A preliminary survey and range extension of millipedes species introduced in Brazil (Myriapoda, Diplopoda)

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Abstract. The present study provides historical and new records of the introduced millipedes species in Brazil, Oxidus gracilis (C.L. Koch, 1847), Orthomorpha coarctata (Saussure, 1860) (Paradoxosomatidae), Prosopodesmus jacobsoni (Silvestri, 1910) (Haplodesmidae), Trachyjulus calvus (Pocock, 1893a), Glyphiulus granulatus (Gervais, 1847) (Cambalopsidae), Trigoniulus corallinus (Gervais, 1842), Leptogoniulus sorornus (Butler, 1876), Epitrigoniulus cruentatus (Brölemann, 1903) (Pachybolidae), Paraspirobolus lucifugus (Gervais, 1837) (Spirobolellidae), Cylindroiulus britannicus (Verhoeff, 1891), Cylindroiulus truncorum (Silvestri, 1896) (Julidae), and Rhinotus purpureus (Pocock, 1894) (Siphonotidae). Among the 27 federative units in Brazil, 21 states present at least one record of a non-native species. Orthomorpha coarctata was the most widely distributed species, occurring in 15 states. Glyphiulus granulatus (state of Rio Grande do Sul), C. truncorum (São Paulo), and R. purpureus (Amazonas) were recorded from only one Brazilian state. The Southeast region concentrates most of the compiled records (42.6%) and richness by grid (5-7 species), mainly in urban areas of the states of Rio de Janeiro and São Paulo.

Keywords. Invasive species; Synanthropic millipedes; Schubart; Oxidus gracilis; Orthomorpha coarctata.

INTRODUCTION

Members of the class Diplopoda are distributed on all continents, excepting the Antarctica (Hoffman, 1980; Golovatch & Kime, 2009). Millipedes are commonly observed on tropical, subtropical, and temperate forests (Golovatch & Kime, 2009), performing important ecological roles as detritivorous and biogeographical indicators (Schubart, 1942b; Crawford, 1992; Golovatch & Kime, 2009; Suzuki et al., 2013; Nsengimana et al., 2018; Potapov et al., 2019).

Introduced species are widely accepted as one of the main direct causes of biodiversity loss and habitat alteration (Didham et al., 2005). In addition, non-native species have been reported as widely introduced around the world by human activities such as gardening, cultivation of plants, and soil transport. Numerous studies have reported the presence of millipedes in man-made habitats (Vicente & Enghoff, 1999; Golovatch & Kime, 2009; Shelley & Golovatch, 2011), including well-established populations in urban and rural areas (Hopkin & Read, 1992; Korsós et al., 2002; Bogyó et al., 2015). Some millipedes have been reported as pests causing significant economic damage (Butcher, 1936; Kuria & Eijnatten, 1981; Brunke et al., 2012). In Brazil, some introduced millipedes are considered agricultural pests in poly- or monocultures based on observations of immatures and adults feeding on seedlings, tubers, and fruits (Schubart, 1942b; Boock & Lordello, 1952; Lordello, 1954). Importantly, the identification of a given species as introduced depends on the
availability of taxonomic data across large geographical regions. However, except for descriptive papers and taxonomic revisions made mainly by the authors Schubart, Brölemann, and Hoffman in the last century, there is no an updated list of millipede species for Brazil.

Based on a substantial material of millipedes from Brazilian collections, new records of non-native species were detected. In this perspective, to promote further studies regarding the millipedes in the country, the current study presents a preliminary survey of introduced millipedes species and their distribution. Maps for each species and comments on their identifications are provided here.

**MATERIAL AND METHODS**

The occurrence data for the introduced species was extracted from the literature and material deposited in the following institutions (curators in parentheses): IBSP, Instituto Butantan, São Paulo (A.D. Brescovit); INPA, Instituto Nacional de Pesquisas da Amazônia, Manaus (M.L. de Oliveira); MGN, Museu de Ciências Naturais, SEMA, Porto Alegre (R. Ott); MCTP, Museu de Ciências e Tecnologia da Pontífícia Universidade Católica do Rio Grande do Sul, Porto Alegre (R. Teixeira); MHNCI, Museu de História Natural do Capão do Imbuia, Curitiba (V. Abilhoa); MNRJ, Museu Nacional, Universidade Federal do Rio de Janeiro, Rio de Janeiro (A.B. Kury); MPEG, Museu Paraense Emílio Goeldi, Belém, Pará (A.B. Bonaldo); MZ/Unisinos, Museu de Zoologia da Unisinos, São Leopoldo, Rio Grande do Sul (E.N.L. Rodrigues); MZSP, Museu de Zoologia, Universidade de São Paulo (R. Pinto-da-Rocha); UFMG, Universidade Federal do Mato Grosso, Cuiabá (A. Chagas-Jr.).

Morphological observations and drawings were made using a Leica MZ 12 stereomicroscope. Photographs were taken with a Leica DFC 500 digital camera mounted on a Leica MZ 16A stereomicroscope and extended focal range images were composed with Leica Application Suite version 2.5.0, at IBSP. The specimens are preserved in 70% or 80% ethanol. The determination of the species was based on the descriptive notes and revisions performed by Schubart (1942c, 1946a, b), Mauriès (1980), Blower (1985), Korsós & Enghoff (1990), Shelley & Lehtinen (1999), Likhitrakarn et al. (2011), Golovatch et al. (2007, 2012), Wesener (2014) and Nguyen et al. (2017). All records obtained are mapped in the Figs. 1-2 and Table 1.

The geographical coordinates and collection data were obtained from the original literature (when provided) or the labels for each specimen consulted. We used the centroids of the municipalities when the exact locality was not provided. The data of the species are noted for each taxon according to the following pattern: Material examined: State: County, locality [geographical coordinates], data, collector (voucher); Historical records: State: County, locality [geographical coordinates], data, collector (reference consulted). The records gathered from the literature were compiled with all information provided by their respective authors, although some of these records only the localities were informed.

