# Geographical and altitudinal distribution of *Brachycephalus* (Anura: Brachycephalidae) endemic to the Brazilian Atlantic Rainforest

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Mountains of the Brazilian Atlantic Forest can act as islands of cold and wet climate, leading to the isolation and speciation of species with low dispersal capacity, such as the toadlet species of the genus *Brachycephalus*. This genus is composed primarily by diurnal species, with miniaturized body sizes (< 2.5 cm), inhabiting microhabitats in the leaf litter of montane forests. Still little is known about the geographical distribution, altitudinal range, and ecological limits of most *Brachycephalus* species. In this study we review the available data on the geographical and altitudinal distribution of *Brachycephalus* based on occurrence records compiled from literature and museums, both for the genus as a whole and separately for the three recently proposed groups of species (*ephippium*, *didactylus*, and *pernix*). The final ensemble dataset comprised 333 records, 120 localities, 28 described species, and six undescribed ones. Species were recorded in six relief units, the richest of which being the Serra do Mar, with 30 species. When the Serra do Mar is subdivided into three subunits, Northern, Central and Southern Serra do Mar, the number of species increase from north to the south, with records of six, nine, and 16 species, respectively. We were able to estimate the extent of occurrence of nearly half of the described species, and the resulting estimates indicate that many of them show remarkably small ranges, some of which less than 50 ha. *Brachycephalus* species are present from sea level to roughly 1,900 m a.s.l., with the highest richness being found between 751 and 1,000 m a.s.l. (21 spp.). The species with the broadest altitudinal range

were *B. didactylus* (1,075 m) and *Brachycephalus* sp. 1 (1,035 m), both in the *didactylus* group, and *B. ephippium* (1,050 m), of the *ephippium* group. The broadest altitudinal amplitude for species of the *pernix* group was recorded for *B. brunneus* (535 m). The lowest altitudinal records for the *pernix* group were at 845 m a.s.l. in the state of Paraná and at 455 m a.s.l. in the state of Santa Catarina. The altitudinal occurrence in the *pernix* species group seems to decrease southward. Syntopy between species is also reviewed.

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2 **endemic to the Brazilian Atlantic Rainforest**

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28 *Short title*: Distribution of *Brachycephalus* spp.

31 **Abstract**

32 Mountains of the Brazilian Atlantic Forest can act as islands of cold and wet climate, leading to

33 the isolation and speciation of species with low dispersal capacity, such as the toadlet species of

34 the genus *Brachycephalus*. This genus is composed primarily by diurnal species, with

35 miniaturized body sizes (< 2.5 cm), inhabiting microhabitats in the leaf litter of montane forests.

36 Still little is known about the geographical distribution, altitudinal range, and ecological limits of

37 most *Brachycephalus* species. In this study we review the available data on the geographical and

38 altitudinal distribution of *Brachycephalus* based on occurrence records compiled from literature

39 and museums, both for the genus as a whole and separately for the three recently proposed

40 groups of species (*ephippium*, *didactylus*, and *pernix*). The final ensemble dataset comprised 333

41 records, 120 localities, 28 described species, and six undescribed ones. Species were recorded in

42 six relief units, the richest of which being the Serra do Mar, with 30 species. When the Serra do

43 Mar is subdivided into three subunits, Northern, Central and Southern Serra do Mar, the number

44 of species increase from north to the south, with records of six, nine, and 16 species,

45 respectively. We were able to estimate the extent of occurrence of nearly half of the described

46 species, and the resulting estimates indicate that many of them show remarkably small ranges,

47 some of which less than 50 ha. *Brachycephalus* species are present from sea level to roughly

48 1,900 m a.s.l., with the highest richness being found between 751 and 1,000 m a.s.l. (21 spp.).

49 The species with the broadest altitudinal range were *B. didactylus* (1,075 m) and *Brachycephalus*

50 sp. 1 (1,035 m), both in the *didactylus* group, and *B. ephippium* (1,050 m), of the *ephippium*

51 group. The broadest altitudinal amplitude for species of the *pernix* group was recorded for *B.*

52 *brunneus* (535 m). The lowest altitudinal records for the *pernix* group were at 845 m a.s.l. in the

53 state of Paraná and at 455 m a.s.l. in the state of Santa Catarina. The altitudinal occurrence in the

54 *pernix* species group seems to decrease southward. Syntopy between species is also reviewed.

57 **Introduction**

59 *Brachycephalus* Fitzinger is a genus of miniaturized diurnal toadlets (usually < 2.5 cm in snout-

60 vent length) that inhabit the forest floor of montane regions along the Atlantic Rainforest of

61 southeastern and southern Brazil (Izecksohn 1971; Giaretta & Sawaya 1998; Pombal et al. 1998;

62   Napoli et al. 2011; Pie et al. 2013; see Rocha et al. [2000] and Pombal & Izecksohn [2011] for

63   reports of nocturnal activity). *Brachycephalus* presents direct development and a reduction in the

64   number and size of digits (Hanken & Wake 1993; Pombal 1999; Yeh 2002). Some species are

65   aposematic (yellow, orange or yellow with light red), of which some were confirmed as

66   harboring neurotoxins (tetrodotoxin and analogues; Sebben et al. [1986]; Pires et al. [2002,

67   2003]; Schwartz et al. [2007]).

68       Recently, Kaplan (2002) proposed that the genus *Psyllophryne* Izecksohn should be

69   considered as a junior synonym of *Brachycephalus*. *Psyllophryne* included two species, *P.*

70   *didactyla* and *P. hermogenesi*, "with dorsal surfaces brown, tiny body sizes [snout-vent length

71   8.6–10.2 mm], body leptodactyliform, and long-distance jumpers" (Napoli et al. 2011). There are

72   currently 29 described species of *Brachycephalus* (Frost 2015; see Pie & Ribeiro 2015; Ribeiro

73   et al. 2015), and although 20 of them were described within the last 10 years, it is likely that

74   many more species are still waiting to be described. Moreover, ecological data on species of the

75   genus *Brachycephalus* is still limited. To date it only includes data on the breeding behavior of

76   *B. ephippium* (Pombal et al. 1994; Pombal 1999); vocal activity of *B. hermogenesi* (Verdade et

77   al. 2008); advertisement calls of *B. ephippium* (Pombal et al. 1994), *B. hermogenesi* (Verdade et

78   al. 2008), *B. pitanga* (Araújo et al. 2012), *B. tridactylus* (Garey et al. 2012), and *B. crispus*

79   (Condez et al. 2014); abundance estimates of *B. didactylus* (Van Sluys et al. 2007; Almeida-

80   Santos et al. 2011; Rocha et al. 2013; Siqueira et al. 2014) and its diet (Almeida-Santos et al.

81   2011); the diet of *B. brunneus* (Fontoura et al. 2011), *B. garbeanus* (Dorigo et al. 2012), and *B.*

82   *pitanga* (Oliveira & Haddad 2015); and microhabitat preference of *B. garbeanus* (Dorigo et al.

83   2012).

84       A recently-proposed phylogenetic hypothesis for the genus indicated their separation into

85   three main clades, with still some uncertainty regarding relationships within each clade

86   (Clemente-Carvalho et al. 2011a). Based on the species studied by Clemente-Carvalho et al.

87   (2011a), one clade included *B. didactylus* and *B. hermogenesi*; a second clade, included *B.*

88   *brunneus*, *B. ferruginus*, *B. izecksohni*, *B. pernix*, and *B. pombali*; and a third clade included *B.*

89   *alipioi*, *B. ephippium*, *B. garbeanus*, *B. nodoterga*, *B. pitanga*, *B. toby*, and *B. vertebralis*. Two

90   morphological traits - the presence/absence of dermal co-ossification and body shape - were used

91   to distinguish three groups of species (Ribeiro et al. 2015), namely *ephippium*, *didactylus*, and

92   *pernix* groups. The first was defined by the presence of dermal co-ossification and bufoniform

93    body shape and includes the following species, distributed in southeastern Brazil (from the state

94    of Espírito Santo south to the state of São Paulo): *B. alipioi*, *B. bufonoides*, *B. crispus*, *B.*

95    *ephippium*, *B. garbeanus*, *B. guarani*, *B. margaritatus*, *B. nodoterga*, *B. pitanga*, *B. toby*, and *B.*

96    *vertebralis* (Ribeiro et al. 2015). The *didactylus* group was defined by the absence of dermal co-

97    ossification and a leptodactyliform body shape and includes *B. didactylus*, *B. hermogenesi*, and

98    *B. pulex* (Ribeiro et al. 2015). Finally, the *pernix* group was defined by the absence of dermal co-

99    ossification and bufoniform body shape, and includes the following species, distributed in

100   southern Brazil (states of Paraná and Santa Catarina): *B. auroguttatus*, *B. boticario*, *B. brunneus*,

101   *B. ferruginus*, *B. fuscolineatus*, *B. izecksohni*, *B. leopardus*, *B. mariaeterezae*, *B. olivaceus*, *B.*

102   *pernix*, *B. pombali*, *B. tridactylus*, and *B. verrucosus* (Ribeiro et al. 2015). Later, an additional

103   species from the pernix group was described from southern Brazil (Pie & Ribeiro 2015): *B.*

104   *quiririensis*. On the other hand, the holotype of *Brachycephalus atelopoide* is currently missing

105   (Pombal 2010) and no population of this species in nature is known. Therefore, given that

106   diagnostic characters could not be inspected, *B. atelopoide* was not assigned to any of the species

107   groups (Ribeiro et al. 2015). A recent study by Padial et al. (2014) indicated that *B. hermogenesi*

108   would be closely related to a species of the *ephippium* group, implying that the *didactylus* and

109   *ephippium* clades were not monophyletic, but the authors used the same dataset as the original

110   Clemente-Carvalho et al. (2011a) study. One possibility for this incongruence is that Padial et al.

111   (2014) only analyzed the concatenated dataset, which could have masked variations among

112   different among loci that were accounted for in species tree analyses by Clemente-Carvalho et al.

113   (Ribeiro et al. 2015).

114       An intriguing aspect of *Brachycephalus* is the high level of microendemism found in most

115   of its species. For instance, extensive field surveys often find species confined to one or a few

116   adjacent mountaintops along the Atlantic Forest (Pie et al. 2013), suggesting that their

117   diversification is strongly linked to the topographical characteristics of their habitats. Therefore,

118   to understand the origin and distribution of *Brachycephalus*, it is crucial to integrate species

119   occurrence data with the geographical attributes of the biomes where they are found. The

120   Atlantic Forest, the second largest forested biome of South America, can be divided at least into

121   eight broad relief units, of which three correspond to higher altitude regions, namely plateaus

122   ("Planaltos"), mountain ranges ("Serras"), and escarpments ("Escarpas") (IBGE 1993). The

123   highest mountains of the Atlantic Forest biome occur in the Serra da Mantiqueira and Serra do

124    Mar. Their formation is associated with tectonic events dating back to the Paleocene, which

125    caused an uplift of an eastern sector of southeastern Brazil and led to a depression in the eastern

126    border. This region was subsequently submerged by the ocean and led to the formation of the

127    Santos basin (Almeida & Carneiro 1998). A second downgrade occurred further inland,

128    establishing the Serra da Mantiqueira (it extends throughout the states of Espírito Santo, Minas

129    Gerais, Rio de Janeiro, and São Paulo; Almeida & Carneiro [1998]), which is currently divided

130    by the "Paraíba do Sul" river valley into northern and southern rims (IBGE 1993, 2006; IBAMA

131    2007). The Serra do Mar, formed between 300 and 400 million years before present, contitutes

132    the new eastern border of the Brazilian plateau that was progressively eroded westward, leaving

133    remnants that formed coastal islands (Almeida & Carneiro 1998). This edge of the plateau, called

134    Serra do Mar, was interrupted from the southern state of São Paulo by headward erosion of the

135    Ribeira river valley and from its lower limit in northeastern state of Santa Catarina by headward

136    erosion of the Itajaí Açu river valley (Almeida & Carneiro 1998).

137        Millions of years of erosion processes have shaped the escarpments and mountains in

138    eastern and southern Brazil. Instead of forming a continuous massif range, several blocks of high

139    elevation isolated by lower areas have been formed, constituting a mountain range. These blocks

140    receive one or more regional names of "Serras", the highest of which being Serra do Caparaó

141    (2,892 m a.s.l.) and Serra do Itatiaia (2,791 m a.s.l.), both part of Serra da Mantiqueira. The Serra

142    do Mar in its northern limit (northern state of Rio de Janeiro) is characterized by several

143    "Serras", with the highest peak reaching up to 2,230 m a.s.l. Its middle section presents a

144    distinctive structure, featuring a high plateau at the border between the states of Rio de Janeiro

145    and São Paulo, which decreases in altitude southward until southeast of São Paulo city. In this

146    region around the São Paulo city, the Serra do Mar is characterized as a border of the plateau

147    (Almeida & Carneiro 1998), reaching 800–900 m a.s.l., whereas in the border between the states

148    of São Paulo and Rio de Janeiro its altitude reaches up to 2,050 m a.s.l. In the state of Paraná, the

149    Serra do Mar is characterized again by several "Serras" with altitudes from 500 to 1,000 m above

150    the plateau (Maack 1981); the highest peak reaches up to 1,800 m a.s.l. (*sensu* Google Earth

151    [satellite image from 2015], or 1,922 m a.s.l., *sensu* Maack [1981]). The Serra do Mar in the state

152    of Santa Catarina has a very short extension (about 45 km in a north/south straight line). The

153    highest altitudes are found only near the border with the state of Paraná, where it reaches up to

154  1,524 m. Further south, the Serra do Mar becomes increasingly lower, reaching only ~600 m

155  a.s.l. on the southern edge of occurrence of this relief unit.

