Diversity and population characteristics of terrestrial isopods (Crustacea, Oniscidea) across three forest environments in southern Brazil

Priscila da Silva Bugs[1], Paula Beatriz Araujo[1], Milton de Souza Mendonça Júnior[2] & Ricardo Ott[3]

1. Departamento de Zoologia, Instituto de Biociências, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves, 9500, Bairro Agronomia, 91501-970 Porto Alegre, RS, Brazil. (priscilabugs@gmail.com; pabearaujo@gmail.com)
2. Departamento de Ecologia, Instituto de Biociências, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves, 9500, Bairro Agronomia, 91501-970 Porto Alegre, RS, Brazil. (milton.mendonca@ufrgs.br)
3. Museu de Ciências Naturais, Fundação Zoobotânica do Rio Grande do Sul, Rua Dr. Salvador França, 1427, Bairro Jardim Botânico, 90690-000 Porto Alegre, RS, Brazil. (rott@fzb.rs.gov.br)

ABSTRACT. Terrestrial isopods are important and dominant component of meso and macrodecomposer soil communities. The present study investigates the diversity and species composition of terrestrial isopods on three forests on the Serra Geral of the state of Rio Grande do Sul, Brazil. The area has two natural formations (Primary Woodland and Secondary Woodland) and one plantation of introduced *Pinus*. The pitfall traps operated from March 2001 to May 2002, with two summer periods and one winter. There were 14 sampling dates overall. Of the five species found: *Alboscia silveirensis* Araujo, 1999, *Atlantoscia floridana* (van Name, 1940), *Benthana araucariana* Araujo & Lopes, 2003 (Philoscidae), *Balloniscus glaber* Araujo & Zardo, 1995 (Balloniscidae) and *Styloniscus otakensis* (Chilton, 1901) (Styloniscidae); only *A. floridana* is abundant on all environments and *B. glaber* is nearly exclusive for the native forests. The obtained data made it possible to infer about population characteristics of this species. The Similarity Analysis showed a quantitative difference among the Secondary forest and *Pinus* plantation, but not a qualitative one. The operational sex ratio (OSR) analysis for *A. floridana* does not reveal significant differences in male and female proportions among environments. The reproductive period identified in the present study for *A. floridana* was from spring to autumn in the primary forest and *Pinus* plantation and during all year for the secondary forest. The OSR analysis for *B. glaber* reveals no significant differences in abundance between males and females for secondary forest, but the primary forest was a significant difference. The reproductive period for *B. glaber* extended from summer to autumn (for primary and secondary forest). This is the first record for Brazil of an established terrestrial isopod population in a *Pinus* sp. plantation area, evidenced by the presence of young, adults and ovigerous females, balanced sex ratio, expected fecundity and reproduction pattern, as compared to populations from native vegetation areas.

KEYWORDS. Abundance, reproduction, *Pinus* sp. plantation, *Atlantoscia floridana*, *Balloniscus glaber*.

RESUMO. Diversidade de isópodos terrestres (Crustacea, Oniscidea) em três ambientes florestais no sul do Brasil. Os isópodos terrestres são um importante e dominante componente nas comunidades de meso e macro-decompositores de solo. O presente estudo investiga a diversidade e composição de espécies de isópodos terrestres em três formações vegetais diferentes na Serra Geral do Rio Grande do Sul, Brasil. A área compreende duas formações naturais (Mata Primária e Mata Secundária) e área de plantio de *Pinus* sp. As armadilhas do tipo *pitfall* ficaram operantes de março de 2001 a maio de 2002, compreendendo dois períodos de verão e um de inverno. Contabilizaram-se 14 datas amostrais até a retirada das armadilhas. Foram identificadas cinco espécies de isópodos terrestres: *Alboscia silveirensis* Araujo, 1999, *Atlantoscia floridana* (van Name, 1940), *Benthana araucariana* Araujo & Lopes, 2003 (Philoscidae), *Balloniscus glaber* Araujo & Zardo, 1995 (Balloniscidae) e *Styloniscus otakensis* (Chilton, 1901) (Styloniscidae); somente *A. floridana* foi abundante em todos ambientes e *B. glaber* abundante nas formações naturais. Os dados obtidos possibilitaram a realização de inferências sobre as características populacionais destas espécies. A Análise de Similaridade revelou diferença quantitativa entre as áreas, mas não diferença qualitativa. A análise da Proporção Sexual Operacional (OSR) de *A. floridana* não revelou diferenças significativas entre a proporção sexual entre as áreas. O período reprodutivo identificado no presente estudo, para *A. floridana*, compreende da primavera até o outono na Mata Primária e plantio de *Pinus*, e durante o ano todo na Mata Secundária. A Proporção Sexual Operacional (OSR) de *B. glaber* não apresentou diferenças entre quantidade de machos e fêmeas na Mata Secundária, porém a Mata Primária apresenta diferença entre esta proporção. O período reprodutivo para *B. glaber* estende-se do verão até o outono (Mata Primária e Secundária). Este é o primeiro registro para o Brasil do estabelecimento de populações de isópodos terrestres em área de plantio de *Pinus* sp., evidenciado pela presença de jovens, adultos e fêmeas ovígeras, equilíbrio da proporção sexual, padrões esperados de fecundação e reprodução, comparados ao de populações em áreas com vegetação nativa.

