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Community of terrestrial isopods (Crustacea, Oniscidae): Differences between natural and labored environments

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Abstract
The structure and diversity of terrestrial isopod communities are described and compared in natural and labored environments. Samples collected by hand from July 2010 to June 2011 at the San José Department, Uruguay. As a result, 4 species belonging to 3 families and 3 genera were identified: *Armadillidium vulgare* (Latreille, 1804), *Armadillidium nasatum* (Budde-Lund, 1885), *Porcellio laevis* (Latreille, 1804) and *Balloniscus sellowi* (Brandt, 1833). *Armadillidium nasatum* (Budde-Lund, 1885) and *Porcellio laevis* (Latreille, 1804) were recorded for the first time in Uruguay. Species richness values are low in both environments. Species assemblages were dominated by *Armadillidium vulgare* and *Armadillidium nasatum* in both environments. *Porcellio laevis* was exclusively for the natural environment. Both habitats had lower values of Shannon-Wiener diversity, due to the high dominance of *Armadillidium vulgare*.

Keywords: Terrestrial isopods, diversity, natural and labored environments, Uruguay

1. Introduction

The terrestrial isopods are part of the suborder Oniscidea which is composed of 3710 species currently known, those that have achieved to exploit almost the entire range of terrestrial ecosystems [1, 2]. They are fundamental representatives of the soil fauna, having an important role in the functioning of the ecosystems [3]. They are considered beneficial organisms since they play a transcendental role in the recycling of nutrients, fragmenting the decomposing plant material exposing a larger area of the resource to be attacked by microorganisms [4, 5]. They also have a high sensitivity to responses from different environmental variables, as well as the ability to accumulate heavy metals through food and to survive in areas polluted by industrial waste, which constitute them as potential bioindicators of environmental quality [6]. Nevertheless in the last years, they are considered emerging pests of direct seeding, causing economic losses in crops of soybeans, corn and pastures [7, 8]. They cause transverse and longitudinal lesions at the base of the seedlings and in the cotyledons, producing the yellowing and broken of the same ones. At high densities they also eat seeds, cotyledons and tender leaves. The damage is manifested in irregular patches, intensifying in areas with high volume of stubble and high humidity in the soil [8, 9]. No studies in Uruguay have focused on an analysis of oniscidean diversity, only three species have been cited prior to this study: *Balloniscus sellowii* (Brant, 1833) *Armadillidium vulgare* (Latreille, 1804) and *Neotroponiscus plaumanni* (Andersson, 1960) [10, 11]. In Uruguay there are still large tracts of natural habitats with native vegetation, but some regions such as the southwest littoral, have large human modifications due to cattle rising and agriculture. Distribution patterns of terrestrial isopods in systems with and without human influence can reveal the purported negative effects of economic land use [12]. In order to provide basic information that allows taking and recommending monitoring and conservation measures, it is important to know the fauna of terrestrial isopods present in the area [13, 14]. Thus, the present study aims to describe, analyze and compare the diversity and abundance of terrestrial isopods between natural and labored environments.

2. Materials and Methods

2.1 Study Area and Sampling

The sampling station is located at Department of San José, Uruguay (Figure 1). Samples were taken from two environments, natural and labored, located at a distance of 500 m between them. The native environment (34°17´00.01´´ S/56°54´00.0´´ W) is a gently rolling grassland where trees appear in isolated patches or as a riparian forest characterized by *Celtis spinosa*, *Iodina rhombifolia*, *Shinus longifolius*, *Acacia caven* and *Maytenus ilicifolia* [15, 16]. The labored environment is an agricultural area (34°16´59.50´´S/56°54´19.61´´W) with conventional tillage of *Zea mays*. Samples were taken monthly, from July 2010 to June 2011. Terrestrial isopods were hand searched in both sites by two people for 40 minutes along two independent transects of 20 m long spaced approximately 40 m apart, summing a total of 33 h of sampling effort. Samples were transported to the laboratory in polythene bags containing soil from the sampling site. During the monthly sampling, in each environment, the soil temperature was taken at a depth of 6 cm, using an electronic thermometer (Digi-Scense Model N° 8528-30) and the soil moisture was measured using the gravimetric method[17], from core samples collected at each sampling sites (d= 10 cm, h= 2cm).

