

## **A Newly Introduced and Invasive Land Slug in Brazil: *Meghimatium pictum* (Gastropoda, Philomycidae) from China**

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## A newly introduced and invasive land slug in Brazil: *Meghimatium pictum* (Gastropoda, Philomycidae) from China

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**ABSTRACT.**—The land slug *Meghimatium pictum* (Stoliczka, 1873), native to China, is recorded for the first time in Brazil. This is also the first record of a species of the eastern Asiatic genus *Meghimatium* on the American continents. The species was identified using morphological criteria and analysis of the cytochrome oxidase subunit I, COI. Our records indicate this species is widely distributed in southern and southeastern Brazil, in the States of São Paulo, Paraná, Santa Catarina and Rio Grande do Sul, in disturbed and natural areas. We morphologically characterize *M. pictum* (external characteristics, reproductive system, jaw and radula) and provide some biological information based on field observations. We also discuss when *M. pictum* was probably introduced, from whence it came, possible pathways of introduction, and its characteristics as an invasive species and potential agricultural pest.

Key words: mollusk, exotic, herbivore, *Pallifera*.

### ABBREVIATIONS

APA: Área de Proteção Ambiental  
RPPN: Reserva Particular do Patrimônio Natural  
MNRJ: Museu Nacional do Rio de Janeiro, Rio de Janeiro, Brazil  
MZSP: Museu de Zoologia da Universidade de São Paulo, São Paulo, Brazil  
CMS-DPE: Superintendência de Controle de Endemias do

Estado de São Paulo, São Paulo, Brazil  
MHNCI: Museu de História Natural Capão da Imbuia, Curitiba, Paraná, Brazil  
MCTP: Museu de Ciências e Tecnologia da Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil  
MCNU: Museu de Ciências Naturais da Universidade Luterana do Brasil, Canoas, Rio Grande do Sul, Brazil  
USDA: United States Department of Agriculture

## INTRODUCTION

Land slugs are mollusks with a reduced and internal (in most families) or completely absent shell (Runham and Hunter, 1970). Some species have been able to achieve nearly world-wide distribution through human activities. Being phytophagous they are more likely to arrive on plants and food; some become serious agricultural pests (Runham and Hunter, 1970; Thomé, 1993; Robinson, 1999). In Brazil, there is only one native family of land slugs without a shell (Veronicellidae). All the other slugs are introduced Palearctic species. The most common are *Limax maximus* Linnaeus, 1758, *Limacus flavus* (Linnaeus, 1758) (both Limacidae) and *Deroceras laeve* (Müller, 1774) (Agriolimacidae) (Agudo-Padrón and Lenhard, 2010). All of them including the less common species were introduced to South America as a result of European colonization (Rumi et al., 2010).

The Philomycidae includes slugs that have the mantle region covering the entire dorsal region, not only the anterior part, as seen in all the other introduced slugs in Brazil. They have a large shell sac but no evidence of a shell. These characteristics make philomycids externally similar to veronicellids. The philomycids, however, differ, having one breathing pore that is a short slit near the anterior right

mantle edge (Thomé et al., 2006). Philomycids are also syntremous (male and female portion of the reproductive system with a common gonopore) instead diatremous as in veronicellids (male and female portion of the reproductive system with separated apertures). Philomycids occur in India, Japan and China to Java and Sulawesi (Indonesia) and in damp temperate and tropical eastern North America south to Colombia; they are also recorded as introduced in Hawaii (Pilsbry, 1948; Cowie, 1997; Wiktor et al., 2000). Currently, all the Asiatic species of Philomycidae are included in the genus *Meghimatium* van Hasselt, 1823 (Tsai and Wu, 2008). The American species are included in three other genera: *Phylomicus*, *Pallifera*, and *Megapallifera* (Fairbanks, 1990).

The objective of this study was to record for the first time to Brazil the Chinese land slug *Meghimatium pictum* (Stoliczka, 1873), and also the eastern Asiatic genus *Meghimatium* on American continents. We morphologically characterize *M. pictum* (external characteristics, reproductive system, jaw, and radula) and also provide some biological information based on field observations. We also discuss when *M. pictum* was probably introduced, from whence it came, possible pathways of introduction, and its characteristics as an invasive species and potential agricultural pest.

