SPATIAL DISTRIBUTION OF LYMNAEIDAE (MOLLUSCA, BASOMMATOPHORA), INTERMEDIATE HOST OF Fasciola hepatica LINNAEUS, 1758 (TREMATODA, DIGENEA) IN BRAZIL

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SUMMARY

Snails of the family Lymnaeidae act as intermediate hosts in the biological cycle of Fasciola hepatica, which is a biological agent of fasciolosis, a parasitic disease of medical importance for humans and animals. The present work aimed to update and map the spatial distribution of the intermediate host snails of F. hepatica in Brazil. Data on the distribution of lymnaeids species were compiled from the Collection of Medical Malacology (Fiocruz-CMM, CPqRR), Collection of Malacology (MZUSP), “SpeciesLink” (CRIA) network and through systematic surveys in the literature. Our maps of the distribution of lymnaeids show that Pseudosuccinea columella is the most common species and it is widespread in the South and Southeast with few records in the Midwest, North and Northeast regions. The distribution of the Galba viatrix, G. cubensis and G. truncatula showed a few records in the South and Southeast regions, they were not reported for the Midwest, North and Northeast. In addition, in the South region there are a few records for G. viatrix and one occurrence of Lymnaea rupesstris. Our findings resulted in the first map of the spatial distribution of Lymnaeidae species in Brazil which might be useful to better understand the fasciolosis distribution and delineate priority areas for control interventions.

KEYWORDS: Lymnaeids; Fasciolosis; Spatial distribution; Snails; Brazil.

INTRODUCTION

Snails of the family Lymnaeidae are small Basommatophora hermaphrodites, approximately 10 mm long and 6 mm wide. The lymnaeids species is widely distributed around the tropical and subtropical areas of the Americas, Europe, Asia, Africa, and Oceania and inhabits natural (streams, ponds, swamps) or artificial (irrigation ditches, small dams, floodplain) types of water collections.

The importance of the lymnaeids is due to the fact that they act as intermediate hosts in the biological cycle of the digenetic trematode Fasciola hepatica Linnaeus, 1758 (Trematoda, Digenea), biological agent of fasciolosis, which is a parasitic disease of medical importance for both humans and animals.

Based on an increasing number of human cases since 1980, MACOMA et al. proposed that fasciolosis should be considered an important parasitic human disease rather than just a secondary zoonotic disease with an estimated number of infected people of more than 2.4 million people worldwide. The economic losses caused by this disease include a significant impact on the livestock industry due to the high costs for therapeutic treatments in cattle, goat, and sheep breeding. SMOOKER et al. calculated a global cost of more than two billion dollars a year because of the infection.

In Brazil, the lymnaeids species already recorded are: Pseudosuccinea columella (Say, 1817), Galba viatrix d’Orbigny, 1835, Galba truncatula (Mueller, 1774), Galba cubensis Pfeiffer, 1839 and Lymnaea rupesstris Paraense, 1982. Except for L. rupesstris, the other species have proved to be susceptible to infection by F. hepatica. Regarding the identification of lymnaeids species, their systematics is confused and there are a lot of difficulties in identifying some species using only morphological characters, so molecular markers are frequently necessary. Here, we used the taxonomy proposed by BAKER for the species P. columella.

The present work aimed to update and map the spatial distribution of the intermediate host snails of F. hepatica in Brazil.

MATERIAL AND METHODS

Malacological data: Data on the distribution of lymnaeids species were obtained from: i) Collection of Medical Malacology (Fiocruz-CMM) of the Laboratory of Medical Helminthology and Malacology, René Rachou Research Center (Fiocruz/MG); ii) Collection of Malacology of the Museum of Zoology of University of São Paulo (MZUSP); iii) “SpeciesLink” (CRIA) network (http://www.splink.org.br/), by using the keyword Lymnaeidae in the database search; iv) systematic surveys in scientific articles, gray literature, dissertations, theses, and communications, by using the combined keywords: Lymnaea/
Galba/Pseudosuccinea/Lymnaeidae + occurrence + Brazil; Lymnaeidae + Galba/Pseudosuccinea/Lymnaeidae + distribution + Brazil; Lymnaeidae + Galba/Pseudosuccinea/Lymnaeidae + record + Brazil; Lymnaeidae/Galba/Pseudosuccinea/Lymnaeidae + collection + Brazil; Fasciola + occurrence + Brazil; Fasciola + distribution + Brazil; Fasciola + record + Brazil; Fasciolosis + occurrence + Brazil; Fasciolosis + distribution + Brazil and Fasciolosis + record + Brazil. According to the type of database (or sites), terms were used in English or Portuguese: Google scholar, Web of Knowledge, Scielo, PubMed, Periódicos Capes (Capes Journals) and Banco Digital de Teses e Dissertações (Theses and Dissertations Digital Database). The data collected had information relative to the occurrence of lymnaeids per state and municipalities of Brazilian regions and if the snails were found naturally infected by F. hepatica.

In the majority of the data used, the identification of the lymnaeids species was made using only morphological characters except when the data are from Fiocruz-CMM, where molecular markers were utilized to confirm the morphological identification. The molecular technique used was the polymerase chain reaction and restriction fragment length polymorphism (PCR-RFLP) targeted to the first and second internal transcribed spacers (ITS1 and ITS2) rDNA and to the mitochondrial 16S ribosomal gene (16S rDNAmt)19,22.

Data management and mapping: Data management, visualization and mapping were carried out in ArcGIS version 9.3 (ESRI; Redlands, CA, USA).

RESULTS

Reports on five species of Lymnaeidae were found in Brazil. Tables 1 and 2 summarize the distribution per locality of species in the five regions of Brazil (Fig. 1 and 2), South (Fig. 3), Southeast (Fig. 4), Midwest, North and Northeast regions (Fig. 5). In the “SpeciesLink” (CRIA) network, we found data relative to four collections: Collection of Molluscs of Museum of Science and Technology, PUCRS; Collection of Molluscs of National Institute of Research of Amazônia, INPA; Malacological Collection of Biological Science Department, DCBio/UFES and Collection of Malacology of Oswaldo Cruz Institute, Fiocruz-CMIOC. The information about the localities where the specimens occurred was not available from the Collection of Malacology of Oswaldo Cruz Institute, Fiocruz-CMIOC, because of this, we did not add these data to our results. The data came from the Collection of Medical Malacology, Fiocruz-CMM, were already available to us.

Lymnaeids were reported in 417 municipalities and one ecological reserve (Taim) of 16 states, which corresponds to 7.5% of all municipalities in Brazil. Pseudosuccinea columella was reported in 400 (95.7%) localities while G. viatrix in 10 (2.4%), G. cubensis in six (1.4%), G. truncatula in three (0.7%) and L. rupestris in one (0.2%). In 25 (6%) municipalities: Bom Jesus, Cambará do Sul, Erval Grande, Estrela, Ibirubá, Porto Alegre, São Borja, São Francisco de Paula, Selbach, Três Coroas, Vacaria and Viamão of Rio Grande do Sul State; Piracicaba, Presidente Prudente, São Paulo and Ubatuba of São Paulo State; Rio de Janeiro, Nova Friburgo, Teresópolis and Vassouras of Rio de Janeiro State; Ouro Branco and Caraça of Minas Gerais State; Campos Novos/SC; Curitiba/PR and Belém/PA; it was not possible to accomplish a complete identification of the specimens collected. Occurrence of more than one species was reported in 13 municipalities (3.1%): Dom Pedrito, Pelotas and Santa Vitória do Palmar in the state of Rio Grande do Sul; Florianópolis (P. columella and G. viatrix) and Seara (L. rupestris, P. columella and G. viatrix) in the state of Santa Catarina; Teresópolis (P. columella; G. cubensis and G. truncatula), Nova Friburgo (P. columella and G. truncatula), Paraba do Sul, Petrópolis, Rio de Janeiro and Três Rios (P. columella and G. cubensis) in the state of Rio de Janeiro; Belo Horizonte (P. columella, G. viatrix and G. cubensis) and Rio Acima (P. columella, G. viatrix and G. truncatula) in the state of Minas Gerais.