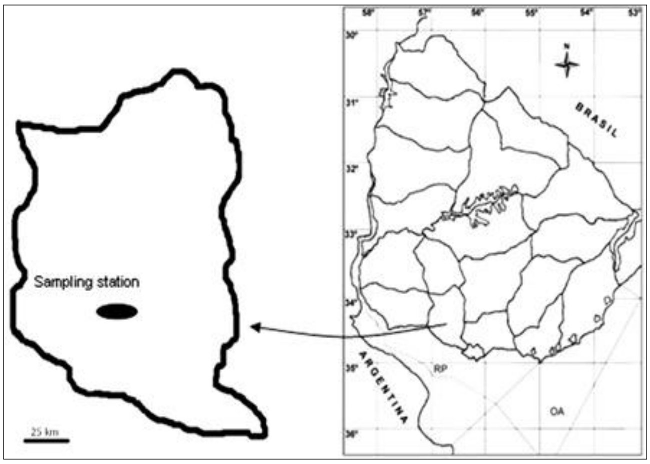

Fig 1: Location of the sampling sites in Department of San José, Uruguay

2.2 Laboratory Procedures and Data Analysis

The collected isopods were sorted on white trays and preserved in 70% ethanol. Species were identified under a compound binocular microscope using the keys of [5, 18, 19] and counted. In order to compare the significance of the diversity differences between the number of species and their abundance we applied the Mann Whitney test. Spearman`s coefficient rank correlation was used to identify relationship between isopod abundance and environmental parameters (soil temperature and soil moisture). To estimate that our sampling methods were efficient, sampled-based species accumulation curves for each locality were plotted. The expected richness was calculated using the nonparametric estimators Chao 2, Jackknife 1, Jackknife 2 and Boostrap. The ecological indices used to assess the diversity in each sampling site were: the Shannon-Wiener (H´) diversity index, Simpson (D) dominance index, and the Pielou evenness index [20, 21]. In order to estimate the significance of the diversity differences between habitats we applied ANOVA [22]. Similarities among sites were calculated using Sorensen's index (IS_S) for presence-absence data. Analyses were done using the freely available software PAST 2.14 [23] and EstimateS v8 [24].

3. Result

A total of 12.623 individuals of the following 4 species were identified: *Armadillidium vulgare*, *Armadillidium nasatum*, *Balloniscus sellowii* and *Porcellio laevis* (Table 1). *Armadillidium nasatum* and *Porcellio laevis*, are cited for the first time for the Uruguay. Except *Porcellio laevis*, who was found only in the native environment, the other species are all common for both of the habitats. *Armadillidium vulgare* was the most abundant species in both environments and together with *Armadillidium nasatum* they constituted 99, 9% of the total catch (Table 1). *Balloniscus sellowii* and *Porcellio laevis* were only recorded occasionally and in very low abundance.

Table 1: Isopod species recorded in the native (NE) and labored (LE) environments, with indices of diversity and evenness. % - percent share of total individuals.

Species name	NE	LE	TOTAL	%
Armadillidium vulgare	8879	613	9492	75,2
Armadillidium nasatum	2729	389	3118	24,7
Ballaniscus sellowi	2	2	4	0,03
Porcellio laevis	9	0	9	0,07
Number of isopod species (S)	4	3		
Number of isopod individuals (N)	11619	1004		
Shannon-Wiener Index (H')	0,55	0,65		
Simpson Index (D)	0,64	0,55		
Pielou´s evenness index (J´)	0,39	0,59		

Species–accumulation curves stabilized after only half the samples were taken for both environments (Figure 2). Three out of four species richness estimators returned values effectively identical to the observed richness, although one estimator predicts less species to be found in the native environment and more species in the labored environment (Table 2)