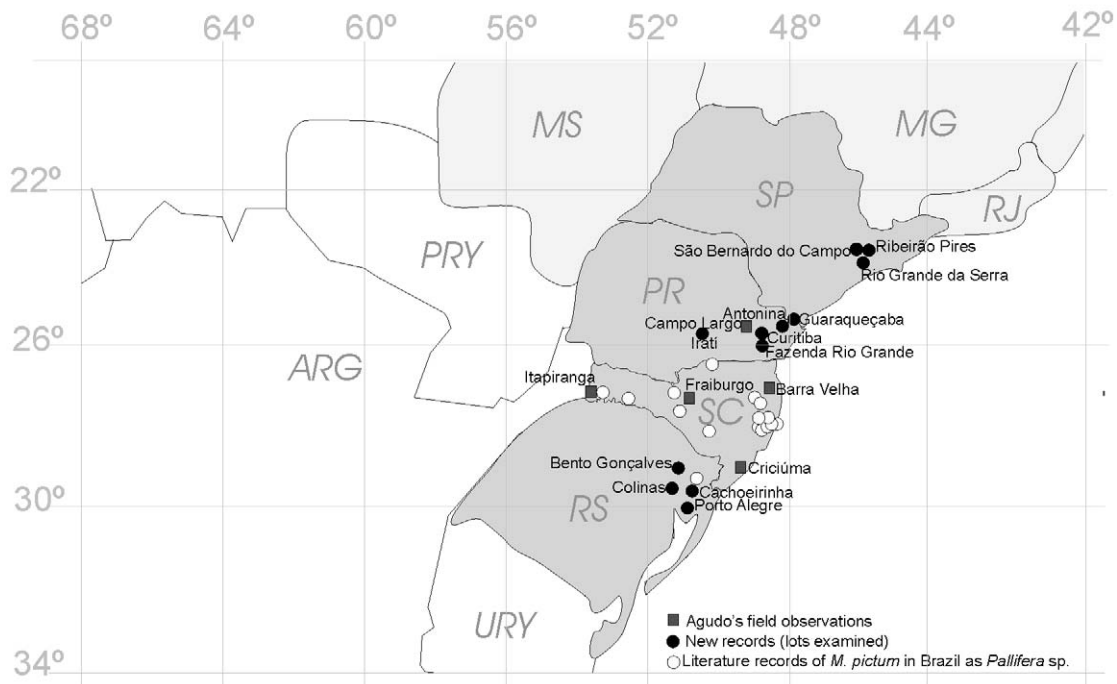


Fig. 1. Map showing the known distribution of *Meghimatium pictum* in Brazil. SP- São Paulo; PR- Paraná; SC- Santa Catarina; RS- Rio Grande do Sul.

## MATERIAL AND METHODS

Our study is based on analyses of 156 specimens of *M. pictum* included in 34 lots from different localities from southern and southeastern Brazil, and two localities from southern China. The material (preserved in 70% alcohol) is deposited in the collections of the MNRJ (Rio de Janeiro), MZSP (São Paulo), CMS-DPE (São Paulo), MHNCI (Curitiba), MCTP (Porto Alegre), and MCNU (Canoas). In the reported distribution, we also considered some field observations in Santa Catarina (of Agudo-Padrón) and records of Thomé et al. (2006), Agudo and Bleicker (2006), and Agudo-Padrón (2008), who incorrectly referred to this form as *Pallifera* sp. (Fig. 1).

**China, Guangdong Province:** MZSP 93847: Zhong Cun, Da Fu Shan Forestry Park, 28.V.2008 (1 ex.) (Bankit 1343617); USDA 120066: Zhong Cun, Da Fu Shan Forestry Park, 28.V.2008 (3 ex.).

**Brazil, São Paulo State:** CMS-DPE 360: Ribeirão Pires, 03.VIII.2009 (7 ex.); CMS-DPE 95: Ribeirão Pires, 23.I.2009 (1 ex.) (Bankit 13433611); CMS-DPE 114: São Bernardo do Campo, 28.I.2009 (1 ex.); CMS-DPE 129: Ribeirão Pires, 02.II.2009 (1 ex.); CMS-DPE 404: Rio Grande da Serra, 03.IX.2009 (1 ex.).

