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Craniometrical differentiation of gray brocket deer species from Brazil

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Abstract: The genus *Mazama* (brocket deer) constitutes successful adaptive radiation, with a wide distribution in the Neotropical region. However, the taxonomy and systematics of its species and subspecies is still controversial. The objective of this contribution was to carry out a comparative craniometric study of specimens deposited in Brazilian museums of *M. gouazoubira* (Mg) and *M. nemorivaga* (Mn), in order to characterize these cryptic species. We performed 36 measures on 87 skulls of adult specimens (*Mg* = 32 females and 27 males; *Mn* = 14 females and 14 males). The sample was compared by analysis of variance and multivariate analysis of principal components and discriminant. In most cranial measurements, males and females of *M. gouazoubira* were 5% larger, with the exception of 3 measures: premolar-prosthion, basifacial axis, and least breadth between the orbits, that were larger in males and females of *M. nemorivaga*. This study showed significant differences between the two taxa that would validate the distinction of both species. To examine in more detail the dynamics of the variation of these two taxa it is necessary to increase the sample size in order to analyse them in a geographical and genetic context.

Key words: Craneometrical, gray brocket deer, *Mazama gouazoubira, Mazama nemorivaga.*

Resumen: Diferenciación craniométrica de las especies de corzuelas pardas de Brasil. El género *Mazama* constituye una exitosa radiación adaptativa, con una amplia distribución en la región Neotropical. Sin embargo, la taxonomía y sistemática sus especies y subespecies es todavía motivo de controversias. El objetivo de esta contribución fue realizar un estudio craneométrico comparativo de ejemplares depositados en museos de Brasil de *M. gouazoubira (Mg)* y *M. nemorivaga* (*Mn*), con el fin de caracterizar estas especies cripticas. Se tomaron 36 medidas en 87 cráneos de ejemplares adultos (*Mg* = 32 hembras y 27 machos; *Mn* = 14 hembras y 14 machos). La muestra se comparó mediante análisis de la varianza y análisis multivariados de componentes principales y discriminante. En la mayoría de las medidas craneanas los ejemplares machos y hembras de *M. gouazoubira* fueron un 5% más grandes, con la excepción de 3 medidas: premolar - prosthion, eje basifacial y el ancho menor entre orbitas, que presentaron mayor tamaño en los ejemplares machos y hembras de *M. nemorivaga*. Este estudio permitió mostrar que existen diferencias significativas entre los dos taxa, que validarían la distinción de ambas especies. Para examinar con más detalle la dinámica de la variación de estos dos taxa es necesario aumentar el tamaño de las muestras y analizarlas en un contexto geográfico y genético.

Palabras clave: Craneometría, corzuelas grises, *Mazama gouazoubira, Mazama nemorivaga.*

INTRODUCTION

The genus *Mazama* Rafinesque, 1817 represent a successful adaptive radiation of South American deers, that has a wide distributional range in the Neotropical region, extending from the State of Vera Cruz in Mexico to central Argentina (from sea-level to 4,900 m a.s.l.; see Allen, 1915; Black-Decima *et al.,* 2010; Rossi *et al.,* 2010). The taxonomy of the genus is complex and controversial, concerning both the species as well as the subspecies systematics. Until 1850, only two species of *Mazama* were recognized. In 1878 Sir Victor Brooke performed a detailed review of this genus and recognized six species, but only four of them were well established. In 1898, Lydekker identified seven species, six of them clearly distinguishable. However, when Allen (1915) performed the first systematic review of the genus *Mazama*, he recognized 16 forms of

red brocket deer and eight forms of gray brocket deer. During the decade of 1960, Cabrera simplified this scenario identifying two main groups and four species: a) Red brockets: *Mazama americana (M. a. americana*, *M. a. rufa, M. a. sheila, M. a. zetta, M. a. zamora), Mazama rufina (M. r. rufina, M. r. briceni)* and b) Gray brockets: *Mazama gouazoubira (M. m. gouazoubira*, *M. g. murelia, M. g. tchudii, M. g. superciliaris, M. g. cita),* and *Mazama chunyi*.

M. nemorivaga was firstly described by Cuvier in 1817, from a specimen from Cayenne, in French Guiana. Subsequently, Allen (1915) recognized this taxon within his gray brocket deer species group and restricted the geographical range of *M. nemorivaga* for individuals from the region of French and British Guyanas. Miranda-Ribeiro (1919), in his extensive taxonomic study of Brazilian deer, described a small species of gray brocket deer in the state of Rondonia and named it *M. rondoni*. However, Cabrera & Yepes (1960) and Cabrera (1960) not recognized this species, proposing it as a synonym of *M. gouazoubira superciliaris*. In 1987, Czernay updates the taxonomy of *Mazama* and recognized six species: *M. americana*, *M. gouazoubira*, *M. rufina*, *M. nana*, *M. chunyi* and *M. bricenii*.

Mazama gouazoubira

The "gray brocket or brown brocket deer" (*Mazama gouazoubira*) is the most abundant deer in South America (Duarte, 1996), being classified by the IUCN Red List (2009) as a least concern. However, in Brazil, the regional classification of the species is variable, being considered as threatened in some states (e.g., Rio de Janeiro; Bergallo *et al*., 2000).

It is a small to medium sized species, with an average weight ranging from 11-25 kg and an average height of 50 cm (Duarte, 1998; Rossi, 2000). The general coloration of individuals varies from dark gray to reddish brown (Pinder & Leeuwenberg, 1997). The submandibular and periophthalmic regions are lighter, light cream coloured. Most individuals have a white spot above the eyes, which characterizes the species and below the tail. They have large and rounded ears and non-branched antlers, characteristic of all species of the genus *Mazama* (Duarte, 1996; Duarte, 1998). The antlers are present only in males and have the form of a spike of 56.3 to 117.3 mm in length. They are conical or laterally compressed, straight or slightly curved medially, and parallel or slightly divergent from each other, and positioned at a sharp angle with respect to the dorsal surface of the skull. The burr contains elongated and more or less deformed tubercles of different sizes (Black-Decima *et al.,* 2010).

The skull has a long rostrum that occupies 47-51 % of the total length of the skull (Fig. 1). The premaxillaries are punctually united to nasals or completely separated from them by an anterior projected bar of the maxillaries. The lacrymal pit is shallow or moderately deep. The orbit is rounded or more or less squared, with a vertical diameter between 25.6 and 31.9 mm. The auditory bulla is small but wide, with its greatest width ranging from 10.4 to 13.3 mm; its ventral surface is adorned with crests or projections. The dental formula is 0/3i 0/1c 3/3pm 3/3m x 2 = 32. Small upper canines can be seen in some adult specimens. The length of the maxillary tooth row ranges from 45.2 to 55.9 mm (Black-Decima *et al.,* 2010).