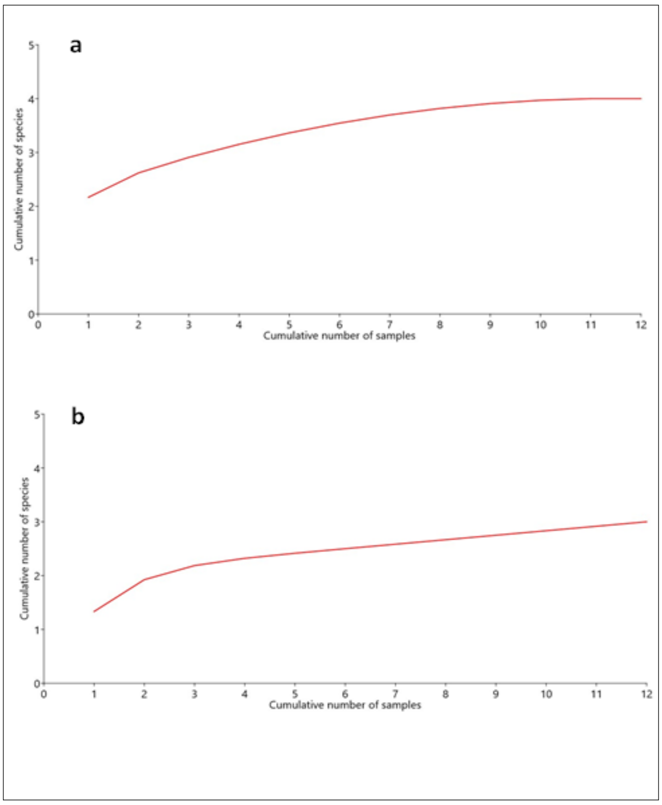

Fig 2: Species–accumulation curves showing the rate of species accumulation with increasing sample effort, a - natural, b – labored.

Table 2: Species richness estimators for the Oniscidea in natural and labored environment

Estimador index	NATURAL	LABORED
Chao 2	4	3
Jacknife 1	4	3,9
Jacknife 2	2,5	4,7
Boostrap	4,2	3,3

The native environment had the highest abundance (11.619 individuals) and the differences between habitats was significant (U = 13; p<0.05). The highest abundance values occurred in June (winter) for the native environment (1.858 individuals) and in April (fall) for the labored environment (413 individuals), mainly due to the presence of *Armadillidium vulgare*. During November to January (spring/summer) the number of individuals decreased in the native environment (29 individuals), and the presence of *Armadillidium nasatum* was not recorded in this period. On the other hand, in the labored environment the presence of isopods was not recorded from October to January (spring / summer) (Figure 3). In both environments, soil moisture was positively correlated with the isopod total monthly catch ($R_{snatural}$ = 0, 67, p = 0, 01; $R_{slabored}$ = 0, 68, p = 0, 01) and soil temperature was negatively correlated ($R_{snatural}$ = -0, 60, p = 0, 03; $R_{slabored}$ = - 0, 56, p = 0, 05).