**Brazil, Paraná State:** MNRJ 11823: Guaraqueçaba, APA de Guaraqueçaba, RPPN Salto Morato, 06.II.2007 (1 ex.); MNRJ 11819: Antonina, RPPN Cachoeira (1 ex.); MZSP 93838: Irati, Floresta Nacional de Irati, 25-30.I.2010 (6 ex.); MZSP 93844: Irati, Floresta Nacional de Irati, 25-30.I.2010 (1 ex.); MZSP 93846: Irati, Floresta Nacional de Irati, 25-30.I.2010 (1 ex.); MZSP 93841: Curitiba, Parque Municipal Bosque Reinhardt Maack, 11, 14-16.XII.2009 (34 ex.); MZSP 93842: Curitiba, Parque Municipal Bosque Reinhardt Maack, 11, 14-16.XII.2009, (1 ex.) (Bankit 1343606); MZSP 93845: Curitiba, Parque Municipal Bosque Reinhardt Maack, 11, 14-16.XII.2009 (1 ex.); MZSP 29002: Curitiba, VII.1998 (2 ex.); MHNCI 4789: Fazenda Rio Grande, 16.III.2010 (1 ex.); MHNCI 4790: Fazenda Rio Grande, 16.III.2010 (3 ex.); MHNCI 4791: Fazenda Rio Grande, 17.III.2010 (1 ex.); MHNCI 4792: Fazenda Rio Grande, 17.III.2010 (1 ex.); MHNCI 4793: Fazenda Rio Grande, 19.III.2010 (3 ex.); MHNCI 4794: Fazenda Rio Grande, 19.III.2010 (1 ex.).

**Brazil, Santa Catarina State:** MCP 9173: Biguaçu, 04.VIII.2006 (29 ex.); MCP 9174: Antônio Carlos, 13.VIII.2006 (16 ex.); MZSP 93835: Palhoça, 01.II.2010 (18 ex.); MZSP 93840: Palhoça, 01.II.2010 (1 ex.); MZSP 93836: Palhoça, 01.II.2010 (1 ex.) (Bankit 1343614).

**Brazil, Rio Grande do Sul State:** MCP 9175: Canela, 20.XI.2005 (2 ex.); MCP 9172: Canela, 26.VIII.2006 (1 ex.); MCP 9176: Bento Gonçalves, 19.II.2007 (2 ex.); MZSP 93837: Porto Alegre, 14.III.2006 (1 ex.); MZSP

93839: Canela, 20.XI.2005 (2 ex.); MCNU 003: Colinas, 09.V.2009 (1 ex.); MCNU 004: Cachoeirinha, Parque Ecológico Ambiental Souza Cruz, 22.VIII.2010 (1 ex.); MCNU 005: Cachoeirinha, Horto Florestal Municipal Chico Mendes, 04.VII.2009 (7 ex.); MCP 9182: Gravataí, 09.X.2010 (1 ex.).

The species was identified using morphological criteria and analysis of the cytochrome oxidase subunit I (COI) (Table 1-2). From each lot, whenever possible, specimens of different sizes were dissected under stereomicroscope, and the internal morphology compared to the literature on the group (Stoliczka, 1873; Pilsbry, 1948; Fairbanks, 1990; Wiktor et al., 2000; Tsai et al., 2005; Tsai et al., 2008). In order to compare the morphology we also examined specimens of *M. bilineatum* (Benson, 1842) from Qing Xiu Mountain Garden, Nanning, Guangxi Zhuang Autonomous Region, China (lots CMS-DPE 1079 and USDA 120068, with 1 and 13 specimens, respectively) and a specimen of *M. fruhstorferi* Collinge, 1901 from Jeju Island, Province of Jeju, South Korea (USDA 120067).

Pictures of the reproductive system (having the main morphological diagnostic specific characters in Philomycidae) were obtained with a DFC 280 digital camera attached to a stereomicroscope. Three radulae and three jaws of *M. pictum* were extracted and analyzed under the scanning electron microscope LEO 440 of the Pontifícia Universidade Católica (PUCRS) (lots MZSP-93839 and MZSP-93843) and the JOE – JSM 6390 of the National Museum of Rio de Janeiro (MNRJ) (lot MNRJ 11823). To confirm our morphological determination, we also sequenced the cytochrome oxidase I gene from a few specimens from Brazil and China and compared these sequences to those from *Meghimatium* species available in GenBank (Tsai et al., 2005) (Table 1). The primers and protocols used to amplify this marker are according to Gomes et al. (2010).