PALAVRAS-CHAVE. Abundância, reprodução, plantações de *Pinus* sp., *Atlantoscia floridana*, *Balloniscus glaber*.

Terrestrial isopods are known as pillbugs and are included in the Oniscidea suborder, presently including 3,939 known species as of 2011 (Schmalfuss, 2003; Ahyong *et al.*, 2011). The terrestrial isopod fauna in forest ecosystems is important for organic matter processing and nutrient cycling. These organisms are responsible for fragmenting the accumulated leaf litter, along with other members of the detritivore guild (Quadros & Araujo, 2008; Boelter *et al.*, 2009). Many species of terrestrial isopods are not limited to natural environments, with most introduced species associated to anthropogenic environments. Since many species of terrestrial isopods are being transported by humans, they are increasingly being considered synanthropic.

Brazil concentrates a large part of the biodiversity of the planet; however there are many threats to this diversity in various forms of landscape occupation (Tabarelli *et al.*, 2005; Overbeck *et al.*, 2007). If on one hand monoculture greatly simplifies ecosystems making it hard for local species to establish themselves in these disturbed environments, on the other hand environmental changes due to exotic plant introduction, for example *Pinus* species, might on its turn favour the establishment of exotic species of terrestrial isopods (Magrini *et al.*, 2010)

or even native species (Quine & Humphrey, 2010). *Pinus* have been planted in commercial scale in Brazil for over 30 years. Initially, the more extensive areas with plantations occurred in the southern and south-eastern regions, with *Pinus taeda* and *Pinus elliottii*.

Tree monocultures, although important economically, result in a series of negative effects to the fauna given the low diversity of resources present (Vallejo *et al.*, 1987). The arthropod fauna richness exhibits a tendency to follow plant richness, since many animals depend directly and/or indirectly on plants for survival (Battirola *et al.*, 2007). Areas with ecological dominance from a single tree species can thus be expected to harbour fewer animals and reduced arthropod species diversity (Battirola *et al.*, 2007). This reduction has consequences for ecosystem functioning, as smaller populations of fewer species in the soil fauna would lead to slower and less efficient soil nutrient cycling.

Terrestrial isopods as members of the soil fauna are expected to respond to such environmental changes, although given their limited dispersal abilities, they are probably very sensitive to changes in soil chemical and physical proprieties (Paoletti & Hassall, 1999) thus responding rapidly to environmental changes (Nakamura *et al.*, 2003) and to a monoculture ageing process (Purchart *et al.*, 2013). However, there are no studies on the consequences of *Pinus* plantation monocultures to populations of terrestrial isopods in Brazil. It is thus important to try and understand not only how many and which species are present in these areas, but also how they are managing to survive in these environments. The impact of *Pinus* must be evaluated not only in terms of species diversity alone, but also considering the life history of the species present.

Distribution patterns of terrestrial isopods in systems with and without human influence can reveal the purported negative effects of economic land use, helping direct future forest management (Lindenmayer & Franklin, 2002). Thus, the present study aims to compare the occurrence and distribution of terrestrial isopods in three different nearby forest environments: primary and secondary forest and an old *Pinus* plantation, in the Serra Geral of the state of Rio Grande do Sul. In addition to diversity data, population information on the terrestrial isopods present were compared among different forest environments, analysing life history traits as reproductive period, fecundity and operational sex ratio (OSR).

MATERIAL AND METHODS

Study area. The "Centro de Pesquisas e Conservação da Natureza Pró-Mata" (heretofore Pró Mata, between 29°27' – 29°35'S and 50°08' – 50°15'W), is located in São Francisco de Paula municipality, state of Rio Grande do Sul, southern Brazil. This area is the stage for the contact of three ecoregions (as defined by the WWF, Olson *et al.*, 2001): moist araucaria forest (NT

0101), alto Paraná Atlantic forests (NT 0150) and the Uruguayan savannah (NT 0710, represented by altitude savannah ecotones). Besides the vegetation typical of those ecoregions, there is the recorded presence of some species from the Semidecidual Seasonal Forest, found to the southwest (Bertoletti & Teixeira, 1995), and a growing area has been occupied by *Pinus* silviculture. The soil is typical of the Serra Geral Formation, with a thick sequence of vulcanites, eminently basaltic, containing effusive acid rocks, abundant at the top. Geomorphologically this area is in the east border of the Araucaria highlands (Bertoletti & Teixeira, 1995).

