

## Exotic, Peregrine, and Invasive Earthworms in Brazil: Diversity, Distribution, and Effects on Soils and Plants

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**ABSTRACT.**—Humans have transported exotic earthworms throughout the world, and in some situations these may become invasive, modifying soil properties and processes, and plant growth significantly; either positively or negatively. Fifty-one exotic and up to seven peregrine native earthworm species are known from Brazil, generally from agroecosystems or other disturbed sites close to human habitations. Eight species are considered invasive, and another sixteen are potentially invasive; however, little is known of the effects of most of these species on plants, soil properties, processes, and native species. Lumbricids and some acanthodrilid species are found primarily in the south and southeast of Brazil, where the cooler subtropical climate is more suitable to their activities. Other acanthodrilids (primarily *Dichogaster* spp.), the megascolecid *Amyntas* spp. and *Pontoscolex corethrurus* are widespread throughout Brazil, and sometimes invade native ecosystems, thus serving as disturbance indicators. However, only a few earthworm species have been studied in more detail, mainly the *Amyntas* spp. and *P. corethrurus*. Available results seem to indicate that the activities of these earthworm species can lead to both positive and negative effects on soils, plants and the native biota, and that this may depend on the site's characteristics (soil, climate and vegetation types). Nevertheless, considering the large diversity of earthworms in Brazil, and the little available information, much more work is warranted (and urgently necessary) to adequately assess and predict the diversity, distribution and potential environmental impacts, positive or negative, of invasive earthworms in Brazil.

**KEYWORDS.**—Oligochaetes, biodiversity, invasive species, soil function, biogeography, Brazil

### INTRODUCTION

Earthworms are essentially terrestrial animals, and the majority of the known species (around 3800; Reynolds 1994) inhabit the top (A) soil horizon where most of the organic matter (main source of food) is found; however, some species may burrow as deep as 9 m (Righi 1997) and others inhabit 'suspended soils;' i.e., soil accumulated in tree epiphytes such as bromeliads (Fragoso and Rojas 1996). Although some earthworms, particularly epigeics and anecics, but also some endogeic species (generally after large rainstorms) frequently move about on the soil surface, the natural

rate of dispersal of most earthworm species seems to be low, generally less than 10 m per year. Some species, however, such as *Tuiba diana* (Adis and Righi, 1989), *Lumbricus terrestris* (Mather and Christensen, 1988) and several *Amyntas* spp. (e.g., Reddy 1980) are known to migrate en-masse or large distances (dozens of meters) at certain times of the year. Hence, because of their generally limited active dispersal, earthworms may be good candidates to study biogeography, continental drift (Cernovitov 1935b), and climate and vegetation changes (James and Brown 2006).

Passive dispersal of earthworms may be more important than most people realize (Gates 1954). Plants and soil have been transported by humans for millennia (McNeely 1996), and this has contributed to the spread of earthworms well beyond their

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home ranges. Over 100 exotic earthworm species, i.e., species found outside their native ranges, mainly transported by humans, have spread throughout the world (Lee 1987) and are generally found in disturbed habitats, close to human habitations. Peregrine earthworms are species that may be native to a country but have colonized areas outside their native range. Invasive earthworms are species introduced deliberately or unintentionally (usually transported by humans) outside their native habitats, that successfully establish themselves in, and then modify (possibly out-competing native species, if present) otherwise intact native ecosystems. Generally, invasive species tend to be associated with negative impacts to humans and/or native ecosystems and their fauna and flora (McNeely et al. 2001). The invasion alters not only the biological components, but also the other properties and processes of the ecosystem, including its function.

Herein we explore the diversity and distribution of exotic, peregrine and invasive earthworms in Brazil, and their effects on soils and plants in various ecosystems. To write this review, we surveyed all the literature citations on earthworms in Brazil, as well as the record books from the main earthworm collections in the country (Museum of Zoology of the University of São Paulo, National Museum in Rio de Janeiro, Instituto Nacional de Pesquisas da Amazônia Museum in Manaus and the Oligochaete Collection at the University of Rio dos Sinos in São Leopoldo).

#### DIVERSITY

Exotic earthworm invasions and colonization of new habitats by peregrine earthworms have probably been occurring for centuries in Brazil. However, no one can say precisely when the first exotic earthworm arrived in Brazil. In 1867, Kinberg described *Amyntas gracilis* from specimens collected in the Botanical Garden of Rio de Janeiro. At the time, it was not known that the species was exotic, and originally from somewhere in Asia. This species and other

Asian megascolecids probably arrived much earlier, soon after the establishment of trade routes between the Old and the New Worlds (Chang 1997). Many of these trading ships carried both ballast (which could contain earthworms), as well as plants with soil that could also contain earthworms (Lee 1985, 1987).

The first list of earthworms in Brazil (Perrier 1877) included two native species (*Pontoscolex corethrurus* and *Glossoscolex giganteus*), and three exotics: *Perichaeta dicystis* (considered nomen dubium/incertum by Michaelsen 1900; but probably *Metaphire californica*, according to Moreira 1903), *Perichaeta tricystis* (considered nomen dubium/incertum by Michaelsen 1900; but probably *Amyntas gracilis*, according to Moreira 1903), and a eudrilid (probably *Eudrilus eugeniae*). Twenty-six years later, Moreira (1903) listed 20 valid earthworm species from Brazil. Of these, nine species were exotic and 11 native. Finally, in the last review of earthworms in Brazil, Michaelsen (1927) listed 51 valid species, of which 15 (29%) were exotic and 36 native species (James and Brown 2006).

The current list of earthworms in Brazil includes 306 species from 65 genera (Brown and James 2006). Of the total, 255 are native species (83%) and 51 may be exotics (17%). The exact proportion of natives and exotics is difficult to define due to the uncertain origin of some earthworm species, particularly several ocnerodrilids and species with few collection records or for which very little data is available. The exotic species (Appendix 1), belong mainly to the families Lumbricidae (13 species in 7 genera), Megascolecidae (11 species in 5 genera), Ocnerodrilidae (12 species in 4 genera), Acanthodrilidae (12 species in 4 genera), Eudrilidae (2 species in 2 genera) and Almididae (1 species).

Of the 51 exotic species, only eight (*P. corethrurus*, 2 spp. of *Amyntas*, 2 spp. of *Eukerria* and 3 spp. of *Dichogaster*) are invasive with known ability to colonize new areas and become the dominant species, causing changes to the soil and consequently to the populations of other organisms (animals, plants and microorganisms) living therein. Another 16 species (Appendix 1)

can be considered potentially invasive, as they have been found in several locations, and are known to become dominant species and alter soil processes, but nothing is yet known of their effects on Brazilian soils and habitats. The remaining species are exotics or peregrine natives that may or may not be invasive. This will only be known for certain once more research and collection efforts are performed to assess their distribution in Brazil, their populations and effects on soils.

#### DISTRIBUTION

Although exotic species represent only a small proportion of Brazil's total earthworm diversity (17%), they are widely distributed in the country (Appendix 1, Fig. 1). However, most species are associated mostly or strictly with disturbed habitats and where native species are rare or absent (Brown and James 2006). Exotic and peregrine native species have been spread, mostly unintentionally, through the transport of soil, potted plants, nursery transplants and live individuals (e.g., tossed fish bait), among other means.