156      The mountainous regions of the Atlantic Forest might have contributed to the formation and

157  distribution limits of *Brachycephalus* in several ways. For instance, mountains could have

158  supported population remnants of many species during warmer periods throughout the

159  Quaternary (e.g. Carnaval et al. [2009]; Brunes et al. [2010]; Thomé et al. [2010]; Amaro et al.

160  [2012]; see also Wollenberg et al. [2011]; Páez-Moscoso & Guayasamin [2012], and Giarla et al.

161  [2014] for similar scenarios in other montane regions), mainly due to their distinctly colder and

162  wetter climatic conditions. Hence, they played an important role in the diversification of animals

163  with low dispersion capacities, including certain birds (Mata et al. 2009) and amphibians (Cruz

164  & Feio 2007; Brunes et al. 2010; Thomé et al. 2010). This has been confirmed in an investigation

165  of the environmental niches of different *Brachycephalus* species groups, given that they were

166  shown to occupy distinct regions of climatic space (Pie et al. 2013). That analysis included most

167  of the described species (as well some that were undescribed) and was based occurrence records

168  associated with species descriptions, museum specimens, and a few comprehensive references.

169  They have also presented new geographical distribution limits for the genus and records of

170  altitude for all species. However, no study to date has explored explicitly the altitudinal variation

171  and provided estimates of geographical distributions of *Brachycephalus* species.

172      Understanding the ecological limits, geographical distributions, and altitudinal ranges of

173  *Brachycephalus* species is of considerable importance, particularly to direct more effective

174  conservation actions. In the present study, we address the aforementioned aspects by reviewing

175  the geographical and altitudinal distribution of *Brachycephalus* based on records compiled from

176  literature and museum specimens. In particular, expanding a previous effort by Pie et al. (2013),

177  we now include the entire literature on *Brachycephalus*, which nearly tripled the number of

178  sources in relation to that study. We analyze the geographical distribution and altitudinal

179  amplitude of occurrence of the genus as a whole, as well as separately based on their species

180  groups.

181

182  **Materials and methods**

183

184  *Species records*

185     In an earlier paper (Pie et al. 2013), occurrence records of *Brachycephalus* species were obtained

186     from the SpeciesLink portal (www.splink.org.br), as well as from DZUP (Coleção de

187     Herpetologia, Departamento de Zoologia, Universidade Federal do Paraná, state of Paraná,

188     Brazil) and MHNCI (Museu de História Natural Capão da Imbuia - Prefeitura Municipal de

189     Curitiba) collections, and from the species descriptions themselves. For this paper we expanded

190     that dataset by compiling additional records from DZUP and from a broader review of the

191     literature. A few unpublished records obtained by the authors in southern Brazil were also

192     included to improve the dataset. Collection, handling and preservation permits were issued by

193     ICMBIO (22470–1 and 22470–2). We carried out the same careful analysis as in Pie et al. (2013)

194     to check the precise geographical coordinates of point records using topographic maps (at

195     different scales), resources of the Google Earth software, including the titles of photographs

196     associated with different locations, and descriptive information of localities in other publications.

197     The final dataset used for the analyses included only those records which coordinate precision

198     index value was between 1.1 and 3.0, according to McLaren et al., reprinted in Knyazhnitskiy et

199     al. (2000). To help further revisions, we also listed occurrence records considered imprecise after

200     our revision (see Results). Although there are methods for georeferencing imprecise locations

201     (e.g. Wieczorek et al. 2004), we preferred to discard the records that did not meet these

202     standards.

203         Altitudinal records were either compiled from the literature or, when that information was

204     unavailable, by plotting occurrence records on Google Earth. The altitudinal range of some

205     species were obtained directly from the literature or from the field by the authors. The altitudinal

206     range represents the lower and higher altitudinal occurrence record of a species in a given

207     locality. Although some records had precise locations, they were located on slopes where the

208     exact altitude of the record was difficult to ascertain and therefore were omitted from further

209     analysis, but not from the compiled table, to assist future revisions.

210         All records were associated with Brazilian relief units (IBAMA 2007) by simply plotting

211     each record against a map of the limits of different relief units. In two of the major relief units,

212     we also analyzed our data separately for their subunits as follows: the Serra da Mantiqueira as

213     "Northern Serra da Mantiqueira" (states of Espírito Santo and adjacent Minas Gerais) and

214     "Southern Serra da Mantiqueira" (states of Minas Gerais, Rio de Janeiro, and São Paulo), and the

215     Serra do Mar as "Northern Serra do Mar" (state of Rio de Janeiro), "Central Serra do Mar"

216    (southern state of Rio de Janeiro and state of São Paulo), and "Southern Serra do Mar" (southern

217    state of São Paulo and states of Paraná and Santa Catarina). The Serra da Mantiqueira we

218    subdivided into two sectors because this unit comprises naturally two sectors, isolated by the

219    "Paraíba do Sul" relief unit (IGBE 1993, 2006; IBAMA 2007). The Serra do Mar we subdivided

220    into sectors according to the interruption of escarpments (IGBE 2006). Geographical coordinates

221    are based into the WGS84 datum.

222

223    *Geographical distribution measurement*

224    We tentatively provide estimates of species geographical distributions as their "extent of

225    occurrence", *sensu* IUCN (2012), using two methods. The first is an adaptation of "minimum

226    convex polygon" (Mohr 1947), as Reinert et al (2007), which allowed for changing the shape of

227    the minimum convex polygon, whenever it was possible, to remove areas that are obviously

228    unsuitable for the persistence of the species, such as cities, plantations, bodies of water, and

229    vegetation in the early stages of regeneration, as well areas beyond the altitudinal amplitude

230    record of the species. In the second method, we made polygons by considering the lowest

231    altimetric quota with records of the species, while also omitting unsuitable areas (as above). We

232    made these environmental and altitudinal assessments and produced the resulting polygons using

233    Google Earth Pro 7.1.4.1529. We then measured the areas encompassed by each polygon using

234    GEPath 1.4.5. Although we disregarded unsuitable areas when drawing the polygons, we treated

235    the resulting measurements as "extent of occurrence" and not "area of occupancy" (*sensu* IUCN

236    2012) because micro habitat requirements can prevent the species from occurring in some parts

237    of the area within the polygons. Unfortunately, we were unable to determine occurrence

238    polygons of many species when the abovementioned criteria led to obviously unrealistic

239    distribution polygons, primarily for the following reasons: 1) when there were exceedingly few

240    records that were usually very scattered and/or encompassed vast degraded areas, or 2) when the

241    altitudinal range of occurrence of a species based on their altitudinal limits encompassed

242    unreasonably large areas (usually heading west).

243

244    *Species groups*

245    All described species in the present compilation were assigned to one of the three species groups

246    by Ribeiro et al. (2015), except for *B. atelopoide* (see above). The present compilation also

247 includes some undescribed species not yet assigned to one of the three groups; all of them were

248 mentioned as new species or potentially new species in the respective source of their records.

249 Two of them were here assigned to the *ephippium* group because they probably represent

250 populations of *B. ephippium* that could be split into two species, one of which from the state of

251 Rio de Janeiro (Siqueira et al. 2013; see also Siqueira et al 2011) and the other from the state of

252 São Paulo (Pie et al. 2013). A third undescribed species was assigned to the *didactylus* group

253 because it represents a population to be split from *B. hermogenesi* (Pie et al. 2013), a

254 representative species from the *didactylus* group. Finally, the other three populations were

255 assigned to the *pernix* group because they were previously assigned to the "pernix clade" (Pie et

256 al. 2013), whose members all belong to the *pernix* group (Ribeiro et al. 2015).

257

258 **Results**

259

260 The final dataset is composed of 333 records (from 73 distinc sources) of 120 localities (three of

261 which representing novel unpublished records). These records involve the geographic occurrence

262 of 28 formally known and six undescribed species, including 82 previous records that had been

263 excluded based on the accuracy criteria indicated above (Tab. 1). Species were recorded in six

264 relief units, the richest of them being Serra do Mar, with 30 species (six undescribed; Fig. 1),

265 followed by Serra da Mantiqueira and Leste Catarinense, with three species each (Tab. 2).

266 Northern Serra da Mantiqueira has records of all three species of this relief unit, while Southern

267 Serra da Mantiqueira has records of only one species. In Serra do Mar, species richness increases

268 from north to south, with records of six species (one undescribed) in Northern Serra do Mar, nine

269 (one undescribed) in Central Serra do Mar, and 16 (four undescribed) in Southern Serra do Mar

270 (Tab. 2; Fig. 1). Finally, Pré-Litorâneas, Paraíba do Sul, and Paranapiacaba relief units have

271 records of only one species each (Paranapiacaba has records of an undescribed species; Tab. 2).

272 The northernmost and southernmost records are 1,592 km distant from each other in a straight

273 line; the species recorded in these limits are *B. pulex* and *B. fuscolineatus*, respectively (Tab. 1).

274 The *didactylus* group comprises four species (one undescribed) encompassing the broadest

275 geographical distribution of all three groups, from the northernmost record for the genus (state of

276 Bahia, with *B. pulex*) southward to the north of Santa Catarina state, with *Brachycephalus* sp. 1

277 (Tab. 1; Fig. 2B). Three species occur in Serra do Mar (one undescribed), but only one species

278 occurs in each of Northern, Central and Southern Serra do Mar (Southern Serra do Mar has

279 records of one undescribed species; Tab. 3). Only one species occurs in the three remaining relief

280 units with presence of this group (Pré-Litorâneas, Serra da Mantiqueira, and Paranapiacaba, with

281 the latter being represented by an undescribed species; Tab. 3). There are no records of this

282 group inland in the "Southern Serra da Mantiqueira" but there are records relatively further

283 inland in "Paranapiacaba", in the state of Paraná (Fig. 2B).

284      The *ephippium* group comprises 13 species (two undescribed; Tab. 1). It has a more

285 intermediate geographical distribution in relation to the overall latitudinal distribution of the

286 genus, from the state of Espírito Santo to southern state of São Paulo (Fig. 2C); the species

287 recorded in those extreme geographical limits are *B. alipioi* and *B. ephippium*, respectively. The

288 group is represented in all relief units encompassed in this region (Serra da Mantiqueira, Paraíba

289 do Sul, and Serra do Mar; Tab. 1; Fig. 2C). It is highly represented by species in Serra do Mar

290 (12 species, two of which undescribed; Fig. 1), whereas in Serra da Mantiqueira there is records

291 of two species and in Paraíba do Sul of only one (Tab. 3). Northern Serra da Mantiqueira has two

292 species, while Southern Serra da Mantiqueira has only one (Tab. 3). Northern Serra do Mar has

293 five species (one undescribed) and Central Serra do Mar has eight species (also with one

294 undescribed); Southern Serra do Mar does not harbor any species of this group (Tab. 3; Fig. 1).

295      The *pernix* group is the most species-rich group, with 17 species (three undescribed; Tab. 1).

296 It has the smallest geographical distribution, restricted to the states of Paraná and Santa Catarina,

297 southern Brazil (Fig. 1D), comprising the southernmost distribution of the genus, with *B.*

298 *fuscolineatus* being recorded 87 km south of the border of the state of Paraná; the northernmost

299 species is *B. tridactylus* (Tab. 1). Per relief unit, 15 species (three undescribed) occurs in

300 Southern Serra do Mar and three in Leste Catarinense (Tab. 3; Fig. 1).

301      We were able to determine the extent of occurrence of 17 species (51.5% of all species with

302 records at precise locations; Tab. 4). Two species of the *didactylus* group have the highest

303 estimated extent of occurrence, with over 500 thousand ha, namely *Brachycephalus* sp. 1 and *B.*

304 *hermogenesi*. On the other hand, estimates of extents of occurrence for all remaining species did

305 not reach 20 thousand ha. With proportionally intermediate extent of occurrence, there are tree

306 species from the *ephippium* group (*B. garbeanus*, *B. margaritatus*, and *B. pitanga*), with

307 estimates between 2-19 thousand ha, and five species from the *pernix* group (*B. olivaceus*, *B.*

308 *brunneus*, *B. ferruginus*, *Brachycephalus* sp. 6, and *B. quiririensis*), with estimates between 1-6

309   thousand ha (Tab. 4). There are four species with small extent of occurrence, between 100-500

310   hectares, one from the *didactylus* group - *B. pulex* - and three from the pernix group - *B. pernix*,

311   *B. izecksohni*, and *B. leopardus* (Tab. 4). Finally, there are three species from the *pernix* group

312   with highly reduced extents of occurrence, namely *B. tridactylus*, *B. fuscolineatus*, and *B.*

313   *boticario*, with 41.42 ha, 23.63 ha, and 11.07 ha, respectively (Tab. 4).

314       *Brachycephalus* species are found from sea level to at least 1,900 m a.s.l. (Tab. 1 and 3).

315   The *ephippium* group was characterized by species with the broadest altitudinal amplitude (1,700

316   m; Tab. 4). The *didactylus* and *pernix* groups had similar altitudinal amplitude (1,110 m and

317   1,185 m, respectively; Tab. 4). However, the altitudinal occurrence of the *didactylus* group

318   started at sea level, whereas the *pernix* group began at mid-elevations (455 m a.s.l.; Tab. 4).

