SHORT COMMUNICATION

Reassessing overlooked information about the diagnosis of *Brachycephalus atelopoide* (Anura: Brachycephalidae), a neglected problem for the taxonomy of the genus

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The anuran genus *Brachycephalus* is divided into three phenetic species groups based on body shape and presence/absence of hyperossification (Ribeiro et al. 2015), characteristics that are relatively easy to examine in preserved specimens. Pie et al. (2018) reported a third feature (the *linea masculinea*) that differentiates these species groups, in addition to body shape and hyperossification. On the basis of these characters, all species of *Brachycephalus* can be assigned to one of the three species groups (e.g., Bornschein et al. 2019) except for one—*B. atelopoide* Miranda-Ribeiro, 1920, whose holotype is presumed to be lost (Pombal 2010). In 1920, Miranda-Ribeiro described four varieties of *B. ephippium* (Spix, 1824)—viz., *atelopoide, nodoterga, garbeana*, and *bufonoides* (Miranda-Ribeiro 1920). At the time, these “varieties” were not recognized as species because some frogs were found on the presumptive type localities that departed from their original description (Miranda-Ribeiro 1920). Seventy years later, the variety *nodoterga* was recognized as a full species of *Brachycephalus* (Heyer et al. 1990) when it was found at Estação Biológica de Boracéia, municipality of Salesópolis, state of São Paulo, Brazil.

Pombal (2010) reassessed the taxonomic status of the varieties of *Brachycephalus* described by Miranda-Ribeiro (1920) and...
recognized all of them as valid species. He also confirmed that specimens of *B. garbeanus* Miranda-Ribeiro, 1920 had been collected at the municipality of Nova Friburgo, state of Rio de Janeiro, Brazil, with additional reports of populations of this species having been reported since (e.g., Clemente-Carvalho et al. 2011, Dorigo et al. 2012). No recent reports exist of known populations of *B. atelopoide* and *B. bufonoides* Miranda-Ribeiro, 1920.

The *atelopoide* variety described by Miranda-Ribeiro (1920) was based on one individual of 30 that “perfectly” matched *B. ephippium* collected at Piquete, on the slope of the Mantiqueira Mountain Range, municipality of Piquete, state of São Paulo, Brazil. The *atelopoide* variety was distinguished by lacking “cephalic coating” and “dorsal shields”, and by having “protruding warts over the skin” (Miranda-Ribeiro 1920). *Brachycephalus ephippium* lacks protruding warts and has conspicuous hyperossification plates on the dorsal surfaces of head and body (e.g., Clemente-Carvalho et al. 2009); see the plate depicting *B. ephippium* in Miranda-Ribeiro (1920).

Hyperossification associated with a bufoniform body shape is the diagnosis of the *Brachycephalus ephippium* species group (Ribeiro et al. 2015), which includes *B. bufonoides*, *B. garbeanus*, and *B. nodoterga* Miranda-Ribeiro, 1920 (Bornschein et al. 2016a). However, *B. atelopoide* was not included in any of the three species groups of *Brachycephalus* (sensu Ribeiro et al. 2015) because presence/absence of hyperossification could not be determined (Bornschein et al. 2016a). In addition to the *B. ephippium* group, *Brachycephalus* also includes the *B. pernix* and *B. didactylus* groups that lack hyperossification. Both the *B. pernix* and *B. ephippium* groups have bufoniform bodies that distinguish them from members of the *B. didactylus* group with their leptodactyliform body shape (Ribeiro et al. 2015). Miranda-Ribeiro (1920) did not describe the body shape of *B. atelopoide*, but given that he distinguished *B. atelopoide* from a series of specimens identified as *B. ephippium* based on ossification characteristics and skin texture (Miranda-Ribeiro 1920), one would expect that it also had a bufoniform body.