### Table 1. Federative units in Brazil with records of introduced species. Abbreviations: AC = Acre; AL = Alagoas; AM = Amazonas; BA = Bahia; DF = Distrito Federal; ES = Espírito Santo; GO = Goiás; MT = Mato Grosso; MS = Mato Grosso do Sul; MG = Minas Gerais; PA = Pará; PB = Paraíba; PR = Paraná; PE = Pernambuco; RJ = Rio de Janeiro; RS = Rio Grande do Sul; RO = Rondônia; SC = Santa Catarina; SP = São Paulo; TO = Tocantins.

| Order Polydesmida | North | Northeast | Central-West | Southeast | South |
|-------------------|-------|-----------|--------------|-----------|-------|
| Paradoxosomatidae |       |           |              |           |       |
| Ooides gracilis   | +     |           |              |           |       |
| Orthomorpha coarcta | +     |           |              |           |       |
| Haplogmesmatidae  |       |           |              |           |       |
| Protocampus jacobsoni |       |           |              |           |       |
| Cambalopsidae     |       |           |              |           |       |
| Trachyjulus calvus | +     |           |              |           |       |
| Glyphiulus granulatus | +     |           |              |           |       |
| Pachybolidae      |       |           |              |           |       |
| Trigranulium carinatum | +     |           |              |           |       |
| Epigranulium soranus | +     |           |              |           |       |
| Spirobolidae      |       |           |              |           |       |
| Paranespolus lucifugus | +     |           |              |           |       |
| Julidae           |       |           |              |           |       |
| Cylindrojulus truncatus | +     |           |              |           |       |
| Siphonolidae      |       |           |              |           |       |
| Rhinotus purpureus | +     |           |              |           |       |

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**RESULTS**

**Order Polydesmida**

**Family Paradoxosomatidae**

*Oxidus gracilis* (C.L. Koch, 1847)

(Figs. 1A, 4B, 5A)

**Descriptive notes:** See Nguyen et al. (2017: 6, figs. 1-2).

**Note:** Based on examined material, immatures and females of *O. gracilis* cannot be identified and morphologically distinguished from those of *Orthomorpha coarctata*.

**Identification:** The species can be easily distinguished from autochthones Neotropical paradoxosomatids mainly by gonopod features (Fig. 5A). Males of *O. gracilis* are recognized by femorite strongly expanded distally; postmoral spine pointed tuberculiform; postmoral process lamellar and bent upwards from midpart, serrated at distolateral portion; solenosphere with mesal lobe well-developed (see Nguyen et al., 2017).

**Distribution:** *Oxidus Cook, 1911* occurs in the SE Asia (Jeekel, 1968; Nguyen et al., 2017), while the species *O. gracilis* is widely distributed around the world due to commercial activities (Nguyen & Sierwald, 2013), occurring in USA and Hawaii (Shelley et al., 1998), Europe (Blower, 1985), and Asia (Korsós, 2004; Nguyen et al., 2017). The species is considered urban and agricultural pest (O’Neill & Reichle, 1970). In Brazil, the species presents a large distribution range, occurring in urban and

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**Figure 1.** Distribution maps of *Oxidus gracilis*, *Orthomorpha coarctata* (Polydesmida, Paradoxosomatidae), *Prosopodesmus jacobsoni* (Polydesmida, Haplodesmidae), *Glyphiulus granulatus* (Spirostreptida, Cambalopsidae), *Trachyjulus calvus* (Spirostreptida, Cambalopsidae), *Epitrigoniulus cruentatus* (Spirobolida, Pachybolidae), and *Cylindroiulus britannicus* (Julida, Julidae).
rural areas, greenhouses, caves, and in forests partially preserved (Iniesta et al., 2020).

**Material examined:**

**Amazonas:** Manaus [-03.063877°S; -60.036493°W], Embrapa Amazonônia Ocidental, banana plantation, near the Climatology laboratory, 28.iv.2016, T.M. Almeida & A.E.C. Silveira coll., 12♂ 8♀ 2 immatures (INPA);

**Distrito Federal:** Sobradinho [-15.65854°S; -47.791846°W], cave Face Leste, 26.vi.2013, M.P. Bolfarini coll., 2♂ (IBSP 5509);

**Mato Grosso do Sul:** Corumbá [-19.577553°S; -57.037810°W], cave California, 17.iii.2001, C.S. Escarpinati coll., ♀ (IBSP 4276); Bodoquena [-20.631661°S; -56.652781°W], cave Victoria, 27.i.2000, R. Ferreira coll., 2♂ 2♀ (IBSP 3602); Itacarambi [-15.092057°S; -44.133344°W], Vilarejo Fabião II, 05.vii.2011, J.P.P. Pena-Barbosa coll., ♀ (IBSP 3726); Cordisburgo [-19.050250°S; -44.209663°W], Morena cave, 12-15.x.2007, ♀ (IBSP 3558); ♀ (IBSP 3556); ♀ (IBSP 3557); Lagoa Santa [-19.635088°S; -43.898478°W], 21.x.1947, O. Schubart coll., 5♂ 3♀ 3 immatures (MZSP); Vicosa [-20.756373°S; -42.883016°W], EAV, 14.x.1947, O. Schubart coll., 2♂ (MZSP); Ouro Preto [-20.395727°S; -43.502578°W], 17.x.1947, O. Schubart coll., 4♂ ♀ 1 immature (MZSP); Rio Acima [-20.088882°S; -45.391390°W], cave 0020_VG43, 02-10.vii.2011, R. Andrade coll., ♀ ♀ (IBSP 6622); 2♂ ♀ (IBSP 6671); cave SPD_38, 25-27.vii.2013, Bessi et al., coll., ♀ ♀ (IBSP 7150); ♀ (IBSP 7149); Matozinhos [-19.565584°S; -44.078665°W], cave LF_22, 16.viii-14. ix.2017, Eq. Spelayon coll., 2♂ ♀ (IBSP 7473); Espirito...