*Pontoscolex corethrus* and some species of *Amyntas*, for example, are commonly used as fish-bait and are widely known and distributed in Brazil. Exotic Megascolecidae (e.g., *Amyntas* or *Metaphire* spp.) and some Acanthodrilidae (mainly *Dichogaster* spp.) are found throughout the country (Appendix 1, Fig. 2). More will be said about these species in a separate section below. Other acanthodrilids (mainly *Microscolex* spp.) and the Lumbricidae (except *Eisenia fetida* and *E. andrei* that are used for vermiculture) have a more restricted distribution (Appendix 1, Fig. 3). These latter species are found mainly in the colder, subtropical regions of Brazil, particularly Rio Grande do Sul (RS), where the climate is more suitable for their activities.

The peregrine native species *Pontoscolex corethrus* was described by the German naturalist Fritz Müller in 1857 from individuals collected in Itajaí, in the state of Santa Catarina. Even 150 years ago, Müller

(1857) already considered the earthworm extremely common and widespread: "*the brush-tail, the commonest of earthworms of this country (Brazil), . . . may be found in almost every clod of arable land.*" Given the importance of this earthworm species in Brazil and the tropics in general, more details on *P. corethrus* are given in a separate section below.

The first large-scale inventories of earthworm species in Brazil were undertaken in the late 1960's by Christa Knäpper and Josef Hauser in RS and by Caballero (1973), in the Cerrado biome in northwest São Paulo state (SP). In RS, diversity and distribution was studied in various habitats in 36 counties (Knäpper 1972a,b; 1976, 1977, 1979; Knäpper and Porto 1979; Righi and Knäpper 1965; Righi 1967b,c). The authors found 26 species, 22 of them exotic (85%), mainly in the Megascolecidae (8 species), Lumbricidae (8 species) and Acanthodrilidae (5 species) families. This high proportion of exotics is probably because most of the samples were taken in disturbed habitats. On the other hand, Caballero's thesis covered 48 counties, but revealed only eight species, five of which were exotic. This lower diversity may be due to the smaller number of sample sites, as well as the sampling method employed (Caballero performed quantitative sampling only, while in RS samples were taken mostly qualitatively to assess biodiversity).

Still today, large parts of Brazil remain unexplored and with no records of native or exotic earthworms (Brown and James 2006, Fig. 1). In fact, the states of Rio Grande do Norte, Alagoas and Piauí have no earthworm records (Fig. 4) and 11 other states have less than 10 sample sites, or collections taken in only restricted geographical areas (Fig. 1). No state has had more than 20% of its counties sampled, and most of the samples thus far have been taken in the southeastern and southern states (where the highest number of exotic species are found; Fig. 4), or close to cities and/or roads. Therefore, the samples taken up to now are grossly inadequate, particularly for biomes like the Cerrado, Pantanal, Caatinga, Pampas and Amazonia. Hence, the

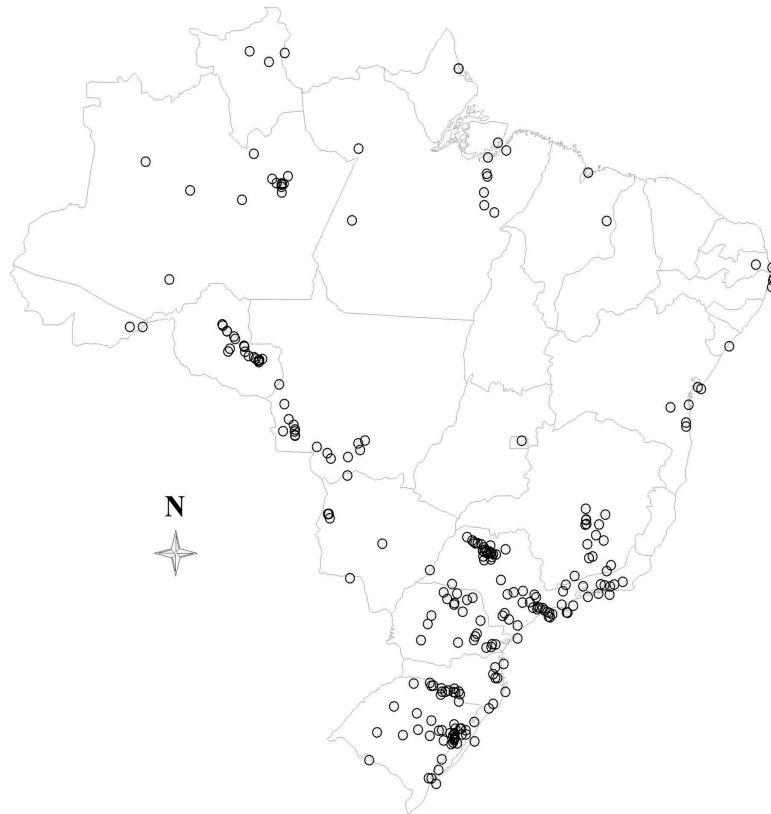


FIG. 1. Known distribution (collection localities) of the exotic earthworm species (Ex. in Appendix 1) in Brazil.

true number of exotic species in each Brazilian state (Fig. 4) is probably greater than the number of known species. Considering that most of the collection efforts and searches for new species have occurred in preserved habitats or places where native species are more likely to be present than exotics, it is very likely that further samples taken in disturbed habitats throughout Brazil will reveal not only new exotic species, but also significantly increase the range of occurrence of the anthropochores. However, it is unlikely that the total diversity will greatly exceed 60 species, since only 51 widespread exotics are presently known in the tropics (Fragoso et al. 1999).

For example, up to 1997, only 10 earthworm species were known for Paraná: four native and six exotic species: *Amyntas corticis*, *A. gracilis*, *A. morrisoni*, *Pheretima darnleiensis*, *Metaphire californica*, *M. schmardae* (Voss 1986; Chang 1997). Beginning in 2001,

samples taken mostly in Northern and Eastern Paraná, in only 11% (43) of the state's 399 counties, revealed 48 species, raising the total to 54 species. Of this total, 20 were exotic species and 34 were native (more than 20 were new to science; Sautter et al. 2006). On average, at each new site sampled, about one new species or record for the state was found.

These results highlight the urgent need for more extensive sampling and inventorying of the diversity and distribution of Brazilian earthworms (both exotic and native species). It is expected that these studies will also help to assess the preservation status of several Brazilian ecosystems, since the earthworm community at a particular site, and the ratio of native to exotic species present can be used as a good indicator of habitat or ecosystem disturbance (both past and present) (Paoletti 1999; Fragoso et al. 1997).