Recent studies have shown that the extent of hyperossification in species of the *Brachycephalus ephippium* group varies intraspecifically and ontogenetically (Clemente-Carvalho et al. 2009, 2011, Campos et al. 2010, Pombal 2010). Pombal (2010) mentioned that the extent of hyperossification varies individually in *B. garbeanus*, being less well developed in smaller (and presumably more immature) frogs (see also Clemente-Carvalho et al. 2009, 2011). Hyperossification also varies ontogenetically in *B. ephippium* (Campos et al. 2010, Goutte et al. 2019). Thus, we might question the level of developmental maturation of the specimen described as *B. atelopoide*, as well its specific status.

Herein, we revise the diagnosis of *Brachycephalus atelopoide* by reviewing its original description and comparing this taxon with the other varieties that were described by Miranda-Ribeiro (1920), redescribed by Pombal (2010), and referenced in other taxonomic studies. We agree with Ribeiro et al. (2015), who suggested that the taxonomic status of *B. atelopoide* should be revisited. The type material of the other varieties described by Miranda-Ribeiro (1920) was not examined because the specimens are in poor condition and because there are excellent photographs available in Pombal (2010). The material we have examined of the other species is listed in Appendix I.

Upon reviewing Miranda-Ribeiro (1920), we noted three features in the description of *Brachycephalus atelopoide* that warrant discussion with respect to the description of *B. nodoterga*, which also was described based on a single individual. First, Miranda-Ribeiro (1920) mentioned that the varieties *nodoterga* and *atelopoide* have the same body shape, but *nodoterga* differs by having more abundant, large, elongate warts, in pairs, that might be ossified [osteoderms?]. This may indicate that
nodoterga lacked hyperossification (i.e., “cephalic coating” and body “dorsal shields”), as does atelopoide. However, in the redescriptions of B. nodoterga, Pombal (2010) reported hyperossification along the vertebrae and a pair of bony dorsal plates. Hyperossification of the trunk and of the center and sides of the head of the type of B. nodoterga is evident in Pombal (2010: Fig. 2); see also Figs. 5 and 6 of Clemente-Carvalho et al. (2009) and Fig. 6 of Haddad et al. (2010). Second, Miranda-Ribeiro (1920) reported that nodoterga was 15 mm long and apparently immature, like atelopoide. Pombal (2010) reported that the holotype of nodoterga was 12.4 mm in snout–vent length (SVL). Finally, Miranda-Ribeiro (1920) commented that nodoterga has a larger number of warts, which were themselves larger and more elongate, than did atelopoide. However, in the redescriptions of B. nodoterga, Pombal (2010) mentioned only the presence of “sparse protuberances, like warts”.