**Figure 2.** Distribution maps of *Trigonius carallinis*, *Leptogoniulus sorornus* (Spirobolida, Pachybolidae), *Cylindroiulus truncorum* (Julida, Julidae), *Paraspirobolus lucifugus* (Spirobolida, Spirobolellidae), and *Rhinotus purpureus* (Polyzoniida, Siphonotidae).
Santo: Sooretama [-19.1979°S; -40.0913°W], 24.ii.2011, A.F.R. Teixeira coll., 2♀ (MCN); Rio de Janeiro: Rio de Janeiro [-22.921765°S; -43.169510°W], O. Schubart coll., 22 immatures (MNRJ 11749); São Paulo: Arujá [-22.668644°S; -46.320865°W], 06.xii.1995, Vigilância Sanitária Guarulhos coll., 3♀ (IBSP 944); Guarulhos [-23.678875°S; -46.543425°W], 28.ii.2002, Prefeitura Municipal de Guarulhos coll. (IBSP 903); Olímpia [-20.741815°S; -48.911570°W], xi.1916, E. Garb coll., σ (MZSP); Santo André [-23.678234°S; -46.543425°W], x.1939, B.L. Bastiani coll., 2♂ 3♀ (IBSP 28); São Paulo [-23.567300°S; -46.633047°W], 01.i.1956, J. Becker coll., 2♂ 3♀ (MNRJ); 2♂ 2♀ (IBSP 34); iv.1939, F. Paes de Barros coll., 2♂ 5♀ (IBSP 34); vii.1940, W. Bücherl coll., 4♂ 9♀ (IBSP 23); Tremembé [-23.464143°S; -46.625706°W], 10.x.2001, L. Goes & L. Silva coll., 9♀ (MNRJ); Santana [-23.501011°S; -46.626233°W], 08.x.1998, Centro Zoonoses Prefeitura Municipal de São Paulo coll., 9♀ (IBSP 678); Vila Gomes [-23.576975°S; -46.732075°W], 26.viii.1998, F. Henrique coll., 2♀ 3♂ (IBSP 683); Saúde [-23.619984°S; -46.635291°W], 14.xi.2000, P. Kitamoto coll., 10♂ 12♀ 1 immature (IBSP 825); Jardim Rizzo [-23.572008°S; -46.732739°W], 20.xi.1998, Equipe IBSP coll., 3♀ 2♂ 3♀ (IBSP 673); Mogi das Cruzes, Parque São Martinho [-23.614280°S; -46.236089°W], 17.xi.2018, R.S. Bouzan coll., 3♂ 2♀ 2 immatures (IBSP 7757); Paraná: Piraquara

Figure 3. Introduced species in Brazil: (A) Brazilian regions; (B) Proportion of species by states and regions; (C) Richness by grid 1°×1°. See Table 1 for the abbreviations of the states.
Historical records: *Rio de Janeiro*: Petrópolis [-22.921765°S; -43.169510°W], O. Schubart coll. (Schubart, 1945b); *São Paulo*: Amparo, Fazenda São Bento [-22.668644°S; -46.737739°W], 08.iii.1943, F. Lane coll., 9♂ 1♀ immature (Schubart, 1945a); Mogi Guacu [-22.185269°S; -47.097326°W], 06.vi.1941, 6♂ 9♀ imatures (Schubart, 1944); Monte Alegre [-22.691374°S; -46.628625°W], 12.iv.1944, 9♂ 7♀ imatures (Schubart, 1945a); Estação Experimental, 12.iv.1944, 13♂ 7♀ (Schubart, 1945a); Pirassununga [-22.067267°S; -47.395011°W], 17.i.1940, 10♂ 11♀ 5 immature (Schubart, 1944); 03.iv.1940, 5♂ 7♀ 26 imatures (Schubart, 1944); 22.v.1940, 9♂ 1♀ immature (Schubart, 1944); 30.vii.1940, 5♂ 5♀ (Schubart, 1944); 13.i.1941, 4♂ 3♀ 2 immature (Schubart, 1945a); Fazenda São Domingos, 22.ix.1940, 16♂ 21♀ 1 immature (Schubart, 1945a); Fazenda Graciosa, 25.x.1940, 52♂ 31♀ 21 immature (Schubart, 1945a); Cachoeira, 23.x.1940, 9♀ (Schubart, 1944); 10.i.1941, 2♂ 1 immature (Schubart, 1944); Fazenda Pedra Branca, 15.ii.1941, J. Gaspar coll., 2♂ 9♀ (Schubart, 1944); Rio Claro [-22.429577°S; -47.518696°W], 03.vi.1944, 22♂ 13♀ 13 immature (Schubart, 1944); Santa Rita [-23.516379°S; -46.414041°W], 03.xi.1940, 9♀ (Schubart, 1944); *Paraná*: Curitiba [-25.495342°S; -49.303308°W], 31♂ 23♀ (Schubart, 1953); Pirajuara [-25.454547°S; -49.062333°W], Banhado (Schubart, 1953); *Santa Catarina*: Florianópolis [-27.602630°S; -48.541769°W], iv.1946, Gofferjé coll. (Schubart, 1953); *Rio Grande do Sul*: São Francisco de Paula, Centro de Pesquisas e Conservação da Natureza Pró-Mata [-29.481206°S; -50.173833°W], 2016, P.E.S. Rodrigues et al. coll. (Rodrigues et al., 2017).

*Orthomorpha coarctata* (Saussure, 1860) (Figs. 1B, 4A, 5B)

Descriptive notes: See Likhitarkarn et al. (2011: 12, figs. 4-8).

Note: Based on examined material, immatures and females of *O. coarctata* cannot be identified and morphologically distinguished from those of *Oxidus gracilis*. The species was placed in the genus *Asiomorpha* by Verhoeff (1939), and its taxonomic position is under discussion (see Likhitarkarn et al., 2011, 2019; Nguyen & Sierwald, 2013). For a listing purpose, we maintained the species in *Orthomorpha* according to the latest taxonomic reviews (for more details, see Likhitarkarn et al., 2011, 2019).