319       The altitudinal class with the highest species richness was 751–1,000 m a.s.l., with 21

320   species (three undescribed; Fig. 3A). The highest species richness for the *didactylus* group was

321   also found between 751–1,000 m a.s.l., including all four species of the group (one undescribed;

322   Fig. 3B). The highest richness of the *ephippium* group was evenly recorded between 751–1,000

323   m, comprising eight species (one undescribed; Fig. 3C). Finally, most species of the *pernix* group

324   were found between 1,001–1,250 m a.s.l., totalizing 10 species (three undescribed; Fig. 3D).

325       The species with the broadest altitudinal range was *B. didactylus* (1,075 m; starting at 35 m

326   a.s.l.) and *Brachycephalus* sp. 1 (1,035 m; starting at 25 m a.s.l.), both included in the *didactylus*

327   group, and *B. ephippium* (1,050 m; starting from 200 m a.s.l.), included in the *ephippium* group

328   (Tab. 4). The largest altitudinal occurrence amplitude for species of the *pernix* group was

329   recorded in *B. brunneus* (535 m; starting at 1,095 m a.s.l.; Tab. 4). The lowest records for the

330   *pernix* group were at 845 m a.s.l. in the state of Paraná and at 455 m a.s.l. in the state of Santa

331   Catarina, southern Brazil (Tab. 1). This illustrates the tendency for the altitudinal distribution of

332   species of the *pernix* group to decrease with increasing latitude (Fig. 4).

333       Syntopy in *Brachycephalus* is rare, being reported for the *didactylus* and *ephippium* groups

334   in state of Rio de Janeiro and São Paulo, and for the *didactylus* and *pernix* groups in the state of

335   Paraná and Santa Catarina (Tab. 1). Between *didactylus* and *ephippium* groups, syntopy has been

336   reported in four localities: between *B. didactylus* and *B. ephippium* in the Reserva Ecológica Rio

337   das Pedras, Rio de Janeiro (Carvalho-e-Silva et al. 2008; Almeida-Santos et al. 2011; Rocha et

338   al. 2013); between *B. didactylus* and *B. margaritatus* in the Sacra Família do Tinguá, Rio de

339   Janeiro (Izecksohn 1971; Pombal 2001; Ribeiro et al. 2005; Alves et al. 2006, 2009; Silva et al.

340    2007; Verdade et al. 2008; Clemente-Carvalho et al. 2009; Campos 2011; Pombal & Izecksohn

341    2011; Pie et al. 2013); between *B. didactylus* and *Brachycephalus* sp. 2 in Theodoro de Oliveira,

342    Rio de Janeiro (Siqueira et al. 2011, 2013); and between *B. hermogenesi* and *B. ephippium* in the

343    Reserva Florestal de Morro Grande, São Paulo (Dixo & Verdade 2006; Verdade et al. 2008).

344    Between *didactylus* and *pernix* groups, two cases of syntopy have been recorded (MRB, LFR &

345    MRP, pers. obs.), one between *Brachycephalus* sp. 1 (*didactylus* group) and *B. tridactylus*, in

346    Reserva Particular do Patrimônio Natural Salto Morato, at 900 m a.s.l., and the another one

347    between *Brachycephalus* sp. 1 and *B. olivaceus* at Castelo dos Bugres, between 800–835 m a.s.l.

348    (Tab. 1).

349        Sympatry and possibly syntopy also between *didactylus* and *ephippium* groups was reported

350    in the state of São Paulo in two localities (Tab. 1): between *B. hermogenesi* and *Brachycephalus*

351    sp. 3 in the Reserva Biológica do Alto da Serra de Paranapiacaba (Verdade et al. 2008; Pie et al.

352    2013) and between *B. hermogenesi* and *B. nodoterga* in the Estação Biológica de Boracéia

353    (Pombal et al. 1998; Pombal 2001, 2010; Ribeiro et al. 2005; Alves et al. 2006, 2009; Pimenta et

354    al. 2007; Verdade et al. 2008; Haddad et al. 2010; Pombal & Izecksohn 2011; Pie et al. 2013). A

355    sympatry may occur between species of a single group, particularly the *ephippium* group, in the

356    state of Rio de Janeiro (Tab. 1): between *B. bufonoides* and *B. garbeanus* in the Serra de Macaé

357    (Miranda-Ribeiro 1920; Pombal 2010; Pombal & Izecksohn 2011) and between *B. ephippium*

358    and *B. vertebralis* in the Pedra Branca, municipality of Parati (Pombal 2001, 2010; Clemente-

359    Carvalho et al. 2009; Pombal & Izecksohn 2011; Pie et al. 2013). Both need confirmation (see

360    Pombal 2001).

361

362    **Discussion**

363

364    The northernmost and southernmost relief units are poorly represented by records of

365    *Brachycephalus*, namely Pré-Litorâneas and Leste Catarinense, respectively. This suggests the

366    possibility that the genus occurs farther north and south from the most extreme records known

367    today (see Fig. 2). Interestingly, the potential distribution of *Brachycephalus* through

368    environmental niche modeling (Pie et al. 2013) is consistent with the possibility of a wider

369    distribution of the genus to the south of the current distribution, spreading widely through the

370    Leste Catarinense relief unit (see Figs 3a, b, e, f and Fig 4a of Pie et al [2013]). Forests at lower

371 altitudes in the Pré-Litorâneas region are different from those in mountains at higher altitudes,

372 displaying, for example, little moss on tree trunks and scarce epiphytic plants (MRB & RB-L

373 per. obs.). We believe it is possible that the occurrence of the genus in this relief unit is restricted

374 to mountains. Examples of locations of scarce humid mountains of this region can be seen in

375 Maurício et al. (2014), who mapped the occurrence of an endemic mountain bird to the Pré-

376 Litorâneas relief unit, the *Scytalopus gonzagai*. The environmental niche modeling of

377 *Brachycephalus* indeed indicates a small area of suitable habitats in this region (see Fig. 3b of

378 Pie et al. [2013]).

379       The occurrence of *B. ephippium* in distinct relief units should be the subject of further

380 scrutiny. In particular, populations under that name might indeed represent cryptic species that

381 would have to be split (see also Dixo & Verdade 2006; Silva et al. 2007; Clemente-Carvalho et

382 al. 2008, 2011b; Campos et al. 2010; Campos 2011; Siqueira et al. 2013; Trevine et al. 2014).

383 Similar conditions were detected in a montane bird, *Scytalopus speluncae* (taxonomy according

384 to Maurício et al. [2010]), which has to be split into several new species. In fact, the distribution

385 of *S. speluncae* is congruent with that of *B. ephippium* in some relief units (Mata et al. 2009;

386 MRB & RB-L pers. obs.). The occurrence of *B. ephippium* around the city of São Paulo is of

387 particular interest, given this region is characterized as a contact between Serra da Mantiqueira

388 and Serra do Mar relief units (IBGE 1993).

389       For a long time, all known species of *Brachycephalus* of the *pernix* group had their

390 geographical distribution limited to a single "Serra", i.e., in a massif range with high altitudes,

391 isolated from other "Serras" by areas of lower altitudes. Pie et al. (2013) were the first to report

392 the occurrence of more than one species of the *pernix* group in a single "Serra", and here we

393 report on other similar situations. In addition, the present study is the first to report the

394 occurrence of a species of this group distributed in two "Serras". This is the case of *B. brunneus*,

395 distributed in Serra dos Órgãos (not to be confused with the homonym "Serra" of the state of Rio

396 de Janeiro) and Serra da Graciosa (Tab. 1). Distributions of more than one sepecies in a single

397 "Serra" involve the cases of *B. ferruginus* and *Brachycephalus* sp. 4, distributed in Serra do

398 Marumbi, and *B. leopardus*, *B. auroguttatus*, and *B. quiririensis*, distributed in Serra do

399 Araçatuba/Serra do Quiriri, a single mountain massif in the border of the states of Paraná and

400 Santa Catarina (Tab. 1). These cases do not represent syntopy because all of them are isolated

401 from each other by more than 3 km. The occurrence of two species of the *ephippium* group in a

402    single Serra are known for long time, i.e. 1920 (involving *B. bufonoides* and *B. garbeanus*;
403    Miranda-Ribeiro [1920]) and 2001 (involving *B. ephippium* and *B. vertebralis*; Pombal [2001]).
404        Is interesting to note that the species with low altitudinal records (and also with high
405    altitudinal amplitude of occurrence) are the ones of greatest extent of occurrence measured,
406    perhaps indicating that its relatively plastic condition provide them of major opportunity to
407    establishment through a continuous Atlantic Forest. In the other way, species with medium to
408    high lower limit of altitudinal occurrence, and also with moderate altitudinal amplitude of
409    occurrence, have very reduced extent of occurrence, indicating proportionaly reduced plasticity
410    and subjection of environmental and topographic constrains. In a study on a Neotropical bird,
411    Reinert et al. (2007) showed that a very detailed estimate of the species extent of occurrence
412    resulted in an area seven times greater than the area of occupancy, which underscores how much
413    the extent of occurrence of *Brachycephalus* could be overstimated. In comparison, the small
414    extent of occurrence of the *Brachycephalus* are not the smaller "range" of species in the worl;
415    among the samaller, there are an isopod and a fisch, with less than 0.01 ha of occurrence, each
416    (Brown et al. 1996). However, there are between the smallest "ranges" of vascular plants and
417    fishes of the world (< 100 ha) and much smaller thant the smallest "ranges" of birds and
418    mammals of the world (~1,000,000 ha; Brown et al. [1996]).
419        The altitudinal records indicate that the *pernix* and *ephippium* groups are indeed "montane
420    groups" (Figs. 1 and 3), even though the altitudinal amplitude of species of the *ephippium* group
421    might be underestimated. Occasional records below 500 m a.s.l. for species of both montane
422    groups do not mean that all "montane species" of the genus normally occur at lower altitudes,
423    with the absence of lower records resulting from sampling bias. Rather, one could expect that
424    species of the *pernix* group at higher latitudes would tend to be recorded at lower altitudes due to
425    climatic compensation. Moreover, local records at lower altitudes of species of montane groups
426    can be due to particular local conditions of high moisture resulting from peculiar topographical
427    features. Regardless of the extreme altitudinal records, each species must have an altitudinal
428    range that corresponds to its climatic optimum (see Fig. 1). Studies estimating abundance along
429    altitudinal transects can be used not only to determine altitudinal ranges but also the climatic
430    optimum for each species. These data are of particular interest in the context of long-term studies
431    to assess the impact of climatic changes, with gradual modification in the abundances and even
432    changes in the altitudinal range being expected over time (see Corn 2005; Jump et al. 2012).

433   All records of *pernix* group species in the state of Paraná were either made in cloud forests

434   ("Floresta Ombrófila Densa Alto-montana" *sensu* Veloso et al. [1991]) or in the transition zones

435   between cloud forest and montane forests ("Floresta Ombrófila Densa Montana"). The only

436   exception is *B. tridactylus*, which occurs in montane forest (this study, since there is no available

437   description for the forest type in the species description by Garey et al. [2012]). Cloud or elfin

438   forests are pygmy tropical forests that occur in highly humid regions at the cloud level, between

439   1,000 to 2,500 m a.s.l. (Walter 1977). In the state of Paraná, these forests occur from 900 m to

440   about 1,850 m a.s.l. (Struminski 1997; Bornschein et al. 2012). The lowest record of *B. pombali*

441   (845 m a.s.l.), in the transition between cloud forest and montane forest, probably represents the

442   lowest altitude of this transition in the state of Paraná. In Santa Catarina, species from the *pernix*

443   group occur in cloud forests, montane forests, and in the transition between them. The only

444   known exception of forest habitat in the *pernix* group involves the observation of *B. izecksohni*,

445   also in herbaceous montane fields ("campos de altitude" or "Refúgio Vegetacional", *sensu*

446   Veloso et al. [1991]; MRB pers. obs.).

447   The few cases of syntopy between species, not only show little altitudinal overlap, but also

448   involve species of different groups, consistent with the notion that closely related species remain

449   allopatric. Localities with sympatry and syntopy are particularly interesting for further studies

450   related to the altitudinal distribution of species. On the other hand, sympatry between species of

451   the groups *ephippium* and *pernix* is not expected, given that a gap of 208 km occurs between

452   species of these groups. It is interesting to note that only the montane species groups, i.e.

453   *ephippium* and *pernix*, are highly species-rich, yet they tend not to show sympatry (although

454   there are some species distributed very close each other, and that there are cases of distinct

455   species occurring in a single "Serra"). We believe that these conditions suggest that these groups

456   evolved in allopatry and/or parapatry while the Atlantic Forest experienced retraction and

457   isolation as island between grasslands. During the Quaternary, climatic conditions changed

458   cyclically from cold and dry to warmer and wet periods, and these shifts were responsible for the

459   cyclical retraction and expansion of forest coverage, respectively (e.g. Behling & Lichte 1997;

460   Behling et al. 2002, 2005, 2007; Behling 2007; Langone et al. 2008; Behling & Safford 2010;

461   Enters et al. 2010; Hessler et al. 2010). In colder climates, montane forests may have migrated to

462   lower altitudes, allowing species of *Brachycephalus* to disperse. In subsequent warmer and wet

463    climate, the montane forest may have migrated to higher altitudes, isolating populations of

464    *Brachycephalus* and favoring speciation.