This species occupies dense and continuous forests to open savannahs with small patches of forests. It is an easily found species, occupying the Cerrado to the south of the Amazon River up to the north of Argentina and Uruguay (Ávila-Pires, 1959; Duarte, 1996; González & Elizondo, 2010). This diversity of ecosystems and seasonal regimes can influence several aspects of their ecology (selection, habitat, diet, density and reproduction), in addition to their social behaviour, causing certain variations within and between populations. This species is relatively resilient; being capable to live in agroecosystems intermixed with small forest fragments (Pinder & Leeuwenberg, 1997; Rodrigues *et al*., 2014, 2017). In the Amazonian region, it is probably replaced by *Mazama nemorivaga*, a hypothesis that has not been fully tested (Duarte, 1996; Rossi, 2000; Black-Decima *et al*., 2010; Rossi *et al*., 2010)

Mazama nemorivaga

The "Amazonian brown brocket deer" (*Mazama nemorivaga*) has a wide distribution and inhabit in many protected areas of Amazonian basin forests. Although this species is threatened by loss of habitat and local hunting (mainly for subsistence), it had been classified by the IUCN Red List (2016) as a least concern. However, we infer that it must be suffering a certain degree of threat since its habitat is being extensively altered by deforestation and agricultural activities, in addition to the hunting pressure that is the object (Rossi & Duarte, 2016).

The Amazonian brown brocket deer is a small deer, about 15 kg average weight and 48 cm height (Rossi *et al.,* 2010). The pelage of the head

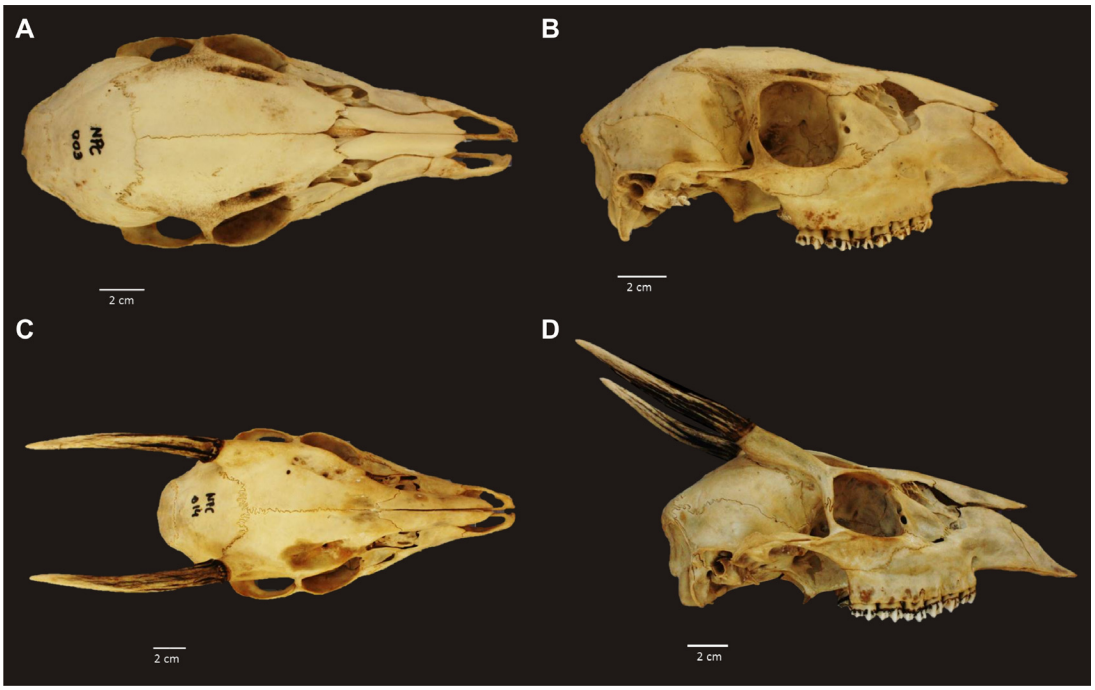

Fig. 1. Skull of an adult female (NPC 003) and adult male (NPC014) of *Mazama gouazoubira*. A) Dorsal view of adult female, B) Lateral view of adult female, C) Dorsal view of adult male, D) Lateral view of adult male.

exhibits a dark brown frontal tuft, tipped with black or not; small and barely defined buff spots on the edges of the upper lip; a whitish and not sharply defined spot on the anterior border of the chin, followed by dark buff and barely defined bands; and orange-brown inferior and superior orbital bands, not sharply defined, with yellow hairs mainly in the lateral areas. A diagnostic characteristic is the absence of the tarsal tuft. The adult males have spike-like antlers, ranging from 27.7 to 108.0 mm in length. Antlers are conical, usually slender, straight or slightly curved medially, and quite bent in relation to the dorsal surface of the skull; they may be parallel or slightly divergent between each other. The burr contains small spherical or elongated and more or less deformed tubercles (Rossi *et al.,* 2010).

The skull has a long rostrum that corresponds to 47-52 % of the total length of the skull (Fig. 2). The premaxillaries are usually separated from the nasals by an anterior projected bar of the maxillaries. The depth of the lachrymal pit varies among individuals; in some it is shallow, while in others it is deep. The orbit is large, with vertical diameter between 28.0 to 34.0 mm, and may be rounded or more or less squared in shape. The auditory bulla is small and narrow, with its greatest width ranging from 8.2 to 11.4 mm; its ventral surface is adorned with crests and small projections. Small upper canines are rarely seen in adult specimens. The dental formula is 0/3i 0/1c 3/3pm 3/3m x 2 = 32. The length of the maxillary toothrow ranges from 46.2 to 53.2 mm. The length of the maxillary toothrow ranges from 46.2 to 53.2 mm (Rossi *et al.,* 2010).

Its geographical range is extended from Brazil, French Guiana, Suriname, Guyana, Venezuela, Colombia, Panama (Isla San José), Ecuador, Peru, and probably northern Bolivia (Rossi & Duarte, 2008). In Brazil it is present in the states of Amazonas, Pará, Rondônia, Amapá, north of Mato Grosso, and northwest of Maranhão (Rossi, 2000). This species seems to be restricted to the Dense Ombrophilous Forests of the Amazonian Region and particularly in the State of Maranhão. It may also occur in the transitional areas between the Cerrado and Seasonal Forest and possibly in the Deciduous Seasonal Forest (Rossi, 2000; Rossi *et al*., 2010).