The characteristics of the holotype of Brachycephalus atelopoide relative to those of B. nodoterga suggest that B. atelopoide is a juvenile only about 12 mm long, having few warts on the body and presumably about the same level of hyperossification on the head and back as the holotype of B. nodoterga. These features were overlooked by Pombal (2010), as well as in most other studies of Brachycephalus. Of the 20 species of Brachycephalus species described between 2011 and 2020, most authors disregarded B. atelopoide. Thirteen species were described without mentioning B. atelopoide in their diagnoses—viz., B. albolineatus Bornschein, Ribeiro, Blackburn, Stanley, and Pie, 2016, B. auroguttatus Ribeiro, Firkowski, Bornschein, and Pie, 2015, B. boticario Pie, Bornschein, Firkowski, Belmonte-Lopes, and Ribeiro, 2015, B. coloratus Ribeiro, Blackburn, Stanley, Pie, and Bornschein, 2017, B. curupira Ribeiro, Blackburn, Stanley, Pie, and Bornschein, 2017, B. fuscolineatus Pie, Bornschein, Firkowski, Belmonte-Lopes, and Ribeiro, 2015, B. guarani Clemente-Carvalho, Giaretta, Condez, Haddad, and Reis, 2012, B. leopardus Ribeiro, Firkowski, and Pie, 2015, B. mariaeterezae Bornschein, Morato, Firkowski, Ribeiro, and Pie, 2015, B. olivaceus Bornschein, Morato, Firkowski, Ribeiro, and Pie, 2015, B. quiririensis Pie and Ribeiro, 2015, B. tridactylus Garey, Lima, Hartmann, and Haddad, 2012, and B. verrucosus Ribeiro, Firkowski, Bornschein, and Pie, 2015 (Clemente-Carvalho et al. 2012, Garey et al. 2012, Pie and Ribeiro 2015, Ribeiro et al. 2015, 2017, Bornschein et al. 2016b). Of the seven other species descriptions that do mention B. atelopoide in their diagnoses, we noted the following: (1) one (B. mirissimus Pie, Ribeiro, Confetti, Nadaline, and Bornschein, 2018; Pie et al. 2018) lacked a comparison because the holotype B. atelopoide is lost; (2) another (B. pulex Napoli, Caramaschi, Cruz, and Dias, 2011; Napoli et al. 2011) was compared without citing the source of data; (3) Brachycephalus crispus Condez, Clemente-Carvalho, Haddad, and Reis, 2014 (Condez et al. 2014) was compared using features that differ from those of the original description (Miranda-Ribeiro 1920) and redescriptions (Pombal 2010) of B. atelopoide; (4) the four remaining species descriptions included comparisons with the diagnosis of B. atelopoide. Brachycephalus margaritatus Pombal and Izecksohn, 2011 was compared with a holotype of B. atelopoide without hyperossification (Pombal and Izecksohn 2011). Brachycephalus sulfuratus Condez, Monteiro, Comitti, Garcia, Amaral, and Haddad, 2016 and B. actaeus Monteiro, Condez, Garcia, Comitti, Amaral, and Haddad, 2018 were compared to a holotype with an intermediate condition of hyperossification of the skull and skeleton (Condez et al. 2016, Monteiro et al. 2018) (these studies agreed with our interpretation, although these authors did not justify their conclusions). And last, B. darkside Guimarães, Luz, Rocha, and Feio, 2017 was compared with a holotype with osteoderms (Guimarães et al. 2017).

If ones assumes that the holotype of Brachycephalus atelopoide had an intermediate level of hyperossification, the species resembles
a juvenile *B. ephippium*. Campos et al. (2010) reported on the levels of hyperossification in the heads and vertebrae of juveniles of *B. ephippium* with SVLs of 8.1 mm, 10.6 mm, 12.8 mm, and 13.6 in SVL in contrast to adults of this species that attain a SVL to 19.7 mm (Pombal 2001). However, *B. ephippium* does not possess large and elongate warts. If *B. atelopoide* had an intermediate amount of hyperossification, it would also resemble adult *B. nodoterga*, *B. alipioi* Pombal and Gasparini, 2006, *B. crispus*, *B. guarani*, *B. pitanga* Alves, Sawaya, Reis, and Haddad, 2009, *B. toby* Haddad, Alves, Clemente-Carvalho, and Reis, 2010, and *B. vertebralis* Pombal, 2001, all of which have lower hyperossification than adult *B. ephippium* (Campos et al. 2010, Haddad et al. 2010, Clemente-Carvalho et al. 2012, Condez et al. 2014, 2020). In having large warts, *B. atelopoide* resembles *B. nodoterga*, *B. pitanga*, *B. crispus* (Campos et al. 2010, Condez et al. 2014, 2020), and especially *B. pitanga*, which has fewer of these warts.