Specimens of P. columella and G. viatrix were reported in 403 localities (96.4%). P. columella was reported naturally infected with F. hepatica in 11 municipalities of the states of Rio Grande do Sul, São Paulo, Minas Gerais and Rio de Janeiro, G. viatrix was found naturally infected in three municipalities of Rio Grande do Sul while Lymnaea sp. was found in one municipality of Minas Gerais. In Dom Pedrito/RS, both species were found naturally infected.

DISCUSSION

Our study resulted in the first map of the spatial distribution of Lymnaeidae species, intermediate host snails of F. hepatica in Brazil. The presence of host snails could reflect the disease distribution, and these data are essential for describing the risk areas of fasciolosis since there is an increase of the association between the global number of human cases and the presence of the intermediate host snail30.

PARAENSE35 showed that G. viatrix had few records in the South and P. columella was distributed mainly in the South and Southeast, where a high number of fasciolosis cases occurs66, with few records in the Midwest region. After that, the same author reported two new localities of P. columella for the states of Amazonas and Bahia67 in the North and Northeast respectively. This agrees with our study where we also reported a low presence of this species in these regions. Our final maps about spatial distribution of lymnaeids snails show that P. columella is the most common species and it is widespread in the South and Southeast with few records in the Midwest, North and Northeast regions. Galba viatrix is predominantly distributed in the South (eight records) with only two records for the Southeast region (Belo Horizonte and Rio Acima, Minas Gerais State). The distribution of G. viatrix, G. cubensis and G. truncatula comprises few records in Southeast and South regions. They were not reported for the Midwest, North and Northeast. For the South region, the species L. rupestris was only described and found in the Nova Teutônia district in Seara municipality at Santa Catarina State64.

Despite the few records showed by G. viatrix in our study, according to MATTOS & UENO52 this intermediate host is considered the most efficient species in the transmission of F. hepatica due to its high susceptibility when compared with P. columella52. However, P. columella showed to be the most distributed species (Fig. 1; 95.7%) and is certainly the most important intermediate host in Brazil. This is probably due to its biological aspects, such as its high capacity for self-fertilization, favorable condition in dispersion and colonization of new habitats20,35. Pseudosuccinea columella is commonly found in most human or animal fasciolosis outbreaks while the occurrence of G. viatrix is, currently, restricted to the state of Rio Grande do Sul24,33,63,76,104 and in Minas Gerais32.
**Table 1**

Distribution of *Pseudosuccinea columella* per municipalities and regions of Brazil

| Regions/States                  | Localities                      | Geographic coordinates | Species   | Articles/“SpeciesLink” (CRIA) network |
|---------------------------------|---------------------------------|------------------------|-----------|--------------------------------------|
| **1) South**                    |                                 |                        |           |                                      |
| **Rio Grande do Sul**           | Agudo                           | 29°38'53"S 51°15"W    | *P. columella* | 1                                    |
|                                 | Arroio Grande                   | 32°14'53"S 51°05"W    | *P. columella* | 2                                    |
|                                 | Cachoeira do Sul                | 30°02'52"S 51°48"W    | *P. columella* | 4                                    |
|                                 | Camaquã                         | 30°51'51"S 51°43"W    | *P. columella* | 4; 5; 6                              |
|                                 | Candiota                        | 31°35'53"S 51°43"W    | *P. columella* | MCP-Moluscos                        |
|                                 | Capão do Leão                    | 31°46'52"S 51°30"W    | *P. columella* | 4; 2                                 |
|                                 | Dom Pedrito                     | 30°58'54"S 51°40"W    | *P. columella* | 4                                    |
|                                 | Eldorado do Sul                 | 29°50'51"S 51°18"W    | *P. columella* | 81                                   |
|                                 | Gramado                         | 29°23'50"S 52°52"W    | *P. columella* | Fiocruz-CMM                          |
|                                 | Guaíba                          | 30°06'51"S 51°19"W    | *P. columella* | 4                                    |
|                                 | Morro Reuter                    | 29°32'51"S 51°04"W    | *P. columella* | 4                                    |
|                                 | Nova Petrópolis                 | 29°20'51"S 51°10"W    | *P. columella* | 4                                    |
|                                 | Pelotas                         | 31°46'52"S 51°20"W    | *P. columella* | 8; 9; Fiocruz-CMM                    |
|                                 | Porto Alegre                    | 30°01'51"S 51°13"W    | *P. columella* | 11; 4                                |
|                                 | Rosário do Sul                  | 30°15'54"S 51°55"W    | *P. columella* | 12                                   |
|                                 | Santa Maria                     | 29°41'53"S 51°48"W    | *P. columella* | 13                                   |
|                                 | Santa Vitória do Palmar          | 33°31'53"S 52"W      | *P. columella* | 4                                    |
|                                 | Santo Antônio da Patrulha        | 29°49'50"S 51°30"W    | *P. columella* | 84                                   |
|                                 | São Borja                       | 28°39'55"S 51°59"W    | *P. columella* | 15                                   |
|                                 | São Leopoldo                    | 29°45'51"S 51°08"W    | *P. columella* | MZUSP                                |
|                                 | São Martinho da Serra           | 29°32'53"S 51°51"W    | *P. columella* | 13                                   |
|                                 | Sapucaia do Sul                 | 29°49'51"S 51°09"W    | *P. columella* | 12                                   |
|                                 | Reserva ecológica do Taim        | 32°29'52"S 52°35"W    | *P. columella* | 4                                    |
|                                 | Rio Pardo                       | 29°99'52"S 52°35"W    | *P. columella* | MCP-Moluscos                         |
|                                 | Taquara                         | 29°38'50"S 51°46"W    | *P. columella* | 4; 87                                |
|                                 | Tramandaí                       | 29°59'50"S 51°07"W    | *P. columella* | 4                                    |
|                                 | Triunfo                         | 29°56'51"S 51°43"W    | *P. columella* | 16; Fiocruz-CMM                      |
|                                 | Viamão                          | 30°04'51"S 51°01"W    | *P. columella* | 4                                    |
| **Santa Catarina**              |                                 |                        |           |                                      |
|                                 | Araranguá                       | 28°56'49"S 51°28"W    | *P. columella* | 4                                    |
|                                 | Biguaçu                         | 27°29'48"S 51°39"W    | *P. columella* | 18; 19; 20                           |
|                                 | Blumenau                        | 26°54'49"S 51°40"W    | *P. columella* | 18; 19; 20                           |
|                                 | Brusque                         | 27°05'48"S 51°55"W    | *P. columella* | 18; 19; 20                           |
|                                 | Camboriú                        | 27°01'48"S 51°39"W    | *P. columella* | 18; 19; 20                           |
|                                 | Criciúma                        | 28°41'49"S 51°22"W    | *P. columella* | 18; 19; 20                           |
|                                 | Florianópolis                   | 27°35'48"S 51°33"W    | *P. columella* | 4; 17; 18; 19; 20                    |
|                                 | Itá                            | 27°29'52"S 52°32"W    | *P. columella* | MCP-Moluscos                         |
|                                 | Joinville                      | 26°17'48"S 51°50"W    | *P. columella* | 4                                    |
|                                 | Lages                          | 27°48'50"S 51°19"W    | *P. columella* | 4                                    |
|                                 | Lauro Müller                    | 28°23'49"S 51°24"W    | *P. columella* | MZUSP                                |
|                                 | Nova Trento                     | 27°17'48"S 51°55"W    | *P. columella* | 18; 19; 20                           |
|                                 | Palhoça                        | 27°38'48"S 51°40"W    | *P. columella* | 18; 19; 20                           |
|                                 | São João do Sul                 | 29°13'49"S 51°48"W    | *P. columella* | 18; 19; 20                           |
|                                 | Seara                          | 27°12'52"S 51°19"W    | *P. columella* | 4; 24                                |
|                                 |                                 |                        |           |                                      |

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Table 1
Distribution of *Pseudosuccinea columella* per municipalities and regions of Brazil (cont.)