Sampling. Three different forest ecosystem types were sampled with simple replication resulting in six areas: primary forest (with little human disturbance – two blocks of approximately 5.5 and 9.5 ha, 2.7 km apart from each other), secondary forest (with some human disturbance in the near past, but not in the last 15 years – two blocks of 4 ha and 4.3 ha, 2.9 km apart from each other) and *Pinus* plantation *(Pinus taeda* Linnaeus and *Pinus elliottii* Engelm – respectively around 3 ha and 10 ha blocks, 400 m apart from each other). The primary forest has the marked presence of *Araucaria angustifolia* (Bert.) O. Kuntze, a tall, canopy conifer species. The secondary forest is in the highland slope areas of Pró-Mata, with rare large trees and bamboo patches interspersed leaving this latter component as an important part of the leaf litter. The *Pinus* was planted long ago, in 1950, having thus a shrub layer formed by juvenile and small individuals of native tree species (Souza & Lorenzi, 2008). In each of the six areas two subareas were chosen, on which two independent transects were placed at last 50 apart from each other. For each transect there were five pitfall traps 10 m apart from each other. The preserving liquid was formaldehyde 4% with drops of domestic detergent to minimise surface tension. The liquid was renewed every other 30 days. Traps operated from March 2001 to May 2002, with two summer periods and one winter. There were 14 sampling dates overall. Trap contents were brought to the lab and searched throughout to separate the isopods.

Data analysis. Isopod abundance and species richness was compared among environments using a one-way ANOVA. Likewise, an ANOSIM (analysis of similarity, Clarke, 1993) with 10,000 permutations was employed to test for differences in species composition among forest environments. Both a quantitative (Bray-Curtis) and qualitative (Simpson) index were used to clarify the influence species abundances has on species composition. To identify the taxon responsible for differences between two or more environments and to quantify its contribution to this difference a SIMPER (Similarity Percentage) analysis was used (Clarke & Warwick, 1994). All analyses were implemented with Past software (Hammer *et al.*, 2003).

The two most frequent species were investigated regarding their operational sex ratio (OSR) (Emlen & Oring, 1977), fecundity and reproductive period. To calculate the OSR ovigerous and post-ovigerous females were excluded,

since having a marsupium they are no longer eligible for a new copulation (Araujo & Bond-Buckup, 2005). Females with cephalothorax length lower than that of the smaller ovigerous female found in the literature (Araujo & Bond-Buckup, 2005) were not considered either. A *G*-test (Sokal & Rohlf 1995) was employed to verify differences among forest areas in isopod sex ratio, and against the neutral (Fisherian) expectation of a 1:1 sex ratio. Females were divided in three size classes: small, medium and large, to estimate average fecundity. The reproductive period was identified as the time of the year when ovigerous and post-ovigerous females were present.

RESULTS

Overall there were 622 individuals, belonging to five species of terrestrial isopods: *Alboscia silveirensis* Araujo, 1999, *Atlantoscia floridana* (van Name, 1940) and *Benthana araucariana* Araujo & Lopes, 2003 (Philoscidae), *Balloniscus glaber* Araujo & Zardo, 1995 (Balloniscidae) and *Styloniscus otakensis* (Chilton, 1901) (Styloniscidae). These species represent 35.7% of the known Oniscidea fauna for the Serra Geral of state of the Rio Grande do Sul. The ANOVA revealed no differences among the areas either for abundance ($F_{4.25}$ = 1.604; p = 0.254) (actually an index of activity) or richness ($F_{4.25}$ = 1.016; p = 0.400) (Fig.1). *Atlantoscia floridana* was abundant in all areas, with the second most abundant being *B. glaber*, significantly present in primary and secondary forests. Of the five recorded species, only *A. silveirensis* was not recorded from the *Pinus* plantations (Tab. I). Some species showed very low
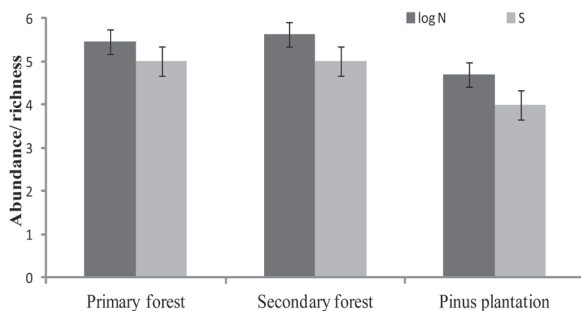
abundance, being represented by few individuals, especially when considering environments separately. The primary forest had *A. silveirensis* as a doubleton; the secondary forest had three singletons (*A. silveirensis*, *B. araucariana* and *S. otakensis)* and *Pinus* plantations had one singleton (*B. glaber*) and one doubleton *(B. araucariana)*.

The ANOSIM revealed a quantitative difference between secondary forest and *Pinus* plantation (Tab. II), but not a qualitative difference (Tab. III), that is, the species identities do not change much between these environments, but their abundances do. *Atlantoscia floridana* abundance changes among environments were the main responsible for these quantitative composition differences among

Tab. II. Analysis of Similarity (ANOSIM) between environments based on Bray-Curtis (Mean rank within: 25.28; Mean rank between: 36.58; *R*=0.3426*; p*=0.0399; α = 0.05).