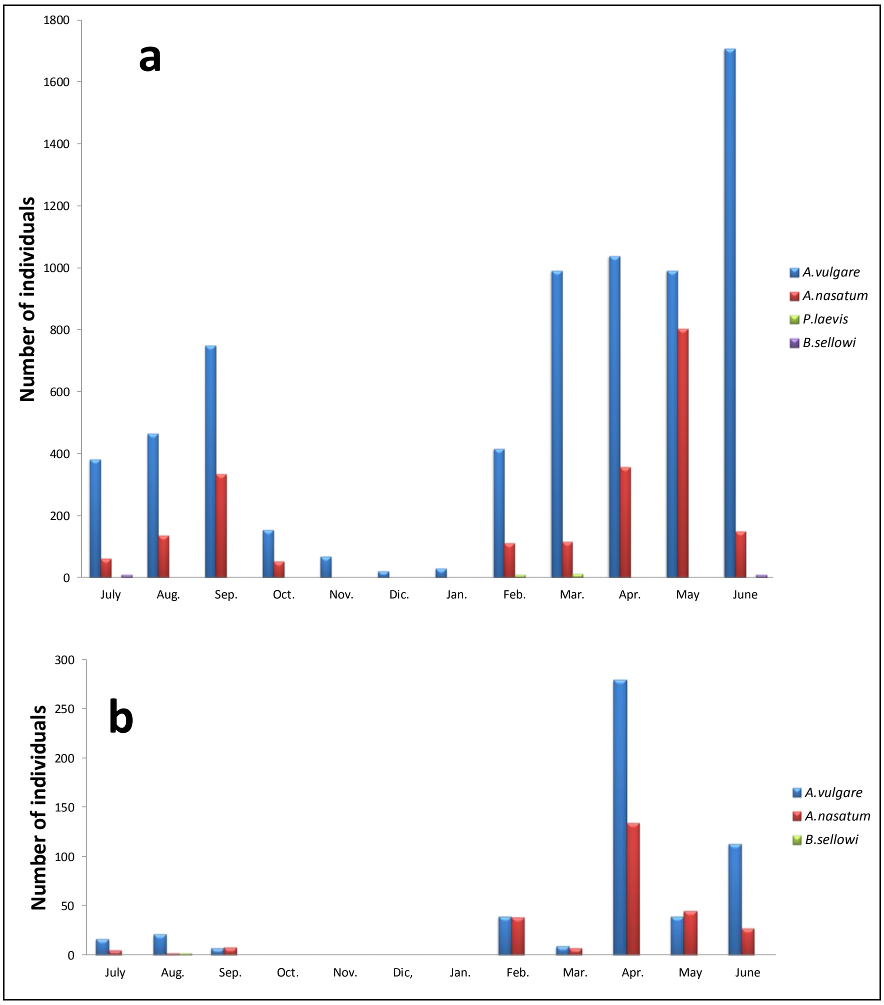

Fig 3: Total number of individuals of terrestrial isopods captured monthly in natural (a) and labored (b) environments.

The α-diversity indexes are summarized in Table 1. The species diversity index was higher on the labored environment (H'= 0, 65), which is the most balanced environment too (J´ = 0, 59). Simpson´s dominance index was higher in the natural environment (D = 0, 64). However there were not significant differences in the Shannon Wiener diversity index (H´) (F: 1.43; p>0.05; df: 1), the dominance (F: 1.32; p>0.05; df: 1) and the evenness (F: 1.14; p>0.05; df: 1) between the two environments (Table 1). Sørensen index revealed a high similarity of over all species richness (85%) between both environnments.

4. Discussion

This is the first record for Uruguay with an established terrestrial isopod population in natural and labored environments. Four species of terrestrial isopod were collected, two of which are reported for the first time from Uruguay; *Armadillidium nasatum* and *Porcellio laevis.* Also this study extended the area of occurrence of *Armadillidium vulgare* previously recorded to Montevideo and *Balloniscus sellowii*, recorded to Rocha, Maldonado and Salto [10, 11]. The number of species found is low. This agrees with other studies on isopod diversity in the Neotropical region, 7 species were identified in Rio Grande do Sul (southern Brasil) [12, 25, 26, 27], 4 species in the south-eastern of Argentina [28] and 5 in three localities of Boyacá, Colombia [8, 29]. Sample-based species accumulation curves stabilized for both environments, assuring sample sufficiency in terms of species present in the areas. Three out of four species richness estimators returned values effectively identical to the observed richness.

According with Messina *et al*. [30] it seems, therefore, that we can expect the recorded species richness to be very close to its true value in nature.

Terrestrial isopod community structure does not differ among the sites, only *Porcellio laevis* is exclusive for the native environment. The presence of this species exclusively in this environment is unusual, because this is a widespread and cosmopolitan species that appears to be strongly synanthropic. Although it has also been registered associated with agricultural crops and pastures, such as cotton plantations.

gardens and abandoned land [31, 32]. Its nocturnal activity may be the cause of not having collected it in the samplings of the labored environment as well as the low registered number of this species [33, 34]. Regarding species abundances the isopod fauna is dominated in both environments by introduced species, *Armadillidium vulgare* and *Armadillidium nasatum*. The high abundance of these species has been registered in several other ecosystems [7, 35, 36, 37, 38]. They are eurytopic species commonly found in natural and agro ecosystems [7]. This result is in agreement with the observer by Figini [28] and Martinez *et al*. [8] in a population of terrestrial isopods in natural and labored environments from Argentina and Colombia respectively. On the other hand, it disagrees with those registered in different studies in natural and rural environments from Brazil, in which the predominant species were *Atlantoscia floridana* and *Balloniscus sellowi* [6, 39, 40, 41].