| Regions/States          | Localities              | Geographic coordinates | Species   | Articles/“SpeciesLink” (CRIA) network |
|-------------------------|-------------------------|------------------------|-----------|---------------------------------------|
| Santa Catarina          | Tubarão                 | 28°28/49w00            | *P. columella* | 18; 19; 20                           |
|                         | Urubici                 | 28°00/49w35            | *P. columella* | 25                                    |
| Paraná                  | Antonina                | 25°42/48w71            | *P. columella* | 91                                    |
|                         | Balsa Nova              | 25°58/49w63            | *P. columella* | 91                                    |
|                         | Bocaiúva do Sul         | 25°12/49w06            | *P. columella* | 26; 91                                |
|                         | Cambará                 | 23°02/50w04            | *P. columella* | Fiocruz-CMM                           |
|                         | Campina Grande do Sul   | 25°30/49w05            | *P. columella* | 91                                    |
|                         | Campo Largo             | 25°45/49w53            | *P. columella* | 91                                    |
|                         | Contenda                | 25°67/49w52            | *P. columella* | 91                                    |
|                         | Curitiba                | 25°25/49w16            | *P. columella* | 27; 4; 28; 24; 87; 52; 91;            |
|                         |                         |                        |           | Fiocruz-CMM MZUSP                     |
|                         | Dionísio Cerqueira (Barração) | 26°15/53w38        | *P. columella* | 4                                     |
|                         | Morretes                | 25°28/48w49            | *P. columella* | 4; 91                                 |
|                         | Paranaguá               | 25°30/48w30            | *P. columella* | MZUSP                                 |
|                         | Quatro Barras           | 25°36/49w07            | *P. columella* | 91                                    |
|                         | Rio Branco do Sul       | 25°19/49w31            | *P. columella* | 91                                    |
|                         | São José dos Pinhais    | 25°32/49w12            | *P. columella* | 87; 91                                |
|                         | Tunas do Paraná         | 24°58/49w05            | *P. columella* | 26; MZUSP                             |
| 2) Southeast            | Águas de Santa Bárbara  | 22°52/49w14            | *P. columella* | 29                                    |
|                         | Altinópolis             | 21°04/47w22            | *P. columella* | 30                                    |
|                         | Álvares Machado         | 22°04/51w28            | *P. columella* | 31                                    |
|                         | Americana              | 22°44/47w19            | *P. columella* | 80                                    |
|                         | Américo Brasiliense     | 21°43/48w06            | *P. columella* | 30                                    |
|                         | Angatuba                | 23°29/48w24            | *P. columella* | 29                                    |
|                         | Anhembi                 | 22°47/48w07            | *P. columella* | 29                                    |
|                         | Araçoiaba da Serra      | 23°30/47w36            | *P. columella* | 29                                    |
|                         | Aramina                 | 20°05/47w47            | *P. columella* | 30                                    |
|                         | Arandu                  | 23°08/49w03            | *P. columella* | 29                                    |
|                         | Araraquara              | 21°47/48w10            | *P. columella* | 30                                    |
|                         | Areiópolis              | 22°40/48w39            | *P. columella* | 29                                    |
|                         | Atibaia                 | 23°69/46w33            | *P. columella* | 80                                    |
|                         | Avanhandava             | 21°27/49w56            | *P. columella* | MZUSP                                 |
|                         | Avaré                   | 21°54/49w21            | *P. columella* | 29                                    |
|                         | Barão de Antonina       | 23°37/49w33            | *P. columella* | 29                                    |
|                         | Barra Bonita            | 22°29/48w33            | *P. columella* | 33                                    |
|                         | Barretos                | 20°33/48w34            | *P. columella* | 30                                    |
|                         | Batatais                | 20°53/47w35            | *P. columella* | 30                                    |
|                         | Bebedouro               | 20°56/48w28            | *P. columella* | 30                                    |
|                         | Boa Esperança do Sul    | 21°59/48w23            | *P. columella* | 30                                    |
|                         | Bofete                  | 23°05/48w15            | *P. columella* | 29                                    |
|                         | Boituva                 | 23°17/47w40            | *P. columella* | 29                                    |
|                         | Borborema               | 21°37/49w04            | *P. columella* | 30                                    |
|                         | Botucatu                | 22°53/48w26            | *P. columella* | 29                                    |
## Table 1

### Distribution of *Pseudosuccinea columella* per municipalities and regions of Brazil (cont.)

| Regions/States | Localities            | Geographic coordinates | Species          | Articles/“SpeciesLink” (CRIA) network |
|----------------|------------------------|------------------------|------------------|---------------------------------------|
| São Paulo      | Brodowski              | 20s59/47w39            | *P. columella*    | 30                                    |
|                | Brotas                 | 22s17/48w07            | *P. columella*    | MZUSP                                 |
|                | Buri                   | 23s47/48w35            | *P. columella*    | 29                                    |
|                | Cabreúva               | 23s18/47w07            | *P. columella*    | 29                                    |
|                | Caçapava               | 23s05/45w42            | *P. columella*    | 4; 80                                 |
|                | Caiúá                  | 21s49/51w59            | *P. columella*    | 31                                    |
|                | Cajurú                 | 21s16/47w18            | *P. columella*    | 30                                    |
|                | Campinas               | 22s53/47w05            | *P. columella*    | 34; 4; 35; 36; 80                     |
|                | Cândido Rodrigues      | 21s19/48w37            | *P. columella*    | 30                                    |
|                | Capão Bonito           | 24s00/48w20            | *P. columella*    | 29                                    |
|                | Capela do Alto         | 23s27/47w44            | *P. columella*    | 29                                    |
|                | Caraguatatuba          | 23s27/45w24            | *P. columella*    | MZUSP                                 |
|                | Cárass dos Coqueiros   | 21s16/47w10            | *P. columella*    | 30                                    |
|                | Catiguá                | 21s03/49w03            | *P. columella*    | 37                                    |
|                | Cerqueira Cesar        | 23s01/49w09            | *P. columella*    | 29                                    |
|                | Cerquilho              | 23s09/47w44            | *P. columella*    | 29                                    |
|                | Cesário Lange          | 23s13/47w57            | *P. columella*    | 29                                    |
|                | Colina                 | 20s43/48w32            | *P. columella*    | 30                                    |
|                | Colômbia               | 20s10/48w41            | *P. columella*    | 30                                    |
|                | Conchas                | 23s01/48w00            | *P. columella*    | 29                                    |
|                | Coronel Macedo         | 23s38/49w18            | *P. columella*    | 29                                    |
|                | Cravinhos              | 21s20/47w43            | *P. columella*    | 30                                    |
|                | Cristais Paulista      | 20s23/47w25            | *P. columella*    | 30                                    |
|                | Descalvado             | 21s54/47w37            | *P. columella*    | 30                                    |
|                | Dourado                | 22s06/48w18            | *P. columella*    | 30                                    |
|                | Eldorado               | 24s30/48w05            | *P. columella*    | 41                                    |
|                | Estrela do Norte       | 22s29/51w39            | *P. columella*    | 31                                    |
|                | Fernando Prestes       | 21s15/48w41            | *P. columella*    | 30                                    |
|                | Franca                 | 20s31/47w23            | *P. columella*    | 30                                    |
|                | Guará                  | 20s19/48w19            | *P. columella*    | 30                                    |
|                | Guapiaçú               | 20s47/49w13            | *P. columella*    | 37                                    |
|                | Guapiara               | 24s10/48w32            | *P. columella*    | 29                                    |
|                | Guará                  | 20s25/47w49            | *P. columella*    | 30                                    |
|                | Guaraci                | 20s29/48w56            | *P. columella*    | 37                                    |
|                | Guareí                 | 23s22/48w10            | *P. columella*    | 29                                    |
|                | Guaruja                | 23s58/46w15            | *P. columella*    | MZUSP                                 |
|                | Ibaté                  | 21s57/47w59            | *P. columella*    | 30                                    |
|                | Ibirá                  | 21s04/49w14            | *P. columella*    | 37                                    |
|                | Ibitinga               | 21s45/48w49            | *P. columella*    | 30                                    |
|                | Ibiúna                 | 23s38/47w13            | *P. columella*    | 29                                    |
|                | Iepê                   | 22s38/51w06            | *P. columella*    | 31                                    |
|                | Igarapava              | 20s02/47w44            | *P. columella*    | 30; Fiocruz-CMM                        |
|                | Indiana                | 22s08/51w15            | *P. columella*    | 31                                    |
|                | Iperó                  | 23s21/47w42            | *P. columella*    | 29                                    |
Table 1