Identification: The species can be easily separated from autochthones Neotropical paradoxosomatids mainly by gonopod features (Fig. 5B). Males of *O. coarctata* are recognized by a single terminal lobeule on gonopod tip; spikes and denticles either missing or nearly missing (Likhitarkarn et al., 2011, 2019).

Distribution: The species is widely distributed in the tropics (Nguyen & Sierwald, 2013), occurring in USA, Hawaii (Shelley et al., 1998), Caribbean islands (Nguyen & Sierwald, 2013), and SE Asia (Korsós, 2004). *Orthomorpha coarctata* is distributed predominantly in the North and Southeast regions in Brazil, occurring in urban and rural areas, greenhouses, forests, and islands.

Material examined: *Acre*: Rio Branco [-09.95938889°S; -67.85665556°W], 09.x.2017, J.A. Rafaela coll., ♀ (INPA); *Amazonas*: Boca do Têfê [-03.488378°S; -64.843366°W], mata rio Solimões, ix.1952, Equipe IBSP coll., 6♂ 2♀ (IBSP 106); Careiro da Várzea, Ilha do Careiro [-03.16607500°S; -59.73265278°W], 08.vii.1997, K. Vohland coll., ♀ (INPA); Manaus, Residencial Nascentes do Tarumá [-02.99222222°S; -60.03416667°W], 05.vii.2016, T. Mahlmann coll., 20♂ 61♀ (INPA); Igarapé Cururu [-03.12666667°S; -59.94055556°W], 22-24. ii.2007, N.O. Aguiar et al., ♀ (INPA); Bosque da Ciência [-03.09743889°S; -59.98781389°W], 07.v.2017, T.M. Almeida coll., 31♂ 13♀ (INPA); Instituto Nacional de Pesquisas da Amazônia, campus II [-03.096214°S; -59.989578°W], 20.iv.2016, 2♂ (INPA); campus INPA, secondary forest [-03.13333333°S; -60.01666667°W], 03.viii.1995, J. Adis et al., coll., 21♂ 10♀ (INPA); campus de Universidade Federal do Amazonas (UFAM) [-03.10022444°S; -59.97850000°W], 07.x.2005, M.L. Custódio coll., ♀ (INPA); Embrapa Amazonia Ocidental, banana plantation, near the Climatology laboratory [-02.8936805566°S; -59.97306667°W], 28.iv.2016, T.M. Almeida & A.E.C. Silveira colle, ♀ (INPA); Reserva Florestal Adolpho Ducke [-02.96334444°S; -59.92283333°W], 17.v.2014, 7♂ 6♀ (INPA); 23.vii.2015, 2♂ (INPA); 20.xii.2018, T.M. Almeida coll., 6♂ 4♀ (INPA); Presidente Figueiredo [-01.797655°S; -59.973033°W], 16.vii.1996, K. Vohland coll., ♀ (INPA); *Rondônia*: Porto Velho, Parque Municipal [-10.738177°S; -62.218467°W], 02.i.2010, G. Miranda coll., ♀ 2♂ 1 immature (MNRI); Porto Velho, campus Universidade Federal de Rondônia – UNIR [-08.76349167°S; -63.906575°W], tree trunk, 14.xi.2016, A. Andriolo coll., ♀ (INPA); *Pará*: Piracuara [-03.161651°S; -55.992846°W], 08.vii.2013, J. de Fronte coll., ♀ (INPA); Belterra, urban area [-03.161651°S; -54.965476°W], 26-29.x.2009, Equipe IBSP coll., ♀ (IBSP 7758); *Maranhão*: João Pessoa [-07.124538°S; -34.845187°W], O. Schubart
Figure 4. Introduced species in Brazil, habitus: (A) Orthomorpha coarctata; (B) Oxidus gracilis; (C, D) Glyphiulus granulatus; (E) Trigonius corallinus; (F) Rhinotus purpureus. Scale bars: 2 mm (A, B, E); 500 µm (C, D); 200 µm (F).
Prominent millipedes were found in various locations across Brazil, with the following records:

**Teixeira coll.**
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  (MCN); **Rio de Janeiro:** Mangaratiba, Rio Junqueira [−22.930954°S; −44.038933°W], O. Schubart coll., 71♂ (MCN 11697); Rio de Janeiro [−22.921765°S; −43.169510°W], 28.i.1951, J. Becker coll., 2♂ (MCN); O. Schubart coll., ♂ (MCZS); **São Paulo:** Ubatatiba [−23.446317°S; −45.087149°W], 12-13.ix.1998, R. Martins coll., ♀ (IBSP 680), Piracicaba [−23.059153°S; −46.360347°W], x.1996, S. Rocha coll., ♂ (IBSP 691); Itu [−23.272062°S; −47.299290°W], 11.i.1985, R. D'Avila coll., 13♂ [IBSP 667]; São Paulo, Jardim Rizzo [−23.572008°S; −46.732379°W], 20.xi.1998, Eq. IBSP coll., ♂ (IBSP 7759); **Parana:** Curitiba [−25.495342°S; −49.303308°W], 2♂ (IBSP 7760).

