

RESEARCH ARTICLE

What do we know about the harvestmen (Arachnida: Opiliones) from Paraná State, Brazil? A diversity hotspot in the southern Atlantic Forest

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ABSTRACT. The knowledge of the diversity and distribution of Opiliones in Brazil can be considered suitable. However, while the harvestmen fauna of the southern Atlantic Forest is also well-known, several gaps remain and they are still far from complete, notably those in Paraná. Thus, investigations on regional assemblages focused on primary data are critical for promoting many key research fields such as taxonomic and phylogenetic studies, as well as encouraging conservation efforts. This study provides a comprehensive overview of the knowledge on diversity, distribution, and the history of Opiliones research from the state of Paraná. Knowledge gaps are identified and the background of taxonomic studies, highlighting the key contributors, is also discussed. A total of 1115 records were compiled, with 584 from Paraná for 118 species belonging to five families. This compilation allowed to identify 60 endemic species and 106 type localities (including invalid specific names) for the state. Despite being one of the three Brazilian states with the greatest diversity of harvestmen, this knowledge is concentrated in a small region in the First Plateau and is the result of the efforts of a few researchers and collectors over a few decades. To overcome these limitations further sampling is required in the state's western region. This study is a very first step toward to achieve a comprehensive database of knowledge about Opiliones from one of the richest hotspots for these invertebrates in the world. We encourage similar approaches that consider the state of art for other research fields such behavior, ecology, and natural history in the state, as well as to other neotropical areas.

KEY WORDS. Araucaria Forest, biodiversity, historiography, Marumbi massif, species checklist, Wallacean shortfall.

INTRODUCTION

Arachnids of the order Opiliones can be found in most of the terrestrial ecosystems on all continents, except Antarctica (Pinto-da-Rocha et al. 2007). According to Kury et al. (2020), Opiliones are divided into four living suborders Cyphophthalmi, Dyspnoi, Eupnoi and Laniatores and have 6,637 species distributed in 1,645 genera and 65 families. Despite the great diversity of species and habitats, most species show limited distribution range, with high rates of endemism (Pinto-da-Rocha et al. 2007, DaSilva et al 2017). This can be partially explained by to their low vagility and

dispersal capacity of these animals, with temperature and humidity levels as main ecological filters, which explains their highest richness in tropical forested regions (Bragagnolo et al. 2007).

In the large territory of Brazil, there are about 1,000 species of harvestmen in 304 genera (Kury 2023), which are distributed in the 26 States plus the Federal District. There is not an up-to-date checklist dedicated to the Opiliones of the state of Paraná, however a catalog published two decades ago referred to 103 species (Kury 2003a). Paraná geography, with total area of almost 200,000 km², is characterized by a division into four altitudinal gradients, known as littoral

zone and plateaus. The First Plateau or Plateau of Curitiba, capital of the State, has a temperate climate, with mild summers and frequent frosts in the winter, however, it is greatly influenced by the montane formations of Atlantic Forest in the Serra do Mar, which presents great altitudinal variation and acts as a barrier to the warm and humid winds coming from the Atlantic Ocean. The Second and Third Plateaus maintain a temperate climate, however they have lower humidity (Labiak 2014).

Most of knowledge on arachnology in Brazil can be referred to the pioneering works of Cândido Firmino de Mello-Leitão (1888–1948). He published the very first catalogue of Opiliones species for Brazil (Mello-Leitão 1932). Only several decades later other checklists of species became available such that of the Annotated Catalogue of the Laniatores of the New World (see Kury 2003a), which contains all harvestmen of that suborder registered in Brazil, and in the Catalog of the Brazilian Taxonomic Fauna (Kury 2023), thus the Brazilian harvestmen are comparatively well-studied in comparison with any other South American countries. In 2020 a team of authors made public the World Catalogue of Opiliones project, which aims to compile an updated list of valid names of Opiliones and create an online database (WCO-Lite) that serves as an official reference for the taxonomy and nomenclature of harvestmen around the world, in an agile and practical way (see Kury et al. 2020).

Studies that aim to understand living biodiversity are essential, especially when considering the high extinction rates that result in the disappearance of species even before they are studied, which makes inventories a priority for the conservation of species (Lindenmayer et al. 2012). Research on harvestmen has been important for many fields of biological sciences such as developmental and evolutionary biology, in addition to the taxonomic studies (Giribet and Sharma 2015). Giribet and Sharma (2015) point out that harvestmen have “primitive” sets of character states not observed in other arachnids such as spiders and mites, thus serving as model organisms for the study of development and evolutionary processes in arachnids, facilitating inferences on phylogenetic research and about genetic mechanisms that promote morphological changes throughout the evolutionary history of Chelicerata.