Environment	Primary forest	Secondary forest	*Pinus* plantation
Primary forest	0	0.1097	0.2827
Secondary forest	0.1097	0	0.0301
Pinus plantation	0.2827	0.0301	0

Tab. III. Analysis of Similarity (ANOSIM) between environments based on Simpson (Mean rank within: 31.56; Mean rank between: 34.23; *R*=0.08102; *p*= 0.1689; α = 0.05).

Environment	Primary forest	Secondary forest	*Pinus* plantation
Primary forest	0	0.1132	0.8579
Secondary forest	0. 1132	0	0.3076
Pinus plantation	0. 8579	0.3076	0

Tab. IV. Similarity Percentage (SIMPER) of species according to environments, in Pró-Mata, São Francisco de Paula, RS.

Species	Contribution	Primary forest	Secondary forest	*Pinus* plantation
Atlantoscia floridana	25.67	36.5	48.5	26.3
Balloniscus glaber	18.3	19.8	20.5	0.25
Styloniscus otakensis	1.003	0.75	0.25	0.75
Benthana araucariana	0.8722	0.75	0.25	0.5
Alboscia silveirensis	0.4158	0.5	0.25	0

Fig. 1. Abundance (log N) ANOVA ($F_{4.25}$= 1.6038; p=0.2536; gl=2) and richness of species (S) of terrestrial isopods at Pró-Mata, São Francisco de Paula, RS, Brazil from March 2001 to May 2002. ANOVA ($F_{4.25}$= 1.0161; p=0.4000; gl=2) according to the different forests. Bars represent the standard error (α = 0.05).

Tab. I. Abundance of species in each forest, obtained with pitfall traps at Pró-Mata, São Francisco de Paula, RS, Brazil from March 2001 to May 2002.

Species/area	Primary forest	Secondary forest	*Pinus* plantation
Atlantoscia floridana	145	194	105
Balloniscus glaber	79	82	1
Styloniscus otakensis	3	1	3
Benthana araucariana	3	1	2
Alboscia silveirensis	2	1	0

environments (SIMPER - Similarity Percentage, Tab. IV).

All classes of size *A. floridana* are present in all environments. The operational sex ratio (OSR) analysis for *A. floridana* does not reveal significant differences in male and female proportions among environments (primary forest: χ^2 = 0.097; df = 1; p = 0.756; secondary forest: χ^2= 3.571; df =1; p = 0.059; *Pinus* plantation: χ^2 = 1.067; df = 1; p = 0.302). The *G*-test on the expected Fisherian sexual proportion (1:1) is not significant either (*G* = 2.168; df = 1; p = 0.141). The smallest ovigerous *A. floridana* female occurred in the *Pinus* plantation (0.968 mm), with the largest size found in the secondary forest (1.800 mm). Data on isopod fecundity appears in Table V. The reproductive period identified in the present study for *A. floridana* was from spring to autumn in the primary forest and *Pinus* plantation and during all year for the secondary forest.

Tab. V. Ovigerous female and fecundity of *Atlantoscia floridana* (van Name, 1940) according to environment, in Pró-Mata, São Francisco de Paula, RS, Brazil.

Environment	Size class	Smallest ovigerous female (mm)	Largest ovigerous female (mm)	Mean size ovigerous female (mm) ± standard error	Mean number of eggs/mancas found in ovigerous female ± standard error	Minimum and maximum number of eggs/mancas found in ovigerous females	Fecundity equation
Primary forest	Small (N = 9)	1.27	1.41	1.33 ± 0.02	6.44 ± 1.04	2/11	$y = 41.939x - 49.246; R^2 = 0.5294; p = 0.0255$
	Medium (N =6)	1.43	1.56	1.52 ± 0.02	12.33 ± 0.61	10/14	$y = 9.2827x - 1.7347; R^2 = 0.0794 ; p = 0.7534$
	Large (N = 2)	1.59	1.70	1.64 ± 0.06	11 ± 3.0	8/14	$y = 9.2827x - 1.7347; R^2 = 0.0794; p = 0.1792$
Secundary forest	Small (N = 26)	1.14	1.35	1.26 ± 0.01	7.54 ± 0.5	3/14	$y = 20.986x - 18.977; R^2 = 0.3054; p = 0.0037$
	Medium (N = 14)	1.37	1.58	1.45 ± 0.02	9.5 ± 0.91	6/19	$y = 20.986x - 18.977; R^2 = 0.3054; p = 0.5623$
	Large (N = 5)	1.587	1.80	1.65 ± 0.04	14 ± 1.82	10/20	$y = 20.986x - 18.977; R^2 = 0.3054; p = 0.0035$
Pinus plantation	Medium (N = 9)	1.16	1.30	1.25 ± 0.01	6.33 ± 0.62	4/9	$y = 20.986x - 18.977; R^2 = 0.3054; p = 0.5912$
	Large (N = 9)	1.35	1.52	1.43 ± 0.021	8.33 ± 0.47	7/11	$y = -11.023x + 24.107; R^2 = 0.2398; p = 0.0255$

Tab. VI. Ovigerous female and fecundity of *Balloniscus glaber* Araujo & Zardo, 1995 according to environment, in Pró-Mata, São Francisco de Paula, RS, Brazil. No ovigerous female recorded in *Pinus* plantation.