Duarte (1998), based on significant morphological and karyotypic differences, reconsidered the existence of *M. rondoni* as a separate species from *M. gouazoubira,* as originally was proposed by Miranda-Ribeiro (1919). Later, Rossi (2000) performed a taxonomic revision based on morphological analysis of specimens from seven

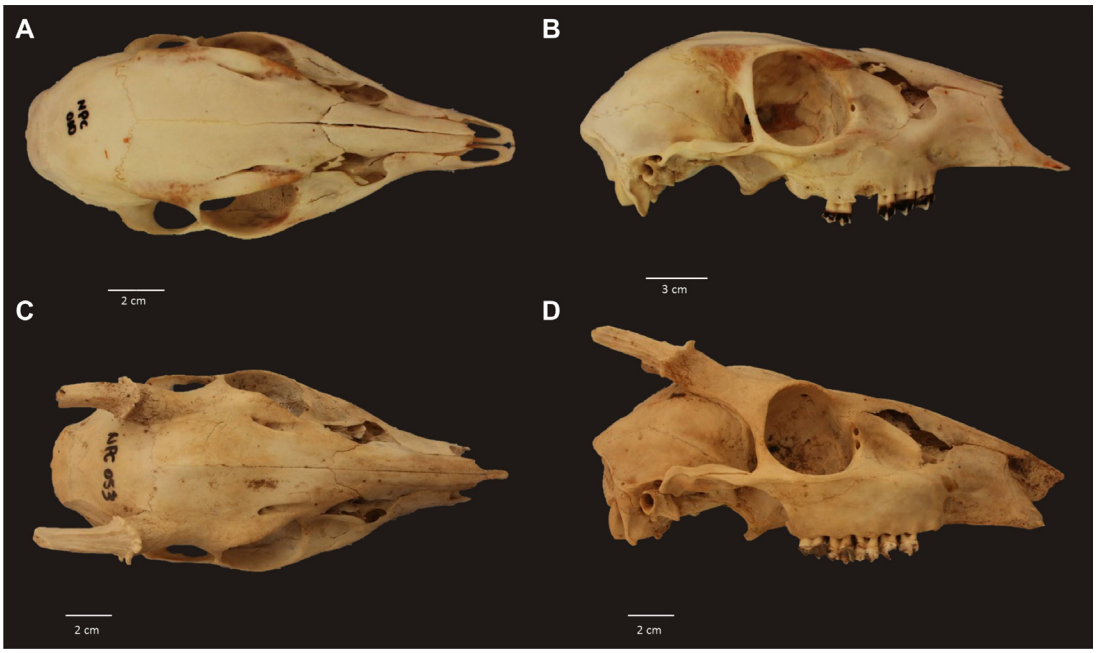

Fig. 2. Skull of an adult female (NPC 010) and adult male (NPC053) of *Mazama nemorivaga*. A) Dorsal view of adult female, B) Lateral view of adult female, C) Dorsal view of adult male, D) Lateral view of adult male.

northern Brazilian states and considered that the species *M. rondoni* is a synonym of *M. nemorivaga*. Currently, *M. nemorivaga* is recognized as a valid species, occupying the Amazonian region (Duarte *et al.,* 2008; Duarte *et al.,* 2010; Duarte & González, 2010; Fiorillo *et al*., 2013; Rossi & Duarte, 2016).

Comparative craniometrical study

Previous craniometrical studies on South American deer were reported by Wemmer & Wilson (1987), and Merino *et al.* (2005), which analysed interspecific variation and phylogenetic relationship. Skull morphometry can be a useful tool for analysing intraspecific variation as has been reported by Cabrera (1943), González *et al*. (2002), and Rossi (2000) from several Brazilian *Mazama* species. The craniometric study of Rossi (2000), that included an extensive sampling of brocket deer species failed to distinguish two different species of red brockets deer (*M. americana* and *M. bororo*) but discriminated by canonical analysis the two gray brockets (*M. gouazoubira* and *M nemorivaga*). As a part of an integrative project, Carranza *et al.* (2017) found evidence revealing weak premating behaviour isolation between *M. gouazoubira* and *M nemorivaga*, being more common at intraspecific interactions and suggesting discrimination between species. Cursino & Duarte (2017) identified significant differences on the morphology of the spermatozoa and the ejaculate of both species. One of the characteristics that most clearly differentiated between them was the colour of the ejaculate (white for *M. gouazoubira* and reddish for *M. nemorivaga*), and sperm head dimensions.

Our aim was to carry out a comparative craniometric study between *M. gouazoubira* y *M. nemorivaga*, based mostly on specimens deposited in Brazilian museum's collections, in order to analyse the intra and interspecific variation between these two cryptic species. Our purpose was to determine if there are differential cranial characteristics between these two taxa, to initiate a morphological database that allows examining in more detail the dynamics of the geographic and genetic variation to determine priority conservation units.

MATERIAL AND METHODS

Collections analysed and measurements performed

We reviewed the mammal collections of the following Brazilian museums: National Museum of Rio de Janeiro (MNRJ), Museum of Zoology of the University of São Paulo (MZUSP), Museum of Biology Professor Mello Leitão (MBML),

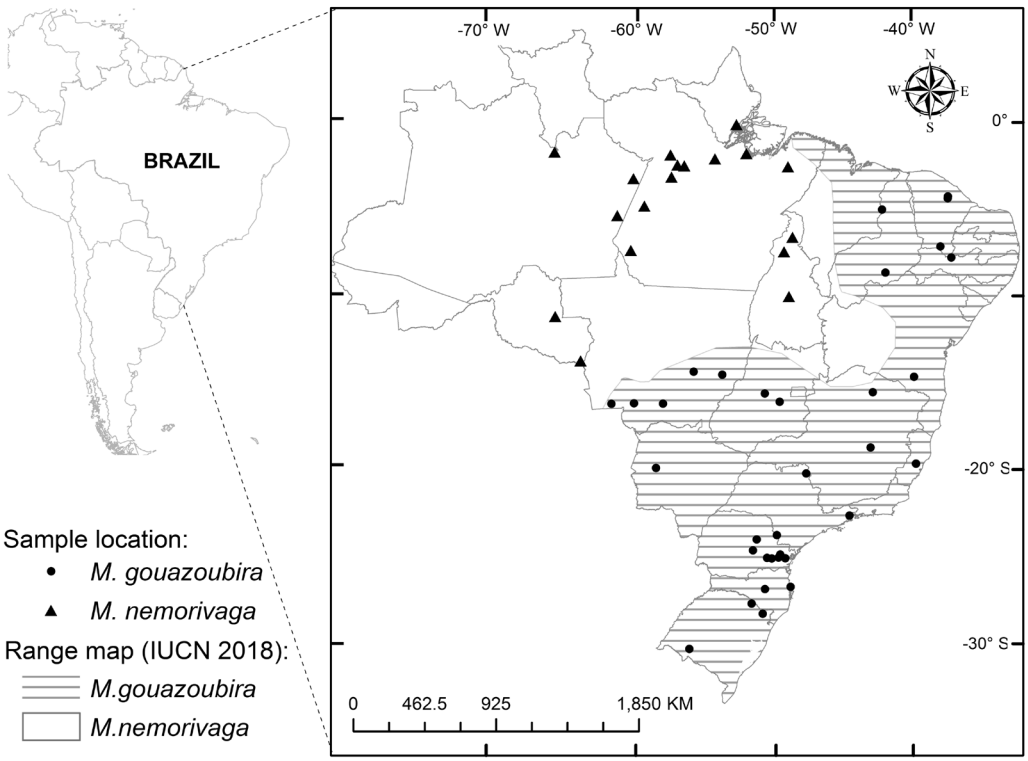

Fig. 3. Individuals measured and mapped with ArcGIS 10.1 according with the information recorded on the museum collections detailed in Appendix II.