## RESULTS

**Family PHILOMYCIDAE Gray, 1847**  
**Genus *Meghimatium* van Hasselt, 1823**  
***Meghimatium pictum* (Stoliczka, 1873)**

**Distribution in Brazil** (Fig. 1)

**São Paulo:** Ribeirão Pires, São Bernardo do Campo, Rio Grande da Serra.

**Paraná:** Campo Largo (field observations of A. I. Agudo-Padrón), Fazenda Rio Grande (Fazenda Experimental Gralha Azul), Guaraqueçaba (RPPN Salto Morato), Antonina (RPPN Cachoeira), Irati (Floresta Nacional de Irati), Curitiba (Parque Municipal Bosque Reinhardt Maack and in the city), Fazenda Rio Grande.

**Santa Catarina:** Antônio Carlos, Biguaçu, Chapecó, Blumenau, Brusque, Florianópolis (Capoeiras – mainland; Campeche, Ingleses, Lagoinha Pequena, Ratoles, Rio Tavares – island), Lages, Palhoça, Piratuba, Santo Amaro da Imperatriz, São José, São Pedro de Alcântara, Treze Tílias (Agudo and Bleicker 2006, Agudo-Padrón 2008 cited as *Pallifera* sp.); Barra Velha, Criciúma, Fraiburgo, Itapiranga (A. I. Agudo-Padrón's field observation).

**Rio Grande do Sul:** Canela (Thomé et al., 2006; cited as *Pallifera* sp.), Colinas, Cachoeirinha, Bento Gonçalves, Porto Alegre.

**Distribution in Asian region** (Fig. 2)

**China:** Gansu, Shaanxi, Yunnan, Zhejiang, Guangdong, Guizhou, Jiangxi provinces in mainland China (Stoliczka,

1973; Wiktor et al., 2000), and Taiwan (Taitung, Yilan, Taipei, Nantou, Taichung County) (Tsai et al., 2005; Tsai and Wu, 2008).

*Habitat.*—Specimens were found in high-humidity sites, from highly disturbed (in all States) to undisturbed areas in the State of Paraná. In disturbed areas *M. pictum* was found with other exotic species, such as the snails *Achatina fulica* (Bowdich, 1822), *Subulina octona* (Bruguière, 1789), and the slug *Limacus flavus*. In Paraná it was found in several areas of preservation (APAs), private reserves (RPPN) and National or Municipal forests, and parks with natural vegetation. In these areas, it was found with the native slug *Vaginulus taunaisii* Férussac, 1821 and native

Table 1. List of specimens from which we sequenced the cytochrome oxidase I (COI) (600pb), locality, voucher-specimens and GenBank accession numbers.

Taxon	Locality	Voucher-specimens	GenBank accession number
			COI
<i>M. pictum</i>	China, Guangzhou, Zhongcun	MZSP 93847	Bankit 1343617
<i>M. pictum</i>	Brazil, São Paulo, Ribeirão Pires	CMS-DPE-95	Bankit 1343611
<i>M. pictum</i>	Brazil, Paraná, Curitiba	MZSP-93842	Bankit 1343606
<i>M. pictum</i>	Brazil, Santa Catarina, Palhoça	MZSP-93836	Bankit 1343614