Distribution of *Pseudosuccinea columella* per municipalities and regions of Brazil (cont.)

| Regions/States | Localities       | Geographic coordinates | Species      | Articles/“SpeciesLink” (CRIA) network |
|----------------|------------------|------------------------|--------------|--------------------------------------|
| **São Paulo**  |                  |                        |              |                                      |
|                | Irapuã           | 21s17/49w24            | *P. columella* | 37                                   |
|                | Itaberá          | 23s51/49w08            | *P. columella* | 29                                   |
|                | Itá              | 23s24/49w05            | *P. columella* | 29                                   |
|                | Itapetinga       | 23s36/48w03            | *P. columella* | 29                                   |
|                | Itapéva          | 23s58/48w52            | *P. columella* | 29                                   |
|                | Itápolis         | 21s35/48w48            | *P. columella* | 30                                   |
|                | Itaporanga       | 23s42/48w29            | *P. columella* | 29                                   |
|                | Itararé          | 24s06/49w20            | *P. columella* | 29                                   |
|                | Itariri          | 24s17/47w03            | *P. columella* | 4; 32                                |
|                | Itatinga         | 23s06/48w36            | *P. columella* | 29                                   |
|                | Itu              | 23s15/47w17            | *P. columella* | 29                                   |
|                | Ituverava        | 20s20/47w47            | *P. columella* | 30                                   |
|                | Jaboticabal      | 21s15/48w18            | *P. columella* | 30                                   |
|                | Jaguariúna       | 22s42/46w59            | *P. columella* | 36                                   |
|                | Jardimópolis     | 21s01/47w45            | *P. columella* | 30                                   |
|                | João Ramalho     | 22s15/50w46            | *P. columella* | 31                                   |
|                | Junqueirópolis   | 21s31/51w26            | *P. columella* | 31                                   |
|                | Louveira         | 23s05/46w58            | *P. columella* | 36                                   |
|                | Luis Antônio     | 21s33/47w42            | *P. columella* | 30                                   |
|                | Mairinque        | 23s32/47w11            | *P. columella* | 29                                   |
|                | Marinópolis      | 20s26/50w49            | *P. columella* | 37                                   |
|                | Martinópolis     | 22s08/51w10            | *P. columella* | 31                                   |
|                | Matão            | 21s36/48w21            | *P. columella* | 30                                   |
|                | Miguelópolis     | 20s10/48w01            | *P. columella* | 30                                   |
|                | Miracatu         | 24s16/47w27            | *P. columella* | 36; 41                               |
|                | Monte Alto       | 21s15/48w29            | *P. columella* | 30                                   |
|                | Monte Aprazível  | 20s45/49w42            | *P. columella* | 37                                   |
|                | Monte Azul Paulista | 20s54/48w38          | *P. columella* | 30                                   |
|                | Morro Agudo      | 20s43/48w03            | *P. columella* | 30                                   |
|                | Narandiba        | 22s24/51w31            | *P. columella* | 31                                   |
|                | Nova Europa      | 21s46/48w33            | *P. columella* | 30                                   |
|                | Nova Granada     | 20s31/49w18            | *P. columella* | 37                                   |
|                | Novo Horizonte   | 21s28/49w13            | *P. columella* | 37                                   |
|                | Olimpia          | 20s44/48w54            | *P. columella* | 37                                   |
|                | Orlândia         | 20s43/47w53            | *P. columella* | 30                                   |
|                | Oswaldo Cruz     | 23s37/46w34            | *P. columella* | 31                                   |
|                | Palestina        | 20s21/49w25            | *P. columella* | 37                                   |
|                | Palmiral         | 22s46/50w12            | *P. columella* | 37                                   |
|                | Panorama         | 21s20/51w51            | *P. columella* | 31                                   |
|                | Paraíso          | 20s59/48w46            | *P. columella* | 37                                   |
|                | Parapuã          | 21s46/50w47            | *P. columella* | 31                                   |
|                | Pardinho         | 23s04/48w22            | *P. columella* | 29                                   |
|                |                  |                        |              |                                      |
Table 1

Distribution of *Pseudosuccinea columella* per municipalities and regions of Brazil (cont.)

| Regions/States | Localities              | Geographic coordinates | Species       | Articles/“SpeciesLink” (CRIA) network |
|----------------|-------------------------|------------------------|---------------|-------------------------------------|
| São Paulo      | Patrocínio Paulista     | 20s37/47w16            | *P. columella* | 30                                   |
|                | Pedregulho              | 20s14/47w28            | *P. columella* | 30                                   |
|                | Pereiras                 | 23s04/47w58            | *P. columella* | 29                                   |
|                | Piedade                 | 23s41/47w25            | *P. columella* | 29                                   |
|                | Pilar do Sul            | 23s48/47w43            | *P. columella* | 29                                   |
|                | Piquerobi                | 21s52/51w43            | *P. columella* | 31                                   |
|                | Piquete                 | 22s36/45w10            | *P. columella* | 30                                   |
|                | Piracicaba               | 22s43/47w39            | *P. columella* | 36                                   |
|                | Pirangi                  | 21s09/48w39            | *P. columella* | 30                                   |
|                | Pirassununga             | 21s59/47w25            | *P. columella* | 4; 36; 80                            |
|                | Pitanguieiras            | 20s59/48w12            | *P. columella* | 30                                   |
|                | Planalto                 | 21s21/49w55            | *P. columella* | 37                                   |
|                | Portal                   | 20s59/48w02            | *P. columella* | 30                                   |
|                | Porangaba                | 20s54/47w53            | *P. columella* | 29                                   |
|                | Porto Feliz              | 23s12/47w31            | *P. columella* | 29                                   |
|                | Pradópolis               | 21s21/48w03            | *P. columella* | 30                                   |
|                | Presidente Bernardes     | 22s00/51w33            | *P. columella* | 31                                   |
|                | Rancharia                | 22s13/50w53            | *P. columella* | 31                                   |
|                | Redenção da Serra        | 23s13/45w32            | *P. columella* | 38                                   |
|                | Regente Feijó            | 22s13/51w18            | *P. columella* | 31                                   |
|                | Registro                 | 24s29/47w51            | *P. columella* | 36                                   |
|                | Restinga                 | 20s34/47w29            | *P. columella* | 30                                   |
|                | Ribeirão Bonito          | 22s02/48w10            | *P. columella* | 30                                   |
|                | Ribeirão Branco          | 24s11/48w46            | *P. columella* | 30                                   |
|                | Ribeirão Preto           | 22s10/47w48            | *P. columella* | 30                                   |
|                | Rinção                   | 21s34/48w04            | *P. columella* | 30                                   |
|                | Rinópolis                | 21s43/50w43            | *P. columella* | 31                                   |
|                | Rio Claro                | 22s23/47w33            | *P. columella* | 31                                   |
|                | Riversul                 | 23s48/49w24            | *P. columella* | 29                                   |
|                | Rubimência               | 20s10/50w59            | *P. columella* | 37                                   |
|                | Sales                    | 21s20/49w30            | *P. columella* | 37                                   |
|                | Sales Oliveira           | 20s46/47w56            | *P. columella* | 30                                   |
|                | Salesópolis              | 23s31/45w50            | *P. columella* | 78; MZUSP                            |
|                | Salto                    | 23s11/47w17            | *P. columella* | 29                                   |
|                | Salto de Pirapora        | 23s38/47w34            | *P. columella* | 29                                   |
|                | Sandovalina              | 22s26/51w46            | *P. columella* | 31                                   |
|                | Santa Adélia             | 21s14/48w47            | *P. columella* | 37                                   |
|                | Santa Mercedes           | 21s20/51w45            | *P. columella* | 31                                   |
|                | Santa Rita do Passa Quatro | 21s42/47w28         | *P. columella* | 30                                   |
|                | Santa Rosa do Viterbo    | 21s28/47w21            | *P. columella* | 30                                   |
|                | Santo Anastácio          | 21s57/51w38            | *P. columella* | 31                                   |
|                | Santo Expedito           | 21s30/51w23            | *P. columella* | 31                                   |
|                | São Carlos               | 21s59/47w53            | *P. columella* | 30                                   |
|                | São Joaquim da Barra     | 20s34/47w52            | *P. columella* | 30                                   |
Table 1
Distribution of *Pseudosuccinea columella* per municipalities and regions of Brazil (cont.)