Museum of Zoology of the Pontifical Catholic University of Rio Grande do Sul (PUC-RS), Museum of Zoology of the Federal University of Pernambuco (UFPE), Emilio Goeldi Museum Paraense (MuseoGoeldi), Museum of Natural History Capão da Imbuia (MHNCI), Museum of Zoology of the Federal University of Paraíba (UFPB) and Museum of the Deer Research and Conservation Center of UNESP (NUPECCE). The specimens we included in this study were originally nominated as: *Mazama gouazoubira*, *M simplicicornis*, *M. rondoni, M nemorivaga,* and *Mazama* sp.

We measured 106 skulls, but we only included in the comparative analyses 87, because they were adults and almost complete specimens of *M. gouazoubira* (*Mg*: 32 females and 27 males) and *M. nemorivaga* (*Mn*: 14 females and 14 males). Individual specimens were classified mostly based on its geographical origin and overall morphology, following Miranda Ribeiro (1919).

We took 36 measurements using digital caliper (precision 0.05 mm) following the criteria of the standard measurements for cervids of Von den Driesch (1976; see Appendix I). We also considered the data about age, sex and geographical location. (Appendix II). We plotted coordinates on a map using ArcGIS 10.1 (ESRI 2011) based on geographical information from each specimen label (Fig. 3).

Statistical analysis

We analysed the morphological variation of the sample, considering separately the effects of sexual dimorphism and taxonomic information. We classified the sample by sex and species, obtaining the averages, standard deviation and the variance of each variable. First, we conducted a Cluster analysis using the linkage model and Euclidean distances. To avoid the effect of sexual dimorphism, we analysed adult males and females separately.

We performed a factorial analysis in order to have an overview of the variation to simplify and reduce the 36 variables in 5 Factors. The factors were extracted using the method of the principal components (correlation matrix). Main components were log-transformed and rotated with the standard VARIMAX method. The projection of the individuals on the most informative fac-

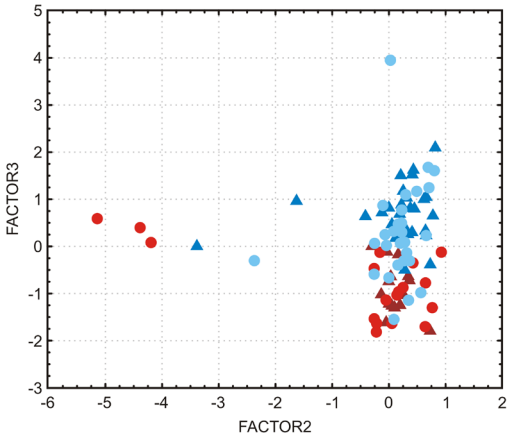

Fig. 4. Categorized two dimensions scatterplot of Factor 2 and 3 between sexes (circles –females; triangles – males) and species *M. gouazoubira* (blue) and *M. nemorivaga* (red).

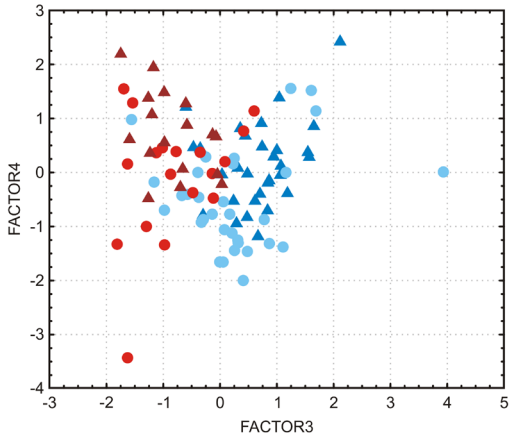

Fig. 5. Categorized two dimensions scatterplot of Factor 3 and 4 between sexes (circles –females; triangles – males) and species *M. gouazoubira* (blue) and *M. nemorivaga* (red).

tors was conducted by graphic means to detect the possible groups of specimens belonging to the same species and sex.

Analysis of variance (ANOVA) was used to test whether the factors presented statistically significant differences in relation to the sex and species (Sokal & Rohlf, 1969). The 36 original variables were also analysed using 2-way ANOVA. The advantage of the ANOVA is that this technique allows us to test if there are significant differences between groups and classified according to a specific criterion (e.g., species) after eliminating variation that could be attributed to other classification criteria (e.g., sex). The employed software to carry out all analyses was Statistica (StatSoft 1995).

We performed a stepwise discriminant function to analyse the patterns of differentiation and to classify individuals by sex and species (Sneath & Sokal, 1973; Sokal & Rohlf, 1969). Using the Statistica software, we build a step wise step-by-step model of discrimination to review and evaluate all variables that contribute most to the discrimination between sexes and species (using the same probability model for each class of classification). Next, that variable will then be included in the model, and Statistica software will proceed to the next step.

RESULTS AND DISCUSSION

Our results showed that gray brocket deer (*M. gouazoubira)* exhibited a wider intraspecific variation than the Amazonian brown brocket deer (*M. nemorivaga*). The averages of 36 measures are summarized in Appendix III, discriminated by sex and species. A wide intraspecific variability is observed as shown by the wide range of standard deviation of most measurements. In addition, most specimens belonging to *M. gouazoubira* were larger in most of the variables, being approximately 5% larger in both sexes. The exceptions were 3 measures: premolar-prosthion (PREPO), basifacial axis (BACR), and least breadth between the orbits (LBBO), which were larger in *M. nemorivaga* in both sexes. These results are indicative of differences in the skull shape between *M. gouazoubira* and *M. nemorivaga.*

When we analysed the behaviour of the variables using the Euclidean distance for performing a cluster analysis, we observed a diffuse morphometric differentiation pattern. To avoid the effect of sexual dimorphism, we considered separately the samples of adult males and females, retrieving not clear cluster aggrupation in any case. This would be explained by the wide intraspecific variability, also seen in standard deviation values (Appendix III). Alternatively, this situation would be a reflect of the large intra and interspecific variability of both species, that also have been evidenced by cytogenetic and molecular data (Duarte *et al.,* 2008; González *et al.,* 2010; Fiorillo *et al.,* 2013).

Because cluster analysis was not efficient to discriminate between the two taxa, we proceed to perform a Factorial Analysis, that allows us to simplify and summarize the 36 morphometric variables. As a result, we reduced them to 5 factors that account for 70% of the total variance of cranial measurements (Table 1). When individuals were discriminated by sex, we observed that

TABLE 1. Factors extracted from 36 cranial variables, using the principal components method and rotated to normalize them with the procedure VARIMAX (see Appendix I by the abbreviation of the variable names). The values correspond to the correlation coefficients between the variables and each factor. The red colour indicates if the variables that have a strong association ($| r | > 0.7$) with the factor.

