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Article

Major range extensions for three species of porcupines (Rodentia: Erethizontidae: *Coendou*) from the Brazilian Amazon

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Abstract: We report range extensions for three species of Amazonian erethizontids, *Coendou bicolor*, *C. ichillus*, and *C. nycthemera*. We record *C. ichillus* for the first time in Brazil, from Rio Japurá, state of Amazonas. We record *C. bicolor* for the first time in the state of Amazonas, which represents a range extension of approximately 905 km. We also extend the occurrence of *C. nycthemera* 620 km to the south into Mato Grosso state. All records are based on museum specimens, highlighting the importance of scientific collections as biodiversity databases and emphasizing the lack of research on Amazonian porcupines.
Keywords: Coendou bicolor, Coendou ichillus, Coendou nycthemera, museum specimens, new record.

Extensão de distribuição de três espécies de porcos-espinhos, gênero *Coendou* (Rodentia: Erethizontidae) da Amazônia brasileira.

Resumo: Aqui nós relatamos ampliação de distribuição de três espécies de eretizontídeos amazônicos: *Coendou bicolor, C. ichillus* e *C. nycthemera*. Nós registramos pela primeira vez *C. ichillus* no Brasil, no Rio Japurá, estado do Amazonas. Registramos *C. bicolor* pela primeira vez no estado Amazonas, o que representa uma ampliação de distribuição de aproximadamente 905 km. Também estendemos a ocorrência de *C. nycthemera* 620 km ao sul, no estado de Mato Grosso. Todos os registros são baseados em espécimes de museu, enfatizando a importância das coleções científicas como bancos de dados da biodiversidade e a destacando ausência de pesquisas para porcos-espinhos amazônicos.
Palavras-chave: Coendou bicolor, Coendou ichillus, Coendou nycthemera, espécime de museu, novo registro.

Introduction

New World porcupines (family Erethizontidae) are nocturnal and arboreal rodents with prehensile tails and with hairs modified into sharped quills (Emmons 1997). Erethizontids are distributed from Canada to Uruguay and Argentina (Emmons 1997, Voss 2015). There are 17 species recognized in the family Erethizontidae of which 15 belong to the genus *Coendou* Lacépède, 1799 (Voss 2015, Feijó & Langguth 2013, Mendes Pontes et al. 2013). Brazil is the country with the highest diversity of erethizontids, which includes the Atlantic forest endemic, *Chaetomys subspinosus*, together with nine species of *Coendou,* of which five are endemic to the country: *C. nycthemera, C insidiosus, C. roosmalenorum, C. baturitensis* and *C. speratus* (Feijó & Langguth 2013, Voss 2015, Mendes Pontes et al. 2013, de Freitas et al. 2013).

As cryptic animals, rarely observed in the wild and underrepresented in collections, there are several gaps in the knowledge about the distribution of most porcupine species (Leite et al. 2011, Voss et al. 2013, Feijó & Langguth 2013, Mendes Pontes et al. 2013). The records for many species are limited to a small number of specimens (e.g. *Coendou melanurus* as pointed by Voss et al. 2001) or biased towards the surroundings of urban centres and river margins (see maps 405-417 in Voss 2015). Several new distributional records of porcupine species were made recently: *Coendou bicolor* had new records from Brazil (de Freitas et al. 2013) and a possible record for Colombia (Ramírez-Chaves et al. 2016), *Coendou speratus* had a distributional gap filled in northeastern Brazil (Nascimento & dos Santos 2014), *Coendou ichillus* had new records from Peru (Gregory et al. 2015) and Colombia (Ramírez-Chaves et al. 2016), and *Coendou rufescens* had new records for Ecuador (Narváez-Romero et al. 2018).

In this report, we present new geographical records and updated distribution maps of three species of Amazonian *Coendou*, with the first records of *C. ichillus* for Brazil and major range extensions of *C. bicolor* and *C. nycthemera*.