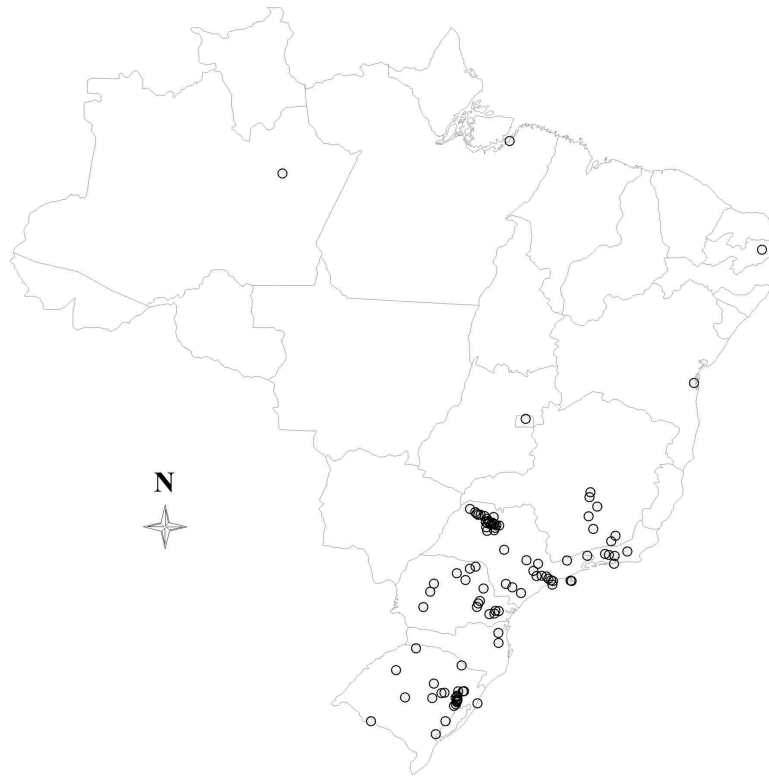


FIG. 2. Known distribution (collection localities) of the exotic (Asiatic origin) invasive earthworm species *Amynthus gracilis* (Megascolecidae) in Brazil.

*Special case 1. Amynthus and Dichogaster spp.*

Megascolecids such as *A. gracilis* (Fig. 2), and acanthodrilid such as *D. bolau*i and *D. saliens* are widespread, although they are mostly associated with anthropic habitats (cities, agroecosystems), and especially common in and near homes (gardens, orchards), city parks and urbanized areas. In particular, these species seem to do well in soils with higher organic matter content and agroecosystems lacking tillage (no-tillage, NT). These systems now occupy >20 million ha in Brazil, 5.5 million of which are in Paraná. *Amynthus* spp. are more abundant in regions with a cooler, subtropical climate, while *Dichogaster* spp. are present in regions with both drier and hotter (e.g., in the Cerrado), as well as cooler climates (Brown et al. 2003).

The adoption of NT in Brazil has been instrumental in soil conservation and in-

covering soil organic matter contents, thereby increasing the availability of food (particularly on the soil surface) and improving the soil as a habitat for saprophytes and decomposers, including earthworms. Hence, various authors (reviewed in Brown et al. 2003) observed a significant increase in earthworm populations after adoption of NT. For instance, Voss (1986), reported a large increase in *Amynthus corticis* and *A. gracilis* populations from practically nil up to 108 individuals  $m^{-2}$ , after only four years of NT in the region of Ponta Grossa, Paraná. Nearby in Arapoti, Peixoto and Marochi (1996) followed an *Amynthus* spp. (mainly *A. corticis* and *A. gracilis*) invasion front and found that the population had reached approximately 200 individuals  $m^{-2}$  after 6.5 years of NT. In fact, farmers in the region even developed a means of enhancing earthworm invasion and inoculation, by spreading farm yard manure containing high populations of *Amynthus* spp.

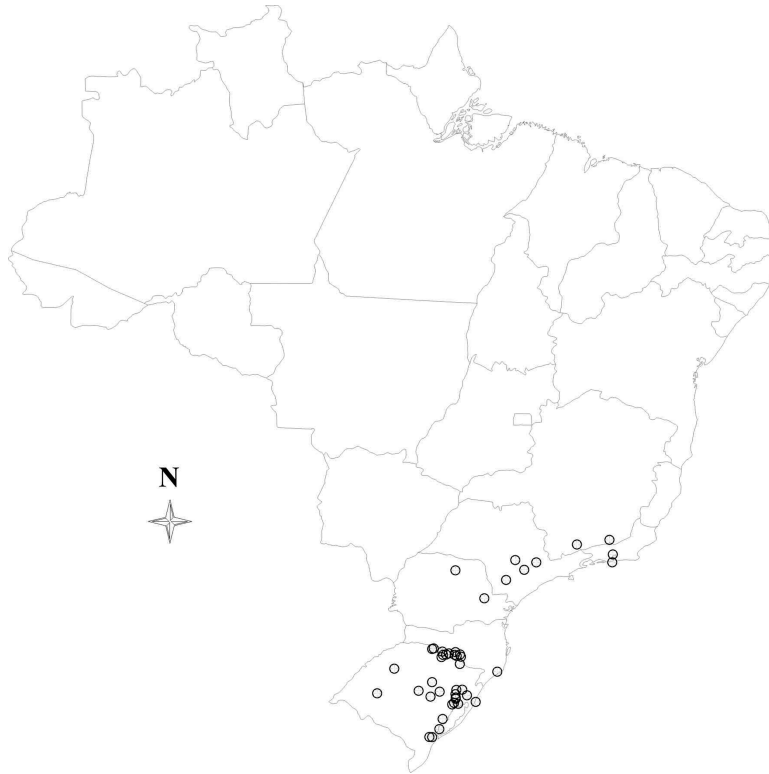


FIG. 3. Known distribution (collection localities) of the 13 species belonging to the exotic (mainly European) earthworm family Lumbricidae in Brazil.

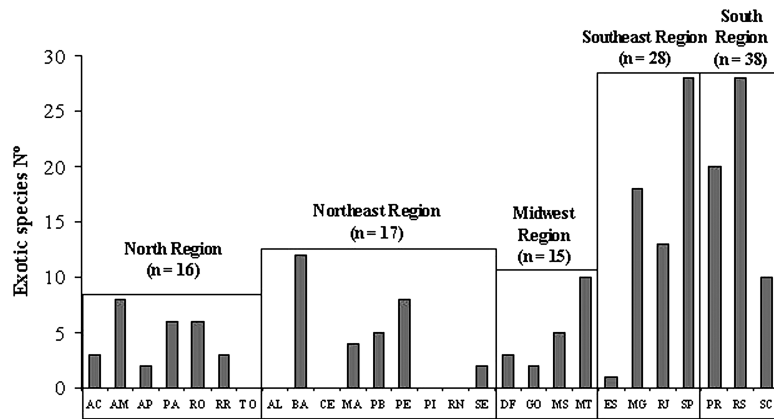


FIG. 4. Number of exotic earthworm species found in each state and total diversity of exotics in the main regions (value in parentheses) of Brazil. For state abbreviations see footnote in Appendix 1.

on wide contour bunds and other strategic areas in their fields. It is presumed that these fields were devoid of native earthworms before adoption of NT (due to long-term conventional tillage), and that it was

necessary to inoculate these exotics to enhance their invasion. This seems to be true for many places. Nonetheless, at a few sites, mainly in Paraná, native species have been found in long-term NT fields where con-

ventional cultivation had taken place previously (Brown et al. 2004), indicating that promotion of this and other earthworm inoculation techniques must be regarded with caution, until more is known of the effect of earthworm invasion on native species.

Various *Dichogaster* and *Amyntas* spp. and other earthworms of the Megascolecidae family have a high potential to colonize new areas and may become invasive. They often rise to the soil surface to move about and may, therefore, be able to cover large distances in a short period of time. Furthermore, their reproductive mode (many are parthenogenetic), small cocoon size and relatively short life cycle (r-selection; Satchell 1980) also aid spread to and colonization of new areas.