465        In relation to the species distributed close to each other or in single "Serras", without

466    apparent geographic barriers, it is possible that the expansion and retraction of forests did not

467    occur homogeneously across attitudinal quotas, but it might have occurred as isolated patches

468    even in restricted areas. In areas where climatic conditions favored the return of a vast forest

469    cover, geographically close species would have lost the corresponding environmental barriers,

470    remaining allopatric probably due to ecological requirements. The most notable case of

471    proximity between species occurs in northeastern state of São Paulo, where higher mountains are

472    absent and five species occur in a single plateau (*B. crispus*, *B. guarani*, *B. pitanga*, *B. toby*, and

473    *B. vertebralis*). In this region, the forests may have been confined in valleys during the periods of

474    retraction in the forest distribution.

475        In conclusion, *Brachycephalus* is restricted to the eastern portion of the Atlantic Forest

476    biome, with species occurring in allopatry or at least in parapatry, with rare cases of syntopy.

477    The species of the genus are segregated in three groups of species, with one of them (*didactylus*)

478    including species that respond differently to altitude, occurring in lower altitudes and having

479    greater geographic distributions, being much more ecologicaly tolerant and plastic. Species from

480    the remaining groups (*ephippium* and *pernix*) depend on high altitude conditions and can be

481    found locally in lower altitudes, probably in response to particular microclimatic conditions.

482    Sympatric species include members of distinct species groups and are in contact only in the

483    altitudinal limits of each other (higher limit for the "lowland" species and lower limit for the

484    "montane" species). Apart from a few species, most of them have restricted extents of

485    occurrence, to the point that many are microendemic, occurring in mountain tops with a total

486    extent of occurrence comparable to the smallest range from species around world. The

487    microhabitat requeriments of the species can prevent more realistic estimatives of extent of

488    occurrence, with traditional methodologies possibly resulting in substantial bias. This same

489    feature makes the species of particular interest to monitor climate change through their

490    abundances along altitudinal gradients. The genus also can be used as excellent model to infer

491    historical environmental changes due past climatic changes, given that they are thought to have

492    resulted from vicariant processes following upward migration of montane forests through

493    altitudinal ranges, in past warm and wet climates.