According to Riedel *et al*. [42] the human activity impacts the size of populations of isopods, but doesn't affect the species spectrum. This is reflected in this study, where the native environment had the highest abundance of isopods and the difference between habitats was significant. The floristic composition is very important for terrestrial isopods, *Armadillidium vulgare* feeds preferentially on dicotyledonous plants rather than monocotyledonous [7, 43, 44]. This suggests more favorable habitat conditions in the natural environment Merriam [44] and Rushton and Hassall [45]. Demonstrated that food quality can significantly change the growth rate of *Armadillidium vulgare*, directly affecting the age at the first reproduction, which is a key factor in controlling the population growth. In our study, the high abundance in the native forest could be related with the presences of high quality food (dicotyledonous) which increases exponentially the growth rate of the juveniles [7]. On the contrary, in the agricultural area the low abundance could be associated with the presence of monocotyledonous species (*Zea mays*) which represents a low quality diet for isopods [44, 45, 46]. Furthermore, in accordance with the observations of Paolleti and Hassall [46] the low abundance in the agricultural area could be associated to a combination of direct and indirect effects on management practices. The direct effect on mortality rates results from simplification of habitats structure and reduced availability of shelter sites plus the application of pesticides. The indirect effect is caused by the use of herbicides which reduce the growth rates and the fecundity [47].

Contrary to what has been observed in others works [29, 39, 40, 48, 49], our study reveals that isopod activity was positively correlated with soil humidity and negatively correlated with the temperature. Brigic *et al*. [2] asserts that the key environmental variables that affected isopod spatial distribution are soil moisture and vegetation cover. This is reflected in the variations of both communities during the year, where the peaks of abundance occur in colder months, decreasing abruptly in the warm months in the native environment and disappearing in the labored environment. During the dry summer the isopods migrate deeper into the soil and are not detectable [50]. Vertical migrations were observed in populations of *Armadillidium vulgare* [51, 52] and *Armadillidium nasatum* [53], which during the summer are buried under 10 cm deep, returning to the surface when the soil becomes moist, as a way of better withstanding climatic conditions in the absence of physiological adaptations. In the labored environment, it can also be related to the fact that in the warm months the land is prepared for sowing, causing lack of shelter and food.

In spite of the native environment has the highest number of species, it has low species diversity and evenness indices, and a relatively high species dominance index. This is due to the high dominance of *Armadillidium vulgare*. Similar results were observed in others ecosystems [36, 38, 41, 54, 55, 56, 57].

5. Conclusion

This study represents our first attempt to understand the structure and diversity of terrestrial isopod communities in natural and labored environments from Uruguay. We found that both environments have a similar structure constituted by the species *Armadillidium vulgare*, *Armadillidium nasatum, Balloniscus sellowii* and *Porcellio laevis.* The isopod fauna is dominated in both environments by introduced species, *Armadillidium vulgare* and *Armadillidium nasatum.* For the future it is necessary to extend sampling to other habitats of the country, from where we lack information on oniscids. More data on the biology of the species are also necessary.