Variable	Factor1	Factor2	Factor3	Factor4	Factor5
LT	0.286452	0.869569	0.158049	0.19495	0.100732
CBL	0.843446	0.213922	0.034452	0.03433	0.267019
BL	0.929059	0.14319	0.039895	0.10070	-0.08427
SSL	0.799663	0.231384	0.080415	-0.21113	-0.04072
PREPRO	0.447127	0.052701	-0.06201	0.788386	-0.03294
BACR	0.637126	0.29884	0.081293	-0.60701	-0.02521
BAF	0.748514	0.126449	0.024389	0.472774	-0.34856
NP	0.034558	0.255017	0.874958	0.069166	0.042763
MFL	0.026437	-0.04948	0.801034	0.181996	0.041879
LN	0.012774	-0.06431	0.791171	0.190894	0.026254
LR	0.021269	0.132543	0.890747	-0.09592	0.046451
LP	0.237055	0.864208	0.155263	0.240091	0.071909
ACI	0.278002	0.885506	0.159525	-0.0957	0.095929
GLN	0.021322	0.255239	0.813955	-0.04509	0.158116
MPL	0.802382	0.267948	0.070548	0.220883	-0.37204
OPL	0.715829	0.483821	0.056856	0.145906	0.001632
LLPRMAX	0.117075	0.785392	0.278175	0.06666	0.042813
LCHEE	0.129735	0.839277	-0.05462	-0.18198	-0.01392
LMR	0.148759	0.789334	-0.05142	-0.06263	-0.03669
LPREM	0.063803	0.684516	-0.07619	-0.34069	-0.01773
GLOR	0.245308	0.640309	0.040834	0.40201	0.271366
GHOR	0.166043	0.440228	-0.0316	0.66737	0.136402
GMBOO	0.15532	0.679786	0.145244	-0.00062	0.299191
GBOC	0.842432	0.160279	0.016849	-0.03322	0.351458
GBPP	0.589425	0.042624	0.000396	0.133384	0.351738
GBFM	0.839179	0.093547	-0.0348	-0.04943	0.340387
HFM	0.861991	0.024611	-0.05458	0.18868	0.025944
GBBC	0.221579	0.704721	0.138746	0.17584	0.395395
LFBO	0.130315	0.592853	0.142707	0.04564	0.641238
GBAO	0.553046	0.458219	0.116566	-0.36543	0.151055
LBBO	0.041791	-0.11419	0.413937	0.713914	0.065617
ZYB	0.396123	0.111534	-0.03281	0.0279	-0.07624
GBN	-0.02863	0.189974	0.754229	-0.15539	0.04816
GBPM	0.063795	0.404043	0.204053	0.064715	-0.12393
BNUCR	0.81744	0.188693	0.053509	0.164946	-0.29628
CBURR	-0.07058	0.158828	0.20948	0.061462	0.688217
Expl.Var	**8.636511**	**7.834542**	**4.592067**	**3.087693**	**2.126423**
Prp.Totl	**0.239903**	**0.217626**	**0.127557**	**0.085769**	**0.059067**

sexual dimorphism exists in most of the variables (Fig. 4 and 5), as often occurred in other cervid species, including Neotropical ones, such as the pampas deer (*Ozotoceros bezoarticus;* González *et al*., 2002). The factor 1 was associated with 10 variables; while five represent the skull length, the other five were related to the width in the posterior part of the cranium. However, it should be noted that the skull length (factor 1) did not differ significantly between sexes and species. We found that values for females of *M. gouazoubira*, associated to this factor, were greater than those of the males. The factor 2 was also associated with seven variables (Table I detailed), being three of them related to cranial length and to the length of the dental series. These variables discriminated significantly among species (Fig. 4). As this factor was associated with the dental series measures would be indicating that the two species were adapted to different types of forest habitats and food, as had already been emphasized by Duarte (1998) and Rossi (2000). In contrast, factor 3 was correlated with four of the measures that define the length of the face (Table 1). The factor 4 was associated with the unique three measures that were larger in the *M. nemorivaga* specimens (i.e., PREPRO, BACR and LBBO). In addition, it was the only one with highly significant differences between both sexes and species (Fig. 5). Finally, factor 5 grouped the variables that exhibited low correlation than 70% and only discriminated between sexes.

In order to investigate whether the observed differentiation was statistically significant, we performed an ANOVA using the 36 original variables and the five factors obtained by grouping individuals according to sex and species (Table 2 and 3). Significant differences were observed in the two data sets (Table 2 and 3). Of the 36 variables analysed, 15 did not show significant differences between species and sexes. The 21 variables that discriminated between the two species and that exhibited high significant F values ($p < 0.05$) were those related to the length of the skull and the shape of the face. The ANOVA performed with the five extracted factors also showed highly significant values in 3 of them (Table 3). The variables associated with factors 1 and 3 did not show significant differences. Factors 2, 4 and 5 showed statistically significant differences (Table 3), being a clear indicator that the individuals come from two morphometrically different species.

Subsequently, we performed a discriminant function analysis using 36 skull variables under a step wise forward model to classify the sample according to sex and species. When the en-

Table 2. Analysis of Variance of 36 skull measurements between two gray brocketspecies. For abbreviations see the Appendix I.

Measurements	*F*	*p-value*
LT	3.997955	0.010356571
CBL	0.389642	0.760756033
BL	0.111723	0.953024329
SSL	2.922577	0.038700564
PREPRO	6.999574	0.000296478
BACR	6.399308	0.00059265
BAF	1.155264	0.331865568
NP	2.954273	0.037219479
MFL	0.693537	0.558565874
LN	0.494338	0.687190641
LR	3.873566	0.012094617
LP	2.818688	0.043982157
ACI	10.0679	9.96367E-06
GLN	4.441925	0.006070011
MPL	0.838965	0.476319655
OPL	0.499605	0.683578609
LLPRMAX	4.80377	0.00390652
LCHEE	10.72769	4.95719E-06
LMR	6.447795	0.000560207
LPREM	9.373405	2.10226E-05
GLOR	1.903393	0.135371717
GHOR	2.753001	0.047688236
GMBOO	11.76916	1.68302E-06
GBOC	0.584657	0.626738197
GBPP	0.233286	0.872945328
GBFM	0.770587	0.513712235
HFM	1.083439	0.360748985
GBBC	5.510416	0.001681441
LFBO	12.9956	4.87454E-07
GBAO	4.562587	0.005222755
LBBO	6.59895	0.000470217
ZYB	1.498887	0.220902454
GBN	2.986659	0.035838581
GBPM	1.776872	0.157911201
BNUCR	0.509081	0.677105791
CBURR	144.552	0

Table 3. Factorial ANOVA. References: *F*values 2 degree of freedom and Significant effects $p<0.05$

FACTOR	*F*	*p-value*
FACTOR1	0.25358	0.858575
FACTOR2	7.90992	0.000107
FACTOR3	1.71676	0.169963
FACTOR4	11.89908	0.000002
FACTOR5	18.18664	0

Table 4. Classification Matrix (Rows: Observed Classification, Columns: Expected Classification)

Classification gender	Correct Percentage	Female $p = 0.50$	Male $p = 0.50$
Female	100	45	0
Male	92.68	3	38
Total	96.51	48	38

Table 5. Classification Matrix (Rows: Observed Classification; Columns: Expected Classification)

	Correct Percentage	*M. gouazoubira* $p = 0.50$	*M. nemorivaga* $p = 0.50$
M. gouazoubira	100	59	0
M. nemorivaga	100	0	27
Total	100	59	27

tire sample was considered, the gender discrimination found was significant ($F = 10.86$, $p < 0.0001$), confirming that there is a sexual sharp dimorphism in both species (Table 4). When we considered the whole sample (not separated by sex), we found significant differences between the 2 species ($F = 6.9201$, $p < 0.0001$), with all the individuals correctly classified (Table 5). Our results were also corroborated in a limited sample of gray brockets, that was further analysed using others evidences, such as cytogenetics and biometrics (Rossi, 2000).