**Historical records:**
- Amazonas: **Manaus** [−03.023045°S; −59.965390°W], Bicego coll. (Brolleman, 1904); Embrapa Amazônia Occidental [−02.893744°S; −59.973109°W] (Hoffman et al., 2002); **Pará:** João Pessoa [−07.1150°S; −34.8631°W], 10.vi.1937, E. Cordeiro coll. (Schubart, 1939); **Pernambuco:** Recife [−08.0539°S; −34.8811°W], Bairro dos Afogados, 13.v.1935 (Schubart, 1942); margin of Rio Capibaribe, 30.xii.1935 (Schubart, 1942); margin of Rio Beberibe, 31.xii.1935 (Schubart, 1942); Madalena, 25.iv.1935 (Schubart, 1942); Bairro Torre, 16.vi.1936 (Schubart, 1942); Bairro Dois Irmãos, 1934 (Schubart, 1939); Bairro Tegipio, 1934 (Schubart, 1939); Bairro Várzea, 1934 (Schubart, 1939); Olinda [−08.0089°S; −34.8553°W], banana plantation, 07.iv.1935 (Schubart, 1939); Igarassú [−07.8333°S; −43.9000°W], Ilha Itamaracá [−07.754660°S; −34.837309°W], 25.v.1935 (Schubart, 1939); São Lourenço da Mata, 14.vii.1937 (Schubart, 1939); **Amapá:** Jequiu da Praia [−09.7811°S; −36.0936°W], Lagoa de Jequiá, Porta da Boca, 10.vii.1936, ♀ 1 immature (Schubart, 1939); **Goiás:** Araguacema [−15.912823°S; −52.251231°W], x.1953, H. Sick coll., ♂ (Schubart, 1958a); **Rio de Janeiro:** Rio de Janeiro, Bairro Cachambi [−22.902038°S; −43.273901°W] (Schubart, 1945b); Bairro Deodoro [−22.857652°S; −43.384850°W] (Schubart, 1945b); Bairro do Encantado [−22.896400°S; −43.302050°W] (Schubart, 1945b); Bairro Jacarepaguá [−22.971732°S; −43.391675°W] (Schubart, 1945b); Lagoa Rodrigo de Freitas [−22.973385°W]; [−43.207108°W] (Schubart, 1945b); Bairro do Leblon [−22.984645°S; −43.223162°W] (Schubart, 1945b); Morro dos Dois Irmãos [−22.952544°S; −43.399345°W] (Schubart, 1945b); Serra de Bangu [−22.876050°S; −43.468651°W] (Schubart, 1945b); Bairro Tijuca [−22.935505°S; −43.243112°W] (Schubart, 1945b); São Gonçalo, Engenho Novo [−22.903896°S; −43.268490°W] (Schubart, 1945b); **São Paulo:** Pirassununga [−22.067267°S; −47.395011°W], 17.i.1940, ♀ 1 immature (Schubart, 1944); 03.iv.1940, 9♂ 6♀ (Schubart, 1944); 22.v.1940, 8♂ 3♀ 1 immature (Schubart, 1944); 23.vii.1940, 3♂ 7♀ 12 immature (Schubart, 1944); 13.ii.1941, 4♂ 2♀ (Schubart, 1944); 02.iii.1940, 3♂ 2♀ 10 imatures (Schubart, 1944); 26.ix.1941, 7♂ 4♀ 2 imatures (Schubart, 1944); 12.iii.1940 (Schubart, 1944); 27.ii.1940, A. Aguirre coll., 11♂ 11♀ 14 imatures (Schubart, 1944); Fazenda Petra Branca, 11.i.1942, J. Gaspar coll., 2♀ 2 imatures (Schubart, 1944); Fazenda São Domingos, 22.ix.1940, 20♂ 14♀ (Schubart, 1944).
Family Haplodesmidae

Protopodesmus jacobsoni Silvestri, 1910
(Figs. 1C, 6A)

Descriptive notes: See Brölemann (1920: 226, figs. 141-144).

Identification: Protopodesmus jacobsoni can be separated from other species of Neotropical Haplodesmidae by having mushroom-shaped porosteles (see Enghoff, 1993: fig. 4); telopodite with large lateral lamella; two subapical dentiform processes (Silvestri, 1910: fig. 7; Fig. 11a; Mesibov, 2012: fig. 4).

Distribution: The species is widespread in the tropics and supposedly introduced by human activities (Hoffman, 1999). Some records have been made from USA and Hawaii, West Indies, Cape Verde, Tanzania, India, Indonesia, Fiji, and Taiwan (Loomis, 1950; Enghoff, 1993; Hoffman, 1999; Shelley & Golovatch, 2000; Akkari & Enghoff, 2011; Golovatch et al., 2011; Mesibov, 2012). Its native distribution is uncertain (Mesibov, 2012). In Brazil, the species has been recorded only in urban areas from states of Rio de Janeiro and São Paulo. All records were obtained from the literature.

Historical records: Rio de Janeiro: Niterói, Icarai [-22.903431°S; -43.111570°W] (Schubart, 1947); Pirassununga [-22.067267°S; -43.169510°W] (Schubart, 1947); Rio de Janeiro: Niterói, Icaraí [-22.935505°S; -43.243112°W] (Schubart, 1947); Mogi Guaçu [-22.185269°S; -47.097326°W] (Schubart, 1947). São Paulo: Maria, state of Rio Grande do Sul. (Schubart, 1947).

Material examined: Bahia: Salvador, campus UFBA [-13.004364°S; -48.5085978°W], 2013, C.M.P. Leite coll., σ (UFMT).

Records: Rio de Janeiro: Rio de Janeiro, Bairro Tijuca [-22.9935505°S; -43.243112°W], 17.v.1938, A.C. Aguirre coll., 1♂ 1♀ immature (Schubart, 1946b); 05.vi.1938, A.C. Aguirre coll., ♀ 1 immature (Schubart, 1946b); 04.viii.1940, A.C. Aguirre coll., 2♂ 4♀ immatures (Schubart, 1946b); 30.iv.1940, A.C. Aguirre coll., 5♂ 4♀ immatures (Schubart, 1946b); 05.vi.1940, A.C. Aguirre coll., 9♂ 4♀ immatures (Schubart, 1946b); 11.vi.1940, A.C. Aguirre coll., 4♂ 2 females immatures (Schubart, 1946b); 12.iv.1940, A.C. Aguirre coll., 5♂ 10♀ immatures (Schubart, 1946b); 30.vii.1939, A.C. Aguirre coll., 9♂ (Schubart, 1946b); 15.ix.1939, A.C. Aguirre coll., 9♀ 13♂ 27 immatures (Schubart, 1946b); 13.iv.1946, A.C. Aguirre coll., 2♂ 4♀ 4 immatures (Schubart, 1946b).