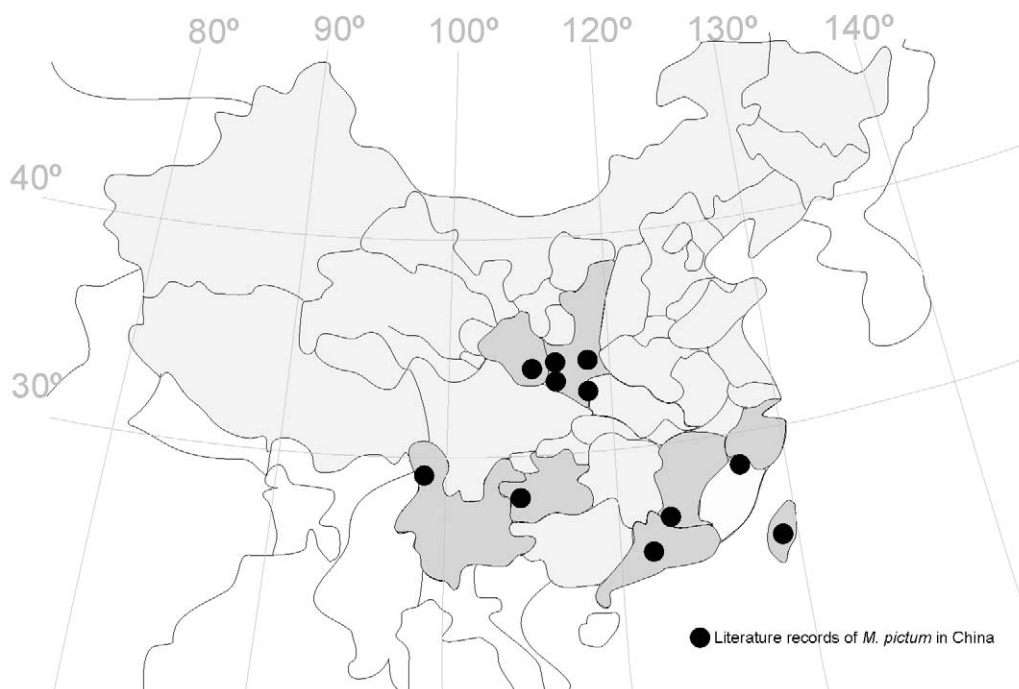


Fig. 2. Map showing the reported distribution of *Meghimatium pictum* in China.

snails, such as *Cyclodontina tudiculata* (Martens, 1868), *Helicina angulifera* Wagner, 1910, *Mirinaba cadeadensis* (Lange-de-Morretes, 1952), and *Simpulopsis pseudosulculosa* Breure, 1975. In Paraná *M. pictum* was also found in disturbed areas in Campo Largo and in Curitiba.

**Habit.**—In the cities during the day, individuals are generally found in wasteland of peripheral areas, under fallen trunks, limbs, stones or all kind of garbage. In the forest, they were found on the woody stem (in resting), inside hollowed trunks or associated with the bryophytes (next to or under) that grow abundantly on the trunks of trees. Some specimens were found up to 1.5 m from the ground in Paraná. This behavior was also described for philomycids in general (Pilsbry, 1948). The specimens were often numerous and close to each other. Dozens of eggs were often found in the environment and, in general, the adults were close to the eggs.

**Dimensions.**—Relatively small and slender slugs. Extended length when alive up to 6 cm and 1.5 cm wide.

**External morphology.**—(Fig. 3A-D) Elongated cylindrical body, with a rounded anterior margin and a pointed posterior margin. The head is long and extends out from beneath the anterior portion of the mantle. The sole occupies the entire ventral body region. There is a visible respiratory pore formed by a short slit near the anterior right mantle edge. Background color of mantle from yellowish to opaque beige, with two dark brown to black lateral stripes, and one medial stripe, often lighter than the lateral ones. Below the lateral stripes (laterally) and surrounding the central medial stripe (dorsally) are found scattered dark brown irregular spots or even short lines (in general lighter than the lateral stripes). Sole cream colored. The head is also cream colored although the ocular tentacles are dark.



Fig. 3. Live specimens of *Meghimatium pictum*. A. Specimen collected in 2000s in Ingleses, Florianópolis, SC, found next to a specimen of *Achatina fulica*; B-C. Specimens collected in Biguaçu, SC (MCP-9173); D. Specimens collected in Da Fu Shan Forestry Park, China (USDA 120066) (photo courtesy of David Robinson).

*Reproductive system.*—(Figs. 4-5) The vagina, evertophallus, and duct of bursa copulatrix (=receptacle or gametolic gland) open into a large, barrel-shaped atrium. The vagina is short and of similar length to the atrium. The evertophallus is short and thick (compared to other species of the genus) and has a constriction halfway along its length. The vas deferens is short and only slightly longer than the penis. The bursa copulatrix is nearly spherical to oval-shaped and is situated a short distance from the atrium through a thin duct. The other genital organs appear to

lack distinguishing characteristics in relation to the other species of the genus.

*Radula and jaw.*—(Figs. 6A-D) Radula with approximately 138 rows and tooth arrangement 31:1:31 and with elongated teeth with slightly curved and arrow-shaped apices; small central tooth with a wide and triangular base; lateral tooth with a rectangular base and with twice the size of the central teeth. Jaw horseshoe-shaped with about 25 plates, in which the central ones are more developed.