6. References

1. Sfenthourakis S, Taiti S. Patterns of taxonomic diversity among terrestrial isopods. ZooKeys. 2015; 515:13-25.
2. Brigic A, Antonovic B, Alegro A, Segota V, Bujan J. Terrestrial isopods (Isopoda: Oniscidea) as unexpected inhabitants of extreme habitats. European Journal of Soil Biology. 2017; 82:66-71.
3. Achouri MS, Hamaied S, Charfi-Cheikhrouha F. The Diversity of Terrestrial Isopoda in the Berkoukech Area, Kroumirie, Tunisia. Crustaceana. 2008; 81(8):917-929.
4. Zimmer M. Effect of temperature and precipitation on a flood plain isopod community: a field study. European Journal of Soil Biology. 2004; 40:139-146.
5. Araujo PB. Suborden ONISCIDEA (Isópodos Terrestres, "tatuzinhos"). In Os crustaceos do Río Grande do Sul. (L. Buckup and G. Bond-Buckup Eds), Edición Universidade/UFRGS, Porto Alegre, Brasil. 1999, 237-256.
6. Quadros A. Os Isopodos Terrestres sao boas ferramentas para monitorar e restaurar áreas impactadas por metáis pesados no Brasil? Oecologia Australis. 2010; 14(2):569-583.
7. Faberi A, López A, Clemente NL, Manetti PL. Importance of the diet in the growth and survivorship and reproduction of the no tillage pest *Armadillidium vulgare* (Crustacea, Isopoda). Revista Chilena de Historia Natural. 2011; 84:407-417.
8. Martinez D, Pérez D, Espindola C. Caracterización de Isópodos Terrestres (Crustacea: Isopoda) y su impacto en cultivos hortícolas de Boyacá. Revista Ciencias Agrícolas. 2014; 31(1):55-64.
9. Saluso A. Isópodos terrestres asociados al cultivo de soja en siembra directa. INTA EEA Paraná. Argentina. www.inta.gov.ar. 15 September, 2017.
10. Lemos de Castro A. Isópodos terrestres introducidos no Brasil (Isopoda, Oniscidea). Boletim do Museu Nacional,