Environment	Size class	Smallest ovigerous female (mm)	Largest ovigerous female (mm)	Mean size ovigerous female (mm) ± standard error	Medium number of eggs/mancas found in ovigerous female ± standard error	Minimum and maximum number of eggs/mancas found in ovigerous females	Fecundity equation
Primary forest	Large (N = 12)	2.25	2.5	2.35	12.58 ± 1.76	5/26	$y = 20x - 34.5; R^2 = 0.0563; p = 0.5365$
Secundary forest	Large (N = 7)	2.28	2.45	2.37 ± 0.03	13.57 ± 3.21	4/31	$y = 69.211x - 150.31; R^2 = 0.2998; p = 0.2023$

There were no significant differences in the abundance of ovigerous and post-ovigerous females among environments (ANOVA, $F_{3,23} = 2.042$; $p = 0.143$).

The second most frequent species, *Balloniscus glaber*, is more abundant in primary and secondary forests, with all age classes found there. In *Pinus* plantations there was a single female recorded in the summer of 2001. The OSR analysis for *B. glaber* reveals no significant differences in abundance between males and females for secondary forest ($\chi^2 = 2.769$; df = 1; $p = 0.096$); for the primary forest, however, there was a significant difference ($\chi^2 = 11.25$; df = 1; $p = 0.0008$). The *G*-test again showed differences from the expected 1:1 Fisherian sex ratio ($G = 12.645$; df = 1; $p = 0.0004$). For this species the fecundity equation was determined, as well as the minimum and maximum number of eggs/mancas found in ovigerous females according to size classes on each environment (Tab. VI). In this case females were considered ovigerous only when having a completely closed marsupium, and all females with any opening in the marsupium were considered post-ovigerous. The smaller and larger ovigerous female occurred in the primary forest (1.59 mm and 2.5 mm respectively). There were no significant differences regarding ovigerous and post-ovigerous female abundance among environments (ANOVA $F_{4,22} = 0.2014$; $p = 0.657$). The reproductive period for *B. glaber* extended from summer to autumn (for primary and secondary forest).

DISCUSSION

This is the first record for Brazil of an established terrestrial isopod population in a *Pinus* sp. plantation area, evidenced by the presence of young, adults and ovigerous females, balanced sex ratio, expected fecundity and reproduction pattern, as compared to populations from native vegetation areas. It is also the first isopod diversity study to complement such diversity data with information on isopod life history traits. Of the five species found, only *A. floridana* is abundant on all environments. *Balloniscus glaber* is nearly exclusive for the native forests, the single individual in the *Pinus* area probably a "tourist" (dispersing through the area instead of inhabiting it). The other species had low abundances on every environment. *Benthana araucariana*, a species originally described for this ecoregion is unexpectedly rare on all environments. *Styloniscus otakensis* is an exotic species, but also not abundant.

Terrestrial isopod diversity is associated to the availability and quality of the food sources present (ZIMMER, 2003) and also the variety of resources and microhabitats the environment offers (LAVELLE, 1996; IRMLER, 2000). However, human disturbance in the studied environments, either through the monoculture of an exotic species or changes induced to native forest, ends up changing the expected environmental structure and function (MORRIS, 2003). *Pinus* plantations offer a smaller amount of resources for the fauna, not only generating a low quality leaf litter

but also restricting litter shelter (LOUREIRO *et al.*, 2006). A *Pinus* plantation in a given area does not lead to complete absence of terrestrial isopods, as both species richness and abundance did not differ from the native forests. The presence of a developed understory in this old *Pinus* area can be actually ameliorating this environment, guaranteeing more microhabitats and better food resources, attracting more isopods, especially habitat generalists. A similar scenario was found in Britain, where well-established plantations of exotic trees were considered emergent ecosystems providing habitat for native species and considered important for biodiversity (QUINE & HUMPHREY, 2010). This would explain *A. floridana* indiscriminate abundance across environments since it is known to have a strong capacity for coping with different, stressful situations (QUADROS *et al.*, 2009).

The quantitative difference in species composition between secondary forest and *Pinus* plantation would indicate that richness and abundance of soil arthropods are larger in native forests than *Pinus* monoculture, but the primary forest being similar to *Pinus* leaves the question open. Actually these two environments have important characteristics in common: the strong predominance of a conifer (*A. angustifolia* in the primary areas) and the importance of these trees for litter formation are coupled with the above mentioned developed understory in the *Pinus* areas chosen here. These could perhaps explain the lack of difference in isopod fauna. More recent *Pinus* plantation areas would probably offer less quantity and lower quality of resources for terrestrial isopods and can thus still be expected to be biologically poorer.

Very rare species in each environment (local *singletons* and local *doubletons*) can be thought of as occasional or "vagrant" (LUCKY *et al.*, 2002), which would mean instead of a local population, an occasional capture revealing dispersal through an inadequate environment. Invertebrate diversity studies in tropical forests indicate a high number of singletons to be common (CODDINGTON *et al.*, 2009). Such evidence reinforces the need for considering species life history data when analyzing diversity data. Despite our knowledge on the biology of the rare species found in this study being scant, the low numbers may also reflect a sampling bias. *Alboscia silveirensis*, for example, is endogeous (QUADROS *et al.*, 2007) being thus found below the superficial soil layer or within rotting logs. These habitat preferences allow us to consider this species as a true occasional in the present study, despite the possibility of it being rare as well.