Duarte *et al.* (2008) analysed a sample of Amazonian brown brocket deer using molecular markers and suggested the existence of two genetically differentiated groups: one would be occurring in the western region of Amazonia and the other in the east. However, it is necessary to increase the sample size to confirm this hypothesis and to evaluate if this genetic difference is also correlated with some kind of craniometric differentiation.

CONCLUSIONS

This study supports previous findings reported by Miranda Ribeiro (1919) and Rossi (2000) that there are two craniometrically distinct species of gray brockets in Brazil: *M. gouazoubira* and *M. nemorivaga*. However, a more detailed analysis of geographical patterns of morphological differentiation need to be conducted in the future, using a larger sample than those presented here. It would be important to extend the sampling to collections outside Brazil for further examination of the morphological variation and taxonomy within gray brocket deer species, in order to determine priority conservation units among them.

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APPENDIX I. List detailed of the cranial measurements taken and their abbreviation according to the criteria explicated by Von den Driesch (1976):

1) Total Length LT,
2) Condylobasal length CBL
3) Basal length BL
4) Short S Length SSL
5) Premolar Prosthion PREPRO
6) Basicranial axis BACR
7) Basifacial axis BAF
8) Nasion-Prosthion NP
9) Median Frontal Length MFL
10) Lambda Nasion LN
11) Lambda Rhinion LR
12) LamdaProsthion LP
13) Acrocranian-infraorbitale ACI
14) Greatest Length of nasal GLN
15) Median palatal length MPL
16) Oral palatal length OPL
17) Lateral length of the premaxilla LLPRMAX
18) Lenght of cheektooth LCHEE
19) Lenght of molar row LMR
20) Length of premolar row LPREM
21)Greatest length of the orbit GLOR
22) Greatest height of the orbit GHOR
23) Greatest mastoid breadth Otion-Otion GMBOO
24) Greatest breadth occipital condyles GBOC
25) Greatest breadth of paraoccipital process GBPP
26) Greatest breadth of foramen magnum GBFM
27) Height of foramen magnum HFM
28) Greatest breadth of the braincase GBBC
29) Least frontal breadth in the orbits LFBO
30) Greatest breadth across the orbits GBAO
31) Least breadth between the orbits LBBO
32) Zygomatic Breadth ZYB
33) Greatest breadth across the nasals GBN
34) Greatest breadth across premaxillae GBPM
35) Basion the highest point of the superior nuchal crest BNUCR
36) Circunference of the burr CBURR

APPENDIX II. List of revised specimens.Acronyms are as follow: Museum of Rio de Janeiro (MNRJ), Museum of Zoology of the University of São Paulo (MZUSP), Museum of Biology Professor Mello Leitão (MBML), Museum of Zoology of the Pontifical Catholic University of Rio Grande do Sul (PUCRS), Museum of Zoology of the Federal University of Pernambuco (UFPE), Emilio Goeldi Museum Paraense (MuseoGoeldi), Museum of Natural History Capão da Imbuia (MHNCI), Museum of Zoology of the Federal University of Paraíba (UFPB), Zoobotanica Foundation of Rio Grande do Sul (FZB), and Museum of the Deer Research and Conservation Center of UNESP (NUPECCE).

	ID	SEX	SPECIES	MUSEUM	ORIGIN
1	3893	female	M.g	FZB	Foz do Juabifi, Esmeralda - RS
2	15750	male	M.g	PUCRS	Bom Jesus-RS
3	1822	male	M.g	PUCRS	BR290, Serra do Caverá, Alegrete - RS
4	91	female	M.g	MHNCI	BR277, km 20, Morretes - PR
5	4085	male	M.g	MHNCI	Capivari, Campina Grande do Sul - PR
6	4101	female	M.g	MHNCI	Klabin Reflorestadora (Próximo Lagoa Telêmaco Borba) - PR
7	519	male	M.g	MHNCI	Fazenda Santa Rita, Palmeira - PR
8	4079	male	M.g	MHNCI	São Luiz do Puruña – PR
9	149	female	M.g	MHNCI	Vale do Rio Ivaí – PR
10	148	female	M.g	MHNCI	Vale do Rio Ivaí – PR
11	154	male	M.g	MHNCI	Chácara do Dr. Loureiro – Curitiba - PR
12	150	male	M.g	MHNCI	Vale Porto São José – PR
13	153	female	M.g	MHNCI	Vale Porto São José – PR
14	13559	male	M.ne	MZUSP	Caxiricatuba, rioTapajós-PA
15	7163	female	M.ne	MZUSP	Caxiricatuba, rioTapajós-PA
16	1153	male	M.g	MZUSP	Itararé-SP
17	814	female	M.g	MZUSP	Franca-SP
18	1848	female	M.g	MBML	São Lourenço, Santa Teresa-ES
19	1823	female	M.g	MBML	Estação Biológica de Santa Lúcia, Santa Teresa-ES
20	27	female	M.g	MNRJ	MT
21	7	male	M.g	MNRJ	Santa Catarina-SC
22	24	male	M.g	MNRJ	Santa Catarina- SC
23	36355	female	M.g	MNRJ	GO
24	60673	male	M.g	MNRJ	Sítio Campo, Campos Sales, Crato-CE
25	60675	female	M.g	MNRJ	Sítio Campo, Campos Sales, Crato-CE
26	60676	female	M.g	MNRJ	Sítio Campo, Campos Sales, Crato-CE
27	60677	female	M.g	MNRJ	Sítio Campo, Campos Sales, Crato-CE
28	63438	male	M.g	MNRJ	Caldeirão Inácio, PN Serra da Capivara, São Raimundo 0nato-PI
29	71065	female	M.g	MNRJ	RPPN Sesc Pantanal, Barão de Meleaço-MT
30	60664	female	M.g	MNRJ	Sítio Campo, Campos Sales, Crato-CE
31	60667	female	M.g	MNRJ	Sítio Campo, Campos Sales, Crato-CE
32	60668	male	M.g	MNRJ	Sítio Campo, Campos Sales, Crato-CE
33	60670	female	M.g	MNRJ	Sítio Campo, Campos Sales, Crato-CE
34	60663	male	M.g	MNRJ	Sítio Campo, Campos Sales, Crato-CE
35	60662	female	M.g	MNRJ	Sítio Campo, Campos Sales, Crato-CE
36	60661	male	M.g	MNRJ	Sítio Campo, Campos Sales, Crato-CE
37	60656	female	M.g	MNRJ	Cabeceira do Paranatinga-MT
38	60655	male	M.g	MNRJ	Sítio Campo, Campos Sales, Crato-CE
39	60647	male	M.g	MNRJ	Vitória da Conquista-BA
40	60646	female	M.g	MNRJ	Vitória da Conquista-BA
41	60645	male	M.g	MNRJ	Vitória da Conquista-BA