In Eastern USA, various *Amyntas* spp. have invaded native deciduous forests, formerly devoid of earthworms, causing major pedoturbation (Burtelow et al. 1998) and changes to the local plant and animal communities (Bohlen et al. 2004). In Brazil, several *Amyntas* spp. have been collected in both secondary and apparently well-preserved Atlantic forests (Tanck et al. 2000; J. Fernandes et al. unpublished data), indicating that these species can also adapt to and colonize these ecosystems. Unfortunately, little is known of the effect of these invasions on the forest soil, its properties, native earthworms and soil/plant biodiversity in Brazil. In fact, relatively little is known of the biology and ecology of several invasive or potentially invasive *Amyntas* and *Dichogaster* spp. in the world, and there is still much room for further research on the topic, especially considering their worldwide distribution.

*Special case 2. Pontoscolex corethrurus:*  
*a peregrine native/invasive species*

*Pontoscolex corethrurus* has the widest distribution of any earthworm in Brazil (Fig. 5), and should be considered a peregrine and often invasive species, wherever it is found outside its presumed center of origin. Righi (1984c) placed the center of diversity of the genus *Pontoscolex* in the

Guyana Shield region, including Northern Brazil and the southern portions of Venezuela, Guyana, Surinam and French Guyana. Hence, he argued that *P. corethrurus* must have originated in this region. In Brazil, it probably disseminated both naturally from its original source as well as aided by Indian groups, who probably transported materials containing cocoons or juvenile earthworms (Lavelle, personal communication; Righi 1990a). A major emigration of Tupi-Guarani Indian tribes from Central Amazonia began about 2000 yr ago, but large-scale movements (fleeing) were also enhanced greatly by the colonization process, especially as the *bandeirantes* (marauding bands of adventurers seeking slaves and riches in Brazil's interior) pushed the borders of Brazil further and further west (Bueno 2003).

In many places where found, *P. corethrurus* is dominant (Lavelle et al. 1994; Barros et al. 2004; Guerra 1994a, b; Guerra and Silva 1994; Caballero 1973). This appears to be true especially in disturbed ecosystems such as pastures, but also in secondary forests, due to its great tolerance for different habitats and soil types (Lavelle et al. 1987), as well as its parthenogenetic reproduction mode (Gates 1973a). Even in some well-preserved Brazilian and Latin American forests, this species is present (Lavelle and Lapied 2003; Brown and James 2006) and can become invasive. For instance, in several Costa Rican national parks and reserves (Lapied and Lavelle 2003), including the research station *Finca La Selva*, where native earthworms (including other species in the Glossoscolecidae family) should be present, the forest soils are completely dominated by *P. corethrurus*, indicating that this earthworm has been modifying the soils and soil processes in the reserve for years (S. James unpublished data). The implications of this phenomenon for the many studies performed at *La Selva* should be considered further.

The large-scale dominance and multiplication of this species in some sites, especially when it is the only earthworm present, may cause negative effects on soil structure (Barros et al. 2004; Chauvel et al. 1999), plant growth (Brown et al. 1999,



FIG. 5. Known distribution (collection localities) of the pantropical earthworm species (native to N Brazil, but peregrine and invasive throughout the rest of the country) *Pontoscolex corethrurus* (Glossoscolecidae) in Brazil.

2004) and local earthworm communities (Lapied and Lavelle 2003). Some of these results are presented in the following section, but further research on this topic is necessary to adequately ascertain the conditions that promote these phenomena and means to contain/reduce/overcome its negative impacts.

*Pontoscolex corethrurus* is the most well studied earthworm in Brazil, and various aspects of its life cycle and activities were first studied by Vanucci (1953), and then later by Ferraz and Guerra (1983), Guerra and Bezerra (1989), Hamoui (1991), Bernardes and Kiehl (1992, 1993, 1994, 1995a,b, 1997), Bernardes et al. (1998), and Soares et al. (1997). These studies confirmed the great versatility of this species to human handling and its adaptation to various food and culture substrates, temperatures and soil conditions. Although much appears to be known about this species, there is clearly much still to be learned about the 'brush-tail' worm.

#### IMPACT OF INVASIVE EARTHWORMS ON SOILS AND PLANTS

According to the Convention on Biological Diversity, invasive species are those that threaten ecosystems, habitats and species (McNeely et al. 2001); therefore they are considered noxious to the ecosystem, its properties and functioning. In the case of earthworms, however, this concept needs further consideration, since invasion, particularly in agroecosystems, may lead to positive or negative impacts to the soil and to plant (crop) production. However, for most of the known invasive or potentially invasive species, field, greenhouse and/or laboratory data are still lacking on the effects of invasion on soil, plants, biodiversity and ecosystem function.

Earthworm activities can have major effects on soil properties and processes, including plant growth and populations of other soil organisms (Brown and Doube 2004; Lee 1985). So far, most of the work

performed in Brazil has been done with only one species: *P. corethrurus* (reviewed by James and Brown 2006). This species can cause major changes to soil pH and nutrient (Ca, Mg, P, K, NO<sub>3</sub>) availability (Langenbach et al. 2002; Guerra 1982), soil physical properties (Barros et al. 2001; 2004; Chauvel et al. 1999) and microbial populations and activity (Guerra and Asakawa 1981). Surface casting by this species at rates of dozens to hundreds of tons ha<sup>-1</sup> yr<sup>-1</sup> were also shown to be an important factor in soil structure formation and pedogenesis (Miklós 1996).

A clear example of the negative effects of *P. corethrurus* invasion under certain soil, climate and vegetation conditions comes from observations and experiments performed near Manaus, in Brazilian Amazonia. In this region, the process of deforestation and sowing of introduced exotic (*Brachiaria* spp.) pastures led to the disappearance of native earthworms and other soil invertebrates, allowing *P. corethrurus* to dominate, reaching densities of up to 365 individuals and biomass of 45 g (wet weight) m<sup>-2</sup> (Barros et al. 1996). This species generated more than 100 Mg surface casts ha<sup>-1</sup> that coalesced during the rainy season, creating a continuous mass of castings and reducing soil macroporosity to a level equivalent to the compaction created by heavy machinery (Barros et al. 2001; Chauvel et al. 1999). The castings also prevented adequate water infiltration, saturating the surface soil and leading to anaerobic conditions and methane emission. In the dry season, large cracks opened on the soil surface, inhibiting root growth and water absorption by the roots, causing the plants to wilt and die, leaving large bare patches in the pasture (Chauvel et al. 1997). The role of a diverse macrofauna assemblage in reversing these negative effects was also clearly established when blocks of soil were transplanted from these pastures back into the forest (Barros et al. 2001). After one year, the structure of the compacted pasture soil was completely restored to levels of those typical in native forest soils.

*Pontoscolex corethrurus* belongs to the "compacting group" of earthworms (Blanchart et al. 2004), but the extent of this type

of phenomenon where it is the dominant species is still unknown, and may be restricted to certain soil, climate and plant conditions. Furthermore, not all effects of *P. corethrurus* on soils and plants are negative. The species was associated with positive effects on plant growth in various greenhouse and field studies throughout the tropics (Brown et al. 1999) and greenhouse trials in Brazil showed how this species aided P uptake by maize plants (Guerra 1982), and increased *Brachiaria decumbens* shoot biomass (Soares and Lambais 1998).