Material and Methods

Specimens (skin, crania, and partial skeletons) of erethizontids were examined in the scientific collections of the American Museum of Natural History (AMNH) in New York, USA; Universidade do Estado de Mato Grosso, campus Alta Floresta (CZAF) in Alta Floresta, Brazil; the Field Museum of Natural History (FMNH) in Chicago, USA; Universidade Federal da Paraíba (UFPB) in João Pessoa, Brazil; Museu Nacional (MNRJ) in Rio de Janeiro, Brazil; Museu Paraense Emílio Goeldi (MPEG) in Belém, Brazil; Museu de Zoologia da Universidade de São Paulo (MZUSP) in São Paulo, Brazil; Universidade de Brasília (UnB) in Brasília, Brazil.

A total of 130 porcupine specimens representing species that occur in the Amazonia were examined (Appendix 1), including the types of *C. baturitensis, C. ichillus,* and *C. prehensilis*. Taxonomic determination was based on published studies (Feijó & Langguth 2013, Handley & Pine 1992, Voss & Angermann 1997, Voss & da Silva 2001, Voss et al. 2001, Voss 2011, 2015). The external measurements are the length of head-and-body (HBL) and length of tail (LT) following the protocol in Voss & Angermann (1997). External measurements were extracted from specimen labels. We estimated the area (in km^2) of species distribution range based on the minimum convex polygon using ArcMap software version 10.2.

Results

Figure 1 shows the updated distribution map of *Coendou bicolor, C. ichillus,* and *C. nycthemera*, and Table 1 has the detailed localities. We did not map the record of "*Coendou* cf. *bicolor*" for Boyacá, Colombia (Ramírez-Chaves et al. 2016) because it is based on a cranium without an associated skin, and the authors did not consider *C. bicolor* distinguishable from *C. prehensilis* by cranial characters alone.

The new records of *Coendou nycthemera* are based on three specimens (CZAF-MA 9, 10, 11, stuffed skins without associated skulls – Figure 2b), an adult male and a female from the right bank of the Rio Teles Pires, and a juvenile (sex undetermined) from the opposite bank of the same river (Table 1). All three records were made in the vicinity of a hydroelectric power plant, the Usina Hidrelétrica Teles Pires, Mato Grosso state, and were previously identified as *"Coendou melanurus*". Brandão et al. (2019) identified one of these CZAF specimens as "*Coendou* cf. *nycthemera*", but those authors could not confirm the identity of the specimen. These new records extend the known geographic range of *C. nycthemera* approximately 620 km from the closest locality to the northwest (Igarapé Auará, on the left bank of Rio Madeira) and 950 km from the closest locality to the northeast (Capitariquará, on Rio Tocantins), representing a southward area extension of about 41% (Figure 1).

Coendou nycthemera can be externally diagnosed from its congeners by its size, length of soft hairs relative to quills, and color pattern of dorsal quills (Table 2). *Coendou nycthemera* is slightly smaller than *C. melanurus* and significantly smaller than *C. baturitensis* and the Amazonian populations referred to *C. prehensilis* (Table 2). The distal band of the tricolored quills of *C. nycthemera* is very short, inconspicuous or absent, and its colour may be whitish, yellowish or orangish (Figure 3d). Furthermore, *Coendou nycthemera* differs from the similar-sized *C. melanurus* and *Coendou roosmalenorum* by lacking a long, soft fur covering its quills (Voss & Angermann 1997, Handley & Pine 1992). The distal band of the guard hairs of *C. melanurus* are always long and pale yellowish (Voss et al. 2001). *Coendou nycthemera* has only bicolored quills on its rump whereas *C. baturitensis* and Amazonian *C. prehensilis* have tricolored and bicolored quills on rump. It also differs from *C. baturitensis* by the dark brownish or black short medial band of the tricolored quills and distal band of bicolored quills (Figure 3). In *C. baturitensis* the medial band of the tricolored quills and the distal band of the bicolored quills are light brownish (Feijó & Langguth 2013).