Glyphiulus granulatus (Gervais, 1847)
(Figs. 1C, 4C-D, 6B)

Descriptive notes: See Golovatch et al. (2007: 12, figs. 1-6).

Identification: Males of G. granulatus are recognized by a median outgrowth of the coxosternum in the anterior gonopods (Golovatch et al., 2007: fig. 5a, b; Fig. 6B) and the typical pattern of carinotaxy. As in T. calvus, the species is easily identified when compared with Brazilian species of Spirostreptida by having tergites longitudinally crest (Fig. 4C-D) and the presence of posterior gonopod. According to the diagnosis made by Golovatch et al. (2012), males are recognized by lateral coxal process of the anterior gonopod being very slender (Fig. 6C); slender and conical medial coxal process; posterior gonopod with axe-shaped flagellum extended and with microgranulate distal lobules (Fig. 6D).

Distribution: G. granulatus has been recorded in SE Asia and in islands in the Pacific and Indian oceans (Shelley, 1998a; Jeekel, 2004; Korsós, 2004; Enghoff et al., 2015). In Brazil, the species occurs only in urban areas in Santa Maria, state of Rio Grande do Sul.

Material examined: Rio Grande do Sul: Santa Maria [-29.6914°S; -53.80808°W], Universidade Federal de Santa Maria, 17.iv.2014, V.M. Silva coll., 8♂ 5♀ (MCN).
Figure 5. (A) Oxidus gracilis, gonopod in mesal view; (B) Orthomorpha coarctata, gonopod in mesal view; (C) Trigonius corallinus, anterior gonopods in anterior view; (D) Trigonius corallinus, telopodite of left posterior gonopod in anterior view; (E) Rhinotus purpureus, anterior gonopod in posterior view; (F) Rhinotus purpureus, posterior gonopod in posterior view. Scale bars: 100 µm (A, B, E, F); 750 µm (C); 1 mm (D).
Order Spirobolida
Family Pachybolidae

*Trigoniulus corallinus* (Gervais, 1842)  
(Figs. 2A, 4E, 5C-D)

**Descriptive notes:** See Shelley & Lehtinen (1999: 1389, figs. 8-14).

**Note:** An overview of its taxonomic status was made by Shelley & Lehtinen (1999).

**Identification:** The species is easily recognized by the strongly reddish color in life (Fig. 9e). According to the diagnosis made by Shelley & Lehtinen (1999, figs. 11-13), males of *T. corallinus* are recognized by the coxae of the anterior gonopods narrowly separated by subtriangular sternum indented in midline; telopodites subtriangular, extending directly mediad (Fig. 5C), telopodites of the posterior gonopods rounded and with broad medial lobe at midlength; two inner projections arising basally from lobe and directed distad; and outer projection with notch on inner margin, expanded distad (Fig. 5D).

**Distribution:** *Trigoniulus corallinus* presents a tropical distribution (Hoffman, 1999; Shelley, 1998b; Shelley & Lehtinen, 1999; Korsós, 2004; Enghoff et al., 2015). In Brazil, the species is distributed predominantly in the North and Northeast regions, occurring in urban and rural areas, greenhouses, and forests. Records from the state of Rio de Janeiro are due to its use for the production of organic compost for agriculture (Antunes et al., 2016, 2019). Species of *Trigoniulinae* distributed in the Neotropical region are supposedly introduced from SE Asia (see Hoffman, 1994; Hoffman et al., 1996).

**Material examined:**  
*Roraima:* Caracaraí, Serra da Mocidade 01.491084°S; -61.7833333°W, 25.i.06.ii.2016, M. Oliveira, F.F. Xavier & T. Mahlmann coll., σ (INPA); Parque Nacional Serra da Mocidade, 01.074634°S; -61.900000001°W, 15-26.ii.2016, F.F. Xavier, R. Boldrini & P. Barroso coll., 2σ 2♂ (INPA). Igarapé Caicubi 00.560220°S; -62.168280°W, Pupunha, pitfall, 22.x.2008, Ana coll., σ ♀ (INPA).  
*Amazonas:* campus INPA 03.0960583°S; -59.9844389°W, 12.vii.2016, D.P. Cordeiro coll., σ (INPA); *Pará:* Belém, Bairro Terra Firme -01.457070°S; -48.451254°W, 22-23. vi.2010, R. Ott coll., 4♂ 6♀ (MCN 659); 17♂ 11♀ 3 imatures (MEPG Myr-00048); *Tocantins:* São Luis 15.2009755°S; -51.852218°W, campus UF, 02.xi.2016, M. Lopes coll., 6♂ 9♀ (IBSP 7449); 13.xi.2016, M. Lopes coll., Quintal de Casa, 4♂ 3♀ (IBSP 7495); Bairro da Cimba, 08.viii.2015, F. Costa coll., 9♂ (IBSP 7496); 16.ix.2014, V.S. Marinho coll., Urban area, 9♀ (IBSP 7497); *Paraíba:* Recife -08.056951°S; -34.929493°W, 26.vi.1946, M.L. Siqueira coll., 2♂ (MZSP); campus Instituto Ricardo Brennand -08.055537°S; -34.959112°W, 27.vii.2010, R. Ott coll., 8♂ (MCN 611); *Rio de Janeiro:* Rio de Janeiro -22.921765°S; -43.169510°W, 13.xii.1954, H. Lopes coll., σ (MZSP).

