertheless, a close analysis of a color picture of this nest, originally published in black and white, indicated that probably there was a mistake. From the five eggs observed in the nest, three color patterns, instead of two, can be identified. One egg presents a coloration pattern similar to that observable for the genus (egg at the bottom of the picture), and it is probably the only true egg of *P. baeri* in the nest. Two eggs were whitish with no or few markings, and two eggs were whitish, but covered with reddish blotches and streaks. We suggest here that both these egg types, rather than only the plain whitish one, are color variants of the Shiny Cowbird eggs, a species with high polymorphism on this character (de la Peña 1987).

Juvenile birds, identified by fuliginous upper parts, throat and foreneck deep buff-yellow, without any red or black in the plumage (Hellmayr 1908), were collected on 9 July (DZUFMG 5439), August (AMNH 520206) and 4 October (MZUSP 35327). One specimen collected in 15 August (ZMB 28827) had almost completely reached the fully definitive plumage, bearing only some reminiscent brownish feathers from its previous plumage.

The diet of *P. baeri* is poorly known. The gizzards of three specimens collected by Snethlage and housed in MNRJ contained seeds and arthropods. Pinto and Camargo (1952) found large quantities of insects in the gizzards of the specimens examined by them. The gizzards of five specimens collected by us contained mainly small arthropods (length <5 mm), as described here: DZUFMG 5438: one ootheca of Blattaria, one Coleoptera, one larva of Lepidoptera, one Hymenoptera, four Araneae, and remains of a flower; DZUFMG 5439: two oothecae of Blattaria, one Hemiptera, five Coleoptera, one larva of Lepidoptera, two Hymenoptera, and remains of a flower; DZUFMG 6214: one Hemiptera, four Coleoptera, one larva of Lepidoptera, and one Araneae; DZUFMG 6215: eight Hemiptera, four Coleoptera, and one larva of Lepidoptera; DZUFMG 6216: two oothecae of Blattaria, three Hemiptera, one Coleoptera, and one Araneae. Data summarized here reveal that *P. baeri* is predominantly insectivore, including small amounts of fleshy fruits and flowers on its diet.

*Paroaria xinguensis* is known from only four localities. The only available natural history data on this species can be obtained from Sick (1950), notes on the labels of the type series specimens and observations conducted by M.L.B. Lima and L. Davi (pers. com.). This species lives in small groups that may reach 15 individuals, eventually associating with mixed species flocks. Its habitat seems to be similar to that of *P. baeri*. Sociability seems to be high during the nonbreeding season, which coincides with the dry months. This fact is indicated by the small gonads of specimens collected in June, July, and August. Active gonads were observed in a female (MNRJ 31209) collected on 11 January, during the wet season. A male molting to the definitive plumage was collected on 4 October 1948 (MNRJ 31210), revealing that the young plumage is similar to that already described for *P. baeri*. The nest of this species is unknown. Diet data are from the stomach contents of the type series specimens, which fed on both arthropods (Coleoptera and Lepidoptera larvae) and fruits (Sick 1950; Schubart et al. 1965).

### Conservation

There are no reliable data on population trends for these species, but this information can be obtained indirectly from their habitat and the main threats suffered by them. *Paroaria baeri* has a relatively small range and inhabits a very specialized habitat: the early successional stages of river-created habitats, periodically disturbed by annual flooding

(Remsen and Parker 1983; Robinson and Terborgh 1997). Maybe this specialized habitat will favor the survival of this species, despite the fact that at least 45% of the original riparian forests of the Rio Araguaia have been logged (Mascarenhas et al. 2009), and 18.7% of the natural vegetation cover of the entire Araguaia watershed has been lost (Trancoso et al. 2010). Observations conducted in Registro do Araguaia, Goiás, revealed that, in spite of the extensive loss of primary riparian forests, “saranzais” are still common in the region. This is because they are restricted to seasonally flooded areas, generally unsuitable for farming. Unflooded areas are now covered by crops and pastures, and only a narrow fringe of disturbed riparian forest remains, mainly dominated by two Polygonaceae species, locally known as “jauseiro” (*Triplaris surinamensis*) and “novateiro” (*Triplaris brasiliiana*) (Castro 1997).

Although *P. baeri* probably does not fit any IUCN category of threat (IUCN 2001), we believe that further investigation and monitoring of its conservation status are desirable. Geomorphic responses of the Araguaia River to catastrophic deforestation of the Cerrado (Machado et al. 2004) have resulted in marked changes in the morphology of river channel during the last three decades, resulting in large sediment loads into the channel, an increase in the number of middle channel bars and a dramatic reduction in the number of medium and small river islands (Latrubesse et al. 2009). Given that the fluvial dynamics of the channel and the type of sediments that form the alluvial plain determine the type of vegetation growing on it (Latrubesse and Stevaux 2006; Morais et al. 2008), the indirect impact of deforestation over the habitat of *P. baeri* needs careful evaluation. Another possible threat is the construction of hydroelectric dams along the Rio Araguaia or its tributaries, which may represent a direct impact on the fluvial dynamics of the channel, which is of paramount importance to the maintenance of river-created habitats with which this taxon is closely tied.