The range extension of *Coendou bicolor* is based on two specimens previously identified as *Coendou prehensilis*, a juvenile of unknown sex (MPEG 24574, stuffed skin and skull) and an adult female (MPEG 37122, stuffed skin without associated skull – Figure 2a), both from Estação Ecológica Mamirauá, Uarini, in Amazonas State (Table 1). These records expand the known distribution of *C. bicolor* approximately 905 km northeast from Senador Guimard, Acre, Brazil, the closest record in Brazil (de Freitas et al. 2013) and approximately 1,250 km northeast from Río Alto Ucayali, Ucayali, Peru, the closest record outside Brazil (Voss 2015). The new record comprises an eastward area extension of 53% (Figure 1). *Coendou bicolor* is a large porcupine (Table 2) and has no distal bands on its quills (Figure 3c) and no tricolored quill on the rump, differing from the Amazonian *C. prehensilis* and the northeastern Brazil *C. baturitensis*, both of which have tricolored quills (Figure 3a-b). *Coendou bicolor* does not have soft fur covering its quills (Voss 2011) differing from *C. melanurus*

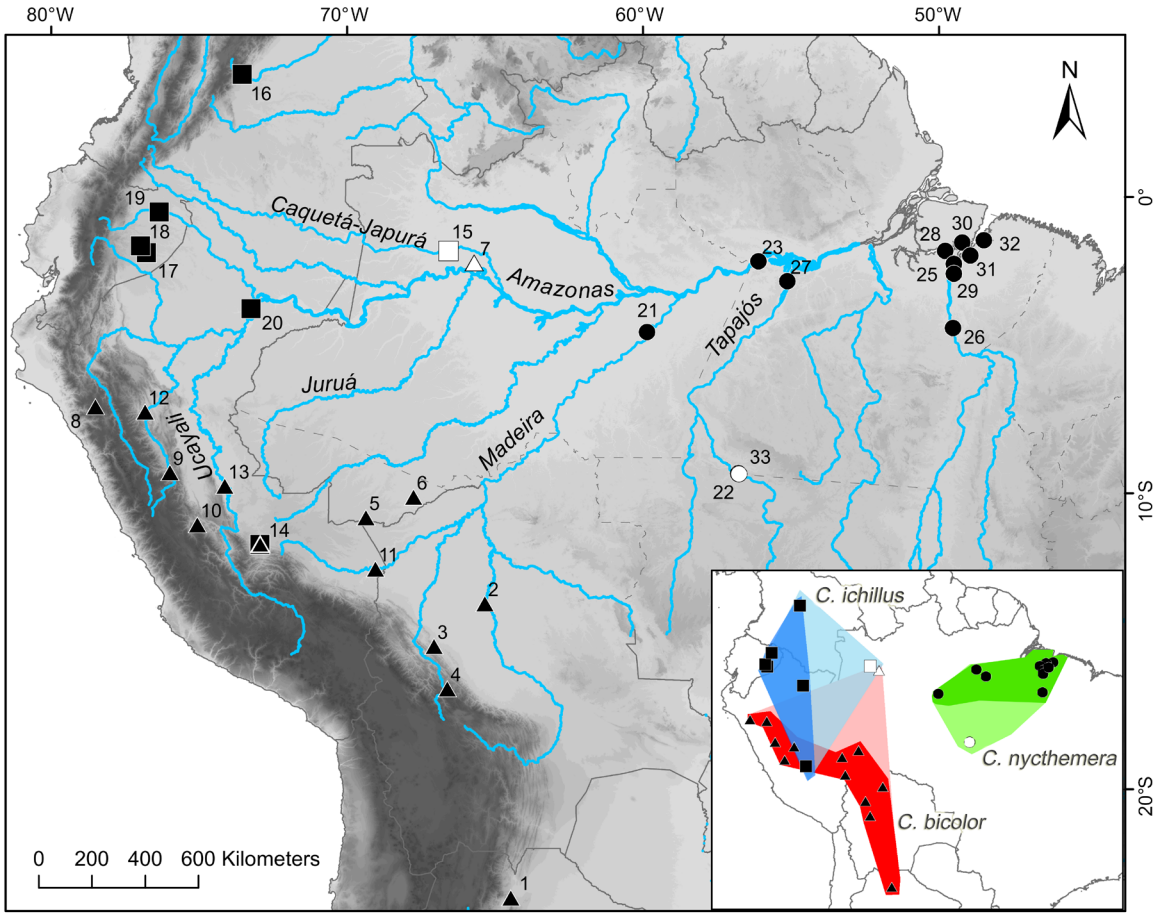

Figure 1. Updated distribution map of *Coendou bicolor* (triangles), *C. ichillus* (squares), and *C. nycthemera* (circles). New records are represented by white symbols. Detailed locality data is in Table 1. Inset map shows the previous distribution (darker shades) and the updated polygon (lighter shades) of *C. bicolor* (red), *C. ichillus* (blue), and *C. nycthemera* (green).