Regarding the invasive species of *Amyntas*, a study performed over two years in Arapoti showed how invasion by *A. gracilis* and *A. corticis* in annual cropping systems enhanced macronutrient availability, soil macroaggregation and water infiltration into the soil, leading to significant plant growth and grain production increases. In the invaded areas, wheat and soybean grain production increased 48 and 51%, respectively, while stubble biomass of oats and wheat increased 22 and 46%, respectively (Fig. 6).

Similarly, Kobiyama et al. (1995) found a significant increase in the shoot growth of the silvicultural species *Mimosa scabrella*, when he inoculated 60 or 90 individuals of *Amyntas* spp. m<sup>-2</sup> into worm-free 2.7 m<sup>2</sup> plots at the Federal University of Paraná in Curitiba. The earthworms also improved soil macroporosity (mainly pores >0.06 mm diam.), hydraulic conductivity and water retention. On the other hand, Santos (1995) found no significant effect of inoculating 30, 60 or 90 *Amyntas* spp. m<sup>-2</sup> on the shoot

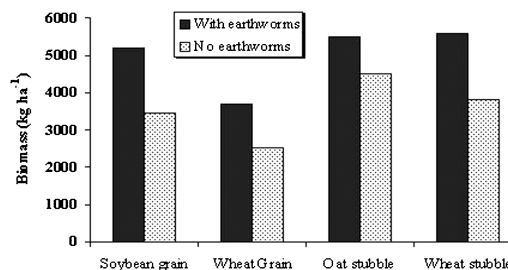


FIG. 6. Soybean and wheat grain production and wheat and black oat dry stubble biomass in areas invaded or not by exotic earthworm species of the genus *Amyntas*, on a Dark Red Latossol (Oxisol) in Arapoti, Paraná State, Brazil (after Peixoto and Marochi 1996).

biomass and yields of black beans or black oats grown in small plots (1 m<sup>2</sup>) at Guarapuava, Paraná. Furthermore, Kusdra (1998) observed a negative effect of *Amyntas* spp. inoculation on black bean nodulation by symbiotic *Rhizobium* and on root and shoot biomass under greenhouse conditions.

Therefore, there is still not a universal formula which can be applied to predict earthworm effects on soils, plants, native species and ecosystem function, and these must be studied on a case-by-case basis, considering the invading and native earthworm species, soil type, climate, plant and habitat conditions of the site. If the ecosystem being invaded is dominated by a diverse assemblage of native species (plants and animals), the effects are likely to be very different from those in already disturbed areas (where native earthworms are generally rare or absent), especially agroecosystems, where earthworm invasion may actually be beneficial.

Few ecological studies have been performed so far, and most of them evaluated only the most common exotic or invasive species (*P. corethrurus* and *Amyntas* spp.). Given the large diversity of other exotic and invasive or potentially invasive species in Brazil (and the rest of the world), and the lack of knowledge on the effects of many species on soil and ecosystem properties and processes, there is clearly still much to be done.

#### RECOMMENDATIONS

Considering the large diversity of earthworms in Brazil and the many native (and some exotic) species still to be found (and described), taxonomic training and capacity building to improve earthworm identification skills should be given top priority. For this purpose, taxonomic keys will help, allowing proper identification of invasive or potentially invasive species by non-specialist Brazilian researchers and students.

The exploration of the many unsurveyed or insufficiently studied habitats and biomes in Brazil should also be prioritized,

to expand the knowledge on earthworm biodiversity, distribution and habitat requirements of native and exotic species, before human disturbance and/or exotic species invasion compromise these goals. The presence of native, exotic and invasive species (especially *P. corethrurus*) inside, on the border, or nearby natural ecosystems should also be determined. This should help assess the use and value of earthworm communities (and the ratio of native to exotic species) as indicators of ecosystem integrity or resistance and resilience to past and future disturbances.

Finally, better controls on the entry and movement of materials containing soil and earthworms should be promoted in Brazil and throughout Latin America, to prevent the entry and spread of additional exotic (and potentially invasive) species in the continent. Furthermore, it is imperative to determine under which conditions natural or disturbed habitats are invaded by earthworms and their effects on the soil, plant and animal communities (microorganisms and invertebrates). These studies should help predict the possibility of invasions of particular ecosystems', the environmental impacts (negative or positive) of earthworm invasion and the possible mitigatory measures needed to reverse or reduce any negative impacts of these invasions.

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APPENDIX 1. List of families, genera and species of exotic (Ex), invasive (In), potentially invasive (PI) or peregrine native (PN: species found out of original range) earthworms found in Brazil, and their distribution in the country's states and counties (modified and expanded from James and Brown 2006)

Family	Counties/states found <sup>1</sup>	Status <sup>2</sup>	References <sup>3</sup>
<b>Glossoscolecidae</b>			
<i>Pontoscolex corethrurus</i> <sup>4</sup> (Müller, 1857)	Most widespread sp. in Brazil. Found in AC, AM, AP, BA, DF, ES, GO, MA, MG, MS, MT, PA, PB, PE, PR, RJ, RO, RR, RS, SC, SE, SP (See Figure 5)	In, PN	Cernosvitov (1934, 1935a), Righi (1971a, 1980, 1982, 1984b,c,d,e, 1988a,b 1990b, 1997, 1998), Righi et al. (1976), Michaelsen (1918), J&B, Luederwaldt (1927), Moreira (1903), Knäpper (1972b, 1976, 1979), Knäpper and Porto (1979), Lenko (1972), Zicsi and Csuzdi (1987), Zicsi et al. (2001), Cognetti de Martiis (1900), Vanucci (1953), Guerra (1988, 1982, 1994a), Guerra and Silva (1994), Caballero (1973), Righi and Guerra (1985), Benham (1900), AG, JR, Peneireiro (1999), Nunes et al. (2006), UNISNOS
<b>Almidae</b>			
<i>Criodrilus lacuum</i> (Hoffmeister, 1845)	Triunfo, Porto Alegre, RS	Ex	Knäpper and Porto (1979), Knäpper (1976)
<b>Ocneroдрilidae</b>			
<i>Eukerria asilis</i> <sup>5</sup> (Righi, 1967)	Ilha de Marajó, PA; Cabo, PE	PN	Righi (1967a, 1971b)
<i>Eukerria eiseniana</i> <sup>6</sup> (Rosa, 1895)	Near Pontes e Lacerda, Cuiabá, Cáceres, MT; Ilha de Maracá, near Bonfim, RR; Presidente Médici, Pimenta Bueno, RO; Ladário, Bela Vista, Terenos, MS; Botucatu, SP; Camaquã, RS; Jaguapitã-PR	Ex or PN, In	Righi (1972, 1984a,d 1988a), Righi and Guerra (1985), MZUSP, L&R, Nunes et al. (2006)
<i>Eukerria garmani argentinae</i> (Jamieson, 1970)	Estrela, Camaquã, RS	Ex?	Righi and Ayres (1975), L&R
<i>Eukerria kukenthali</i> (Michaelsen, 1908)	Codajás, AM	Ex	Righi (1988b)