| Regions/States | Localities | Geographic coordinates | Species          | Articles/“SpeciesLink” (CRIA) network |
|----------------|------------|------------------------|------------------|--------------------------------------|
| **São Paulo**  | São José do Rio Preto | 20°40'49"W17 | *P. columella* | 37 |
|                | São José dos Campos | 23°11'45"W52 | *P. columella* | 4  |
|                | São Manoel     | 22°43'47"W18 | *P. columella* | 29 |
|                | São Miguel Arcanjo | 23°52'47"W59 | *P. columella* | 29 |
|                | São Paulo      | 23°32'46"W38 | *P. columella* | 4; MZUSP |
|                | São Roque      | 23°31'47"W08 | *P. columella* | 29 |
|                | São Simão      | 21°28'47"W33 | *P. columella* | 30 |
|                | São Vicente    | 23°57'46"W22 | *P. columella* | MZUSP |
|                | Sarapuí        | 23°37'47"W49 | *P. columella* | 29 |
|                | Serrana        | 21°12'47"W36 | *P. columella* | 30 |
|                | Sertãozinho    | 21°06'47"W59 | *P. columella* | 30 |
|                | Sorocaba       | 23°28'47"W25 | *P. columella* | 29 |
|                | Tabatinga      | 21°42'48"W40 | *P. columella* | 30 |
|                | Taiaçu         | 21°08'48"W30 | *P. columella* | 30 |
|                | Tatuva         | 21°06'48"W26 | *P. columella* | 30 |
|                | Tapuá          | 21°54'49"W21 | *P. columella* | 29 |
|                | Taquaratinga   | 21°24'48"W29 | *P. columella* | 30 |
|                | Taquaribá      | 23°31'49"W14 | *P. columella* | 29 |
|                | Tarabaí        | 22°17'51"W33 | *P. columella* | 31 |
|                | Tatuí          | 23°21'47"W50 | *P. columella* | 29 |
|                | Taubaté        | 23°00'45"W33 | *P. columella* | 4; 80 |
|                | Terra Roxa      | 20°46'48"W19 | *P. columella* | 30 |
|                | Tietê          | 23°05'47"W42 | *P. columella* | 29 |
|                | Urupês         | 21°08'49"W15 | *P. columella* | 37 |
|                | Vista Alegre do Alto | 21°09'48"W38 | *P. columella* | 30 |
|                | Votorantín     | 23°32'47"W26 | *P. columella* | 29 |

| **Rio de Janeiro** | Angra dos Reis | 23°00'44"W19 | *P. columella* | 42 |
|                   | Aperibé         | 21°37'42"W06 | *P. columella* | 43 |
|                   | Araruama        | 22°50'42"W20 | *P. columella* | 44 |
|                   | Areal           | 22°13'43"W06 | *P. columella* | 45 |
|                   | Barra do Piraí  | 22°27'43"W48 | *P. columella* | 42 |
|                   | Barra Mansa     | 22°32'44"W10 | *P. columella* | 42 |
|                   | Bom Jardim      | 22°09'42"W25 | *P. columella* | 45 |
|                   | Bom Jesus de Itabapoana | 21°07'41"W40 | *P. columella* | 43 |
|                   | Cachoeiras de Macacu | 22°31'42"W42 | *P. columella*’ | 46; 76 |
|                   | Cambuci         | 21°33'41"W54 | *P. columella* | 43 |
|                   | Campos dos Goytacazes | 21°45'41"W20 | *P. columella*’ | 47; 48; 49 |
|                   | Cantagalo       | 21°58'42"W22 | *P. columella* | 45 |
|                   | Cardoso Moreira  | 21°38'41"W45 | *P. columella* | 49 |
|                   | Carmo           | 21°54'42"W36 | *P. columella* | 45 |
|                   | Casimiro de Abreu | 22°27'42"W12 | *P. columella* | 44 |
|                   | Comendador Levy Gasparian | 22°00'43"W12 | *P. columella* | 45 |
|                   | Conceição de Macabu | 22°03'41"W51 | *P. columella* | 49 |
|                   | Cordeiro        | 22°00'42"W21 | *P. columella* | 45 |
Table 1
Distribution of *Pseudosuccinea columella* per municipalities and regions of Brazil (cont.)

| Regions/States | Localities                  | Geographic coordinates | Species       | Articles/“SpeciesLink” (CRIA) network |
|----------------|-----------------------------|------------------------|---------------|---------------------------------------|
| Rio de Janeiro | Duas Barras                 | 22s02/42w31            | *P. columella*| 45                                    |
|                | Engenheiro Paulo de Frontin | 22s33/43w41            | *P. columella*| 46                                    |
|                | Guapimirim                 | 22s29/42w59            | *P. columella*| 50                                    |
|                | Itaboraí                   | 22s43/42w51            | *P. columella*| 46                                    |
|                | Itaúguá                    | 22s51/43w46            | *P. columella*| 46; 51; 85                            |
|                | Itaúla                     | 21s27/41w40            | *P. columella*| 43                                    |
|                | Ituacara                   | 21s38/42w04            | *P. columella*| 43                                    |
|                | Itaperuna                  | 21s10/41w53            | *P. columella*| 43                                    |
|                | Itaiaia                    | 22s25/44w33            | *P. columella*| 42                                    |
|                | Japeri                     | 22s38/43w39            | *P. columella*| 46                                    |
|                | Laje do Muriaé             | 21s11/42w07            | *P. columella*| 43                                    |
|                | Macaé                      | 22s21/41w46            | *P. columella*| 49                                    |
|                | Magé                       | 22s38/43w02            | *P. columella*| 50; 51                                |
|                | Mangaratiba                | 22s56/44w02            | *P. columella*| 46                                    |
|                | Maricá                     | 22s54/42w49            | *P. columella*| 46                                    |
|                | Mendes                     | 22s31/43w44            | *P. columella*| 46                                    |
|                | Miguel Pereira             | 22s26/43w28            | *P. columella*| 46                                    |
|                | Miracema                   | 21s22/42w12            | *P. columella*| 43                                    |
|                | Natividade                 | 21s01/41w58            | *P. columella*| 43                                    |
|                | Niterói                    | 22s52/43w07            | *P. columella*| 46; 53                                |
|                | Nova Friburgo              | 22s15/42w31            | *P. columella*| 45                                    |
|                | Nova Iguacu                | 22s44/43w27            | *P. columella*| 46                                    |
|                | Paracambi                  | 22s29/43w41            | *P. columella*| 46                                    |
|                | Paraíba do Sul             | 22s08/43w16            | *P. columella*| 45                                    |
|                | Parati                     | 23s10/44w43            | *P. columella*| 42                                    |
|                | Paty dos Alferes           | 22s25/43w25            | *P. columella*| 46                                    |
|                | Petrópolis                 | 22s21/43w08            | *P. columella*| 50                                    |
|                | Pinheiral                  | 22s31/44w00            | *P. columella*| 42                                    |
|                | Piraí                      | 22s30/44w00            | *P. columella*| 42                                    |
|                | Porciúncula                | 20s57/42w02            | *P. columella*| 43                                    |
|                | Quités                     | 22s40/44w27            | *P. columella*| 42                                    |
|                | Resende                    | 22s27/44w26            | *P. columella*| 42                                    |
|                | Rio Bonito                 | 22s40/42w37            | *P. columella*| 46                                    |
|                | Rio Claro                  | 22s72/44w13            | *P. columella*| 42                                    |
|                | Rio das Flores             | 22s15/43w58            | *P. columella*| 42                                    |
|                | Rio das Ostras             | 22s29/42w59            | *P. columella*| 44                                    |
|                | Rio de Janeiro             | 22s53/43w12            | *P. columella*| 4; 46; 54; 86                         |
|                | Santa Maria Madalena       | 21s97/41w99            | *P. columella*| 45                                    |
|                | Santo Antônio de Pádua     | 21s53/42w18            | *P. columella*| 43                                    |
|                | São Fidélis                | 21s37/41w44            | *P. columella*| 49                                    |
|                | São Gonçalo                | 22s83/43w05            | *P. columella*| 46; 51                                |
|                | São João de Meriti         | 22s80/43w37            | *P. columella*| 46                                    |
|                | São José de Ubatã          | 21s36/41w93            | *P. columella*| 43                                    |
|                | São José do Vale do Rio Preto | 22s08/42w55          | *P. columella*| 50                                    |
Table 1
Distribution of *Pseudosuccinea columella* per municipalities and regions of Brazil (cont.)