(Voss et al. 2001) and *C. roosmalenorum* (Voss & da Silva 2001). We compared specimen MPEG 24574 with juveniles of other species housed in the visited collections. It has dorsal tricolored quills with a very short orangish distal band and a very wider medial blackish band. Its rump and tail lack tricolored quills and have a soft ventral pelage. These characteristics are more similar to the adult MPEG 37122 than to the juveniles of other species.

The record of *Coendou ichillus* is based on an adult male (MZUSP 11465, Figure 2c), collected on November 21, 1977, on the margins of Rio Japurá, at Limoeiro in Amazonas State (Table 1). The specimen is preserved as an open skin with the cranium and skeleton removed and was previously identified as "*Coendou prehensilis"* by P.E. Vanzolini. This is the first record of *C. ichillus* in Brazil and extends its distribution eastwards approximately 790 km from Iquitos, Peru, the closest known record (Voss & da Silva 2001), representing an increase of 55% on its estimated distribution area (Figure 1). The specimen matches the *C. ichillus* description given by Voss & da Silva (2001) and it is a medium-sized porcupine (Table 2) that differs from the similar *C. melanurus* and *C. roosmalenorum* by the absence of long hairs covering its quills and from *C. nycthemera* by the presence of tricolored bristle-quills on its dorsum (Voss & da Silva 2001). It is also distinct from the larger *C. prehensilis* and *C. baturitensis* by the lack of tricolored quills on the rump and the presence of bristle-like quills on the dorsum (Figure 3g).

Discussion

Natural history information on *Coendou* species is scant in the literature, especially for the Amazonian taxa (Voss, 2015). Even their distribution ranges are poorly defined. For example, Voss (2015) considered *C. nycthemera* associated with the lower Amazonas, Madeira, and Tocantins rivers. With the new record presented here, we demonstrate that *C. nycthemera* occurs further south, along the banks of the Rio Teles Pires in Mato Grosso (Figure 1). Considering the new potential distribution of *C. nycthemera*, it is plausible that it also occurs in the Amazon of the state of Maranhão, as suggested by de Oliveira et al. (2007), and in the northern tip of the state of Tocantins.

Coendou bicolor was previously thought to occur exclusively along the Andean foothills and in adjacent lowland forest (Voss, 2015), our record from the Brazilian state of Amazonas expands its potential distribution area in about 53% towards central Amazon. Similarly, *C. ichillus* had a restricted distribution limited to east Ecuador, north Peru, and Colombia, and the record from Rio Japurá increases by 55% its potential range (Figure 1). Altogether, our findings contribute

Table 1. Locality records of *Coendou bicolor*, *C. ichillus*, and *C. nycthemera*. Localities are ordered by species, country, state/department, and locality, and the #ID refers to map in Figure 1.