In the absence of the holotype of *Brachycephalus atelopoide*, we cannot exclude the possibility that a species described after *B. atelopoide* may be a synonym of this species. For example, both *B. nodoterga* and *B. pitanga* are similar to *B. atelopoide*. Moreover, recently discovered populations of *B. tridactylus* in São Paulo (Appendix I) bear warts that are similar to those described for *B. atelopoide* on the sides of the body (MRB et al., unpub. data, 2019). The taxonomic problem is further complicated by the equivocal descriptions and analysis of Miranda-Ribeiro (1920), who overlooked the presence of hyperossification in *B. nodoterga* and *B. bufonoides* and mistakenly identified three *B. nodoterga* as *B. ephippium* (Pombal 2010). Flaws in diagnoses of recently described species of *Brachycephalus* with respect to *B. atelopoide* also contribute to the confusion. Perhaps the best working solution is to adopt Cochran’s (1955) proposal to place *Brachycephalus atelopoide* in the synonymy of *B. ephippium*, thereby avoiding nomenclatural confusion, according to article #23.9.3 of the International Zoological Nomenclature Code. We hope that in forthcoming taxonomic reviews, the authors will explore the morphological evidence more thoroughly.

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**References**


Reassessing the diagnosis of Brachycephalus atelopoide


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**Appendix I.** Specimens examined. Abbreviations: CFBH = Célrio F. B. Haddad collection, Departamento de Zoologia, Universidade Estadual Paulista, campus de Rio Claro, São Paulo state, Brazil; DZUP = Coleção Herpetológica do Departamento de Zoologia, Universidade Federal do Paraná, Curitiba, Paraná state, Brazil; MHNCI = Museu de História Natural Capão da Imbuia, Curitiba, Paraná state, Brazil; MNRJ = Museu Nacional, Rio de Janeiro, Rio de Janeiro state, Brazil; MZUSP = Museu de Zoologia da Universidade de São Paulo, São Paulo, São Paulo state, Brazil; and ZUEC = Museu de História Natural, Universidade Estadual de Campinas, Campinas, São Paulo state, Brazil.

**Brachycephalus actaeus.** BRAZIL. **SANTA CATARINA:** Serra da Tiririca, municipality of Itapopá MHNCI 10832–10834, 11024–11030.

**Brachycephalus albolineatus.** BRAZIL. **SANTA CATARINA:** Morro Azul, on the border between the municipalities of Pomerode and Rio dos Cedros MHNCI 10291, 10301, 10846; Morro Boa Vista, boundary of the municipalities of Jaraguá do Sul and Massaranduba MHNCI 10290 (holotype), MHNCI 10295–10300 (paratypes), MHNCI 10293 (juvenile), MHNCI two uncatalogued specimens, MNRJ 90349 (paratype); Morro do Garrafão, municipality of Corupá MHNCI 10836–10842; Morro do Schmidt, municipality of Pomerode MHNCI four uncatalogued specimens.

**Brachycephalus alliopoi.** BRAZIL. **ESPIRITO SANTO:** Alto Castelinho, municipality of Vargem Alta MHNCI 10804–10806.

**Brachycephalus aurourostratus.** BRAZIL. **SANTA CATARINA:** Pedra da Tartaruga, municipality of Garuva DZUP 375 (holotype), DZUP 373–374, 376–385, 387–389 (all paratypes); trail to Pedra da Tartaruga, municipality of Garuva MHNCI six uncatalogued specimens.

**Brachycephalus boticario.** BRAZIL. **SANTA CATARINA:** Morro do Cachorro, boundary of the municipalities of Blumenau, Gaspar, and Luiz Alves DZUP 440 (holotype), DZUP 414, 415, 438, 439, 444, 445, 459 (all paratypes), MHNCI three uncatalogued specimens.

**Brachycephalus brunneus.** BRAZIL. **PARANÁ:** Abrigo 1, municipality of Campina Grande do Sul DZUP 517–519; Camapuá, Serra dos Órgãos, boundary of the municipalities of Campina Grande do Sul and Antonina MHNCI 10165–10174; Caratuva, Serra dos Órgãos, municipality of Campina Grande do Sul MHNCI 1919, 1920, 10175–10184, 10733, 10734, MNRJ 40289–40291 (paratypes); Mãe Catira, Serra da Graciosa, municipality of Quatro Barras DZUP 140, 230, MHNCI 10784.