| Regions/States              | Localities                  | Geographic coordinates | Species     | Articles/“SpeciesLink” (CRIA) network |
|-----------------------------|-----------------------------|------------------------|-------------|---------------------------------------|
| **Rio de Janeiro**          | São Sebastião do Alto       | 21s95/42w14            | *P. columella* | 45                                    |
|                             | Sapucaia                    | 21s99/42w90            | *P. columella* | 45                                    |
|                             | Saquarema                   | 22s93/42w49            | *P. columella* | 44                                    |
|                             | Seropédica                  | 22s51/43w45            | *P. columella* | 56; 89; Fiocruz-CMM                    |
|                             | Silva Jardim                | 22s37/42w23            | *P. columella* | 44                                    |
|                             | Sumidouro                   | 22s04/42w67            | *P. columella* | 45                                    |
|                             | Tamoisos                    | 22s72/42w01            | *P. columella* | 44                                    |
|                             | Teresópolis                 | 22s23/42w58            | *P. columella* | 50                                    |
|                             | Trajano de Morais           | 22s07/42w06            | *P. columella* | 45                                    |
|                             | Três Rios                   | 22s05/43w12            | *P. columella* | 4; 45                                  |
|                             | Valença                     | 22s24/43w70            | *P. columella* | 42                                    |
|                             | Varre-Sai                   | 20s93/41w87            | *P. columella* | 43                                    |
|                             | Vassouras                   | 22s40/43w66            | *P. columella* | 11; 46                                 |
|                             | Vila Régia                  | 22s52/44w10            | *P. columella* | 42                                    |
| **Minas Gerais**            | Allenas                     | 21s25/45w56            | *P. columella* | Fiocruz-CMM                           |
|                             | Barbacena                   | 21s13/43w46            | *P. columella* | 4                                     |
|                             | Belo Horizonte              | 19s55/43w56            | *P. columella* | 11; 4; 58; 59; 23; 24 Fiocruz-CMM INPA-Mollusca |
|                             | Betim                       | 19s58/44w04            | *P. columella* | 4; 59; 61 Fiocruz-CMM                  |
|                             | Bicas                       | 21s43/43w04            | *P. columella* | 61                                    |
|                             | Brasópolis                  | 22s27/45w36            | *P. columella* | 61                                    |
|                             | Cacheoeira de Minas         | 22s20/45w46            | *P. columella* | 61                                    |
|                             | Carecaçu                    | 22s02/45w41            | *P. columella* | 61                                    |
|                             | Diamantina                  | 18s13/43w35            | *P. columella* | 4                                     |
|                             | Ferros                      | 19s12/43w01            | *P. columella* | 4                                     |
|                             | Igarapé                     | 20s04/44w18            | *P. columella* | 61                                    |
|                             | Itabirito                   | 20s14/43w47            | *P. columella* | 61                                    |
|                             | Itajubá                     | 22s25/45w28            | *P. columella* | 9; 61; 62; 24; 8 Fiocruz-CMM           |
|                             | Jaboticatubas               | 19s30/43w44            | *P. columella* | 8; 63; Fiocruz-CMM                     |
|                             | Januária                    | 15s26/44w21            | *P. columella* | 64                                    |
|                             | Juiz de Fora                | 21s45/43w20            | *P. columella* | 4; 65; 61; 83 Fiocruz-CMM              |
|                             | Lagoa Santa                 | 19s37/43w53            | *P. columella* | 59                                    |
|                             | Machado                     | 21s39/45w55            | *P. columella* | Fiocruz-CMM                           |
|                             | Mariana                     | 20s21/43w25            | *P. columella* | 66                                    |
|                             | Nova Lima                   | 19s58/43w50            | *P. columella* | 59                                    |
|                             | Ouro Fino                   | 22s16/46w22            | *P. columella* | 4                                     |
|                             | Passos                      | 20s42/46w36            | *P. columella* | MZUSP                                 |
|                             | Pedro Leopoldo              | 19s36/44w02            | *P. columella* | 59                                    |
|                             | Perdões                     | 21s09/45w08            | *P. columella* | Fiocruz-CMM                           |
|                             | Piranguinho                 | 22s23/45w32            | *P. columella* | 61                                    |
|                             | Raposos                     | 19s57/43w48            | *P. columella* | Fiocruz-CMM                           |
Table 1
Distribution of *Pseudosuccinea columella* per municipalities and regions of Brazil (cont.)

| Regions/States | Localities | Geographic coordinates | Species | Articles/“SpeciesLink” (CRIA) network |
|----------------|------------|------------------------|---------|--------------------------------------|
| Minas Gerais   | Ribeirão das Neves | 19s45/44w04 | *P. columella* | 59 |
|                | Rio Acima     | 20s03/43w47 | *P. columella* | Fiocruz-CMM |
|                | Rio Doce      | 20s14/42w53 | *P. columella* | 8  |
|                | Sabinópolis   | 18s39/43w04 | *P. columella* | 4  |
|                | Santa Luzia   | 19s44/43w53 | *P. columella* | 59 |
|                | Santa Rita do Sapucaí | 22s14/45w43 | *P. columella* | 61 |
|                | São Gonçalo do Sapucaí | 22s19/46w19 | *P. columella* | 11; 61 |
|                | Sete Lagosas  | 19s26/44w14 | *P. columella* | 11 |
|                | Timóteo       | 19s34/42w38 | *P. columella* | Fiocruz-CMM |
|                | Três Pontas   | 21s21/45w30 | *P. columella* | 24; Fiocruz-CMM |
|                | Ubá           | 21s07/42w56 | *P. columella* | 4  |
|                | Varginha      | 21s33/45w26 | *P. columella* | 61 |
|                | Vespasiano    | 19s41/43w55 | *P. columella* | 59 |
|                | Vícosa        | 20s45/42w52 | *P. columella* | 11; 4 |
| Espírito Santo | Alegre        | 20s45/41w31 | *P. columella* | 68 |
|                | Atílio Vivacqua | 20s53/41w11 | *P. columella* | 68 |
|                | Cachoeiro do Itapemirim | 20s49/41w06 | *P. columella* | 68 |
|                | Castelo       | 20s36/41w12 | *P. columella* | 68 |
|                | Guaçuí        | 20s45/41w40 | *P. columella* | 68 |
|                | Guarapari     | 20s65/40w51 | *P. columella* | UFES-Malacologia |
|                | Jerônimo Monteiro | 20s47/41w23 | *P. columella* | 68 |
|                | Marataízes    | 21s00/40w49 | *P. columella* | 68 |
|                | Mimoso do Sul | 21s03/41w22 | *P. columella* | 68 |
|                | Muniz Freire  | 20s27/41w24 | *P. columella* | 68 |
|                | Muqui         | 20s56/41w20 | *P. columella* | 68 |
|                | Piúma         | 20s49/40w43 | *P. columella* | 68 |
|                | Presidente Kennedy | 21s04/41w01 | *P. columella* | 68 |
|                | Serra         | 20s12/40w30 | *P. columella* | UFES-Malacologia |
|                | Vartem Alta   | 20s40/41w00 | *P. columella* | 68 |
|                | Itapemirim    | 21s00/40w49 | *P. columella* | 68 |
| 3) Midwest     | Barro Alto    | 14s58/48w55 | *P. columella* | 69 |
|                | Brasília      | 15s46/47w55 | *P. columella* | 4  |
|                | Campinaçu     | 13s44/48w34 | *P. columella* | 69 |
|                | Campinorte    | 14s18/49w88 | *P. columella* | 69 |
|                | Colinas do Sul | 14s08/48w04 | *P. columella* | 69 |
|                | Formosa       | 15s30/47w20 | *P. columella* | 4  |
|                | Goiânia       | 16s41/49w13 | *P. columella* | 4; 24; 77 Fiocruz-CMM |
|                | Minaçu        | 13s31/48w13 | *P. columella* | 69 |
|                | Mineiros      | 17s30/52w32 | *P. columella* | 70 |
|                | Niquelândia   | 14s26/48w27 | *P. columella* | 69 |
|                | Santa Rita do Novo Destino | 15s06/49w06 | *P. columella* | 69 |
|                | Uruaçu        | 14s29/49w07 | *P. columella* | 69 |
Table 1
Distribution of *Pseudosuccinea columella* per municipalities and regions of Brazil (cont.)