#ID	Species	Country	Department/ State/Province	Locality	Coordinates	Source
1	*C. bicolor*	Argentina	Jujuy	Yuto	23°39'S 64°28'W	Lucero (1987)
2	*C. bicolor*	Bolivia	Beni	Puerto Caballo	13°43'S 65°21'W	Voss (2015)
3	*C. bicolor*	Bolivia	Beni	Yucumo	15°10'S 67°04'W	Voss (2015)
4	*C. bicolor*	Bolivia	Cochabamba	Charuplaya	16°36'S 66°37'W	Voss (2015)
5	*C. bicolor*	Brazil	Acre	Brasiléia	10°48'38"S 69°22'05"W	Freitas et al. (2013)
6	*C. bicolor*	Brazil	Acre	Senador Guimard, on AC-040 road	10°07'12"S 67°45'15"W	Freitas et al. (2013)
7	*C. bicolor*	Brazil	Amazonas	Reserva de Desenvolvimento Sustentável Mamirauá	2°12'54.43"S 65°42'35.53"W	MPEG 24574, 37122
8	*C. bicolor*	Peru	Cajamarca	2.5 km N of Monte Seco	7°03'51.32"S 78°30'25.80"W	Voss (2015)
9	*C. bicolor*	Peru	Huánuco	Tingo María	9°17'38.07"S 75°59'39.02"W	Voss (2015)
10	*C. bicolor*	Peru	Junín	Chanchamayo	11°03'25.73"S 75°03'39.99"W	Voss (2015)
11	*C. bicolor*	Peru	Madre de Dios	Reserva Cuzco Amazónico	12°33'00"S 69°02'60"W	Voss (2015)
12	*C. bicolor*	Peru	San Martín	Área de Conservación Municipal Mishquiyacu-Rumiyacu y Almendra	7°14'40.16"S 76°49'33.47"W	Voss (2015)
13	*C. bicolor*	Peru	Ucayali	Río Alto Ucayali	9°45'00"S 74°07'59.99"W	Voss (2015)
14	*C. bicolor* and *C. ichillus*	Peru	Cusco	Confluence of Ríos Camisea and Urubamba	11°43'16.80"S 72°56'31.20"W	Gregory et al. (2015)
15	*C. ichillus*	Brazil	Amazonas	Limoeiro, Japurá, Rio Japurá	1°49'S 66°35'W	MZUSP 11465
16	*C. ichillus*	Colombia	Meta	Villavicencio, km 30 carretera a Caños Negros	4°09'25"'N 73°33'21"W	Ramírez-Chaves et al. (2016)
17	*C. ichillus*	Ecuador	Pastaza	Río Conambo	1°52'S 76°46'60"W	Voss and da Silva (2001)
18	*C. ichillus*	Ecuador	Pastaza	Río Yana Rumi	1°38'S 76°59'W	Voss and da Silva (2001)
19	*C. ichillus*	Ecuador	Sucumbíos	La Selva Jungle Lodge	0°30'S 76°21'60"W	Voss and da Silva (2001)
20	*C. ichillus*	Peru	Loreto	Iquitos	3°45'60"S 73°15'W	Voss and da Silva (2001)
21	*C. nycthemera*	Brazil	Amazonas	Igarapé Auará, Rio Madeira, left bank	4°33′S 59°52′W	Voss (2015)
22	*C. nycthemera*	Brazil	Mato Grosso	Teles Pires Hydroelectric Reservoir, left bank of Rio Teles Pires	9°19′S 56°47′W	CZAF-MA 10
23	*C. nycthemera*	Brazil	Pará	ALCOA harbor, Juruti	2°10′S 56°06′W	MPEG 38377
24	*C. nycthemera*	Brazil	Pará	Belém	1°27′S 48°29′W	Voss (2015)
25	*C. nycthemera*	Brazil	Pará	Cametá	2°15′S 49°30′W	Voss (2015)
26	*C. nycthemera*	Brazil	Pará	Capitariquará, extreme South of Ilha Tocantins, rio Tocantins, 78 km S and 16 km E, Tucuruí	4°25′S 49°32′W	MPEG 12496
27	*C. nycthemera*	Brazil	Pará	Caxiricatuba	2°50′S 55°08′W	MZUSP 5035
28	*C. nycthemera*	Brazil	Pará	Curralinho, Marajó island	1°48′S 49°47′W	Voss (2015)
29	*C. nycthemera*	Brazil	Pará	Mocajuba	2°34′S 49°30′W	Voss (2015)
30	*C. nycthemera*	Brazil	Pará	Muaná	1°31′S 49°13′W	Voss (2015)
31	*C. nycthemera*	Brazil	Pará	Rio Meruú, left margin, PA-151, Km 18. Igarapé-Miri	1°58′S 48°57′W	MPEG 24191
32	*C. nycthemera*	Brazil	Pará	Santa Teresinha, Km 87-94 of the BR-010 road	1°16′S 48°05′W	MZUSP 25591
33	*C. nycthemera*	Brazil	Pará	Teles Pires Hydroelectric Reservoir, right bank of Rio Teles Pires	9°20′S 56°46′W	CZAF-MA 9, CZAF-MA 11.

Figure 2. Skins in dorsal view of **a)** *Coendou bicolor* (MPEG 37122), **b)** *C. nycthemera* (CZAF-MA 10), and **c)** *C. ichillus* (MZUSP 11465).

significantly to a better delimitation of the range of these three Amazonian porcupines.