## APPENDIX 1. Continued

Family	Counties/states found <sup>1</sup>	Status <sup>2</sup>	References <sup>3</sup>
<i>Eukerria saltensis</i> <sup>7</sup> (Beddard, 1895)	São Paulo, SP; Blumenau, SC; MG; Camaquã, RS; Jaguapitã, PR	Ex, In	Righi (1999), Righi (1968b), L&R, Nunes et al. (2006), Ljungström et al. (1975), Michaelsen (1927), Righi (1971b), Gates (1972)
<i>Eukerria stagnalis</i> (Kinberg, 1867)	Estrela, Porto Alegre, Camaquã, RS; Ilha Bela, SP	Ex or PN, PI	Righi and Ayres (1975), Michaelsen (1927), MZUSP, L&R
<i>Eukerria subandina</i> <sup>8</sup> (Rosa, 1985)	Corumbá, MS; Mirante da Serra, RO	Ex or PN	Righi (1984a, 1988a), Cognetti de Martins (1900)
<i>Eukerria urna</i> (Righi, 1967)	Codajás, AM; Itajubá, BA; Ilha do Marajó (próximo de Cachoeira do Arari), PA, Pimenta Bueno, RO; Bonfim, RR	PN	Righi and Guerra (1985), Righi (1967a, 1971b, 1988a,b)
<i>Gordiodrilus habessinus</i> (Michaelsen, 1913)	Near Vilhena, near Ariquemes, Pimenta Bueno, RO; Near Pontes e Lacerda, Cáceres, Nova Alvorada, MT; Ladário, MS	Ex	Righi (1984a,d, 1988a), Righi and Guerra (1985)
<i>Gordiodrilus marculsi</i> (Righi, 1968)	São Paulo, Birigui, Rio Claro, SP; Britânia, GO	Ex or PN	Righi (1968a), MZUSP
<i>Gordiodrilus paski</i> (Stephenson, 1928)	São Paulo, SP	Ex	Righi (1968b)
<i>Nematogenia lacuum</i> (Beddard, 1893)	Cacoal, Pimenta Bueno, Espigão d'Oeste, Ouro Preto do Oeste, RO; In and N of Pontes e Lacerda, Tabuleta, Cáceres, Vila Bela da Santíssima Trindade, MT	Ex	Righi (1984d, 1988a), Righi and Guerra (1985)
<i>Nematogenia panamensis</i> (Eisen 1900)	Botucatu, SP; Salvador, BA	Ex	MZUSP
<i>Ocnodrilus occidentalis</i> <sup>9</sup> (Eisen, 1878)	Ilha de Marajó, PA; Codajás, AM; Poconé, MT; Bela Vista, MS; Lauro Müller, SC, São Paulo, SP; Jaguapitã, PR	Ex, PI?	Righi (1984a, 1988b), MZUSP, Nunes et al. (2006)
Eudrilidae			
<i>Eudrilus eugeniae</i> <sup>10</sup> (Kinberg, 1867)	Itajubá, Jequié, Ilha de Itaparica, BA; Petrópolis, Rio de Janeiro, Nova Friburgo, RJ; Ponta de Pedras, Recife, PE; Maiauté, PA; São Sebastião, Boituva, Campinas, Vinhedo, São Paulo, SP; Primeiro de Maio, Londrina, Ibiaci, PR; Areia, PB; Juiz de Fora, MG (vermiculture); Aracajú, SE; São Luís, MA	Ex, PI?	Righi (1967d, 1968b, 1971b, 1972), Luederwaldt (1927), J&B, Moreira (1903), Gates (1954), Beddard (1891), Guerra and Silva (1994), MZUSP
<i>Hyperiodrilus africanus</i> (Beddard, 1891)	Ponta de Pedras, PE	Ex	Righi (1972)

## APPENDIX 1. Continued

Family	Counties/states found <sup>1</sup>	Status <sup>2</sup>	References <sup>3</sup>
Lumbricidae (See Fig. 3)			
<i>Aporrectodea caliginosa</i> <sup>11</sup> (Savigny, 1826)	Canela, Estrela, Guaíba, Nova Petrópolis, Porto Alegre, Rolante, Herval, São Leopoldo, Mariluz, Sapucaia do Sul, Santa Cruz do Sul, São Francisco de Paula, Canguçu, Piratini, Pinheiro Machado, Sobradinho, Novo Hamburgo, Charqueadas, Ilha G. Medeiros, Viamão, Pelotas, RS	Ex, PI	Righi (1967b), Knäpper (1976), Knäpper and Porto (1979), Knäpper and Hauser (1969), MZUSP, UNISINOS
<i>Aporrectodea rosea</i> <sup>12</sup> (Savigny, 1826)	Porto Alegre, RS	Ex	Michaelsen (1892)
<i>Aporrectodea trapezoides</i> (Dugès, 1828)	Porto Alegre, RS	Ex	Michaelsen (1892), Knäpper (1976)
<i>Bimastos parvus</i> (Eisen, 1874)	Buri, Anhembi, SP; Nova Teutônia, Camaquã, RS	Ex	Cernosvitov (1942), Righi (1968a), J&B, L&R
<i>Dendrobaena veneta</i> (Rosa, 1886)	Porto Alegre, RS	Ex	Knäpper and Porto (1979)
<i>Dendrodrilus rubidus</i> (Savigny, 1826)	Itatiaia, Petrópolis, Rio de Janeiro, RJ	Ex	Michaelsen (1927) Righi (1980), Gates (1972)
<i>Eisenia andrei</i> <sup>13</sup> (Bouché, 1972)	Various sites in SP, PR, RJ, MG, PB & PE; Brasília-DF (vermiculture)	Ex	GB, AG
<i>Eisenia fetida</i> <sup>14</sup> (Savigny, 1826)	Guaíba, Ivotí, Lageado, Porto Alegre, São Leopoldo, Gramado, Guaíba, Belém Velho, Belém Novo, Novo Hamburgo, Mariluz, Sapucaia do Sul, Piratini, Tramandaí, Viamão, Barra do Ribeiro, RS; Tubarão, SC; perhaps various sites in SP, PR, RJ, MG & SC (vermiculture)	Ex	Michaelsen (1892), Knäpper and Porto (1979), Righi (1967b), Knäpper (1972a, 1976), UNISINOS
<i>Eisenia lucens</i> (Waga, 1857)	Santo Ângelo, Fontoura Xavier, Porto Alegre, São Francisco de Paula, RS	Ex	Knäpper and Porto (1979), Knäpper (1976)
<i>Eiseniella tetraedra</i> ( <i>tetraedra</i> ?) (Savigny, 1826)	Several counties in the regions of Itá Machadinho & Campos Novos, SC & RS	Ex	Pacheco et al. (1992)
<i>Eiseniella tetraedra pupa</i> (Eisen, 1874)	Porto Alegre, RS	Ex	Knäpper (1976)
<i>Octolasion cyaneum</i> (Savigny, 1826)	Gramado, Pelotas, Porto Alegre, São Leopoldo, RS	Ex	Righi (1967b), MZUSP, Knäpper (1976), UNISINOS
<i>Octolasion lacteum</i> (Hoffmeister, 1845)	Porto Alegre, RS	Ex	Knäpper (1976)
Megascolecidae			
<i>Amyntas aeruginosus</i> (Kinberg, 1867)	Prudentópolis, PR	Ex	J&B, MZUSP
<i>Amyntas aspergillum</i> <sup>15</sup> (Perrier, 1872)	São Paulo, SP	Ex	Righi (1967c)
<i>Amyntas corticis</i> <sup>16</sup> (Kinberg, 1867)	Serra do Cipó, Juiz de Fora, MG; 16 counties in PR; PN Itatiaia, Seropédica, Nova Friburgo, RJ; 9 counties in RS; 6 counties in SP	Ex, IN	J&B, Krabbe et al. (1993), Knäpper (1977), Knäpper and Porto (1979), Gates (1954), Righi (1980), Voss (1986), Ressetti (2004), GB, Zicsi and Csuzdi (1999)