494

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496

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500

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836

837 Table 1. Records of *Brachycephalus* spp. Altitude is provided in meters (above sea level).

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. didactylus* | Northern Serra da Mantiqueira | *didactylus* | Monumento Natural Serra das Torres (21°00'04"S, 41°13'17"W), municipality of Atílio Vivácqua | ES | ? (600–900?) | Oliveira et al. (2012, 2013) |
| *B. didactylus* | Northern Serra do Mar | *didactylus* | Fazenda Santa Bárbara (22°25'17"S, 42°35'01"W), Parque Estadual dos Três Picos, municipality of Cachoeiras de Macacu | RJ | 500–800 | Siqueira et al. (2009), Almeida-Santos et al. (2011) |
| *B. didactylus* | Northern Serra do Mar | *didactylus* | Reserva Ecológica de Guapiaçu (22°24'00"S, 42°44'00"W), municipality of Cachoeiras de Macacu | RJ | 300–520 | Siqueira et al. (2014) |
| *B. didactylus* | Northern Serra do Mar | *didactylus* | Reserva Ecológica Rio das Pedras (22°59'00"S, 44°06'45"W), municipality of Mangaratiba | RJ | 200–1,110 | *, Carvalho-e-Silva et al. (2008), Almeida-Santos et al. (2011), Rocha et al. (2013) |
| *B. didactylus* | Northern Serra do Mar | *didactylus* | Sacra Família do Tinguá (22°29'11"S, 43°36'18"W), municipality of Engenheiro Paulo de Frontin | RJ | 600 | Izecksohn (1971), Pombal (2001), Ribeiro et al. (2005), Alves et al. (2006, 2009), Silva et al. (2007), Verdade et al. (2008), Clemente-Carvalho et al. (2009), Campos (2011), Pombal & Izecksohn (2011), Pie et al. (2013) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. didactylus* | Northern Serra do Mar | *didactylus* | Theodoro de Oliveira (first position: 22°22'11"S, 42°33'25"W), Parque Estadual dos Três Picos, municipality of Nova Friburgo | RJ | ? (1,100–1,400?) | *, Siqueira et al. (2011) |
| *B. didactylus* | Northern Serra do Mar | *didactylus* | Tinguá (22°35'51"S, 43°24'54"W), municipality of Nova Iguaçu | RJ | 35 | Izecksohn (1971) |
| *B. didactylus* | Northern Serra do Mar | *didactylus* | Vila Dois Rios (23°11'01"S, 44°12'23"W), Ilha Grande, municipality of Angra dos Reis | RJ | 220–240 | *, Rocha et al. (2000, 2001), Van Sluys et al. (2007) |
| *B. hermogenesi* | Central Serra do Mar | *didactylus* | Corcovado (23°28'08"S, 45°11'29"W), municipality of Ubatuba | SP | ? (70?) | Giaretta & Sawaya (1998), Verdade et al. (2008) |
| *B. hermogenesi* | Central Serra do Mar | *didactylus* | Estação Biológica de Boracéia (first position: 23°39'10"S, 45°53'05"W), municipality of Salesópolis | SP | 900 | Pimenta et al. (2007), Verdade et al. (2008) |
| *B. hermogenesi* | Central Serra do Mar | *didactylus* | Fazenda Capricórnio (23°23'27"S, 45°04'26"W), municipality of Ubatuba | SP | 60 | Giaretta & Sawaya (1998), Verdade et al. (2008) |
| *B. hermogenesi* | Central Serra do Mar | *didactylus* | Picinguaba (23°22'21"S, 44°49'53"W), Parque Estadual da Serra do Mar, municipality of Ubatuba | SP | 0–700 | Giaretta & Sawaya (1998), Pimenta et al. (2007), Verdade et al. (2008), Clemente-Carvalho et al. (2009), Pie et al. (2013) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. hermogenesi* | Central Serra do Mar | *didactylus* | Reserva Biológica do Alto da Serra de Paranapiacaba (23°46'40"S, 46°18'45"W), municipality of Santo André | SP | ? (800?) | Verdade et al. (2008) |
| *B. hermogenesi* | Central Serra do Mar | *didactylus* | Reserva Florestal de Morro Grande (23°42'08"S, 46°58'22"W), municipality of Cotia | SP | ? (990?) | Dixo & Verdade (2006), Verdade et al. (2008) |
| *B. pulex* | Pré-Litorâneas | *didactylus* | Serra Bonita (15°23'28"S, 39°33'59"W), municipality of Camacan | BA | 800–930 | Napoli et al. (2011) |
| *Brachycephalus* sp. 1 | Paranapiacaba | *didactylus* | Caratuval (24°51'17"S, 48°43'43"W), near the Parque Estadual das Lauráceas, municipality of Adrianópolis | PR | 900 | Firkowski (2013; without species identification), Pie et al. (2013; as "*Brachycephalus* sp. nov. 1") |
| *Brachycephalus* sp. 1 | Paranapiacaba | *didactylus* | Caratuval (24°51'14"S, 48°42'01"W), Parque Estadual das Lauráceas, municipality of Adrianópolis | PR | 890 | Pie et al. (2013; as "*Brachycephalus* sp. nov. 1") |
| *Brachycephalus* sp. 1 | Paranapiacaba | *didactylus* | Fazenda Primavera (24°53'08"S, 48°45'51"W), municipality of Tunas do Paraná | PR | 1,060 | Pie et al. (2013; as "*Brachycephalus* sp. nov. 1") |
| *Brachycephalus* sp. 1 | Paranapiacaba | *didactylus* | Fazenda Thalia (25°30'58"S, 49°40'12"W), municipality of Balsa Nova | PR | 1,025 | Firkowski (2013; without species identification), Pie et al. (2013; as "*Brachycephalus* sp. nov. 1") |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *Brachycephalus* sp. 1 | Paranapiacaba | *didactylus* | Base of the Serra Água Limpa (24°28'52"S, 48°47'12"W), municipality of Apiaí | SP | 920 | *, DZUP, Firkowski (2013; without species identification) |
| *Brachycephalus* sp. 1 | Southern Serra do Mar | *didactylus* | Alto Quiriri (26°05'34"S, 48°59'41"W), municipality of Garuva | SC | 240 | Pie et al. (2013; as "*Brachycephalus* sp. nov. 1") |
| *Brachycephalus* sp. 1 | Southern Serra do Mar | *didactylus* | Castelo dos Bugres (first position: 26°13'47"S, 49°03'20"W), municipality of Joinville | SC | 790–860 | Pie et al. (2013; as "*Brachycephalus* sp. nov. 1") |
| *Brachycephalus* sp. 1 | Southern Serra do Mar | *didactylus* | Colônia Castelhanos (25°47'58"S, 48°54'40"W), municipality of Guaratuba | PR | 290 | Cunha et al. (2010; as "*Brachycephalus* aff. *hermogenesi*"), Oliveira et al. (2011; as "*B. hermogenesi*"), Pie et al. (2013; as "*Brachycephalus* sp. nov. 1") |
| *Brachycephalus* sp. 1 | Southern Serra do Mar | *didactylus* | Corvo (25°20'17"S, 48°54'56"W), municipality of Quatro Barras | PR | 930 | Firkowski (2013; without species identification), Pie et al. (2013; as "*Brachycephalus* sp. nov. 1") |
| *Brachycephalus* sp. 1 | Southern Serra do Mar | *didactylus* | Dona Francisca (26°09'52"S, 48°59'23"W), municipality of Joinville | SC | 150 | Pie et al. (2013; as "*Brachycephalus* sp. nov. 1") |
| *Brachycephalus* sp. 1 | Southern Serra do Mar | *didactylus* | Estrada do rio do Júlio (26°17'02"S, 49°06'08"W), municipality of Joinville | SC | 650 | Mariotto (2014; as "*Brachycephalus* sp.") |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *Brachycephalus* sp. 1 | Southern Serra do Mar | *didactylus* | Fazenda Pico Paraná (25°13'29"S, 48°51'17"W), municipality of Campina Grande do Sul | PR | 1,050 | Pie et al. (2013; as "*Brachycephalus* sp. nov. 1") |
| *Brachycephalus* sp. 1 | Southern Serra do Mar | *didactylus* | Mananciais da Serra (25°29'29"S, 48°58'40"W), municipality of Piraquara | PR | 1,050 | *, DZUP, Pie et al. (2013; as "*Brachycephalus* sp. nov. 1") |
| *Brachycephalus* sp. 1 | Southern Serra do Mar | *didactylus* | Pico Agudinho (25°36'24"S, 48°43'33"W), Serra da Prata, municipality of Morretes | PR | 385 | Pie et al. (2013; as "*Brachycephalus* sp. nov. 1") |
| *Brachycephalus* sp. 1 | Southern Serra do Mar | *didactylus* | Recanto das Hortências (25°33'24"S, 48°59'38"W), municipality of São José dos Pinhais | PR | 975 | *, DZUP |
| *Brachycephalus* sp. 1 | Southern Serra do Mar | *didactylus* | Reserva Particular do Patrimônio Natural Salto Morato (25°10'00"S, 48°17'21"W), municipality of Guaraqueçaba | PR | 45–900 | *, Pereira et al. (2010; as "*B. hermogenesi*"), Santos-Pereira et al. (2011; as "*B. hermogenesi*") |
| *Brachycephalus* sp. 1 | Southern Serra do Mar | *didactylus* | Sítio Ananias (25°47'08"S, 48°43'03"W), municipality of Guaratuba | PR | 25 | Pie et al. (2013; as "*Brachycephalus* sp. nov. 1") |
| *Brachycephalus* sp. 1 | Southern Serra do Mar | *didactylus* | Truticultura (26°01'33"S, 48°52'02"W), municipality of Garuva | SC | 90 | Pie et al. (2013; as "*Brachycephalus* sp. nov. 1") |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. alipioi* | Northern Serra da Mantiqueira | *ephippium* | Fazenda Aoki or Fazenda dos Japoneses (20°28'24"S, 41°00'36"W), boundary of the municipalities of Vargem Alta and Domingos Martins | ES | 1,070–1,100 | Pombal & Gasparini (2006), Clemente-Carvalho et al. (2009, 2011a, 2012), Pombal & Izecksohn (2011), Pie et al. (2013) |
| *B. alipioi* | Northern Serra da Mantiqueira | *ephippium* | Forno Grande (20°31'41"S, 41°06'51"W), Parque Estadual de Forno Grande, municipality of Castelo | ES | ? (1,430?) | Pie et al. (2013) |
| *B. bufonoides* | Northern Serra do Mar | *ephippium* | Serra de Macaé (22°18'02"S, 42°18'20"W), municipality of Nova Friburgo | RJ | ? (1,100?) | Miranda-Ribeiro (1920), Pombal (2010), Pombal & Izecksohn (2011) |
| *B. crispus* | Central Serra do Mar | *ephippium* | Bacia B, Núcleo Cunha, Parque Estadual da Serra do Mar (23°15'15"S, 45°01'58"W), municipality of Cunha | SP | 800-1,100 | Condez et al. (2014) |
| *B. ephippium* | Northern Serra da Mantiqueira | *ephippium* | Serra do Pai Inácio (20°48'13"S, 42°29'07"W), Parque Estadual da Serra do Brigadeiro, boundary of the municipalities of Ervália and Miradouro | MG | ? (1,350?) | Pombal & Izecksohn (2011) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Condomínio Ermida (23°14'13"S, 46°58'52"W), Serra do Japi, municipality of Jundiaí | SP | 1,225 | Pie et al. (2013) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Hotel Fazenda Pé da Serra (22°51'56"S, 45°31'40"W), municipality of Pindamonhangaba | SP | 700 | Pie et al. (2013) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Lago Azul (22°27'23"S, 44°36'34"W), Parque Nacional do Itatiaia, municipality of Itatiaia | RJ | 750 | Pie et al. (2013) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Maromba (22°25'43"S, 44°37'11"W), Parque Nacional do Itatiaia, municipality of Itatiaia | RJ | 1,125 | Pie et al. (2013) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Monteiro Lobato (22°57'07"S, 45°50'20"W), municipality of Monteiro Lobato | SP | 700 | Pombal & Izecksohn (2011) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Observatório de Capricórnio (22°53'54"S, 46°49'01"W), Serra das Cabras, Joaquim Egídio District, boundary of the municipalities of Campinas and Morungaba | SP | 1,085 | Pombal (1999), Pombal et al. (1994), Pombal & Izecksohn (2011), Pie et al. (2013) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Parque Municipal de Itapetinga (Grota Funda) (23°11'07"S, 46°31'47"W), municipality of Atibaia | SP | 900–1,250 | Giaretta (1999), Giaretta et al. (1999), Clemente-Carvalho et al. (2009, 2011a), Pie et al. (2013) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Reserva Biológica da Serra do Japi (23°17'07"S, 47°00'05"W), Serra do Japi, boundary of the municipalities of Jundiaí and Cabreúva | SP | 1,000 | Giaretta et al. (1997), Pombal & Izecksohn (2011), Clemente-Carvalho et al. (2009, 2016), Pie et al. (2013) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Reserva Ecológica do Trabiju (22°48'01"S, 45°32'03"W), Trabiju, municipality of Pindamonhangaba | SP | ? (1,000?) | Pombal & Izecksohn (2011) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Reserva Pedra Branca (22°56'22"S, 45°41'04"W), municipality of Tremembé | SP | ? (890?) | Pombal & Izecksohn (2011) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Santo Antônio do Pinhal (22°49'28"S, 45°40'20"W), municipality of Santo Antônio do Pinhal | SP | 1,080 | Pombal & Izecksohn (2011) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | São Francisco Xavier (22°53'44"S, 45°58'04"W), municipality of São José dos Campos | SP | 1,000 | Clemente-Carvalho et al. (2008, 2011b, 2016), Pombal & Izecksohn (2011), Pie et al. (2013) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Serra Negra (21°57'28"S, 43°47'20"W), municipality of Santa Bárbara do Monte Verde | MG | ? | Campos (2011; as "BMV MG2") |
| *B. ephippium* | Paraíba do Sul | *ephippium* | Serra da Concórdia (22°20'30"S, 43°44'04"W), Parque Estadual Serra da Concórdia, Barão de Juparanã, municipality of Valença | RJ | ? (900?) | Pombal & Izecksohn (2011) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Alto do Soberbo (22°27'15"S, 42°59'21"W), municipality of Teresópolis | RJ | 1,250 | Pombal & Izecksohn (2011) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Comary (22°27'22"S, 42°58'24"W), municipality of Teresópolis | RJ | 990 | Pombal & Izecksohn (2011) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Floresta dos Macacos (22°58'15"S, 43°15'24"W), municipality of Rio de Janeiro | RJ | ? (450?) | Pombal & Izecksohn (2011) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Garrafão (22°28'04"S, 43°01'52"W), municipality of Guapimirim | RJ | ? (1,785?) | Pombal & Izecksohn (2011) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Pedra Branca (22°55'55"S, 43°28'23"W), Serra da Pedra Branca, municipality of Rio de Janeiro | RJ | 1,000 | Pombal (2001), Pombal & Izecksohn (2011) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Represa do Rio Grande (22°55'58"S, 43°26'36"W), Parque Estadual da Pedra Branca, municipality of Rio de Janeiro | RJ | ? (150?) | Pombal & Izecksohn (2011), Pie et al. (2013) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Reserva Ecológica Rio das Pedras (22°59'00"S, 44°06'45"W), municipality of Mangaratiba | RJ | 200-1,110 | Carvalho-e-Silva et al. (2008) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Riacho Beija-flor (22°27'04"S, 43°00'04"W), Parque Nacional da Serra dos Órgãos, municipality of Teresópolis | RJ | 1,195 | Pie et al. (2013) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Rocio District (22°28'23"S, 43°14'38"W), municipality of Petrópolis | RJ | 950 | Pie et al. (2013) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Serra do Tinguá (22°35'31"S, 43°28'16"W), municipality of Nova Iguaçu | RJ | ? (950?) | Pombal & Izecksohn (2011) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Vale da Revolta (22°26'17"S, 42°56'19"W), municipality of Teresópolis | RJ | 1,035 | Pombal & Izecksohn (2011) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Varginha (22°24'34"S, 42°52'11"W), municipality of Teresópolis | RJ | ? (825?) | Pombal & Izecksohn (2011) |
| *B. ephippium* | Central Serra do Mar | *ephippium* | Bonito (22°42'51"S, 44°34'39"W), Serra da Bocaina, municipality of São José do Barreiro | SP | ? (1,660?) | Pombal & Izecksohn (2011) |
| *B. ephippium* | Central Serra do Mar | *ephippium* | Estação Ecológica de Bananal (22°48'05"S, 44°22'12"W), Serra da Bocaina, municipality of Bananal | SP | ? (1,200?) | Zaher et al. (2005) |
| *B. ephippium* | Central Serra do Mar | *ephippium* | Lídice District (22°50'01"S, 44°11'32"W), municipality of Rio Claro | RJ | ? (650?) | Pombal (2001), Pombal & Izecksohn (2011) |
| *B. ephippium* | Central Serra do Mar | *ephippium* | Pedra Branca (23°10'38"S, 44°47'19"W), Serra da Bocaina, municipality of Parati | RJ | ? (630?) | Pombal (2001), Pombal & Izecksohn (2011) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. ephippium* | Central Serra do Mar | *ephippium* | Penísula do Bororé (23°47'11"S, 46°38'45"W), Represa Billings, Grajaú District, municipality of São Paulo | SP | 780 | Pie et al. (2013; as "*Brachycephalus nodoterga*"), Abbeg et al. (2015; as "clearly refers to another species [than *B. nodoterga* of Pie et al. 2013]") |
| *B. ephippium* | Central Serra do Mar | *ephippium* | Reserva Florestal de Morro Grande (23°42'08"S, 46°58'22"W), municipality of Cotia | SP | ? (990?) | Dixo & Verdade (2006) |
| *B. garbeanus* | Northern Serra do Mar | *ephippium* | Alto Caledônia (22°20'10"S, 42°33'20"W), municipality of Nova Friburgo | RJ | ? (1,070?) | Pombal & Izecksohn (2011) |
| *B. garbeanus* | Northern Serra do Mar | *ephippium* | Baixo Caledônia (22°21'33"S, 42°34'12"W), municipality of Nova Friburgo | RJ | 1,600-1,900 | Pombal & Izecksohn (2011); Siqueira et al. (2011, 2013), Dorigo et al. (2012) |
| *B. garbeanus* | Northern Serra do Mar | *ephippium* | Macaé de Cima (22°21'37"S, 42°17'50"W), municipality of Nova Friburgo | RJ | 1,130 | Clemente-Carvalho et al. (2008 [as "*B. ephippium*"], 2009 [as "*B. ephippium*"], 2011a,b ["b", as "*B. ephippium*"]), Pombal & Izecksohn (2011), Pie et al. (2013) |
| *B. garbeanus* | Northern Serra do Mar | *ephippium* | Morro São João (22°22'47"S, 42°30'34"W), municipality of Nova Friburgo | RJ | ? (1,550?) | Pombal & Izecksohn (2011) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. garbeanus* | Northern Serra do Mar | *ephippium* | Serra de Macaé (22°18'02"S, 42°18'20"W), municipality of Nova Friburgo | RJ | ? (1,100?) | Miranda-Ribeiro (1920), Pombal (2010), Pombal & Izecksohn (2011) |
| *B. garbeanus* | Northern Serra do Mar | *ephippium* | Serra Nevada (22°21'46"S, 42°32'48"W), municipality of Nova Friburgo | RJ | 1,190 | Pombal & Izecksohn (2011) |
| *B. garbeanus* | Northern Serra do Mar | *ephippium* | Theodoro de Oliveira (second position: 22°21'48"S, 42°33'13"W), Parque Estadual dos Três Picos, municipality of Nova Friburgo | RJ | 1,400 | Pombal & Izecksohn (2011), Siqueira et al. (2011, 2013) |
| *B. guarani* | Central Serra do Mar | *ephippium* | Morro Prumirim (23°20'50"S, 45°01'37"W), municipality of Ubatuba | SP | 500–900 | Giaretta (1999; altitude determined by Clemente-Carvalho et al. [2012]), Clemente-Carvalho et al. (2012), Condez et al. (2014) |
| *B. margaritatus* | Northern Serra do Mar | *ephippium* | Castelo Country Club (22°32'21"S, 43°13'08"W), municipality of Petrópolis | RJ | 980 | Pombal & Izecksohn (2011) |
| *B. margaritatus* | Northern Serra do Mar | *ephippium* | Castelo Montebello (22°24'24"S, 42°58'06"W), municipality of Teresópolis | RJ | 920 | Pombal & Izecksohn (2011) |
| *B. margaritatus* | Northern Serra do Mar | *ephippium* | Independência (22°32'58"S, 43°12'27"W), municipality of Petrópolis | RJ | 860 | Pombal & Izecksohn (2011) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. margaritatus* | Northern Serra do Mar | *ephippium* | Morro Azul (22°28'34"S, 43°34'40"W), municipality of Engenheiro Paulo de Frontin | RJ | 620 | Campos (2011; as "BPF RJ2"), Pombal & Izecksohn (2011) |