Our study also suggests broader patterns of sympatry among *Coendou* species. Approximately 100 km south to the new localities of *C. nycthemera* reported here, we (GSTG and TBFS) observed a larger species of *Coendou*, here identified as *C. prehensilis* (ca. 10°20'S 56°58'W – Figure 4), suggesting that these two taxa are sympatric in the region, as has been recorded elsewhere (Handley & Pine 1992). The new localities for *C. bicolor* (locality 7 in Figure 1) and *C. ichillus* (locality 15 in Figure 1) are just 100 km apart in the north-western region of Amazonas state and support the hypothesis that the two taxa occur in sympatry throughout much of their range, as observed by Gregory et al. (2015), who photographed both species using the same branches of a tree in southwestern Peru.

The three species reported here can be differentiated from their congeners based on external traits, particularly the morphology of the quills, which can be assessed in the field or in museums (Table 2, Figure 3). Nevertheless, cranial characters and molecular sequence data are important to provide unequivocal identification of some taxa. It is noteworthy that all the new records presented here are based on misidentified museum specimens. Some individuals, as the *C. ichillus* from MZUSP, were collected about 40 years ago. These results highlight both the importance of scientific collections in preserving a still unknown biodiversity and how poor is our current knowledge about the taxonomy and distribution of Neotropical porcupines.

From a conservation viewpoint, the areas where *Coendou nycthemera* was recorded, in southern (localities 22, 33 in Figure 1) and eastern Amazonia (localities 25, 26, and 28–32, in Figure 1) are under intense pressure from cattle ranching, agricultural developments, and selective logging (Gascon et al. 2001, Yoshikawa & Sanga-Ngoie 2011, Silva & Lima 2018). Therefore, our new record documents an arboreal mammal that is likely being affected by intense deforestation in the southern Amazon of Mato Grosso, in the same manner as monkeys such as *Mico emiliae, Saguinus niger*, and the recently described *Callicebus grovesi*, all of which occur in the region (Garbino et al. 2015, Boubli et al. 2019).

Our paper provides new data on the geographical distribution of *Coendou* species, recording for the first time *C. ichillus* for Brazil and reporting major range extensions for *C. bicolor* and *C. nycthemera*. With the new record of *C. ichillus* for Brazil, there are now 10 species of *Coendou* confirmed in the country (de Freitas et al. 2013, Voss 2015). Considering the most up-to-date catalogue of the Brazilian mammals (Quintela et al. in press), there are now 744 species of mammals in the country.

All records presented herein are based on scientific collections, reinforcing their importance as repositories of still unknown mammalian diversity, even for large species such as erethizontids. We would like to point out that due to the science cuts imposed by the Brazilian federal government (de Oliveira Andrade 2019), it is likely that biodiversity studies based on scientific collections will be severely impacted.

Supplementary material

The following online material is available for this article:
Appendix 1

Acknowledgements

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Author Contributions

Fernando Heberson Menezes - Substantial contribution in the concept and design of the study, Contribution to data collection, Contribution to data analysis and interpretation, Contribution to manuscript preparation.

Guilherme Siniciato Terra Garbino - Substantial contribution in the concept and design of the study, Contribution to data collection, Contribution to data analysis and interpretation, Contribution to manuscript preparation.

Table 2. External diagnostic characters of the Brazilian Amazonian porcupines. See Materials and Methods for measure abbreviations.