	ID	SEX	SPECIES	MUSEUM	ORIGIN
42	60644	female	M.g	MNRJ	Vitória da Conquista-BA
43	60643	female	M.g	MNRJ	Vitória da Conquista-BA
44	60532	female	M.g	MNRJ	Sítio Campo, Campo Sales-CE
45	60531	male	M.g	MNRJ	Sítio Campo, Campo Sales-CE
46	29079	male	M.g	MNRJ	FazendaFlorestaJanaúba-MG
47	25902	female	M.g	MNRJ	Fazenda Três Meninas, Porto Esbiridião-MT
48	13509	male	M.g	MNRJ	Província Conceição do Mato Dentro-MG
49	11979	male	M.g	MNRJ	Xavantina, Rio das Mortes-MT
50	6700	male	M.g	MNRJ	Serra da Bocaína-RJ
51	5837	female	M.g	MNRJ	São Luís de Cáceres – MT
52	5005	male	M.g	MNRJ	Anápolis-GO
53	60672	male	M.g	MNRJ	Sítio Campo, Campos Sales, Crato-CE
54	MR1	male	M.ne	MNRJ	MT
55	841	male	M.ne	MNRJ	Rio Cabixi-RO
56	1359	female	M.ne	MNRJ	Entre os rios Jamari e Gi-Paraná-RO
57	6093	female	M.ne	MNRJ	Lago do Batista, rio Amazonas-sul-AM
58	19200	male	M.ne	MNRJ	Rio Guajurú, Jacurú-200km de Porto de Moz-PA
59	19201	male	M.ne	MNRJ	Rio Guajurú, Jacurú-200km de Porto de Moz-PA
60	19202	male	M.ne	MNRJ	Jacareacanga, rioTapajós-PA
61	60690	male	M.ne	MNRJ	Caxiuanã-PA
62	60696	female	M.ne	MNRJ	Rio Aracá-Mirim-PA
63	60706	female	M.ne	MNRJ	Maués-AM
64	19207	male	M.ne	MNRJ	Rio Guajurú, Jacurú-200km de Porto de Moz-PA
65	30470	female	M.ne	MNRJ	Paraná do Ariaú-AM
66	60671	female	M.ne	MNRJ	Belterra-PA
67	60679	female	M.ne	MNRJ	Estrada Belém-Brasília (Rodobrás) km 131-TO
68	60680	female	M.ne	MNRJ	Estrada Belém-Brasília (Rodobrás) km 131-TO
69	60682	female	M.ne	MNRJ	Curuá, Santarém-PA
70	2391	female	M.g	UFPE	Buriti Cortado, Timon - MA
71	2422	male	M.g	UFPE	Buriti Cortado, Timon - MA
72	6652	male	M.g	UFPB	São José do Belmonte-PE
73	6998	female	M.g	UFPB	APA da Serra de Baturite, Aratuba-CE
74	6598	male	M.g	UFPB	Mulungu-CE
75	1617	male	M.ne	MuseoGoeldi	Manzagão-AP
76	1969	male	M.ne	MuseoGoeldi	Rio Araguaia-TO
77	723	male	M.ne	MuseoGoeldi	RioTocantis TO
78	1970	male	M.ne	MuseoGoeldi	Rio Araguaia- TO
79	4393	male	M.ne	MuseoGoeldi	Taperinha-PA
80	4409	male	M.ne	MuseoGoeldi	Taperinha-PA
81	4393	male	M.ne	MuseoGoeldi	Taperinha-PA
82	4395	male	M.ne	MuseoGoeldi	Taperinha-PA
83	4404	male	M.ne	MuseoGoeldi	
84	4392	female	M.ne	MuseoGoeldi	Taperinha-PA
85	4406	male	M.ne	MuseoGoeldi	Taperinha-PA
86	4394	male	M.ne	MuseoGoeldi	Taperinha-PA
87	4399	female	M.ne	MuseoGoeldi	Taperinha-PA
88	8066	female	M.ne	MuseoGoeldi	Santarém-PA
89	3348	female	M.ne	MuseoGoeldi	
90	3347	female	M.ne	MuseoGoeldi	
91	4391	female	M.ne	MuseoGoeldi	
92	4402	male	M.ne	MuseoGoeldi	Taperinha-PA

ID		SEX	SPECIES	MUSEUM	ORIGIN
93	4403	female	M.ne	MuseoGoeldi	Taperinha-PA
94	22613	female	M.ne	MuseoGoeldi	
95	NPC004	female	M.ne	NUPECCE	Santarém-PA
96	NPC005	female	M.ne	NUPECCE	CriadouroSantarém-PA
97	NPC006	male	M.ne	NUPECCE	CriadouroSantarém-PA
98	NPC010	female	M.ne	NUPECCE	CETAS de Macapá-AP
99	NPC013	female	M.ne	NUPECCE	
100	NPC017	female	M.ne	NUPECCE	
101	NPC008	male	M.g	NUPECCE	Porto Belo-SC
102	NPC009	female	M.g	NUPECCE	Guaíra-SP
103	NPC003	female	M.g	NUPECCE	São Paulo-SP
104	NPC011	female	M.g	NUPECCE	São Paulo-SP
105	NPC012	female	M.g	NUPECCE	Maranguape-CE
106	NPC014	male	M.g	NUPECCE	Pantanal-MS

APPENDIX III. Summary statistics of the analysed variables discriminated by species, sex and all groups pooled together. Abbreviations: *n* = number of specimens; *s.d.* = standard deviation; measures are detailed in Appendix I.

Variables	LT	LT	LT	CBL	CBL	CBL	BL	BL	BL	SSL	SSL	SSL
	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*
***M. gouazoubira* F**	179,18	32,00	15,84	166,50	32,00	36,03	153,63	32,00	31,70	100,63	32,00	21,46
***M. nemorivaga* F**	169,10	14,00	13,36	160,48	14,00	11,30	148,84	14,00	11,68	82,60	14,00	8,45
***M. gouazoubira* M**	183,06	27,00	11,36	171,10	27,00	36,03	149,72	27,00	44,50	99,93	27,00	30,00
***M. nemorivaga* M**	174,61	14,00	5,67	165,76	14,00	7,19	152,49	14,00	6,02	88,86	14,00	13,18
AllGroups	178,03	87,00	13,59	166,84	87,00	30,00	151,46	87,00	31,48	95,62	87,00	22,92