| *B. margaritatus* | Northern Serra do Mar | *ephippium* | Quitandinha (22°31'47"S, 43°12'26"W), municipality of Petrópolis | RJ | 925 | Pombal & Izecksohn (2011) |
| *B. margaritatus* | Northern Serra do Mar | *ephippium* | Sacra Família do Tinguá (22°29'11"S, 43°36'18"W), municipality of Engenheiro Paulo de Frontin | RJ | 600 | Izecksohn (1971; as "*B. ephippium*"), Pombal (2001; as "*Brachycephalus* cf. *ephippium*"), Pombal & Izecksohn (2011), Pie et al. (2013; as "*B. ephippium*") |
| *B. nodoterga* | Central Serra do Mar | *ephippium* | Estação Biológica de Boracéia (second position: 23°38'00"S, 45°52'00"W), municipality of Salesópolis | SP | 945 | Pombal et al. (1998), Pombal (2001, 2010), Ribeiro et al. (2005), Alves et al. (2006, 2009), Haddad et al. (2010), Pombal & Izecksohn (2011), Pie et al. (2013), Abegg et al. (2015), Clemente-Carvalho et al. (2016) |
| *B. nodoterga* | Central Serra do Mar | *ephippium* | Fazenda Paiva Ramos (23°28'21"S, 46°47'25"W), Serra de São Roque, municipality of Osasco | SP | 820 | Abegg et al. (2015) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. nodoterga* | Central Serra do Mar | *ephippium* | Pico do Ramalho (23°51'42"S, 45°21'28"W), Ilha de São Sebastião, municipality of Ilhabela | SP | 700–900 | Ribeiro (2006; as "*Brachycephalus* sp. aff. *nodoterga*"), Pombal & Izecksohn (2011), Pie et al. (2013), Abegg et al. (2015), Clemente-Carvalho et al. (2016) |
| *B. nodoterga* | Central Serra do Mar | *ephippium* | Serra da Cantareira (23°27'13"S, 46°38'11"W), Parque Estadual da Cantareira, municipality of São Paulo | SP | ? (850?) | Miranda-Ribeiro (1920), Ribeiro et al. (2005), Alves et al. (2006, 2009), Clemente-Carvalho et al. (2009, 2011a, 2012, 2016), Haddad et al. (2010), Pombal (2010), Pombal & Izecksohn (2011), Condez et al. (2014), Abegg et al. (2015) |
| *B. pitanga* | Central Serra do Mar | *ephippium* | Fazenda Capricórnio (23°22'36"S, 45°04'07"W), municipality of Ubatuba | SP | ? (450?) | Alves et al. (2009), Campos et al. (2010; as "*Brachycephalus* sp. 2"), Campos (2011), Pie et al. (2013) |
| *B. pitanga* | Central Serra do Mar | *ephippium* | Núcleo Santa Virgínia (23°19'23"S, 45°05'19"W), Parque Estadual da Serra do Mar, municipality of São Luis do Paraitinga | SP | 980–1,140 | Oliveira (2013), Tandel et al. (2014), Oliveira & Haddad (2015) |
| *B. pitanga* | Central Serra do Mar | *ephippium* | SP 125 - municipality of São Luís do Paraitinga (23°22'57"S, 45°09'59"W) | SP | 935–950 | *, DZUP |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. pitanga* | Central Serra do Mar | *ephippium* | Trilha do Ipiranga 50 m from the Rio Ipiranga (23°20'39"S, 45°08'16"W), Núcleo Santa Virgínia, Parque Estadual da Serra do Mar, municipality of São Luis do Paraitinga | SP | 900–960 | Alves et al. (2009), Clemente-Carvalho et al. (2009, 2011a), Araújo et al. (2012), Oliveira (2013), Pie et al. (2013) |
| *B. toby* | Central Serra do Mar | *ephippium* | Morro do Corcovado (23°27'20"S, 45°11'49"W), Parque Estadual da Serra do Mar, municipality of Ubatuba | SP | 750 | Haddad et al. (2010), Clemente-Carvalho et al. (2011a, 2012), Pie et al. (2013), Condez et al. (2014) |
| *B. vertebralis* | Central Serra do Mar | *ephippium* | Morro Cuzcuzeiro (23°18'03"S, 44°47'30"W), Núcleo Picinguaba, Parque Estadual da Serra do Mar, municipality of Ubatuba | SP | 900 | Clemente-Carvalho et al. (2011a), Pie et al. (2013), Condez et al. (2014) |
| *B. vertebralis* | Central Serra do Mar | *ephippium* | Pedra Branca (23°10'38"S, 44°47'19"W), Serra da Bocaina, municipality of Parati | RJ | ? (630?) | Pombal (2001, 2010), Clemente-Carvalho et al. (2009), Pie et al. (2013) |
| *Brachycephalus* sp. 2 | Northern Serra do Mar | *ephippium* | Theodoro de Oliveira (first position: 22°22'11"S, 42°33'25"W), Parque Estadual dos Três Picos, municipality of Nova Friburgo | RJ | 1,100–1,200 | Siqueira et al. (2011 [as "*Brachycephalus* sp."], 2013 [as "*Brachycephalus* sp. nov."]) |
| *Brachycephalus* sp. 3 | Central Serra do Mar | *ephippium* | Paranapiacaba (23°46'30"S, 46°17'57"W), municipality of Santo André | SP | 825 | Pombal & Izecksohn (2011; as "*B. ephippium*"), Pie et al. (2013; as "*Brachycephalus* sp. 1") |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *Brachycephalus* sp. 3 | Central Serra do Mar | *ephippium* | Parque Natural Municipal Nascentes de Paranapiacaba (23°46'10"S, 46°17'36"W), municipality of Santo André | SP | ? (800–1,164?) | Trevine et al. (2014; as "*Brachycephalus* sp.") |
| *Brachycephalus* sp. 3 | Central Serra do Mar | *ephippium* | Reserva Biológica do Alto da Serra de Paranapiacaba (23°46'40"S, 46°18'45"W), municipality of Santo André | SP | 800 | Pie et al. (2013; as "*Brachycephalus* sp. 1") |
| *B. auroguttatus* | Southern Serra do Mar | *pernix* | Pedra da Tartaruga (26°00'21"S, 48°55'25"W), municipality of Garuva | SC | 1,070–1,100 | *, DZUP, Firkowski (2013; without species identification), Ribeiro et al. (2015) |
| *B. boticario* | Leste Catarinense | *pernix* | Morro do Cachorro (26°46'42"S, 49°01'57"W), boundary of the municipalities of Blumenau, Gaspar, and Luiz Alves | SC | 755–795 | *, DZUP, Firkowski (2013; without species identification), Ribeiro et al. (2015) |
| *B. brunneus* | Southern Serra do Mar | *pernix* | Camapuã (25°15'59"S, 48°50'16"W), Serra dos Órgãos, boundary of the municipalities of Campina Grande do Sul and Antonina | PR | 1,595 | Fontoura et al. (2011), Firkowski (2013; without species identification), Pie et al. (2013) |
| *B. brunneus* | Southern Serra do Mar | *pernix* | Caranguejeira (25°20'27"S, 48°54'31"W), Serra da Graciosa, municipality of Quatro Barras | PR | 1,095–1,110 | *, DZUP, Firkowski (2013; without species identification) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. brunneus* | Southern Serra do Mar | *pernix* | Caratuva (25°14'33"S, 48°50'04"W), Serra dos Órgãos, municipality of Campina Grande do Sul | PR | 1,300–1,630 | Ribeiro et al. (2005), Clemente-Carvalho et al. (2009, 2011a), Campos (2011), Fontoura et al. (2011), Pombal & Izecksohn (2011; including "Pico Paraná"), Firkowski (2013; without species identification; including "Pico Paraná"), Pie et al. (2013) |
| *B. brunneus* | Southern Serra do Mar | *pernix* | Getúlio (25°14'18"S, 48°50'13"W), Serra dos Órgãos, municipality of Campina Grande do Sul | PR | 1,450–1,490 | *, Pie et al. (2013) |
| *B. brunneus* | Southern Serra do Mar | *pernix* | Mãe Catira (25°20'51"S, 48°54'25"W), Serra da Graciosa, municipality of Quatro Barras | PR | 1,135–1,405 | Firkowski (2013; without species identification), Pie et al. (2013; as "*Brachycephalus* sp. nov. 2") |
| *B. brunneus* | Southern Serra do Mar | *pernix* | Tupipiá (25°14'31"S, 48°47'47"W), Serra dos Órgãos, municipality of Antonina | PR | 1,260 | Firkowski (2013; without species identification), Pie et al. (2013) |
| *B. ferruginus* | Southern Serra do Mar | *pernix* | Olimpo (25°27'03"S, 48°54'59"W), Serra do Marumbi, municipality of Morretes | PR | 965–1,470 | Alves et al. (2006), Clemente-Carvalho et al. (2009, 2011a), Pombal & Izecksohn (2011), Firkowski (2013; without species identification), Pie et al. (2013) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. fuscolineatus* | Leste Catarinense | *pernix* | Morro do Baú (26°47'58"S, 48°55'47"W), municipality of Ilhota | SC | 640–790 | Firkowski (2013; without species identification), Pie et al. (2013; as "*Brachycephalus* sp. nov. 9"), Ribeiro et al. (2015) |
| *B. izecksohni* | Southern Serra do Mar | *pernix* | Torre da Prata, Serra da Prata (25°37'25"S, 48°41'31"W), boundary of the municipalities of Morretes, Paranaguá, and Guaratuba | PR | 980–1,340 | Ribeiro et al. (2005), Clemente-Carvalho et al. (2009, 2011a), Pombal & Izecksohn (2011), Firkowski (2013; without species identification), Pie et al. (2013) |
| *B. leopardus* | Southern Serra do Mar | *pernix* | Morro dos Perdidos (25°53'22"S, 48°57'22"W), municipality of Guaratuba | PR | 1,400–1,420 | Firkowski (2013; without species identification), Pie et al. (2013; as "*Brachycephalus* sp. nov. 4") |
| *B. leopardus* | Southern Serra do Mar | *pernix* | Serra do Araçatuba (25°54'07"S, 48°59'47"W), municipality of Tijucas do Sul | PR | 1,640 | Firkowski (2013; without species identification), Pie et al. (2013; as "*Brachycephalus* sp. nov. 4"), Ribeiro et al. (2015) |
| *B. mariaeterezae* | Southern Serra do Mar | *pernix* | Reserva Particular do Patrimônio Natural Caetezal, top of the Serra Queimada (26°06'51"S, 49°03'45"W), municipality of Joinville | SC | 1,265–1,270 | Firkowski (2013; without species identification), Pie et al. (2013; as "*Brachycephalus* sp. nov. 6"), Ribeiro et al. (2015) |
| *B. olivaceus* | Southern Serra do Mar | *pernix* | Castelo dos Bugres (second position: 26°13'59"S, 49°03'13"W), municipality of Joinville | SC | 800–835 | Firkowski (2013; without species identification), Pie et al. (2013; as "*Brachycephalus* sp. nov. 7"), Ribeiro et al. (2015) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. olivaceus* | Southern Serra do Mar | *pernix* | Base of the Serra Queimada (26°04'57"S, 49°03'59"W), municipality of Joinville | SC | 985 | Pie et al. (2013; as "*Brachycephalus* sp. nov. 7"), Ribeiro et al. (2015) |
| *B. olivaceus* | Leste Catarinense | *Pernix* | Morro do Boi (26°24'42"S, 49°12'59"W), municipality of Corupá | SC | 690–920 | *, MHNCI, Pie et al. (2013; as "*Brachycephalus* sp. 3") |
| *B. pernix* | Southern Serra do Mar | *pernix* | Anhangava (25°23'19"S, 49°00'15"W), Serra da Baitaca, municipality of Quatro Barras, | PR | 1,135–1,405 | Pombal et al. (1998), Wistuba (1998), Pires et al. (2005), Silva et al. (2007), Clemente-Carvalho et al. (2009, 2011a), Campos et al. (2010), Campos (2011), Pombal & Izecksohn (2011), Firkowski (2013; without species identification), Pie et al. (2013), Ribeiro et al. (2014) |
| *B. pombali* | Southern Serra do Mar | *pernix* | Morro dos Padres (25°36'40"S, 48°51'22"W), Serra da Igreja, municipality of Morretes | PR | 1,060–1,300 | Alves et al. (2006), Clemente-Carvalho et al. (2009, 2011a), Firkowski (2013; without species identification), Pie et al. (2013) |
| *B. pombali* | Southern Serra do Mar | *pernix* | trail to Morro dos Padres (25°35'58"S, 48°51'57"W), municipality of Morretes | PR | 845–1,060 | Pie et al. (2013) |
| *B. quiririensis* | Southern Serra do Mar | *pernix* | Serra do Quiriri (26°01'17"S, 48°59'47"W), municipality of Campo Alegre | SC | 1,240–1,318 | Firkowski (2013; without species identification), Pie et al. (2013; as "*Brachycephalus* sp. nov. 5"), Pie & Ribeiro (2015) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. quiririensis* | Southern Serra do Mar | *pernix* | Serra do Quiriri (26°01'42"S, 48°57'11"W), municipality of Garuva | SC | 1,320–1,380 | Pie et al. (2013; as "Brachycephalus sp. nov. 5"), Pie & Ribeiro (2015) |
| *B. tridactylus* | Southern Serra do Mar | *pernix* | Serra do Morato (25°08'09"S, 48°17'59"W), Reserva Natural Salto Morato, municipality of Guaraqueçaba | PR | 805–910 | *, DZUP, Garey et al. (2012), Bornschein et al. (2015) |
| *B. verrucosus* | Southern Serra do Mar | *pernix* | Morro da Tromba (26°12'44"S, 48°57'29"W), municipality of Joinville | SC | 455–945 | Firkowski (2013; without species identification), Pie et al. (2013; as "*Brachycephalus* sp. nov. 8"), Ribeiro et al. (2015) |
| *Brachycephalus* sp. 4 | Southern Serra do Mar | *pernix* | Morro do Canal (25°30'55"S, 48°58'56"W), municipality of Piraquara | PR | 1,320 | DZUP, Firkowski (2013; without species identification) |
| *Brachycephalus* sp. 4 | Southern Serra do Mar | *pernix* | Morro do Vigia (25°30'33"S, 48°58'58"W), municipality of Piraquara | PR | 1,250 | Firkowski (2013; without species identification), Pie et al. (2013; as "*Brachycephalus* sp. nov. 3") |
| *Brachycephalus* sp. 5 | Southern Serra do Mar | *pernix* | Pedra Branca do Araraquara (25°56'00"S, 48°52'50"W), Serra do Araraquara, municipality of Guaratuba | PR | 1,000 | *, DZUP |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *Brachycephalus* sp. 5 | Southern Serra do Mar | *pernix* | Serra Canasvieiras (25°36'58"S, 48°46'59"W), boundary of the municipalities of Guaratuba and Morretes | PR | 1,080 | *, DZUP, Firkowski (2013; without species identification) |
| *Brachycephalus* sp. 6 | Southern Serra do Mar | *pernix* | Serra do Salto (25°42'07"S, 49°03'44"W), Malhada District, municipality of São José dos Pinhais | PR | 1,095–1,160 | *, DZUP, Firkowski (2013; without species identification), Pie et al. (2013; as "*Brachycephalus* sp. 2") |
| **Excluded records[6]** | | | | | | |
| *B. hermogenesi* | Central Serra do Mar | *didactylus* | Ubatuba | SP | ? | Silva et al. (2007), Campos et al. (2010), Campos (2011) |
| *B. hermogenesi* | Paranapiacaba | *didactylus* | Municipality of Piedade | SP | ? | Condez et al. (2009), Clemente-Carvalho et al. (2011a) |
| *B. alipioi* | Northern Serra da Mantiqueira | *ephippium* | Santa Teresa | ES | ? | Pombal & Gasparini (2006), Pombal & Izecksohn (2011) |
| *B.* cf. *crispus* | Central Serra do Mar | *ephippium* | Cunha | SP | ? | Campos et al. (2010; as "*Brachycephalus* sp. 3"), Campos (2011; as "BCU SP2") |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Atibaia | SP | ? | Pires et al. (2003, 2005), Ananias et al. (2006), Clemente-Carvalho et al. (2008, 2009, 2011a,b, 2016), Campos et al. (2010), Campos (2011; as "BAT SP3"), Pombal & Izecksohn (2011) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Itamonte | MG | ? | Silva et al. (2007), Campos et al. (2010), Campos (2011; as "BIT MG1") |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Itatiaia | RJ | ? | Pombal & Izecksohn (2011) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Joaquim Egídio | SP | ? | Clemente-Carvalho et al. (2016) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Jundiaí | SP | ? | Miranda-Ribeiro (1920), Clemente-Carvalho et al. (2008, 2011b) |
| *B. ephippium* | Southern Serra da Mantiqueira | *ephippium* | Piquete | SP | ? | Miranda-Ribeiro (1920), Pombal & Izecksohn (2011) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Angra dos Reis | RJ | ? | Pombal & Izecksohn (2011) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Floresta da Tijuca, municipality of Rio de Janeiro | RJ | ? | Pombal & Izecksohn (2011) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Guapiaçu (22°26'34"S, 42°45'38"W), municipality of Cachoeira de Macacu | RJ | 35 | Pombal & Izecksohn (2011) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Mangaratiba | RJ | ? | Campos (2011; as "BMA RJ1"), Pombal & Izecksohn (2011) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Parque Nacional da Serra dos Órgãos | RJ | ? | Pombal & Izecksohn (2011) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Rio de Janeiro | RJ | ? | Pombal & Izecksohn (2011) |
| *B. ephippium* | Northern Serra do Mar | *ephippium* | Teresópolis | RJ | ? | Pires et al. (2002, 2005), Silva et al. (2007), Campos et al. (2010), Campos (2011; as "BTE RJ4"), Pombal & Izecksohn (2011) |
| *B. ephippium* | Central Serra do Mar | *ephippium* | Bocaina | SP | ? | Pombal & Izecksohn (2011) |
| *B. ephippium* | Central Serra do Mar | *ephippium* | Cotia | SP | ? | Silva et al. (2007), Campos et al. (2010), Campos (2011; as "BCO SP5") |
| *B. ephippium* | Central Serra do Mar | *ephippium* | Fazenda Papagaio, Serra da Bocaina | SP | ? | Pombal & Izecksohn (2011) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. ephippium* | Central Serra do Mar | *ephippium* | Mogi das Cruzes | SP | ? | Pires et al. (2005), Silva et al. (2007), Campos et al. (2010), Campos (2011; as "BMC SP4"), Pombal & Izecksohn (2011) |
| *B. ephippium* | Central Serra do Mar | *ephippium* | Serra da Bocaina | SP/RJ | ? | Pombal & Izecksohn (2011) |
| *B. garbeanus* | Northern Serra do Mar | *ephippium* | Nova Friburgo | RJ | ? | Silva et al. (2007; as "*B. ephippium*"), Campos et al. (2010; as "*B. ephippium*"), Campos (2011) |
| *B. margaritatus* | Northern Serra do Mar | *ephippium* | Sítio do Pau Ferro, Morro Azul, municipality of Engenheiro Paulo de Frontin | RJ | ? | Pombal & Izecksohn (2011) |
| *B.* cf. *margaritatus* | Northern Serra do Mar | *ephippium* | Petrópolis | RJ | ? | Campos (2011; as "BPT RJ3") |
| *B. nodoterga* | Central Serra do Mar | *ephippium* | Salesópolis | SP | ? | Pires et al. (2005) |
| *B. nodoterga* | Central Serra do Mar | *ephippium* | Santana de Parnaíba | SP | ? | Abegg et al. (2015) |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *B. toby* | Central Serra do Mar | *ephippium* | Ubatuba | SP | ? | Silva et al. (2007; as "*Brachycephalus* cf. *vertebralis*"), Campos et al. (2010; as "*Brachycephalus* cf. *vertebralis*"), Campos (2011) |
| *B. vertebralis* | Central Serra do Mar | *ephippium* | Cunha | SP | ? | Pombal (2001) |
| *B. vertebralis* | Central Serra do Mar | *ephippium* | Parati | RJ | ? | Silva et al. (2007), Campos et al. (2010), Campos (2011) |
| *Brachycephalus* sp. 7 | Central Serra do Mar | *ephippium* | Biritiba-Mirim | SP | ? | Silva et al. (2007; as "*B. nodoterga*"), Campos et al. (2010; as "*Brachycephalus* sp. 1"), Campos (2011; as "BBM SP1") |
| *B. brunneus* | Southern Serra do Mar | *pernix* | Campina Grande do Sul | PR | ? | Silva et al. (2007), Campos et al. (2010), Campos (2011) |
| *Brachycephalus leopardus* | Southern Serra do Mar | *pernix* | Tijucas do Sul | PR | ? | Campos (2011; as "BTS PR") |
| *B. atelopoide* | Southern Serra da Mantiqueira | ? | Piquete | SP | ? | Miranda-Ribeiro (1920) |
| *Brachycephalus* sp. cf. *Brachycephalus* sp. 1 | Paranapiacaba | *didactylus* | Municipality of Ribeirão Grande | SP | ? | Verdade et al. (2008; as "*B. hermogenesi*") |