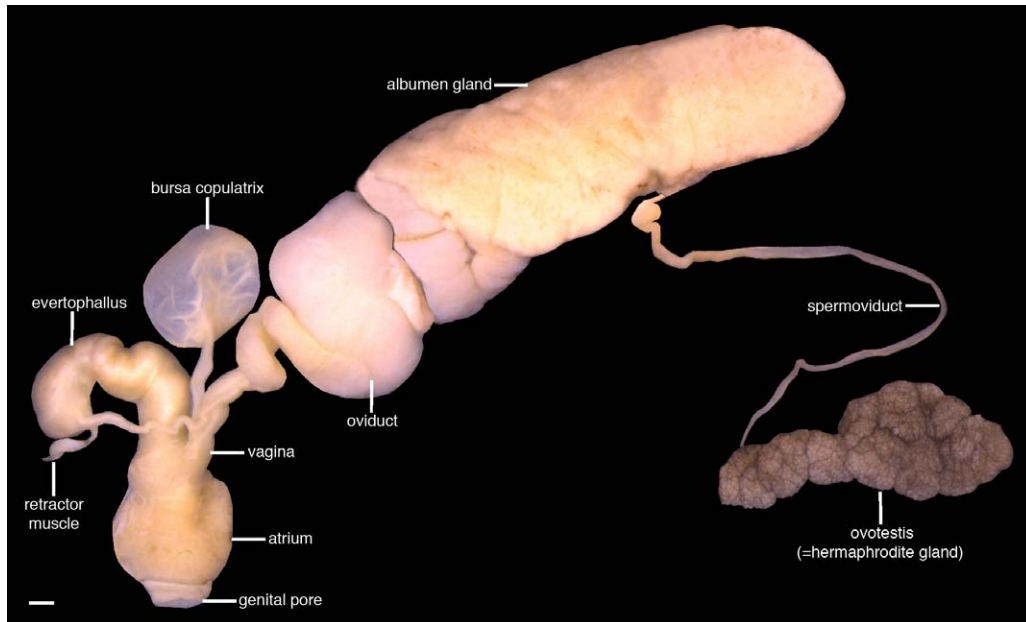


Fig. 4. Reproductive system of *Meghimatium pictum* (Lot MZSP-93847). Scale: 1mm.

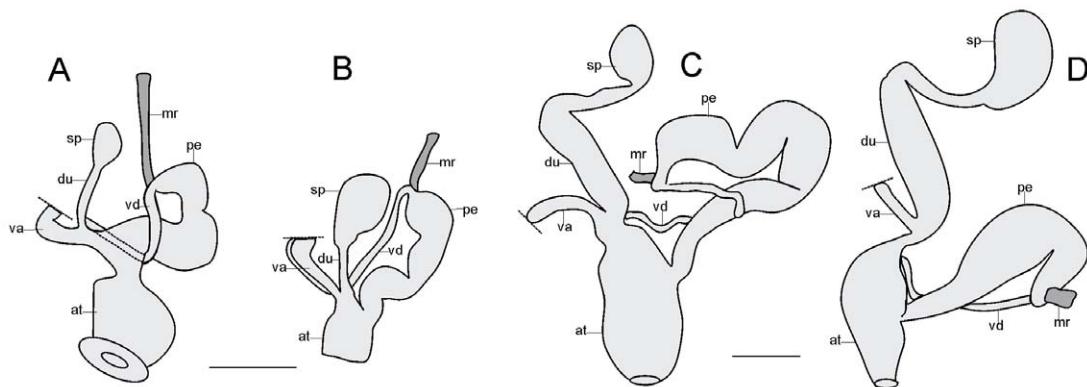


Fig. 5. Reproductive system in four species of *Meghimatium* (modified from Tsai et al., 2005 and Tsai et al., 2008). A. *M. pictum*. B. *M. bilineatum* (Benson, 1842) (sister species of *M. pictum*, according to Tsai and Wu 2008). C. *M. burchi* Tsai and Wu (2008). D. *M. fruhstorferi* (Collinge, 1901).

*Historic of records.*—The first alive specimen of *M. pictum* known to us was in 2002 from Santa Catarina in the neighborhood of “Ingleses” north of the Island of Santa Catarina. This specimen was photographed (Fig. 3A). Subsequently it died, with insufficient time to preserve and study it. Afterwards, specimens were subsequently collected in Rio Grande do Sul (2005), Paraná (2006) and São Paulo (2009). Since Thomé et al. (2006), the form has been called as “*Pallifera* sp.” in the literature (Agudo and Bleicker, 2006; Thomé et al., 2007; Agudo-Padrón, 2008; Agudo-Padrón and Lenhard, 2010).