Variables	PREPRO	PREPRO	PREPRO	BACR	BACR	BACR	BAF	BAF	BAF	NP	NP	NP
	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*
***M. gouazoubira* F**	53,60	32,00	8,36	32,76	32,00	10,30	122,87	32,00	13,04	77,71	32,00	16,91
***M. nemorivaga* F**	63,85	14,00	13,17	21,34	14,00	8,14	125,52	14,00	16,20	70,54	14,00	23,02
***M. gouazoubira* M**	50,42	27,00	11,77	33,18	27,00	11,09	114,70	27,00	34,56	84,39	27,00	7,78
***M. nemorivaga* M**	61,91	14,00	10,05	24,72	14,00	9,16	125,00	14,00	8,08	81,30	14,00	6,58
AllGroups	55,60	87,00	11,67	29,76	87,00	10,99	121,11	87,00	22,17	79,21	87,00	15,17

Variables	MFL	MFL	MFL	LN	LN	LN	LR	LR	LR	LP	LP	LP
	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*
***M. gouazoubira* F**	103,88	32,00	20,36	91,86	32,00	18,13	138,66	32,00	28,47	170,45	32,00	15,15
***M. nemorivaga* F**	103,26	14,00	6,30	92,09	14,00	5,15	115,94	13,00	52,64	162,05	14,00	12,73
M. gouazoubira M	108,12	27,00	5,73	95,35	27,00	5,29	147,00	27,00	9,83	173,47	27,00	10,89
***M. nemorivaga* M**	103,97	14,00	2,76	92,69	14,00	2,53	141,61	14,00	6,24	167,37	14,00	5,65
AllGroups	105,11	87,00	13,06	93,12	87,00	11,59	138,32	86,00	28,71	169,54	87,00	12,77

Variables	ACI	ACI	ACI	GLN	GLN	GLN	MPL	MPL	MPL	OPL	OPL	OPL
	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*
***M. gouazoubira* F**	125,39	32,00	11,07	44,90	32,00	13,47	109,71	32,00	11,37	73,56	32,00	9,59
***M. nemorivaga* F**	114,25	14,00	6,39	40,13	13,00	19,71	103,97	14,00	9,98	69,43	14,00	7,80
***M. gouazoubira* M**	128,93	27,00	8,07	53,23	27,00	7,18	102,07	27,00	30,72	72,38	27,00	16,27
***M. nemorivaga* M**	119,40	14,00	5,58	51,12	14,00	6,82	106,40	14,00	5,74	70,76	14,00	4,85
AllGroups	123,73	87,00	10,10	47,81	86,00	12,93	105,88	87,00	19,04	72,08	87,00	11,32

Continuation

Variables	LLPR MAX	LLPR MAX	LLPR MAX	LCHEE	LCHEE	LCHEE	LMR	LMR	LMR	LPREM	LPREM	LPREM
	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*
***M. gouazoubira* F**	41,59	32,00	5,51	52,51	32,00	4,42	29,22	32,00	2,75	24,16	32,00	2,61
***M. nemorivaga* F**	37,85	14,00	5,11	47,57	14,00	4,55	26,29	14,00	3,16	21,59	14,00	2,68
***M. gouazoubira* M**	43,21	27,00	5,12	53,89	27,00	3,79	30,04	27,00	3,36	24,78	27,00	2,00
***M. nemorivaga* M**	38,72	14,00	2,59	48,80	14,00	2,03	27,52	14,00	1,18	21,84	14,00	1,40
AllGroups	41,03	87,00	5,29	51,54	87,00	4,58	28,73	87,00	3,11	23,57	87,00	2,60

Variables	GLOR	GLOR	GLOR	GHOR	GHOR	GHOR	GMBOO	GMBOO	GMBOO	GBOC	GBOC	GBOC
	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*
***M. gouazoubira* F**	29,79	32,00	1,84	29,16	32,00	2,80	53,55	32,00	3,65	32,18	32,00	6,67
***M. nemorivaga* F**	29,86	14,00	1,97	30,61	14,00	2,60	49,37	14,00	3,60	31,10	14,00	1,54
***M. gouazoubira* M**	30,60	27,00	1,57	29,57	27,00	1,79	55,34	27,00	2,79	33,52	27,00	7,31
***M. nemorivaga* M**	30,76	14,00	0,94	31,00	14,00	1,40	50,92	14,00	3,54	32,20	14,00	1,15
AllGroups	30,21	87,00	1,69	29,82	87,00	2,37	53,01	87,00	3,96	32,43	87,00	5,78

Variables	GBPP	GBPP	GBPP	GBFM	GBFM	GBFM	HFM	HFM	HFM	GBBC	GBBC	GBBC
	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*
***M. gouazoubira* F**	43,47	32,00	14,65	16,72	32,00	3,55	16,31	32,00	3,48	54,41	32,00	4,42
***M. nemorivaga* F**	43,66	14,00	3,08	15,59	14,00	1,21	16,20	14,00	1,88	51,66	14,00	2,88
***M. gouazoubira* M**	45,71	27,00	13,59	16,73	27,00	3,68	15,60	27,00	4,80	56,55	27,00	3,43
***M. nemorivaga* M**	45,54	14,00	2,29	17,31	14,00	1,54	17,71	14,00	1,32	54,28	14,00	2,99
AllGroups	44,53	87,00	11,69	16,64	87,00	3,08	16,30	87,00	3,55	54,61	87,00	3,98

Variables	LFBO	LFBO	LFBO	GBAO	GBAO	GBAO	LBBO	LBBO	LBBO	ZYB	ZYB	ZYB
	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*
***M.gouazoubira* F**	49,41	32,00	3,67	64,62	32,00	11,52	28,41	32,00	6,92	74,94	32,00	15,09
***M.nemorivaga* F**	47,58	14,00	1,76	53,08	14,00	8,21	33,72	14,00	9,99	71,93	14,00	5,57
***M.gouazoubira* M**	54,11	27,00	4,49	66,86	27,00	17,17	28,81	27,00	4,62	72,78	27,00	23,51
***M.nemorivaga* M**	51,72	14,00	2,90	58,12	14,00	6,10	36,14	14,00	1,68	62,02	14,00	26,58
AllGroups	50,94	87,00	4,32	62,41	87,00	13,34	30,63	87,00	6,97	71,70	87,00	19,50

Variables	GBN	GBN	GBN	GBPM	GBPM	GBPM	BNUCR	BNUCR	BNUCR	CBURR	CBURR	CBURR
	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*	Means	*n*	*s.d.*
***M.gouazoubira* F**	17,81	32,00	5,00	18,58	32,00	2,39	44,61	32,00	3,83	0,00	32,00	0,00
***M.nemorivaga* F**	15,26	13,00	7,76	16,47	14,00	5,43	42,22	14,00	2,57	0,00	14,00	0,00
***M.gouazoubira* M**	20,11	27,00	2,83	18,44	27,00	4,25	42,50	27,00	12,72	12,47	27,00	4,75
***M.nemorivaga* M**	16,81	14,00	6,06	15,86	14,00	7,05	43,42	14,00	2,14	12,58	14,00	2,19
AllGroups	17,98	86,00	5,34	17,76	87,00	4,55	43,38	87,00	7,55	5,90	87,00	6,86