**Brachycephalus coloratus.** BRAZIL. **PARANÁ:** Estância Hidroclimática Recreio da Serra, Serra da Baitaca, municipality of Piraquara MHNCI 10273 (holotype), MHNCI 10274–10279 (paratypes), MNRJ 89949, 89950 (paratypes), DZUP 600; Pão de Ló, Serra da Baitaca, municipality of Quatro Barras MHNCI one uncatalogued specimen.

**Brachycephalus curupira.** BRAZIL. **PARANÁ:** Morro do Vigia, municipality of Piraquara MHNCI 10724–10728; Morro do Vigia, municipality of Piraquara MHNCI 10723; Serra do Salto, Malhadá District, municipality of São José dos Pinhais MHNCI 10280 (holotype), MHNCI 10281–10287, 10292 (all paratypes).

**Brachycephalus didactylus.** BRAZIL. **RIO DE JANEIRO:** municipality of Engenheiro Paulo de Frontin ZUEC 10825; Sacra Família do Tinguá, municipality of Engenheiro Paulo de Frontin ZUEC 1132, 1133 (topotypes), MZUSP 13613–13620, 64810, 64811, 46421 (topotypes).

**Brachycephalus ephippium.** BRAZIL. **RIO DE JANEIRO:** Parque Nacional Serra dos Órgãos MZUSP 104140–104147; Vale de Revolta MCZ A-108655. **SAO PAULO:** municipality of Cotia MHNCI 2611–2616.

**Brachycephalus ferruginus.** BRAZIL. **PARANÁ:** Olimpo, Serra do Marumbi, municipality of Morretes MHNCI 125, 128 (topotypes), DZUP 562 (topotype), MHNCI five uncatalogued specimens (topotypes).

**Brachycephalus fuscolineatus.** BRAZIL. **SANTA CATARINA:** Morro do Baú, municipality of Ilhota DZUP 159 (holotype), DZUP 158, 160, 401–405 (all paratypes), MHNCI three uncatalogued specimens; Morro Braço da Onça, municipality of Luiz Alves MHNCI 10850, 10851.

**Brachycephalus hermogenesi.** BRAZIL. **SAO PAULO:** Picinguaba, Parque Estadual da Serra do Mar, municipality of Ubatuba ZUEC 9715 (holotype), ZUEC 9716–9725 (paratypes); Corcovado, municipality of Ubatuba MHNCI 10823–10825.

**Brachycephalus izecksohni.** BRAZIL. **PARANÁ:** Torre da Prata, Serra da Prata, boundary of the municipalities of Morretes, Paranaçu, and Guaratuba CFBH 7381, 7382, 7384 (all paratypes), MHNCI 10835, DZUP 561.

**Brachycephalus leopoldus.** BRAZIL. **PARANÁ:** Morro dos Perdidos, municipality of Guaratuba DZUP 274–283, MHNCI 10783, MHNCI three uncatalogued specimens; Serra do Araçatuba, municipality of Tijuca do Sul MHNCI 10250 (holotype), MHNCI 10239–10249, 10251, 10252 (all paratypes), MHNCI two uncatalogued specimens, DZUP 520–523.

**Brachycephalus mariaeterzeae.** BRAZIL. **SANTA CATARINA:** Reserva Particular do Patrimônio Natural Caetetal, top of the Serra Queimada, municipality of Joinville MHNCI 9811 (holotype), DZUP 372, 393–399 (all paratypes).

**Brachycephalus miríssimus.** BRAZIL. **SANTA CATARINA:** Morro Santo Anjo, municipality of Massaranduba MHNCI 10793 (holotype), MHNCI 10794–10803 (paratypes), MHNCI two uncatalogued specimens.