| Species[1] | Relief units[2] | Group[3] | Locality[4] | State | Altitude | Source[5] |
|---|---|---|---|---|---|---|
| *Brachycephalus* sp. cf. *Brachycephalus* sp. 1 | Paranapiacaba | *didactylus* | Municipality of Tapiraí | SP | ? | Verdade et al. (2008; as "*B. hermogenesi*"), Condez et al. (2009; as "*B. hermogenesi*") |
| *Brachycephalus* sp. cf. *Brachycephalus* sp. 1 | Paranapiacaba | *didactylus* | Municipality of Juquitiba | SP | ? | Verdade et al. (2008; as "*B. hermogenesi*") |
| *Brachycephalus* sp. cf. *Brachycephalus* sp. 1 | Central Serra do Mar | *didactylus* | Estação Ecológica Juréia-Itatins, municipality of Iguape | SP | ? | Verdade et al. (2008; as "*B. hermogenesi*") |
| *Brachycephalus* sp. cf. *Brachycephalus* sp. 1 | Southern Serra do Mar | *didactylus* | Ilha do Cardoso, municipality of Cananéia | SP | ? | Verdade et al. (2008; as "possibly *B. hermogenesi*") |

838  [1] Species and records are ordered by the following criteria: alphabetic order of groups and alphabetic order of species by groups.

839  [2] According to IBAMA (2007), with additional subdivisions (see Materials and methods).

840  [3] For group definitions, see Materials and methods.

841  [4] Geographical coordinates are based on the datum WGS84.

842  [5] DZUP = Coleção de Herpetologia, Departamento de Zoologia, Universidade Federal do Paraná, state of Paraná, Brazil; MHNCI =

843  Museu de História Natural Capão da Imbuia, Prefeitura Municipal de Curitiba, state of Paraná, Brazil.

844  [6] Excluded records represent vague localities, general reference of municipality of locality, and localities that were specified but could

845  not be located or were questionable given exceedingly low associated altitude.

846  * = This study (unpublished data).

847

848  Table 2. Number of species of *Brachycephalus* per relief unit.

| Relief unit[1] | Number of groups | Number of species (undescribed species included) |
|---|---|---|
| Pré-Litorâneas | 1 | 1 (0) |
| Serra da Mantiqueira | 2 | 3 (0) |
|     Northern Serra da Mantiqueira | 2 | 3 (0) |
|     Southern Serra da Mantiqueira | 1 | 1 (0) |
| Paraíba do Sul | 1 | 1 (0) |
| Serra do Mar | 3 | 30 (6) |
|     Northern Serra do Mar | 2 | 6 (1) |
|     Central Serra do Mar | 2 | 9 (1) |
|     Southern Serra do Mar | 2 | 16 (4) |
| Paranapiacaba | 1 | 1 (1) |
| Leste Catarinense | 1 | 3 (0) |

849  [1] According to IBAMA (2007), with additional subdivisions in the units Serra da Mantiqueira

850  and Serra do Mar (see Materials and methods).

852    Table 3. Number of species of *Brachycephalus* per group in each relief unit.

| Relief unit[1] | Number of species per group (undescribed species included) | | |
|---|---|---|---|
| | *didactylus* | *ephippium* | *pernix* |
| Pré-Litorâneas | 1 (0) | 0 | 0 |
| Serra da Mantiqueira | 1 (0) | 2 (0) | 0 |
|    Northern Serra da Mantiqueira | 1 (0) | 2 (0) | 0 |
|    Southern Serra da Mantiqueira | 0 | 1 (0) | 0 |
| Paraíba do Sul | 0 | 1 (0) | 0 |
| Serra do Mar | 3 (1) | 12 (2) | 15 (3) |
|    Northern Serra do Mar | 1 (0) | 5 (1) | 0 |
|    Central Serra do Mar | 1 (0) | 8 (1) | 0 |
|    Southern Serra do Mar | 1 (1) | 0 | 15 (3) |
| Paranapiacaba | 1 (1) | 0 | 0 |
| Leste Catarinense | 0 | 0 | 3 (0) |

853    [1] According to IBAMA (2007), with additional subdivisions in the units Serra da Mantiqueira

854    and Serra do Mar (see Materials and methods).

856    Table 4. Altitudinal distribution and "extent of occurrence" (*sensu* IUCN 2012) of

857    *Brachycephalus* spp. Only confirmed altitudinal records are considered. Extent of occurrence by

858    altitude (Alt) or by an adaptation of the minimum convex polygon (MCP; see text for details).

| Species[1] | Altitudinal distribution (m a.s.l.) | | Extent of occurrence (ha) | |
| --- | --- | --- | --- | --- |
| | Range | Amplitude | Alt | MCP |
| *didactylus* group | 0–1,110 | 1,110 | - | - |
| *B. didactylus* (dida) | 35–1,110 | 1,075 | ? | ? |
| *B. hermogenesi* (herm) | 0–900 | 900 | - | 567,589.87 |
| *B. pulex* | 800–930 | 130 | 488.25 | - |
| *Brachycephalus* sp. 1 (sp.1) | 25–1,060 | 1,035 | - | 778,458.42 |
| *ephippium* group | 200–1,900 | 1,700 | - | - |
| *B. alipioi* | 1,070–1,100 | 30 | ? | ? |
| *B. crispus* (cris) | 800–1,100 | 300 | ? | ? |
| *B. ephippium* (ephi) | 200–1,250 | 1,050 | ? | ? |
| *B. garbeanus* (garb) | 1,130–1,900 | 770 | - | 12,268.00 |
| *B. guarani* (guar) | 500–900 | 400 | ? | ? |
| *B. margaritatus* (marg) | 600–980 | 380 | - | 18,272.87 |
| *B. nodoterga* (nodo) | 700–945 | 245 | ? | ? |
| *B. pitanga* (pita) | 900–1,140 | 240 | - | 2,377.07 |
| *B. toby* (toby) | 750 | 0 | ? | ? |
| *B. vertebralis* (vert) | 900 | 0 | ? | ? |
| *Brachycephalus* sp. 2 (sp.2) | 1,100–1,200 | 100 | ? | ? |
| *Brachycephalus* sp. 3 (sp.3) | 800–825 | 25 | ? | ? |
| *pernix* group | 455–1,640 | 1,185 | - | - |
| *B. auroguttatus* (auro) | 1,070–1,100 | 30 | ? | ? |
| *B. boticario* | 755–795 | 40 | 11.07 | - |
| *B. brunneus* (brun) | 1,095–1,630 | 535 | 5,687.08 | - |
| *B. ferruginus* (ferr) | 965–1,470 | 505 | 5,475.51 | - |
| *B. fuscolineatus* | 640–790 | 150 | 23.63 | - |
| *B. izecksohni* (izec) | 980–1,340 | 360 | 350.43 | - |
| *B. leopardus* (leop) | 1,400–1,640 | 240 | 176.73 | - |

| Species[1] | Altitudinal distribution (m a.s.l.) | | Extent of occurrence (ha) | |
|---|---|---|---|---|
| | Range | Amplitude | Alt | MCP |
| *B. mariaeterezae* (mari) | 1,265–1,270 | 5 | ? | ? |
| *B. olivaceus* (oliv) | 690–985 | 295 | - | 12,531.64 |
| *B. pernix* (pern) | 1,135–1,405 | 270 | 432.10 | - |
| *B. pombali* (pomb) | 845–1,300 | 455 | ? | ? |
| *B. quiririensis* (quir) | 1,240–1,380 | 140 | 1,338.97 | - |
| *B. tridactylus* (trid) | 805–910 | 105 | 41.42 | - |
| *B. verrucosus* (verr) | 455–945 | 490 | ? | ? |
| *Brachycephalus* sp. 4 (sp.4) | 1,250–1,320 | 70 | ? | ? |
| *Brachycephalus* sp. 5 (sp.5) | 1,000–1,080 | 80 | ? | ? |
| *Brachycephalus* sp. 6 (sp.6) | 1,095–1,160 | 65 | 2,211.54 | - |

859   [1] Abreviation in parentheses refers to species acronyms in Fig. 1.