## APPENDIX 1. Continued

Family	Counties/states found <sup>1</sup>	Status <sup>2</sup>	References <sup>3</sup>
<i>Amynthas gracilis</i> <sup>17</sup> (Kinberg, 1867)	Manaus, AM; Ituberá, BA; Brasília-DF; 6 counties in MG; Belém, PA; Areia, PB; 15 counties in PR; 6 counties in RJ; 23 counties in RS; Blumenau, Schroeder, SC; 39 counties in SP (See Figure 3)	Ex, In	Rosa (1894), Moreira (1903), Righi (1967c, 1980, 1997), Caballero (1973), Peneireiro (1999), AG, GB, Righi and Knäpper (1965), J&B, Luederwaldt (1927), Guerra and Silva (1994), Voss (1986), Zicsi and Csuzdi (1999), Lenko (1972), Cernosvitov (1934, 1935a), Ressetti (2004), Chang (1997), Beddard (1891), Gates (1954), Vanucci (1953), Michaelsen (1892, 1900, 1903), L&R, Knäpper and Porto (1979), Knäpper (1972a,b, 1976), Krabbe et al. (1993), MZUSP, UNISINOS
<i>Amynthas morrissi</i> (Beddard, 1892)	Salvador, BA; 15 counties in RS; Curitiba, Castro, PR	Ex, PI	Righi (1971b), Knäpper and Porto (1979), Ressetti (2004), Chang (1997), Krabbe et al. (1993), Knäpper (1972a,b)
<i>Metaphire californica</i> (Kinberg, 1867)	Piracicaba, São Paulo, SP; Caetanópolis, MG; Castro, Curitiba, PR; Rio de Janeiro, RJ; 20 counties in RS; Salvador, BA; Lauro Müller, SC	Ex, PI	Luederwaldt (1927), Righi (1971b, 1980), Chang (1997), Ressetti (2004), Moreira (1903), Krabbe et al. (1993), Knäpper and Porto (1979), Knäpper (1972a,b, 1976), MZUSP, UNISINOS
<i>Metaphire schmardae</i> <sup>18</sup> (Horst, 1883)	Porto Alegre, Estância Velha, Canoas, São Leopoldo, RS; Pomerode, Blumenau, SC; Curitiba, PR; Colina, Cotia, São Paulo, SP; Teresópolis, PN Itatiaia, RJ	Ex, PI	Knäpper and Porto (1979), Hauser et al. (1975), Righi (1967c, 1980), Knäpper (1972a,b), Michaelsen (1927), MZUSP, UNISINOS
<i>Pheretima darnleiensis</i> <sup>19</sup> (Fletcher, 1886)	Campos do Jordão, São Sebastião, São Paulo, São José do Rio Preto, Engenheiro Marsilac, Salesópolis, SP; Curitiba, PR; 15 counties in RS; Conceição de Mato Dentro, Tripuí (near Ouro Preto), MG	Ex, PI	Knäpper (1972a,b), Righi (1965, 1967c, 1980), Righi and Knäpper (1965, 1966), Chang (1997), Caballero (1973), MZUSP, UNISINOS
<i>Polypheretima elongata</i> (Perrier, 1872)	Caetanópolis, Curvelo, Cachoeira dos Macacos, MG; Recife, PE; Itajubá, BA; Anhembi, SP	Ex, PI	Righi (1971b, 1980), J&B
<i>Polypheretima taprobanae</i> (Beddard, 1892)	Rio de Janeiro, RJ; São Paulo, Piracicaba, Paranapiacaba, SP; Santa Cruz do Sul, São Leopoldo, RS	Ex, PI	Luederwaldt (1927), Moreira (1903), Righi (1967c), Knäpper (1976), UNISINOS
<i>Pontodrilus litoralis</i> <sup>20</sup> (Grubbe, 1855)	Several sites along S coast in SP, SC, RJ, RS; Ilha de Itamaracá, PE	Ex, PI	Luederwaldt (1927), Righi (1968b), Moreira (1903), Michaelsen (1900, 1910), MZUSP
Acanthodrilidae <i>Chilota</i> sp. <sup>21</sup>	Barueri, SP	Ex	MZUSP, Lenko (1972)

## APPENDIX 1. Continued

Family Genera species	Counties/states found <sup>1</sup>	Status <sup>2</sup>	References <sup>3</sup>
<i>Dichogaster affinis</i> (Michaelsen, 1890)	Areia, PB; Itaguaí, RAJ; Jaguapitã, Arapotí, Londrina, PR; around Manaus, AM; Calçoene & Lower R. Calçoene, AP; Poconé, Pontes e Lacerda, Chapada dos Guimarães, MT; Inhaúma, Curvelo, MG; Jequié, BA	Ex, In	Guerra and Silva (1994), Righi (1968b, 1971b, 1980, 1984a,d,e, 1990a), GB, Cernosvitov (1934, 1935a), Righi et al. (1978), Nunes et al. (2006)
<i>Dichogaster andina</i> <sup>22</sup> (Cognetti, 1904)	Rio Parú do Oeste, Jacundá, Canoal, PA; Rio Preto da Eva, several sites near Manaus, R. Negro (border AM-RR), AM	Ex, PI	Zicsi and Csuzdi (1999), Righi (1988b), Righi et al. (1978), Adis and Righi (1989)
<i>Dichogaster annae</i> <sup>23</sup> (Horst, 1893)	Blumenau, Florianópolis, SC; Uruçucá, BA; São Paulo, Osasco, SP; Chapada dos Guimarães, MT; RS	Ex, PI	Luederwaldt (1927), Righi (1968b, 1984a,e, 1999), Righi and Ayres (1975)
<i>Dichogaster bolau</i> <sup>24</sup> (Michaelsen, 1891)	Rio Branco, AC; In and near Manaus, Huitanaã (on R. Purús), AM; Corumbá, Uruçum, Carandazinho, MS; Lower R. Calçoene, AP; Itabuna, Itajubá, Jequié, BA; Caxias, MA; 4 counties in MG; 9 sites in MT; Belém, Mocajuba, Cocal (no R. Tocantins), PN Amazônia, PA; Castro, Jaguapitã, Arapotí, PR; Ariquemes, Mirante da Serra, Jí-Paraná, RO; Ilha de Maracá, Bonfim, RR; 8 counties in SP; Florianópolis, Lauro Müller, SC; Ilha de Itamaracá, PE	Ex, In	Cognetti de Martiis (1900), Righi and Guerra (1985), Righi (1968b, 1971b, 1972, 1980, 1984a,d,e, 1988b, 1990a, 1997), Righi et al. (1978), Cernosvitov (1934, 1935a), J&B, MZUSP, Ressetti (2004), Zicsi and Csuzdi (1999), Lenko (1972), Caballero (1973), Nunes et al. (2006)
<i>Dichogaster gracilis</i> (Michaelsen, 1892)	5 sites in RO; João Pessoa, PB; Manaus, AM; 4 sites in MT, Cafeara, PR	Ex, PI	Guerra and Silva, Righi (1988a,b, 1984d), Righi and Guerra (1985), Michaelsen (1928), J&B
<i>Dichogaster modiglianii</i> (Rosa, 1896)	In & N of Pontes e Lacerda, Serra da Campina, MT; Manaus, Chicago (on R. Japurá), AM; Ilha de Maracá, RR	Ex, PI	Righi (1984d, 1990a, 1998), Righi and Guerra (1985), Righi et al. (1978)
<i>Dichogaster saliens</i> (Beddard, 1892)	Rio Branco, AC; In & near Manaus, Tefé, AM; Itajubá, Jequié, BA; Caxias, MA; Cachoeira dos Macacos, Prado, Paraopeba, MG; Bataguaçu, Terenos, MS; 5 sites in MT; Belém, Mocajuba, PA; Jaguapitã, Cafeara, PR; Itaguaí, RJ; Pimenta Bueno, Cacoal, RO; Ibirubá, Fontoura Xavier, RS; Mirassol, Botucatu, São Paulo, Colina, SP	Ex, In	Righi (1968b, 1971b, 1972, 1980, 1984a,d,e, 1988b, 1990a), Righi and Guerra (1985), Righi et al. (1978), J&B, Knäpper and Porto (1979), Caballero (1973), Nunes et al. (2006), J&B
<i>Eodrillus doellojuradoi</i> <sup>25</sup> (Cordero, 1942)	Porto Alegre, RS	Ex	Knäpper (1976)