**Brachycephalus nodoterga.** **SAO PAULO:** Reserva Biológica Tamboré, municipality of Santana de Parnaíba MZUSP 147711–147716.
Brachycephalus olivaceus. BRAZIL. SANTA CATARINA: base of the Serra Queimada, municipality of Joinville MHNCI 9813 (holotype), DZUP 371 (paratype); Castelo dos Bugres, municipality of Joinville MHNCI 9814–9818 (paratypes), MHNCI 10 uncatalogued specimens; Morro do Boi, municipality of Corupá MHNCI 10288, 10289; Pico Jurapê, municipality of Joinville MHNCI one uncatalogued specimen.

Brachycephalus pernix. BRAZIL. PARANÁ: Anhangava, Serra da Baitaca, municipality of Quatro Barras MNRJ 17349 (holotype), CFBH 2597, 2598 (paratypes), MHNCI 1818, 1889, 3000–3004 (all paratypes), MHNCI 1820, ZUEC 9433–9437 (paratypes), MHNCI 9806–9810, 10153–10164.

Brachycephalus pitaonga. BRAZIL. SÃO PAULO: rodovia SP-125, municipality of São Luiz do Paraítinga MHNCI 10733, 10734; Trilha do Ipiranga 50 m from the Rio Ipiranga, Núcleo Santa Virgínia, Parque Estadual da Serra do Mar, municipality of São Luiz do Paraítinga MHNCI 10733, 10734, 10821, 10822, 10843 (all topotypes), DZUP 409 (topotype).


Brachycephalus quiririensis. BRAZIL. SANTA CATARINA: Serra do Quiriri, municipality of Campo Alegre MHNCI 10261 (holotype), MHNCI 10260, 10262–10272 (all paratypes), DZUP 531–535.

Brachycephalus sulfuratus. BRAZIL. SÃO PAULO: Caratuval, near the Parque Estadual das Lauráceas, municipality of Adrianópolis DZUP 139; Corvo, municipality of Quatro Barras DZUP 221–224; Mananciais da Serra, municipality of Piraquara MHNCI 10302; Recanto das Hortências, municipality of São José dos Pinhais DZUP 463; Salto do Inferno, Rio Capivari, municipality of Bocaiuva do Sul MHNCI 9800. SANTA CATARINA: Morro do Garrafão, municipality of Corupá MHNCI 10826–10828.


Brachycephalus tridactylus. BRAZIL. PARANÁ: Serra do Morato, Reserva Natural Salto Morato, municipality of Guaíraçabá MHNCI 10185–10189, 10294, 10729, 10730 (topotypes), CFBH 43887–43890 (topotypes). SÃO PAULO: Bairro Rio Vermelho, municipality of Barra do Turvo MHNCI two uncatalogued specimens; Estrada das Conchas, municipality of Barra do Turvo MHNCI one uncatalogued specimen; Fazenda Fronteira, municipality of Barra do Turvo MHNCI seven uncatalogued specimens; Morro do Bisel, Serra do Guarani, municipality of Cajati DZUP 687; Serra do Pinheiro, municipality of Cajati MHNCI five uncatalogued specimens; Serra Pelada, municipality of Barra do Turvo DZUP 688–691; Torre Embratel, municipality of Cajati MHNCI 10848, 10852, DZUP 676–686.

Brachycephalus verrucosus. BRAZIL. SANTA CATARINA: Morro da Tromba, municipality of Joinville MHNCI 9819 (holotype), MHNCI 9820 (paratype), DZUP 464–478 (paratypes).


Brachycephalus sp. BRAZIL. PARANÁ: Chapeuzinho, boundary of the municipalities of Morretes and Piraquara DZUP 502–504; Pedra Branca do Araraquara, Serra do Araraquara, municipality of Guaratuba DZUP 400; Serra Canasvieiras, boundary of the municipalities of Guaratuba and Morretes MHNCI 10785, DZUP 452, 453. SANTA CATARINA: Morro da Pedra, municipality of Ilhota MHNCI two uncatalogued specimens; Morro da Prata, municipality of Itapetininga MHNCI four uncatalogued specimens; Morro dos Monos; municipality of Luiz Alves MHNCI two uncatalogued specimens.