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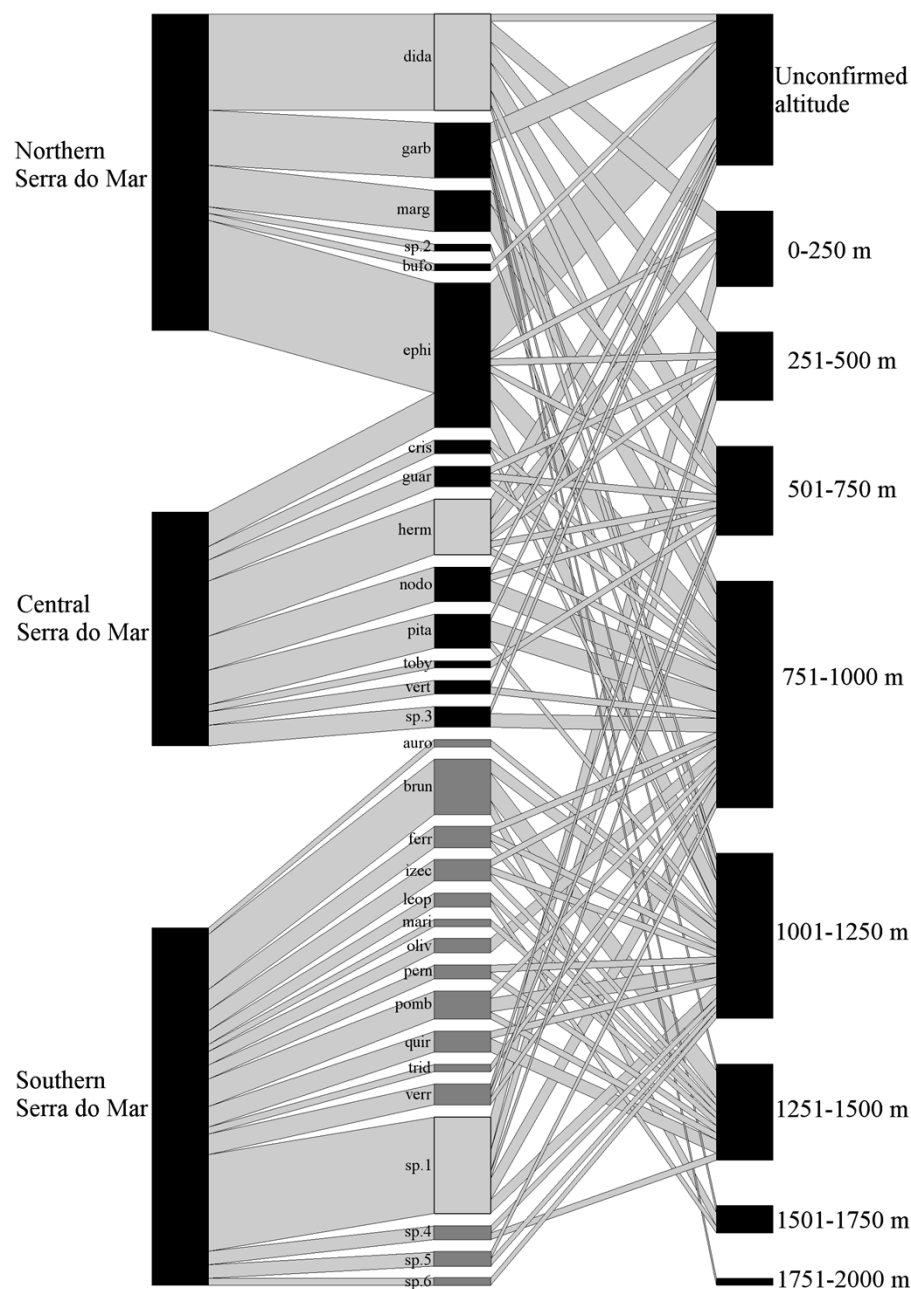
863 Figure 1. Geographical and altitudinal distribution of *Brachycephalus* spp. according to their

864 respective species group (light gray = *didactylus*, black = *ephippium*, and dark gray = *pernix*

865 group) across the three sectors of the Serra do Mar relief unit. The species connections represent

866 the occurrence in each sector of the relief unit (left boxes) and in altitudinal quotas (left boxes).

867 The width of the connections (in both directions) represents the proportional amount of citations

868    in the bibliography for each sector and altitude quotas (wider = more citations). See Tab. 4 for

869    the correspondence of the acronyms with the species name.

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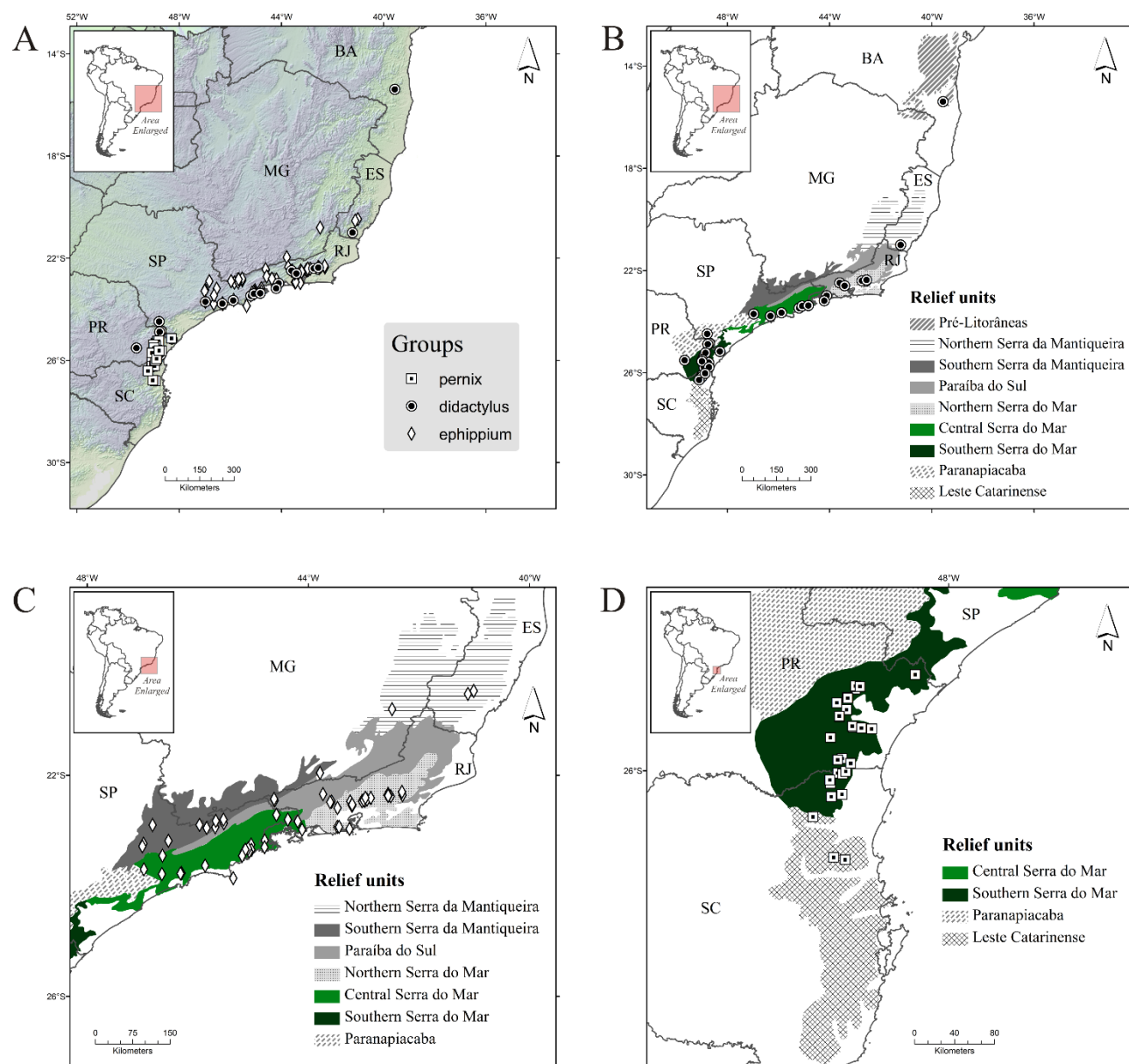
872

873    Figure 2. Occurrence records of *Brachycephalus* spp. A = all species; B = species of the

874    *didactylus* group; C = species of the *ephippium* group; D = species of the *pernix* group.

875    Diamonds = records of the *ephippium* group; circles = records of the *didactylus* group; and

876    squares = records of the *pernix* group. Abbreviations: BA = Bahia; MG = Minas Gerais; ES =

877    Espírito Santo; RJ = Rio de Janeiro; SP = São Paulo; PR = Paraná; and SC = Santa Catarina.

878    Relief units modified from IBAMA (2007).

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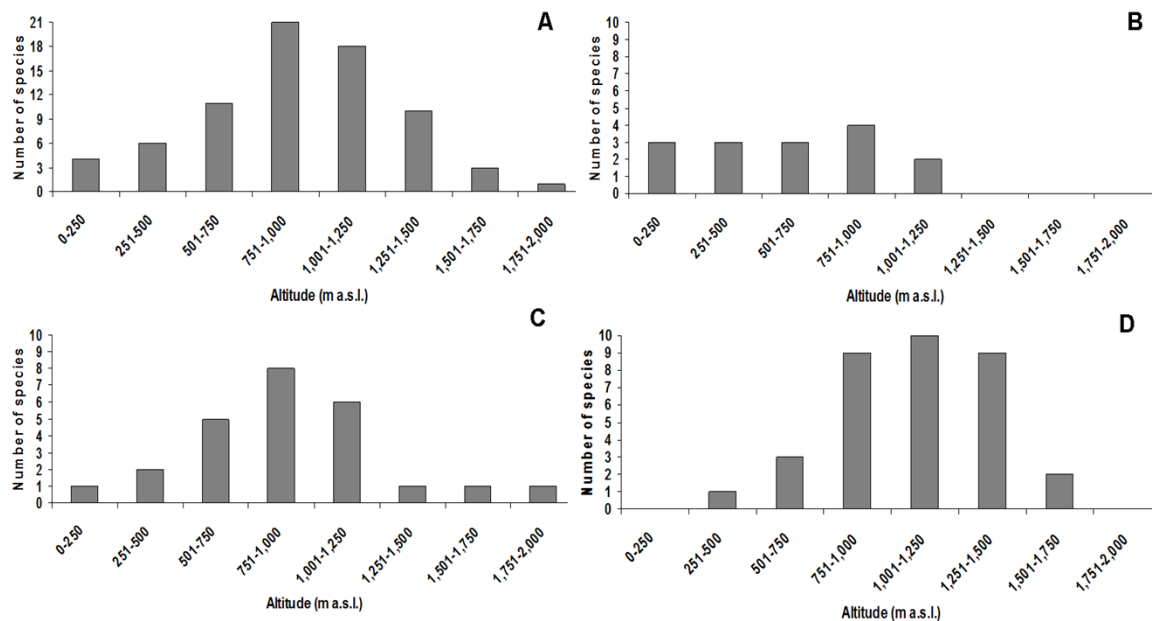
881

882   Figure 3. Species richness of *Brachycephalus* in each altitudinal class (including undescribed

883   species). A = all species; B = species of the *didactylus* group; C = species of the *ephippium*

884   group; D = species of the *pernix* group.

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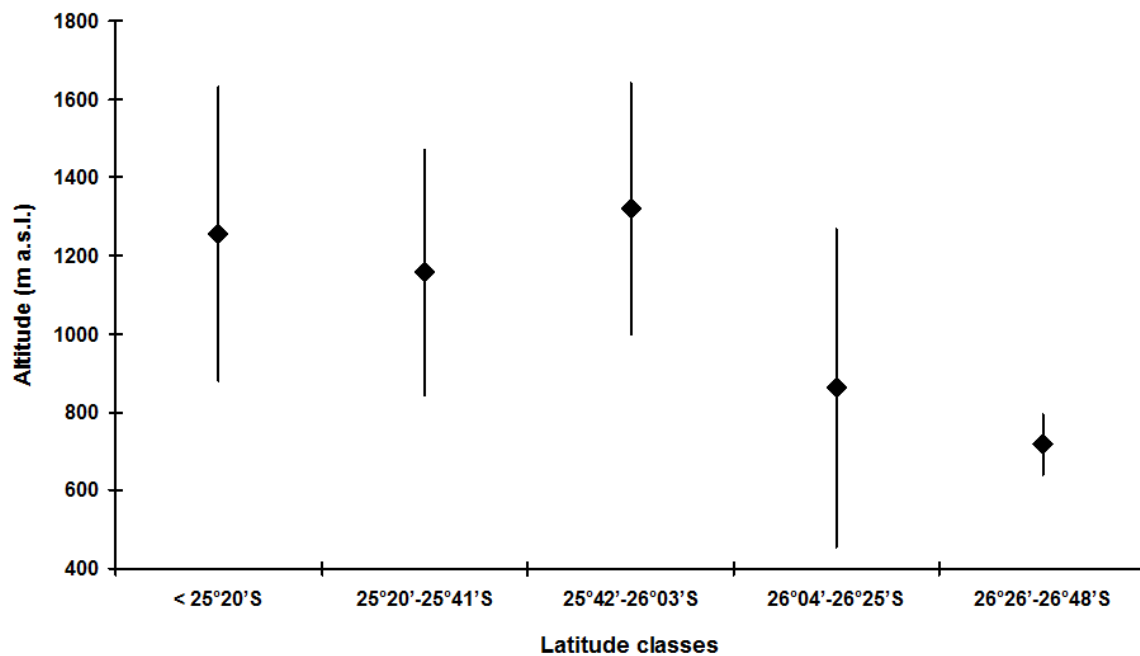
888    Figure 4. Altitudinal amplitude records of *Brachycephalus* spp. from the *pernix* group binned

889    into latitudinal classes (including undescribed species). Diamonds indicate median values.

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