Nova Série Rio De Janeiro GB – Brasil. Zoología. 1971; 2:216-222.
11. Lemos de Castro A. Consideracoes sobre a sinonímia e a distribucao geográfica de *Balloniscus sellowii* (Brandt, 1833) (Isopoda, Balloniscidae). Brasil Journal Biology. 1976; 36(2):391-396.
12. Lindenmayer DB, Franklin JF. Conserving Forest Biodiversity: A Comprehensive Multiscale Approach. (Ed), Island Press, Washington, 2002, 351.
13. Bugs P, Araujo P, de Souza Mendonça M, Ott R. Diversity and population characteristics of terrestrial isopods (Crustacea, Oniscidea) across three forest environments in southern Brazil. Iheringia, Série Zoologia, Porto Alegre. 2014; 104(3):334-340.
14. Carvhalo Lopez E, de Souza Mendoca M, Bond-Buckup G, Araujo PB. Oniscidea diversity across three environments in an altitudinal gradient in northeastern Rio Grande do Sul, Brazil. European Journal of Soil Biology. 2005; 41:99-107.
15. Evia G, Gudynas E. Ecología del paisaje en Uruguay. Aportes para la conservación de la diversidad biológica. (Ed), Dirección de Medio Ambiente, Uruguay, 2000, 173.
16. Di Giacomo AS, Krapovickas S. Conserving the Grassland Important Bird Areas (IBAs) of Southern South America: Argentina, Uruguay, Paraguay, and Brazil. USDA Forest Service Gen. Tech. Rep. 2005; 191:1243-1249.
17. Forsythe W. Física de suelos. (Ed), IICA, San José, Costa Rica, 1975, 212.
18. Araujo PB, Buckup L, Bond-Buckup G. Isópodos terrestres (Crustacea, Oniscidea) de Santa Catarina e Rio Grande do Sul. Iheringia, Série Zoologica. 1996; 81:111-138.
19. Pérez-Schultheiss J. Familias de isópodos terrestres (Crustacea: Isopoda: Oniscidea) de Chile: Sinopsis y Clave de Identificación. Boletín de Biodiversidad de Chile. 2010; 4:63-82.
20. Magurran AE. Diversidad ecológica y su medición. (Ed), Vedrá, España, 1989, 200.
21. Moreno CE. Métodos para medir la biodiversidad. (Ed), Manuales y Tesis SEA, 2001, 84.
22. Daniel W. Bioestadística. Base para el análisis de las ciencias de la salud. (Ed), Limusa, España, 2002, 923.
23. Hammer O, Harper DAT, Ryan PD. PAST: Paleontological Statistics software package for education and data analysis. Retrieved from http://palaeo-electronica.org/. 2001.
24. Colwell RK. EstimateS: statistical estimation of species richness and shared species from samples. http://viceroy.eeb.uconn.edu/estimates. 5 June, 2017.
25. Almerao M, Mendoca M, Quadros A, Pedó E, Silva L, Araujo PB. Terrestrial isopod diversity in the subtropical Neotropics: Itapua State Park southern Brazil. Iheringia, Série Zoologica. 2006; 96(4):473-477.
26. Quadros A, Araujo PB. An assemblage of terrestrial isopods (Crustacea) in southern Brazil and its contribution to leaf litter processing. Revista Brasileira de Zoologia. 2008; 25(1):58-66.
27. Lopes Carvalho ER, Mendoca de Souza M, Bond-Buckup G, Araujo PB. Oniscidea diversity across three environments in an altitudinal gradient in northeastern Rio Grande do Sul, Brazil. European Journal of Soil Biology. 2005; 41(3-4):99-108.
28. Figini E. Diversidad y abundancia de isópodos terrestres (Crustacea) en ambiente natural vs. un ambiente laboreado en el Partido de Balcarce, Provincia de Buenos Aires. Tésis de Ingeniero Agrónomo Facultad De Ciencias Agrarias, Universidad Nacional De Mar Del Plata, 2008, 55.
29. Preciado AF, Martinez J. Estudio de Isópodos Terrestres (Crustacea: Isopoda: Oniscidea) en tres localidades de Bocayá, Colombia. Revista de Ciencias Agrícolas. 2014; 31(2):14-23.
30. Messina G, Cazzolla Gatti R, Droutsa A, Barchitta M, Pezzino E, Agodi A *et al*. A sampling optimization analysis of soil-bugs diversity (Crustacea, Isopoda, Oniscidea). Ecology and Evolution. 2016; 6(1):191-201.
31. Harding P. Is *Porcellio laevis* (Latreille) declining in Britain and Ireland? Bulletin of the British Myriapod & Isopod Group. 2016; 29:23-27.
32. Treviño Flores J, Rodriguez-Almaraz G. Primeros registros de *Porcellio laevis* y *Porcellio scaber* (Crustacea: Oniscidea) del Noreste de México. In La Carcinología en México: el legado del Dr. Alejandro Villalobos 30 años después. (M. López and L. M. Mejía Eds), Universidad de Quintana Roo. Cozumel, Quintana Roo, México, 2013, 13-22.
33. Ianacone J, Alayo M, Abanto M, Sánchez J, Zapata E. *Porcellio laevis* Latreille, 1804 (Isopoda: Porcellionidae) como bioindicador para evaluación de plomo. Rev. Per. Ento. 2001; 42:175-183.
34. Iannacone J, Alvariño L. Influencia de la aclimatación en la tolerancia a altas temperaturas del chanchito de la humedad *Porcellio laevis* (Isopoda: Porcellionidae). Biologist. 2007; 5(2):60-64.
35. Holway D. Effect of Argentine ant invasions on ground-dwelling arthropods in northern California riparian woodlands. Oecologia. 1998; 116:252-258.
36. Singer C, Bello M, Snyder A. Characterizing prevalence and ecological impact of non-native terrestrial isopods (Isopoda, Oniscidea) in tallgrass prairie. Crustaceana. 2012; 85:1499-1511.
37. Tajovský K, Hosék J, Hofmeister J, Wytwer J. Assemblages of terrestrial isopods (Isopoda, Oniscidea) in a fragmented forest landscape in Central Europe. ZooKeys. 2012; 176:189-198.
38. Ferenti S, Cupsa A, Covaciu-Marcov S. Ecological and Zoogeographical significance of terrestrial isopods from Capei Plain Natural Reserve (Romania). Arch. Biol. Sci. 2012; 64(3):1029-1036.
39. Magrini M, Freitas A, Uehara-Prado M. The effects of four types of anthropogenic disturbances on composition and abundance of terrestrial isopods (Isopoda: Oniscidea). Zoologia. 2011; 28(1):63-71.
40. Kern DI, Köhler A. Variação sazonal e estrutura populacional de espécies de isópodos terrestres em uma área em sucessão vegetal. Caderno de Pesquisa. Série Biologia (UNISC). 2012; 24(3):44-56.
41. Cauduro P, Leite da Silva B, Moreira J, Domingues A, Swarowsky A, Schüssler de Vasconcellos N. Diversidade de Crustáceos Terrestres da Suborden Oniscidea na Região de Santa Maria, RS. Disciplinarum Scientia. Série: Naturais e Tecnológicas. 2016; 16(3):501-508.
42. Riedel P, Navrátil M, Tuif H, Tufová J. Terrestrial isopods (Isopoda: Oniscidea) and millipedes (Diplopoda) of the City of Olomouc (Czech Republic). In Tajovský K. Schlaghamerský J & Pižl V. (Eds.) Contributions to Soil Zoology in Central Europe III. 2009, 125-132.
43. Souty-Grosset C, Badenhausser I, Reynolds J, Morel A.