**Historical records:**  
*Amazonas:* Manaus -03.023045°S; -59.965390°W, Bicego coll., 8♂ 2♀ (Brölemann, 1902); Embrapa Amazônia Ocidental -02.893744°S; -59.973109°W (Hoffman et al., 2002); *Pará:* Ananindeua, Aurâ -01.408310°S; -48.397542°W, 05.iii.1958, L. Travassos coll., 3♂ 10♀ (Schubart, 1958b); 04.iii.1958, 1♀ (Schubart, 1958b); Entrada de Utinga -01.425995°S; -48.444631°W, 12.iii.1958, L. Travassos coll., 2♂ 2♀ (Schubart, 1958b); *Pernambuco:* Recife -08.05393°S; -34.88110°W, Bairro dos Afgados, 14.xiii.1934, O. Schubart coll. (Schubart, 1958b); Bairro do Paysandu, 26.iv.1946, M.L. Siqueira coll., 4♂ 6♀ 2♂ immature (Schubart, 1958b); *Rio de Janeiro:* Rio de Janeiro, Bairro Leblon -22.985714°S; -43.224212°W, 25.xi.1941, A.C. Aguirre coll., 2♂ 4♀ (Schubart, 1958b); Bairro Brás de Pina -22.831870°S; -43.296731°W, 25.iii.1947, A.C. Aguirre coll., 2♂ immature (Schubart, 1958b); Bairro do Andaraí -22.927367°W; -43.251211°W, 1953, J. Becker coll., 2♂ (Schubart, 1958b); campus Universidade Rural, km 47 -22.768546°S; -43.687338°W, xii.1957, H.S. Lopes coll., σ ♂ (Schubart, 1958b); Seropédica -22.768582°S; -43.706125°W, 2017, L.F.S. Antunes et al. coll. (Antunes et al., 2019).

*Leptogoniulus sorornus* (Butler, 1876)  
(Figs. 2B, 6E-F)

**Descriptive notes:** See Shelley & Lehtinen (1999: 1383, figs. 1-7).

**Note:** An overview of its taxonomic status was made by Shelley & Lehtinen (1999).

**Identification:** According to the diagnosis made by Shelley & Lehtinen (1999), males of *L. sorornus* are recognized by the coxae of the anterior gonopods widely separated by apically broad and subtruncate sternum (Fig. 6E), and telopodites apically uncinated. Telopodites of the posterior gonopods with broad medial lobe, and apically rounded with notches along the distal margin (Fig. 6F).

**Distribution:** *Leptogoniulus sorornus* presents a tropical distribution (Hoffman, 1999; Shelley & Lehtinen, 1999; Korsós, 2004). In Brazil, the species has been recorded in the old-named state of Guanabara (now known as Rio de Janeiro), São Mateus, and Salvador (approximately 1,500 km from Rio de Janeiro) (Shelley & Lehtinen, 1999). All records were obtained from the literature.

**Historical records:**  
*Bahia:* Salvador -12.97111°S; -38.5108°W, J. Becker coll. (Schubart, 1958b); *Espírito Santo:* São Mateus -18.718937°S; -39.861257°W (Schubart, 1947); *Rio de Janeiro:* Rio de Janeiro -22.9028°S; -43.2075°W (Schubart, 1958b); Corcovado, Jardim Botânico, Caullery coll. (Brölemann, 1929); *São Gonçalo:* -22.8269°S; -43.0539°W, Fazenda Engenho Novo, A.C. Aguirre coll. (Schubart, 1947).
Figure 6. (A) Prosopodesmus jacobsoni, gonopod in mesal view (after Silvestri, 1910); (B) Glyphiulus granulatus, anterior gonopods in posterior view; (C) Trachyjulus calvus, anterior gonopods in anterior view; (D) Trachyjulus calvus, posterior gonopods in anterior view (after Schubart, 1946); (E) Leptogoniulus sorornus, anterior gonopods in anterior view; (F) Leptogoniulus sorornus, telopodite of left posterior gonopod in anterior view (after Shelley & Lehtinen, 1999). Scale bars: 20 µm (B); 100 µm (C, D); 750 µm (E); 1 mm (F). Image (A) not to scale.
Figure 7. (A) *Epitrigoniulus cruentatus*, anterior gonopods in posterior view (after Brollemann, 1903); (B) *Epitrigoniulus cruentatus*, posterior gonopods in anterior view (after Brollemann, 1903). Distal region in detail; (C) *Paraspirobolus lucifugus*, anterior gonopods in anterior view; (D) *Paraspirobolus lucifugus*, posterior gonopod in anterior view (after Attems, 1900); (E) *Cylindroiulus britannicus*, gonopod in anterior view. Detail of telson in lateral view (after Blower, 1985); (F) *Cylindroiulus truncorum*, gonopod in anterior view (after Blower, 1985). Images not to scale.
Epitrioniulus cruentatus (Brölemann, 1903)  
(Figs. 1D, 7A-B)

**Descriptive notes:** See Brölemann (1903: 250, figs. 5-9).

**Identification:** According to the description made by Brölemann (1903), males of *E. cruentatus* can be recognized by coxae of the anterior gonopods separated by subtriangular sternum (Fig. 7A); and telopodites subtriangular (Brölemann, 1903: fig. 5). Telopodites of the posterior gonopods rounded and expanded distad; and with notches along the mesal margin (Brölemann, 1903: figs. 6-8; Fig. 7B).

**Distribution:** *Epitrioniulus cruentatus* occurs in the Indo-Malayan region (Brölemann, 1903). In Brazil, the species has been recorded only in the Amazonian region (Brölemann, 1903, 1909).

**Historical records:**  
**Amazonas:** Manaus [-03.063877°S; -60.036493°W] Embrapa Amazônia Ocidental [-02.893744°S; -59.973109°W] (Hoffman et al., 2002); Belém [-01.451628°S; -48.446535°W] (Schubart, 1947).