| Regions/States | Localities       | Geographic coordinates | Species    | Articles/"SpeciesLink" (CRIA) network |
|---------------|------------------|------------------------|------------|--------------------------------------|
| Mato Grosso   | Cuiaá            | 15s35/56w05            | *P. columella* | 4                                    |
| Mato Grosso do Sul | Aquidauana | 20s27/55w46            | *P. columella* | 4                                    |
|               | Bela Vista       | 22s04/56w31            | *P. columella* | 4                                    |

4) Northeast

| Bahia         | Salvador         | 12s58/38w32            | *P. columella* | 71                                   |
| Ceará         | Fortaleza        | 3s45/38w32             | *P. columella* | 8; Fiocruz-CMM                       |
| Paraíba       | Campina Grande   | 7s12/35w53             | *P. columella* | 72; 73                               |

5) North

| Amazonas      | Benjamin Constant| 4s22/70w01             | *P. columella* | 74                                   |
|              | Careiro          | 3s81/60w34             | *P. columella* | Fiocruz-CMM                          |
|              | Coari            | 4s05/63w08             | *P. columella* | Fiocruz-CMM                          |
|              | Manaus           | 3s06/60w03             | *P. columella* | 74                                   |
|              | Tefé             | 3s18/64w42             | *P. columella* | 71; Fiocruz-CMM                      |
|              | Iranduba         | 3s28/60w18             | *P. columella* | INPA-Mollusca                        |
| Acre          | Rio Branco       | 9s58/67w48             | *P. columella* | 24; Fiocruz-CMM                      |

Table 2
Distribution of *Galba viatrix*, *G. rupestris*, *G. cubensis*, *Lymnaea truncatula* and *Lymnaea* sp. per municipalities and regions of Brazil

| Regions/States | Localities       | Geographic coordinates | Species    | Articles/"SpeciesLink" (CRIA) network |
|---------------|------------------|------------------------|------------|--------------------------------------|
| 1) South      |                  |                        |            |                                      |
| Rio Grande do Sul | Bagé            | 31s19/54w06            | *G. viatrix* | 3                                    |
|                | Bom Jesus        | 28s66/50w43            | *Lymnaea* sp. | MCP-Moluscos                          |
|                | Cambará do Sul  | 28s97/50w31            | *Lymnaea* sp. | MCP-Moluscos                          |
|                | Dom Pedroito    | 30s58/54w40            | *G. viatrix* | 4; 3; 7; 82                           |
|                | Erval Grande    | 27s38/52w57            | *Lymnaea* sp. | MCP-Moluscos                          |
|                | Estrela          | 28s86/51w17            | *Lymnaea* sp. | MCP-Moluscos                          |
|                | Ibirubá          | 28s54/53w09            | *Lymnaea* sp. | MCP-Moluscos                          |
|                | Jaguarão         | 32s33/53w22            | *G. viatrix* | 4; 3                                  |
|                | Lavras do Sul   | 30s48/53w53            | *G. viatrix* | 3                                    |
|                | Pelotas          | 31s46/52w20            | *G. viatrix* | 10                                   |
|                | Porto Alegre     | 30s01/51w13            | *Lymnaea* sp. | MCP-Moluscos                          |
|                | Santa Vitória do Palmar | 33s31/53w22       | *G. viatrix* | 4; 14; 3; 89 Fiocruz-CMM             |
|                | São Borja        | 28s39/55w59            | *Lymnaea* sp. | MCP-Moluscos                          |
|                | São Francisco de Paula | 29s26/50w35         | *Lymnaea* sp. | MCP-Moluscos                          |
|                | Selbach          | 28s37/52w56            | *Lymnaea* sp. | MCP-Moluscos                          |
|                | Três Coroas      | 29s30/50w46            | *Lymnaea* sp. | MCP-Moluscos                          |
|                | Vacaria          | 28s48/50w92            | *Lymnaea* sp. | MCP-Moluscos                          |
|                | Viamão           | 30s04/51w01            | *Lymnaea* sp. | MCP-Moluscos                          |
| Santa Catarina | Campos Novos     | 27s40/51w22            | *Lymnaea* sp. | MCP-Moluscos                          |
|               | Florianópolis   | 27s35/48w33            | *G. viatrix* | 21                                   |
Table 2

Distribution of *G. viatrix*, *G. rupestris*, *G. cubensis* and *L. truncatula* and *Lymnaea* sp. per municipalities and regions of Brazil (cont.)

| Regions/States         | Localities               | Geographic coordinates | Species            | Articles/“SpeciesLink” (CRIA) network |
|------------------------|--------------------------|------------------------|--------------------|--------------------------------------|
| Santa Catarina         | Seara                    | 27s12/52w19            | *G. viatrix*        | 22; 4                                |
|                         |                          |                        | *L. rupestris*      | 23                                   |
| Paraná                 | Curitiba                 | 25s25/49w16            | *Lymnaea* sp.       | MZUSP                                |
| São Paulo              | Presidente Prudente      | 22s43/47w39            | *Lymnaea* sp.       | MZUSP                                |
|                         | São Paulo                | 22s07/51w23            | *G. cubensis*       | 51                                   |
|                         | Ubatuba                  | 23s32/46w38            | *G. cubensis*       | 51                                   |
|                         |                          | 23s25/45w04            | *Lymnaea* sp.       | MZUSP                                |
| Rio de Janeiro         | Nova Friburgo            | 22s15/42w31            | *Lymnaea* sp.       | 45                                   |
|                         | Pará da Sui              | 22s08/43w16            | *G. truncatula*     | Fiocruz-CMM                          |
|                         | Petrópolis               | 22s21/43w08            | *G. cubensis*       | 51                                   |
|                         | Rio de Janeiro           | 22s53/43w12            | *G. cubensis*       | 55                                   |
|                         | Teresópolis              | 22s23/42w58            | *Lymnaea* sp.       | MZUSP                                |
|                         |                          |                        | *G. cubensis*       | 51                                   |
|                         |                          |                        | *G. truncatula*     | Fiocruz-CMM                          |
|                         | Três Rios                | 22s05/43w12            | *G. cubensis*       | 51; 90                               |
|                         | Vassouras                | 22s40/43w66            | *Lymnaea* sp.       | 57                                   |
| Minas Gerais           | Belo Horizonte           | 19s55/43w56            | *G. cubensis*       | 60; Fiocruz-CMM                      |
|                         |                          |                        | *G. viatrix*        | 4                                    |
|                         | Careacu                  | 22s02/45w41            | *Lymnaea* sp.*      | 79                                   |
|                         | Ouro Branco              | 20s30/43w41            | *Lymnaea* sp.       | 67                                   |
|                         | Rio Acima                | 20s03/43w47            | *G. viatrix*        | 63                                   |
|                         |                          |                        | *G. truncatula*     | 60; Fiocruz-CMM                      |
| 3) North               | Pará                     | Belém                  | 1s26/48w29          | MZUSP                                |
|                         |                          |                        | *Lymnaea* sp.       |                                      |