Investigations on the potential of woodlice as bioindicators of grassland habitat quality. European Journal of Soil Biology. 2005; 41:109-116.
44. Merrian HG. Sensitivity of terrestrial isopod populations (Armadillidium) to food quality differences. Canadian Journal of Zoology. 1971; 49:667-674.
45. Rushton SP, Hassall M. Effects of food quality on Isopod Population Dynamics. Functional Ecology. 1983, 359-367
46. Paoletti MG, Hassall M. Woodlice (Isopoda, Oniscidea) their potential for assessing sustainability and use as bioindicators. Agriculture, Ecosystems & Environments. 1999; 74:157-165.
47. Salvio C, Manetti P, Clemente N, López A. Efectos de Carbaryl y. Metaldehído sobre *Armadillidium vulgare* (Crustacea: Isopoda) y *Milax gagates* (Mollusca: Pulmonata) en soja bajo siembra directa Agrociencia. 2014; 18(2):82-89.
48. Antonović I, Brigić A, Sedlar Z, Bedek J, Šoštarić R. Terrestrial isopod community as indicator of succession in a peat bog. ZooKeys. 2012; 176:171-188.
49. Zimmer M. Effects of temperature and precipitation on flood plain isopod community: a field study. 2004, 40:139-146.
50. Tuf I, Tufová J. Communities of terrestrial isopods (Crustacea: Isopoda: Oniscidea) in epigeon of Oak-Hornbeam forest of Slovakia. Ekológia (Bratislava). 2005; 14(2):113-123.
51. Paris O, Pitelka F. Population characteristics of the terrestrial isopod *Armadillidium vulgare* in California Grassland. Ecology. 1962; 43:220-248.
52. Paris O. The ecology of *Armadillidium vulgare* (Isopoda, Oniscidea) in California Grassland: Food, Enemies and Weather. Ecological Monographs. 1963; 33:1-22.
53. Schultz G. Distribution and establishment of a land isopod in North America. Systematic Zoology. 1961; 4(10):193-196.
54. Singer C, Bello N, Snyder B. Characterizing prevalence and ecological impact of non-native terrestrial isopods (Isopoda, Oniscidea) in tallgrass prairie. Crustaceana. 2012; 85(12-13):1499-1511.
55. Gizzi A, Álvarez Castillo H, Manetti P, López A, Clemente N, Studdert G. Caracterización de la meso y macrofauna edáfica en sistemas de cultivo del sudeste bonaerense. Suelo. 2009; 27(1):1-9.
56. Arndt E, Mattern D. Ecological data of isopods (Crustacea: Oniscidea) in laurel forests from the Western Canary Islands. VIERAEA. 2005; 33:41-50.
57. Messina G, Montesanto G, Pezzino E, Sciandrello S, Caruso D, Lombardo M. Plant communities preferences of terrestrial crustaceans (Isopoda: Oniscidea) in a protected coastal area of southeastern Sicily (Italy). Versita. 2014; 69(3):354-362.