In 2010, two specimens of *M. pictum* collected in 1998 as a single lot in Curitiba, Paraná were examined at the Zoology Museum of São Paulo. These would be probably the first collected specimens of *M. pictum*. The lot contained two labels, one determining the specimens as Veronicellidae and other determining them as *Philomycus carolinianus* (Bosc, 1802). However, either of them has been dissected.

*Impact.*—In Brazil, *M. pictum* was found attacking plants in private kitchen garden in Santa Catarina. It was also found in protected areas in Paraná, along with native species. *M. pictum* occurs in the same environment as other introduced land slugs and snails that frequently are found infected with *Angiostrongylus costaricensis* Moreira and Céspedes 1971 and other parasites (Graeff-Teixeira et al., 1994; Rambo et al., 1997; Ohlweiler et al., 2010), although it has not been shown to be a vector.

#### DISCUSSION AND CONCLUSIONS

The land slug *Meghimatium pictum* (Stoliczka, 1873) is recorded for the first time in Brazil. This is also the first record of a species of the eastern Asiatic genus *Meghimatium* on American continents. The records cover a wide distribution for this species in southern and southeastern Brazil, in the States of São Paulo, Paraná, Santa Catarina, and Rio Grande do Sul. The species can be

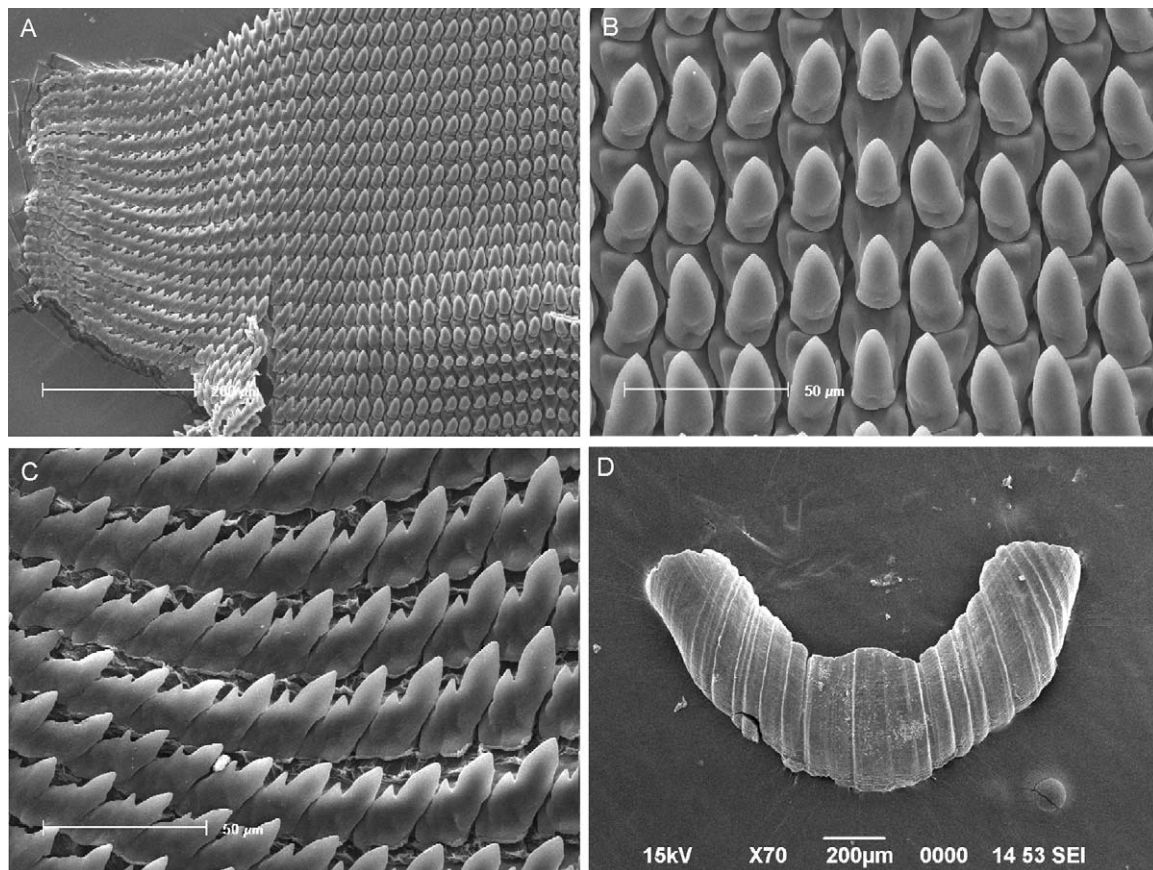


Fig. 6. Radula and jaw of *Meghimatium pictum*. A. Left half (MZSP-93839). B. Central and lateral teeth (on both sides of the central teeth) (MZSP-93839). C. Left half of marginal teeth. D. Jaw (MNRJ 11823).