Environmental preferences of the main species found in this study corroborate the existing information: *A. floridana* and *B. glaber* are abundant species in terrestrial isopods assemblages in southern Brazil (LOPES *et al.*, 2005; ALMERÃO *et al.*, 2006; QUADROS & ARAUJO, 2008). Even considering distinct sampling methods, these species can be confirmed as common for the state of the Rio Grande do Sul.

Atlantoscia floridana is a generalist and can occupy

a gamut of habitats: bromeliads, Polyporaceae fungi, ant nests, rotting logs, litter in forests, including fallen banana tree and coconut tree leaves, underneath stones, coconut skins and decaying matter in general (Lemos de Castro, 1985). Given this high level of adaptation, it is no surprise this species was found in the three environments studied here. *Atlantoscia floridana* life history traits favour a fast habitat colonisation rate (Quadros *et al.*, 2008) justifying its presence even in *Pinus* plantations, with relatively high abundances, as in most cases (Almerão *et al.*, 2006). A proper population in a *Pinus* plantation can be due, as argued above, to a well-developed understory, characteristic of old or abandoned plantation, thus losing the aspect of a monoculture.

Habitat generalist species tend to occupy areas even though food quality is not adequate. *Pinus* leaf litter has many components impalatable to edaphic animals (Vink & Purwanti, 1994), which raises the need for increasing litter palatability and digestibility by weakening its physical and chemical structure through microorganismal actions (Hassall & Rushton, 1984). In the *Pinus* case, fungi can be ingested along with litter (Soma & Saitô, 1983; Hassall & Rushton, 1984). Terrestrial isopods are primarily detritivores, but in the absence of nutritive food, fungi can become a viable option. The high frequency of soil fungi characteristic of monocultures as *Pinus* and *Eucalyptus* plantations lends credence to the observed proliferation of fungivores (Fonseca *et al.*, 2009) and also occasional consumers such as terrestrial isopods.

The information on *A. floridana* reproduction patterns and sex ratio complements what is found in the literature: *A. floridana* does not have a clear reproductive peak during winter on any environments. The fecundity of this species in the present study was relatively lower (2 to 20 eggs) than the known values of 4 to 23 eggs (Araujo & Bond-Buckup, 2005; Quadros *et al.*, 2008). The smaller ovigerous female of *A. floridana* found in the *Pinus* plantation, along with the lower fecundity, is probably associated with low food quality in *Pinus* (Smith & Bradford, 2003), resulting in a faster and lower reproductive investment.

The biology of *B. glaber* has been studied in detail in the latter years (Almerão *et al.*, 2006; Meinhardt *et al.*, 2007; Quadros & Araujo, 2007, 2008; Quadros *et al.*, 2009; Quadros, 2010). It is known to be a habitat specialist (Quadros *et al.*, 2008), justifying it's nearly absence in the *Pinus* plantation. Its geographic distribution is restricted and it has been recorded only from preserved areas or those with little human influence (Araujo & Zardo, 1995). The absence of different age classes in the *Pinus* plantation, especially ovigerous females, suggests *B. glaber* does not find the conditions adequate for establishment there. The fecundity here was higher (4 to 31 eggs) than previously recorded (5 to 20 eggs) (Quadros *et al.*, 2008). In this region the reproductive period of *B. glaber* includes autumn, differently from the previous record of reproduction only during spring and summer (Quadros *et al.*, 2008).

The search for edaphic fauna responses to the negative impact of *Pinus* plantations must be associated to a wealth of information on the target organisms. Not only species diversity data can be revealing, but life history traits can show in more detail how the biology of certain species is affected. Here we have provided records of how terrestrial isopods are living in these environments, and this can serve as a basis for future diversity studies on this group. Monitoring terrestrial isopods in the soil-leaf litter system of *Pinus* plantation areas can result in relevant data important for the management and restoration of disturbed areas.

REFERENCES

Ahyong, S. T.; Lowry, J. K.; Alongo, M.; Bamber, R. N.; Boxshall, G. A.; Castro, P.; Gerken, S.; Karaman, G. S.; Goy, J. W.; Meland, K.; Rogers, D. C. & Svavarsson, J. 2011. Subphylum Crustacea Brünnich, 1772. *In:* Zhang, Z.-Q. ed. Animal Biodiversity: An outline of higher-level classification and survey of taxonomic richness. **Zootaxa 3148**:165-191.

Almerão, M. P.; Mendonça Jr., M. de S.; Quadros, A. F.; Pedó, E.; Silva, L. G. R. & Araujo, P. B. 2006. Terrestrial isopod diversity in the subtropical Neotropics: Itapuã State Park, southern Brazil. **Iheringia**, Série Zoologia 96(4):473-477.