Legends for the tables 1 and 2: The numbers at the column Articles of the tables 1 and 2 are references to the authors that record the occurrence of specimens of *Lymnaeidae*. 1: Simões (2002); 2: Amaral et al. (2007); 3: Ueno et al. (1982); 4: Paraeone (1982a); 5: Mattos et al. (1997); 6: Pereira et al. (2000a); 7: Mattos & Ueno (1985); 8: Coelho (2007); 9: Coelho et al. (2009); 10: Rey (1957); 11: Dacal et al. (1988); 12: Gonzales et al. (1974); 13: Indrusiak (1983); 14: Müller et al. (1998); 15: Martello et al. (2008); 16: Pereira et al. (2008b); 17: Agudo (2004) apud Agudo-Padrão (2008); 18: Agudo (2005); 19: Agudo (2007); 20: Agudo (2006); 21: Agudo-Padrão (2008); 22: Hubendick (1951); 23: Paraeone (1982b); 24: Cardoso et al. (2006); 25: Bellato et al. (1996); 26: Queiroz et al. (2002); 27: Amaral & Busetti (1979) apud Busetti (1982); 28: Busetti (1982); 29: Vaz et al. (1987); 30: Vaz et al. (1986); 31: Vaz et al. (1983); 32: Muniz (2007); 33: Gouveia & Henry (1990); 34: Ueta (1976); 35: Magalhães et al. (1991); 36: Carvalho et al. (2001); 37: Vaz et al. (1992); 38: Maure et al. (1998); 39: Ueta (1980); 40: Tostes et al. (2004); 41: Oliveira et al. (2002); 42: Thiengo et al. (2004a); 43: Thiengo et al. (2006); 44: Thiengo et al. (2002b); 45: Thiengo et al. (2002a); 46: Thiengo et al. (2001); 47: Gomes et al. (2002); 48: Fiuza et al. (2006); 49: Thiengo et al. (2004b); 50: Thiengo et al. (1998); 51: Rezende et al. (1973); 52: Andrade Neto et al. (1999); 53: Medeiros et al. (2002); 54: Fernandez et al. (2001); 55: Nuernberg (1978); 56: Pinheiro & Amato (1996); 57: Lutz (1921); 58: Souza et al. (2002); 59: Souza et al. (1998); 60: Cardoso (2004); 61: Lima et al. (2009); 62: Coelho & Lima (2003); 63: Carvalho et al. (2004); 64: Viana et al. (2007); 65: Martins & Alves (2008); 66: Souza et al. (2006); 67: Silva et al. (1994); 68: Almeida (2010); 69: Thiengo et al. (2005); 70: Teles et al. (1991); 71: Paraeone (1986); 72: Abilio & Watanabe (1998); 73: Abilio et al. (2006); 74: Paraeone (1983); 75: Amato et al. (1986); 76: Bruno et al. (1995); 77: Aratijai et al. (1995); 78: Silva (2010); 79: Oliveira (2008); 80: Ueta (1977); 81: Silva-Santos et al. (1994); 82: Silva-Santos et al. (1877); 83: Martins & Alves (2010); 84: Veenenheiner-Mendes (1992); 85: Pile et al. (1999); 86: Braun (2005); 87: Morretes (1949); 88: Pinheiro et al. (2009); 89: Lara et al. (1988); 90: Nuernberg et al. 1983; 91: Luz et al. (1994). Fiocruz-CMM represents data obtained from the Collection of Medical Malacology, CPqRR, Fiocruz/MG. MCP-Moluscos represents data obtained from the Collection of Moluscos of National Institute of Research of Amazonía, INPA. UFES-Malacologia represents data obtained from the Malacological Collection of Biological Science Department, DCBio/UFES. MZUSP represents data obtained from the Malacological Collection of Zoology Museum of University of São Paulo. The symbol * represents snails found naturally infected with *Fasciola hepatica.*
MEDEIROS, C.; SCHOLTE, R.G.C.; D’ÁVILA, S.; CALDEIRA, R.L. & CARVALHO, O.S. - Spatial distribution of Lymnaeidae (Mollusca, Basommatophora), intermediate host of Fasciola hepatica Linnaeus, 1758 (Trematoda, Digenea) in Brazil. Rev. Inst. Med. Trop. Sao Paulo, 56(3): 235-52, 2014.

In relation to the others susceptible species, G. cubensis occurs only in the Southeast, mainly in Rio de Janeiro State\textsuperscript{19,60,78}. There was a gap of 30 years in its record and until now its presence in other regions was not reported. Galba truncatula is also susceptible to F. hepatica, however with few records (0.7\%) it has never been found naturally infected in Brazil. Lymnaea rupestris was only described and found in one locality and there is no information about its susceptibility. Due to these facts, the role in the transmission of fasciolosis of the species above mentioned remains unknown.

In the present study, it was possible to observe the occurrence of P. columella in several localities of the South (four municipalities) and Southeast (seven municipalities) and of G. viatrix in the South (three municipalities) naturally infected by F. hepatica (Table 1 and 2). In the South region, the presence of extensive endemic areas of fasciolosis is frequent, while in the Southeast and Midwest regions there are only small endemic areas\textsuperscript{41}. Some environmental and climatic factors in the South region provide favorable habitats for the intermediate host snails of F. hepatica, such as low elevation (where there are numerous rice fields), clay soil, humid areas, and a temperate climate. These habitats, as shown by UENO et al.\textsuperscript{39}, contribute to the maintenance of the snails’ life cycle in this region.
Despite the great efforts made by research groups, some important issues related to the nature and precision of the presence of lymnaeid species in Brazil need to be considered when interpreting our findings. The complete distribution of intermediate host snails of *F. hepatica* in Brazil remains unknown, especially due to the large areas that need to be surveyed mainly in the North and Midwest regions. Other restraining factors include the insufficient number of researchers involved in the taxonomy area, which may cause difficulties in identifying the snails at a species level due to the confusing taxonomic situation of the Lymnaeidae family. It was confirmed by our study that in several localities (25 municipalities; 6%) the specific identification was not possible to be done. The identification of specimens is important since knowing the species that act as intermediate hosts in a particular area, we can define priority strategies regarding intermediate hosts biology to control fasciolosis. In Caraça, MG, the occurrence of naturally-infected specimens without specific identification was reported (Table 2).

Another important point concerns the validity of the species identification used from the literature data and malacological collections due to systematics confusion of lymnaeids snails. This identification is essential in order to justify the distribution of lymnaeid species in Brazil. Regarding *L. rupestris* and *P. columella*, there is no problem because these two species can be easily identified using a set of reliable morphological characters and the literature data can be used with a reasonable confidence. However, this is not the case regarding the three other remaining species, *G. viatrix*, *G. cubensis* and *G. truncatula*, because these small species cannot be separated morphologically and only molecular markers allow a clear separation. In our literature search we identified only 19 localities where the specific identification was possible (10 localities with *G. viatrix*, six localities with *G. cubensis* and three localities with *G. truncatula*). Only in the occurrence of *G. cubensis* for Belo Horizonte, MG, *G. truncatula* for Rio Acima, MG and the data from Fiocruz-CMM have the authors already carried out molecular identification.

Studies on the lymnaeid fauna should be increased all over Brazil, mainly where the information is scarce or nonexistent, with the objective to learn more about the spatial distribution of the intermediate host snail of *F. hepatica*. The methodology used and the intermediate host snail final maps could be useful in identifying priority areas for control interventions of fasciolosis, so that limited resources could be allocated most effectively.

**RESUMO**

**Distribuição espacial de Lymnaeidae (Mollusca, Basommatophora), hospedeiros intermediários de *Fasciola hepatica* Linnaeus, 1758 (Trematoda, Digenea) no Brasil**

Moluscos da família Lymnaeidae são hospedeiros intermediários no ciclo biológico de *F. hepatica*, agente etiológico da fasciolose, doença parasitária de importância médica para humanos e animais. O presente trabalho teve como objetivo datar e mapear a distribuição espacial dos hospedeiros intermediários de *F. hepatica* no Brasil. Os dados de distribuição das espécies de limneideos foram obtidos das Coleções de Malacologia Médica (Fiocruz-CMM, CPqRR) e de Malacologia do Museu de Zoologia da Universidade de São Paulo (MZUSP), rede “SpeciesLink” (CRIA) e através de pesquisas sistemáticas na literatura. Os mapas de distribuição dos limneideos mostram que *Pseudosuccinea columella* é a espécie mais comum e distribuída nas regiões Sul e Sudeste, para o estado de Paraíba, Brasil. Rev. Inst. Med. Trop. Sao Paulo, 56(3): 235-52, 2014.

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