recognized from morphological characteristics (external morphology and reproductive system) described above and confirmed by its COI sequence.

The three Brazilian COI sequences were identical to each other (specimens from three different States) and more similar to the sequence from the Guangzhou specimen (99%) than the sequence from the specimen from Taiwan (89-90%), indicating a probable closer relationship between the populations from Brazil and mainland China (Table 2).

Land mollusks include several examples of species that have dispersed outwards from their native area through human-mediated transport, establishing self-sustaining populations in distant parts of the world (Barker, 1982; Tillier, 1992; Hausdorf, 2002; Robinson and Slapcinsky, 2005; Rumi et al., 2010). Because of the potential for impressive diversity and high levels of local endemicity of terrestrial mollusks, malacologists are frequently unfamiliar with the malacofauna of other parts of the world, and a new introduction may remain undetected or unreported for years (Robinson and Slapcinsky, 2005). *M. pictum*, possibly, was accidentally introduced in Brazil through agricultural products. According to USDA reports, *Meghimatium* species have been intercepted in United States from China and Taiwan on *Bougainvillea* sp., bonsai, orchids and especially on mushrooms (David Robinson, personal communication). The discovery of a specimen in the MZSP shows that the species was probably introduced to Brazil in the 1990s, although it was only in the 2000s that it started to be recurrently collected in São Paulo, Paraná, Santa Catarina, and Rio Grande do Sul. Coincidentally with this history, in 1995 a collaboration began between China and Brazil to boost the production of mushrooms in Brazil (Embrapa, 1999), which appear to have been successfully implemented in southern and southeastern Brazil.

Introduced species have been reported to greatly alter

native diversity, transforming native ecosystems as well as contributing to the extinction of endangered species, creating important management challenges (Mack et al., 2000; Agudo-Padrón and Lenhard, 2010). Although as yet there is no record of serious damage, *M. pictum* is undoubtedly an invasive species and potential agricultural pest. It is phytophagous and therefore naturally prone to cause damage to gardens and crops. According to Nuñez et al. (2010), the effects of herbivore introductions extend from the population to the community and ecosystem level. They compete with native species within conservation areas. In Brazil, as in other areas (Hausdorf, 2002), land mollusks rarely invade native environments, being restricted to disturbed environments. The land snail *Achatina fulica* is an example of exotic species that invaded native areas and today is in 23 of the 26 states of Brazil (Colley and Fischer, 2009), as in several other South American countries. *M. pictum* has also potential to cause health problems since it occurs in the same disturbed areas where other land mollusks that serve as intermediate hosts of parasites (Ohlweiler et al., 2010) occur. Finally, it is a hermaphrodite (even capable of self-fertilization) and has high rates of reproduction. There is clearly the urgent need to evaluate the real distribution of *M. pictum* and its possible relationship to mushroom crops in an effort to reduce and control the spread of the species in Brazil and the Americas.

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Table 2. Similarity percentage of the COI sequences (600 bp) among some specimens from Brazil and from China, including a sequence from *Meghimatium bilineatum* and *M. pictum* from Tsai et al. (2005).

Species	Similarity among the sequences				
	1	2	3	4	5
1. <i>M. bilineatum</i> (Taiwan, Nantou, Tsai and Wu, 2008)					
2. <i>M. pictum</i> (Taiwan, Tapei, Tsai and Wu, 2008)	85%				
3. <i>M. pictum</i> (China, Guangzhou, Zhongcun)	86%	89%			
4. <i>M. pictum</i> (Brazil, SP, Ribeirão Pires)	86%	90%	99%		
5. <i>M. pictum</i> (Brazil, SC, Palhoça)	86%	90%	99%	100%	
6. <i>M. pictum</i> (Brazil, PR, Curitiba)	86%	90%	99%	100%	100%

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