	Size	Soft hair	Long dorsal quills/bristle-quills/guard hairs	Short dorsal quills
C. nycthemera	Small (HBL: 344±22mm; LT: 313±25mm) (Voss & Angermann 1997)	Does not cover the quills	Tricolored or bicolored. Basal band short and yellowish, medial band blackish and long. Distal band, when present, very short. May be whitish, yellowish or orangish	Bicolored. Short basal band yellowish and long distal band blackish
C. bicolor	Large (Mean HBL: 457mm; Mean LT: 422 mm) (Voss 2011)	Does not cover the quills	Bicolored. Short basal band slightly yellowish; long distal band blackish	Bicolored. Short basal band yellowish; long distal band blackish
C. ichillus	Small (HBL: 275mm; LT: 245mm)*	Does not cover the quills	Substituted by Tricolored bristle-quills. Basal band is yellowish, medial band is blackish and distal band is whitish. All bands above the same length	Bicolored. Yellowish basal band and blackish distal band, above the same length
Amazonian *C. prehensilis*	Large (HBL: 451±25mm; LT: 453±31mm (Voss 2011)	Does not cover the quills	Bicolored and tricolored. Tricolored quills have basal band slightly yellowish, long blackish medial band and short whitish distal band. Bicolored quills have slightly yellowish basal band and the blackish distal band	Bicolored and tricolored. Tricolored quills have basal band yellowish, long blackish medial band and short whitish distal band. Bicolored quills have yellowish basal band and the blackish distal band
C. melanurus	Small (Mean HBL: 385mm; Mean LT: 373mm) (Voss et al. 2001, p.136)	Covers the quills	Guard hairs. Long yellowish basal band, blackish medial band and long pale yellowish distal band	Bicolored. Long strongly yellowish basal band with an inconspicuous blackish distal band
C. roosmalenorum	Small (HBL ~290mm; LT ~250mm) (Voss & da Silva 2001)	Covers the quills	Substituted by bristle-quills. Long yellowish basal band, blackish medial band and slightly yellowish distal band	Bicolored. Long strongly yellowish basal band with a short blackish distal band
C. baturitensis	Large (HBL: 500mm; LT: 460mm) (Feijó & Langguth 2013)	Does not cover the quills	Bicolored and tricolored. Tricolored quills have whitish basal band, long brownish medial band and short whitish distal band. Bicolored quills have short whitish basal band and long brownish distal band	Bicolored and tricolored. Tricolored quills have whitish basal band, long brownish medial band and short whitish distal band. Bicolored quills have short whitish basal band and long brownish distal band

* based on measurements of the examined specimens.

Thiago Borges Fernandes Semedo - Substantial contribution in the concept and design of the study, Contribution to data collection, Contribution to data analysis and interpretation, Contribution to manuscript preparation.

Mendelson Lima - Contribution to data collection, Contribution to critical revision, adding intelectual content.

Anderson Feijó - Substantial contribution in the concept and design of the study, Contribution to data collection, Contribution to data analysis and interpretation, Contribution to manuscript preparation.

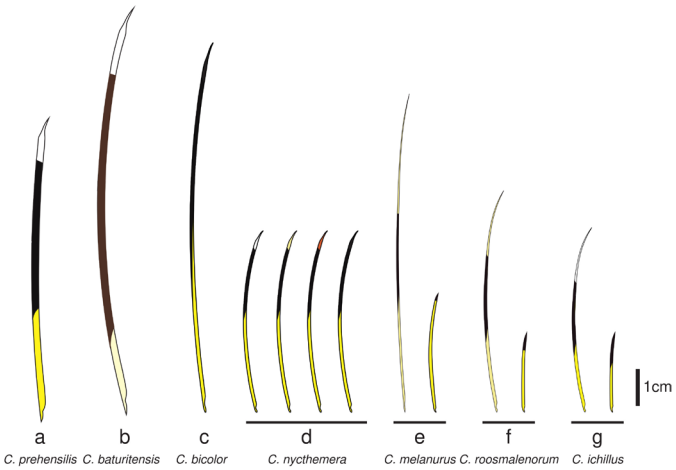

Figure 3. Quills and bristle-quills of selected species of Brazilian porcupines. **a)** Amazonian *C. prehensilis* long tricolored quill, **b)** *C. baturitensis* long tricolored quill, **c)** *C. bicolor* long bicolored quill, **d)** *C. nycthemera* long quills with different distal band colors, **e)** *C. melanurus* tricolored guard hair and bicolored quill, **f)** *C. roosmalenorum* tricolored bristle-quill and bicolored quill, and **g)** *C. ichillus* tricolored bristle-quill and bicolored quill.

Figure 4. *Coendou prehensilis* observed close to Nova Monte Verde, Mato Grosso, Brazil.

Pedro Cordeiro-Estrela - Contribution to critical revision, adding intelectual content .

Itayguara Ribeiro da Costa - Contribution to critical revision, adding intelectual content.

Conflicts of Interest

On behalf of the co-authors, I declare that there is no conflict of interest related to the publication of this manuscript

Ethics

This study did not involve animal experimentation or collecting, as the analyzed specimens were already deposited in scientific collections.

Data Availability

Every information necessary to replicate this study is present in the manuscript text

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