**Family Spirobolellidae**

**Paraspirobolus lucifugus** (Gervais, 1837)  
(Figs. 2C, 7C-D)

**Descriptive notes:** See Attems (1900: figs. 13-16) and Brölemann (1902: 184, figs. 223-227).

**Identification:** According to the descriptions made by Attems (1900) and Brölemann (1902), males of *P. lucifugus* can be recognized by the anterior and posterior gonopods. Coxae of the anterior gonopods separated by wide sternum slightly indented in midline (Attems, 1900: figs. 49a), operated with laterad bent smooth brachit, without setae or protruberances; paracoxal process long, slender and pointed, almost reaching the end of solenomerite (Blower, 1985: fig. 51; Fig. 7F). An overview of its taxonomic status was made by Jeekel (2001). Members of Julida are easily recognized by stipites of gnathochilarium in contact in the midline in their basal part (symphyognathous condition). The species is recognized by three pairs of setae on the anal valves (Blower, 1985: fig. 49a); opisthomerite with finger-shaped projection (Blower, 1985: fig. 49b); promerite simple; mesomerite shorter than promerite (Fig. 7E).

**Distribution:** The order Julida is distributed in the Holarctic region, marginally also in SE Asia and Central America (Enghoff et al., 2015). *Cylindroiulus britannicus* is widespread in Europe and predominantly distributed in the Northwest region (Blower, 1985). The species has been recorded in southern India, New Zealand, South Africa (Hoffman, 1999), Chile, and Argentina (Golovatch, 2014; Shelley et al., 2014). In Brazil, the species has been recorded only in urban areas in the states of São Paulo and Rio de Janeiro. All records of the species were obtained from the literature.

**Historical records:**  
**São Paulo:** Pirassununga [-22.005841°S; -47.424516°W], 23.vii.1940-13.ii.1941, O. Schubart coll., 2♂ 2♀ 4 immatures (Schubart, 1942c); São Paulo, Bairro Santo Amaro [-23.654909°S; -46.703473°W], 1954, O. Schubart coll.,♂♀1 immature (Schubart, 1945a); Água Branca [-23.517304°S; -46.690714°W] (Schubart, 1944); Bairro do Tremembé [-23.468582°S; -46.624367°W] (Schubart, 1947); <strong>Rio de Janeiro:</strong> Itatiaia [-22.458524°S; -44.562840°W] (Schubart, 1947).

**Cylindroiulus truncorum** (Silvestri, 1896)  
(Figs. 2B, 7F)

**Descriptive notes:** Male, see Blower (1985: 162, fig. 51) and Korsós & Enghoff (1990: 347, figs. 1, 5-8, 21, 30, 31).

**Identification:** According to the diagnosis made by Korsós & Enghoff (1990), males of *C. truncorum* are recognized by promerite of gonopods slightly longer than mesomerite, without a deep mesal incision; opisthomerite with laterad bent smooth brachit, without setae or protruberances; paracoxal process long, slender and pointed, almost reaching the end of solenomerite (Blower, 1985: fig. 51; Fig. 7F).

**Distribution:** It is widespread in Europe and North Africa, probably by several events of introduction (Blower, 1985; Korsós & Enghoff, 1990). The species has been reported in Hawaii, North and South America (Shelley et al., 1998; Hoffman, 1999). *Cylindroiulus truncorum* occurs mainly
in synanthropic habitats such as greenhouses, gardens, and parks (Korsós & Enghoff, 1990). In Brazil, the species has been recorded only in urban areas in São Paulo. All records of the species were obtained from the literature.

Historical records: São Paulo: São Paulo, Bairro dos Campos Elíseos [-23.5475°S; -46.6361°W], 03.iii.1944, O. Schubart & J. Schubart coll. (Schubart, 1946a).

Order Polytoniidae
Family Siphonotidae

Rhinotus purpureus (Pocock, 1894)

Descriptive notes: See Mauriès (1980: 1101, fig. 62) and Wesener (2014: 588, figs. 1-2, for the synonym P. malagassum).

Identification: Native species of Polytoniidae in Brazil belong to the genera Siphonotus Brandt, 1837 and Burinia Attems, 1926 (Hoffman, 1977, 1980; Enghoff et al., 2015). Males of R. purpureus are recognized by having sterno-tergite of anterior gonopod with two lobes carrying long setae; coxae with trichostele carrying long setae; third podomerus laterally with short setae and carrying mesally a protruding channel (Mauriès, 1980: fig. 62; Wesener, 2014: fig. 2a; Fig. 5E). Posterior gonopod sternite elongated into two lobes; each one with apical setae; remaining podomerus partly fused and difficult to distinguish; tarsus elongated and apically with short claw (Wesener, 2014: fig. 2b; Fig. 5F).

Distribution: The range extension of R. purpureus is not known and its native area is still uncertain (Hoffman, 1999). The species has been recorded in the Neotropical region (Shelley, 1998c), West Africa, Mauritius, East Indies (Hoffman, 1999), Madagascar (Wesener, 2014), and Asia (Hoffman, 1977; Korsós, 2004). In Brazil, the species has been recorded in urban areas from Manaus and from uncertain localities in the state of Amazonas (see Hoffman et al., 1996, 2002).

Material examined: Amazonas: Manaus, sitio Vida Tropical, AM 010, km 35 [-02.759189°S; -59.920910°W], 11.xi.2017, T.M. Almeida & J.A. Rafael coll., 11♂ 22♀ (INPA).

Historical records: Amazonas: Manaus [-03.063877°S; -60.036493°W], Embrapa Amazônia Ocidental [-02.893744°S; -59.973109°W] (Hoffman et al., 2002).

CONCLUSIONS

Although there are still gaps in knowledge about the millipede fauna in the Neotropical region, this study presents one of the first efforts for a survey of introduced species in Brazil. The findings presented here report 12 introduced species in 21 Brazilian states, with a significant portion of these records related to rural and urban areas. However, our results are far from complete since the number of known introduced species in Brazil is still incipient. In this perspective, additional studies should expand our list of millipede with the inclusion of possible other species.
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AUTHORS’ CONTRIBUTIONS

LFMI, RSB, and ADB planned the manuscript. All authors analyzed the data and contributed actively in the paper writing, editing and revisions.

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