Araujo, P. B. & Bond-Buckup, G. 2005. Population structure and reproductive biology of *Atlantoscia floridana* (van Name, 1940) (Crustacea, Isopoda, Oniscidea) in southern Brazil. **Acta Oecologica 28**(3):289-298.

Araujo, P. B. & Zardo, M. C. L. 1995. Uma nova espécie de *Balloniscus* Budde-Lund (Crustacea, Isopoda, Balloniscidae) do Sul do Brasil. **Revista Brasileira de Zoologia 12**(4):785-790.

Battirola, L. D.; Adis, J.; Marques, M. I. & Silva, F. H. O. 2007. Comunidade de artrópodes associada à copa de *Attalea phalerata* Mart. (Arecaceae) durante o período de cheia no Pantanal de Poconé, MT. **Neotropical Entomology 36**(5):640-651.

Bertoletti, J. & Teixeira, M. B. 1995. Centro de Pesquisas e Conservação da Natureza Pró-Mata (Termo de referência). **Divulgações do Museu de Ciências e Tecnologia –** UBEA/PUCRS **2**:1-47.

Boelter, J. F.; Quadros, A. F. & Araujo, P. B. 2009. Feeding rates and preferences of a Neotropical terrestrial isopod. **Nauplius 17**:107-113.

Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. **Australian Journal of Ecology 18**:117-143.

Clarke, K. R. & Warwick, R. M. 1994. Similarity-based testing for community pattern: the 2-way layout with no replication. **Marine Biology 118**:167-176.

Coddington, J. A.; Agnarsson, I.; Miller, J. A.; Kuntner, M. & Hormiga, G. 2009. Undersampling bias: the null hypothesis for singleton species in tropical arthropod surveys. **Journal of Animal Ecology 78**(3):573-84.

Emler, S. T. & Oring, L. W. 1977. Ecology, sexual selection, and the evolution of mating systems. **Science 197**:215-223.

Fonseca, C. R.; Ganade, G.; Baldissera, R.; Becker, C. G.; Boelter, C. R.; Brescovit, A. D.; Campos, L. M.; Fleck, T.; Fonseca, V. S.; Hartz, S. M.; Joner, F.; Käffer, M. I.; Leal-Zanchet, A. M.; Marcelli, M. P.; Mesquita, A. S.; Mondin, C. A.; Paz, C. P.; Petry, M. V.; Piovensan, F. N.; Putzke, J.; Stranz, A.; Vergara, M. & Vieira, E. M. 2009. Towards an ecologically-sustainable forestry in the Atlantic Forest. **Biological Consevation 142**:1209-1219.

Hammer, Ø.; Harper, D. A. T. & Ryan, P. D. 2003. **PAST - PAlaeontological STatistics Software Package for Education and Data Analysis.** Available at: <http://folk.uio.no/ohammer/past>. Accessed on: 20 November 2010.

Hassall, M. & Rushton, S. P. 1984. Feeding behaviour of terrestrial isopods in relation to plant defences and microbial activity. **Symposium Zoological Society London 53**:487-505.

IRMLER, U. 2000. Chances in the fauna and its contribution to mass loss and N release during leaf litter decomposition in two deciduous forests. **Pedobiologia 44**:105-118.

LAVELLE, P. 1996. Diversity of soil fauna and ecosystem function. **Biology International 33**:3-16.

LEMOS DE CASTRO, A. 1985. Considerações sobre *Atlantoscia alceui* Ferrara & Taiti, 1981 (Isopoda, Oniscidea, Philosciidae). **Revista Brasileira de Biologia 45**(4):417-422.

LINDENMAYER, D. B. & FRANKLIN, J. F. 2002. **Conserving Forest Biodiversity: A Comprehensive Multiscale Approach.** Island Press, Washington. 351p.

LOPES, E. R. C.; MENDONÇA JR., M. S.; BOND-BUCKUP, G. & ARAUJO, P. B. 2005. Oniscidea diversity across three environments in an altitudinal gradient in northeastern Rio Grande do Sul, Brazil. **European Journal of Soil Biology 41**:99-107.

LOUREIRO, S.; SAMPAIO, A.; BRANDÃO, A.; NOGUEIRA, A. J. A. & SOARES, A. M. V. M. 2006. Feeding behaviour of the terrestrial isopod *Porcellionides pruinosus* Brandt, 1983 (Crustacea, Isopoda) in response to changes in food quality and contamination. **Science of the Total Environment 369**:119-128.

LUCKY, A.; ERWIN, T. L. & WITMAN, J. D. 2002. Temporal and spatial diversity and distribution of arboreal Carabidae (Coleoptera) in a western amazonian rain forest. **Biotropica 34**(3):376-386.

MAGRINI, M. J.; ARAUJO, P. B. & UEHARA-PRADO, M. 2010. Crustacea, Isopoda, Onsicidea Latreille, 1802: new continent Record and distribution extension in Brazil. **Check List 6**:217-219.