The only protected area where *P. baeri* has been recorded is the Cantão State Park (90,017 ha). Nevertheless, old records from Bananal Island (Hidasi 1998) suggest the occurrence of *P. baeri* in the large Araguaia National Park (131,868 ha), located in the northern portion of that island (Figure 3), which harbors extensive areas of suitable habitat. In a similar way, *P. baeri* probably occurs in the Araguaia Indigenous Park, with almost 1.5 million ha, located in the southern portion of the same island. This species probably occurs also in the Pimentel Barbosa Indigenous Land, with about 330,000 ha in the Rio das Mortes, where it was collected in the past.

The range of *P. xinguensis* was previously known to be circumscribed by the Xingu Indigenous Park, which with almost 2.6 million ha still preserves the unaltered nature of the region as that observed by Sick in the 1940s (Heckenberger et al. 2003; Schwartzmann and Zimmerman 2005). This is a comforting observation, because 17.1% of the natural vegetation cover of the entire Xingu watershed has been lost, and this is one of the Amazonian watersheds that suffered the highest rates of deforestation during the last decade (Trancoso et al. 2010). The lack of present-day records of *P. xinguensis* until quite recently may be attributable to the poor ornithological sampling of the Xingu watershed (Oren and Albuquerque 1991) as well as to the scarcity of biological studies on Brazilian indigenous lands. The recent records of *P. xinguensis* south of the Xingu Indigenous Park presented here also demonstrate that the range of this species is much wider than previously thought. This taxon seems to suffer no major threats inside the Xingu Indigenous Park, but out of this indigenous land threats are the same as discussed for *P. baeri*. A series of hydroelectric dams are planned to be constructed in Rio Xingu downstream of the Xingu Indigenous Park (Fearnside 2006). Although this development project will probably not affect the range, and consequently the conservation of

*P. xinguensis*, it represents a serious threat to the local biodiversity, highlighting the environmental risks associated with hydroelectric dams.

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**Appendix 1*****Specimens examined****Paroaria baeri*: Brazil

PARÁ: Fazenda Barra das Princesas, Santana do Araguaia, 09°40'S, 50°11'W: MPEG 49191 ♂; Fazenda Fartura, Santana do Araguaia, 09°47'S, 50°12'W: MZUSP 88304 ♂, 88306 ♂, 88305 ♀. TOCANTINS: Margem direita do Rio do Coco, Caseara, 09°15'S, 49°58'W: DZUFMG 6215 ♂, 6214 ♀, 6216 ♀ (Hybrid?). GOIÁS: Ilha acima de Cocalina [= Cocalinho], Rio Araguaia, ca. 14°26'S, 50°59'W: MNRJ 14815 ♂; Praia em frente da Ilha do Bananal, Rio Araguaia, ca. 11°35'S, 50°40'W: MNRJ 14814 ♂, 14813 ♀. DISTRITO FEDERAL: Brasília: RECOR 629 ♀ (probably a cage bird). GOIÁS: Rio Araguaia, near Leopoldina (now Aruanã), 14°54'S, 51°05'W: AMNH 520207 ♂, 520205 ♀ (*HOLOTYPE*), 520206 ♀, LSUMZ 51231 ♂, ZMB 28827 ♀; Barra do córrego Ponte Alta, distrito de Registro do Araguaia, Montes Claros de Goiás, 15°44'S, 51°49'W: DZUFMG 5439 ♂, 5438 ♀. MATO GROSSO: São Domingos, Rio das Mortes, 13°35'S, 51°28'W: FMNH 356584 ♀, MZUSP 35324 ♂, 35325 ♂, 35326 ♂, 35327 ♂, 34259 ♀, 35328 ♀, 35330 ♀; Rio Cristalino, 14°01'S, 51°17'W: MZUSP 17559 ♂, 17558 ♀; Fazenda Mirante do Araguaia, Cocalinho, 14°25'S, 51°01'W: MZUSP 85420 ♀.

*Paroaria xinguensis*: Brazil

MATO GROSSO: Jacaré, baixo [Rio] Culuene, 12°00'S, 53°24'W: MNRJ 31210 ♂, 31209 ♀, 31211 ♀; Diauarúm, alto [Rio] Xingu, 11°12'S, 53°14'W: AMNH 802297 ♂, 802298 ♀, MNRJ 26230 ♂ (*HOLOTYPE*), 31256 ♂, 31259 ♂.