## APPENDIX 1. Continued

Family	Counties/states found <sup>1</sup>	Status <sup>2</sup>	References <sup>3</sup>
<i>Microcolex dubius</i> (Fletcher, 1887)	São Paulo, SP; Taquara, Santana do Livramento, Jaguarão, Pinheiro Machado, Guaíba, Porto Alegre, Pedro Osório, Piratini, Canguçu, Camaquã, RS	Ex, PI	Luederwaldt (1927), Ljungström et al. (1975), Üde (1893), Knäpper (1976), UNISINOS, L&R
<i>Microcolex michaelsoni</i> <sup>26</sup> (Beddard, 1895)	Porto Alegre, RS	Ex	Knäpper (1976)
<i>Microcolex phosphoreus</i> (Dugès, 1837)	Guaíba, RS (and other unspecified sites in RS)	Ex	Michaelson (1927), Moreira (1903), Cognetti de Martiis (1905), Knäpper (1976)

<sup>1</sup>States are abbreviated according to official abbreviations adopted in Brazil. AC = Acre; AL = Alagoas; AM = Amazonas; AP = Amapá; BA = Bahia; CE = Ceará; DF = Distrito Federal; ES = Espírito Santo; GO = Goiás; MA = Maranhão; MG = Minas Gerais; MS = Mato Grosso do Sul; MT = Mato Grosso; PA = Pará; PB = Paraíba; PE = Pernambuco; PI = Piauí; PR = Paraná; RJ = Rio de Janeiro; RN = Rio Grande do Norte; RO = Rondônia; RR = Roraima; RS = Rio Grande do Sul; SC = Santa Catarina; SE = Sergipe; SP = São Paulo; TO = Tocantins.

<sup>2</sup>Ex = Exotic; In = Invasive; PI = Potentially Invasive; PN = Peregrine Native. For explanations, see text.

<sup>3</sup>MZUSP = Museu de Zoologia, Universidade de São Paulo, collection or Righi's collection, now deposited at MZUSP; UNISINOS = Collection at the Universidade do Rio dos Sinos in São Leopoldo, RS (mostly samples collected by Christa Knäpper and Josef Hauser). Personal observations as follows: J&B = S. W. James & G. G. Brown; GB = G. G. Brown; AG = A. Guimarães; L&R = A. C. R. de Lima & C. Rodriguez; JR = Jörg Römbke.

<sup>4</sup>Most widely distributed earthworm in Brasil (Fig. 5). Although native to N Brazil (Guyanan Plateau region in RR, AP and AM), it is a peregrine and invasive species in the rest of the country.

<sup>5</sup>According to Gavrilov (1981), considered a specialist on the genus *Eukerria*, this species, although placed in synonymy with *E. kukenthali* by Jamieson (1970), should remain separate until more specimens have been examined in detail.

<sup>6</sup>Synonym: *Eukerria hortensis*.

<sup>7</sup>This is a widespread ocnodrilid, found in many locations on several other continents. Although this species is considered exotic, its origin may well have been in Central S. America (Argentina-Paraguay region).

<sup>8</sup>Synonym: *Eukerria borelli*.

<sup>9</sup>Gates (1973b) considered *Ocnodrilus hendriei* as a junior synonym of *O. occidentalis*. It is likely that the subspecies *Ocnodrilus hendriei paulistus* Righi, 1968 is also a junior synonym.

<sup>10</sup>Commonly used for vermiculture in the warmer areas of Brazil. Its distribution is generally restricted to areas close to human habitations, and to locations of vermiculture activity, although it can sometimes leave the beds and invade neighboring soils that have good vegetation cover and organic matter in the soil, particularly home gardens with fruit trees or vegetable production.

<sup>11</sup>May be any of three species (*A. trapezoides*, *A. tuberculata* or *A. turgida*), but most likely to be *A. turgida*.

<sup>12</sup>Synonym: *Eisenia rosea* (Blakemore, 2002).

<sup>13</sup>Species mostly restricted to areas close to human habitations, with abundant organic matter. Used for vermiculture.

<sup>14</sup>*E. fetida* is almost always quoted as the earthworm species used by vermiculture producers, although it appears that in most cases, the species is actually *E. andrei* (A. Guimarães and G. Brown, personal observations). Species is also generally restricted to areas close to human habitations, with abundant organic matter.

<sup>15</sup>May actually be *A. gracilis*. *Pheretima aspergillum* (Perrier, 1872), quoted by Righi (1967c) is synonymous with *A. gracilis* (Blakemore, 2002). The specimens at the MZUSP must be looked at for confirmation.

<sup>16</sup>Synonym: *Amyntas* or *Pheretima diffringens*.

<sup>17</sup>Synonym: *Amyntas* or *Pheretima hawayana*.

<sup>18</sup>Synonym: *Amyntas schmardae*.

<sup>19</sup>Synonym: *Pheretima indica*.

<sup>20</sup>Synonym: *Pontodrilus bermudensis*. Some authors place this species in the Acanthodrilidae family.

<sup>21</sup>This species was found in a *Camponotus rufipes* (Formicidae) nest, and is in the collection of G. Righi at the MZUSP. It was not identified to species level.

<sup>22</sup>In the lower R. Negro region close to Manaus (at confluence with R. Solimões), adults of this species were observed to ascend and descend tree trunks with flooding of the forest floor (Adis and Righi, 1989).

<sup>23</sup>Includes *D. servi*, *D. parva* and *D. silvestris cacaois* that were considered by Righi as separate species. Placed in synonymy by Csuzdi (1995).

<sup>24</sup>Found mostly in agricultural areas or disturbed soils close to human habitation. Also found in bromeliad in Santos (Zicsi and Csuzdi 1999).

<sup>25</sup>This species originally known only from its type locality, in Tierra del Fuego, in the tip of South America. Doubtful record?

<sup>26</sup>This species is known only from a few locations in southernmost South America (Zicsi and Csuzdi, 2006). Doubtful record?