MEINHARDT, H.; QUADROS, A. F. & ARAUJO, P. B. 2007. Growth curve of *Balloniscus glaber* Araujo & Zardo (Crustacea, Isopoda, Oniscidea) from Parque Estadual de Itapuã, Rio Grande do Sul, Brazil. **Revista Brasileira de Zoologia 24**(4):1108-1112.

MORRIS, D. W. 2003. How can we aplly theoris of habitat selection to wildlife conservation and management? **Wildlife Research 30**:303-319.

NAKAMURA, A.; PROCTOR, H. & CATTERALL, C. 2003. Using soil and litter arthropods to assess the state of rainforest restoration. **Ecological Management & Restoration 4**:20-28.

OVERBECK, G. E.; MÜLLER, S. C.; FIDELIS, A.; PFADENHAUER, J.; PILLAR, V. D.; BLANCO, C. C.; BOLDRINI, I. I.; BOTH, R. & FORNECK, E. D. 2007. Brazil's neglected biome: The South Brazilian Campos, Perspectives in Plant Ecology. **Evolution and Systematics 9**:101-116.

PAOLETTI, M. G. & HASSALL, M. 1999. Woodlice (Isopoda: Oniscidea): their potential for assessing sustainability and use as bioindicators. **Agriculture, Ecosystems and Environment 74**:157-165.

PURCHART, L.; TUF, I. H.; HULA, V. & SUCHOMEL, J. 2013. Arthropod assemblages in Norway spruce monocultures during a forest cycle – A multi-taxa approach. **Forest Ecology and Management 306**:42-51.

QUADROS, A. F. 2010. Os isópodos terrestres são boas ferramentas para monitorar e restaurar áreas impactadas por metais pesados no Brasil? **Oecologia Australis 14**(2):569-583.

QUADROS, A. F. & ARAUJO, P. B. 2007. Ecological traits of two neotropical oniscideans (Crustacea: Isopoda). **Acta Zoologica Sinica 53**:241-249.
_____. 2008. An assemblage of terrestrial isopods (Crustacea) in southern Brazil and its contribution to leaf litter processing. **Revista Brasileira de Zoologia 25**:58-66.

QUADROS, A. F.; ARAUJO, P. B. & SOKOLOWICZ, C. C. 2008. Reproduction of neotropical isopods (Crustacea: Oniscidea) in southern Brazil: similarities and differences relative to temperate and tropical species. *In*: ZIMMER, M.; CHARFI-CHEIKHROUHA, F. & TAITI, S. eds. **Proceedings of the International Symposium of Terrestrial Isopod Biology, ISTIB-07**:81-90.

QUADROS, A. F.; CAUBET, Y. & ARAUJO, P. B. 2009. Life history comparison of two terrestrial isopods in relation to habitat specialization. **Acta Oecologica 35**:243-249.

QUINE, C. P. & HUMPHREY, J. W. 2010. Plantations of exotic tree species in Britain: irrelevant for biodiversity or novel habitat for native species? **Biodiversity and Conservation 19**:1503-1512.

SCHMALFUSS, H. 2003. World catalog of terrestrial isopods (Isopoda: Oniscidea). **Stuttgarter Beiträge zur Naturkunde A 654**:1-341.

SMITH, V. C. & BRADFORD, M. A. 2003. Litter quality impacts on grassland litter decomposition are differently dependent on soil fauna across time. **Applied Soil Ecology 24**:197-203.

SOKAL, R. R. & ROHLF, F. J. 1995. **Biometry: the principles and practice of statistics in biological research**. 3ed. New York, W. H. Freeman and Co. 887p.

SOMA, K. & SAITÔ, T.1983. Ecological studies of soil organisms with references to the decomposition of pine needles. **Plant and Soil 75**:139-151.

SOUZA, V. C. & LORENZI, H. 2008. **Botânica Sistemática - Guia ilustrado para a identificação das famílias de Fanerógamas nativas e exóticas no Brasil, baseado em APG II.** Nova Odessa, Plantarum. 704p.

TABARELLI, M.; PINTO, L. P.; SILVA, J. M. C.; HIROTA, M. & BEDÊ, L. 2005. Challenges and Opportunities for Biodiversity Conservation in the Brazilian Atlantic Forest. **Conservation Biology 19**:695-700.

VALLEJO, L. R.; FONSECA, C. L. & GONÇALVES, D. R. P. 1987. Estudo comparativo da mesofauna do solo entre áreas de *Eucaliptus citriodora* e mata secundária heterogênea. **Revista Brasileira de Biologia 47**(3):363-70.

VINK, K. & PURWANTI, E. S. 1994. Population dynamics of two sympatric isopod species in a pine forest in central Java, Indonesia. **Journal of Tropical Ecology 10**:417-430.

ZIMMER, M. 2003. Habitat and resource use by terrestrial isopods (Isopoda: Oniscidea). *In*: SFENTHOURAKIS, S.; ARAUJO, P. B.; HORNUNG, E.; SCHMALFUSS, H.; TAITI, S. & SLÁVECZ, K. eds. **The biology of terrestrial isopods V**. Leiden, Brill. p.243-261. (Crustaceana Monographs 2).