The Opiliones assemblage of the Serra do Mar in the state of Paraná has been one the first to receive attention from researchers in Brazil and this fauna was reasonably well investigated during the 1940s (e.g., Soares 1945, Soares and Soares 1947a, 1947b, 1949). Paraná occupies the third place in species-richness among Brazilian states for Laniatores, just

behind Rio de Janeiro and São Paulo States (see Kury 2003a). The coastal area and the first Plateau have been identified as one of the Atlantic Forest’s richest hotspots for Opiliones (cf. Nogueira et al. 2019). Further than its elevated diversity, the fauna of Serra do Mar in the Marumbi massif deserves to be highlighted for its high levels of endemism, which represent a biotic component with unique evolutionary history (e.g., DaSilva et al. 2017). Nonetheless, knowledge about the diversity and distribution of harvestman species in Paraná remains limited, and specific studies on this regional fauna are needed to provide primary data for essential research fields such as taxonomy and phylogenetics as well as to stimulate conservation actions.

The goal of this study is thus to provide an overview of the current knowledge regarding the diversity and distribution of Opiliones in the state of Paraná. We present a comprehensive checklist of harvestman species for the state, compiling occurrence data to identify putative knowledge gaps and summarizing the background history of taxonomic studies highlighting some key contributors.

MATERIAL AND METHODS

Terminology and nomenclature

The system of classification, as well as the validity, spelling, authorship, and date of the names of the taxonomic categories follow Kury et al. (2023).

Data collection, databasing and georeferencing

The list of species for Paraná from 1758 to 2023 was elaborated based on the catalogue of Laniatores by Kury (2003a) as a starting point and updated through searches carried out in the following electronic databases: Web of Science, SciELO, Scopus, Jstor, Wiley-Blackwell, Scientific Direct, Biodiversity Heritage Library and Google Scholar with the keyword “Opiliones” and filter for the period from 2002 to 2023. The OmniPaper project (Kury 2003b) made it practical to access older publications. The data were digitized in an electronic spreadsheet with the list of species with occurrence records in the state of Paraná, containing information such as provenance original data, georeferenced site, and altitude.

Georeferencing was initially conducted using the Index of Geographical Names of the IBGE (2011). For localities not initially found, further investigations were carried out by consulting databases such as the Railway Stations of Brazil (<http://www.estacoesferroviarias.com.br/index.html>), Falling Rain Software, Ltd. (<http://www.fallingrain.com>) and virtual collections of the Herbário do Museu Botânico Municipal

de Curitiba (<https://specieslink.net/search/>), Virtual Herbarium (<https://reflora.jbrj.gov.br/reflora/herbarioVirtual/>) and National Register of Caves of Brazil (<https://sbcnc.org.br/Default.aspx>). For sites which no precise data were available, we used the coordinates of the municipality based on IBGE (2011).

Historiography of the collectors

The historiography of collectors, researchers and publications were tracked based on first cited occurrence of a species to the state and from the type series of which the type locality is Paraná. We scrutinized all literature focusing on taxonomic papers and original descriptions identifying turning points in knowledge to propose key periods in the study of Opiliones from Paraná.

Images and maps

To illustrate Opiliones from Paraná, specimens collected close to the type localities were photographed using a dedicated 100 mm macro lens into a digital DSLR camera.

Maps and heatmaps with georeferenced occurrence records were generated using the software QGIS (QGIS Development Team 2016). The projections of the administrative boundaries (at State level) follow official databases in shapefile format (e.g., IBGE 2011) and the classification based on the topography of the territory of Paraná, from the coastal plain to the third plateau, was generated from maps in raster format based on Cigolini et al. (1998) and made available online (Caramori 2023).

Gaps of knowledge

To identify gaps of taxonomic and distribution knowledge of Opiliones from Paraná two approaches were undertaken: (1) inspection of literature data and (2) density of distribution records.

The data from literature were investigated with digitization into a spreadsheet with all publications that recorded species from Paraná (see supplementary material Table S1: primary data compiled from literature with records of Opiliones from Paraná). It was arranged by the year of publication and later, a graph with cumulative percentage of harvestmen registered for Paraná was generated. The historical records (richness) with the number (gross) and cumulative (%) of Opiliones from Paraná were based on the first publication citing the occurrence of a specific taxon in the state. Kury's (2003a) catalogue is used for comparisons of total number of Laniatores species with the top ten richest Brazilian states.

Heatmaps were created using the “styled geohash density map” and “graduated style” tools of the Density Analysis complement (<https://github.com/NationalSecurityAgency/qgis-densityanalysis-plugin>). For the styled geohash density map, the equal count (quartile) mode was used, while for the graduated style the continuous mode was used. For both, 15 color classes were applied.

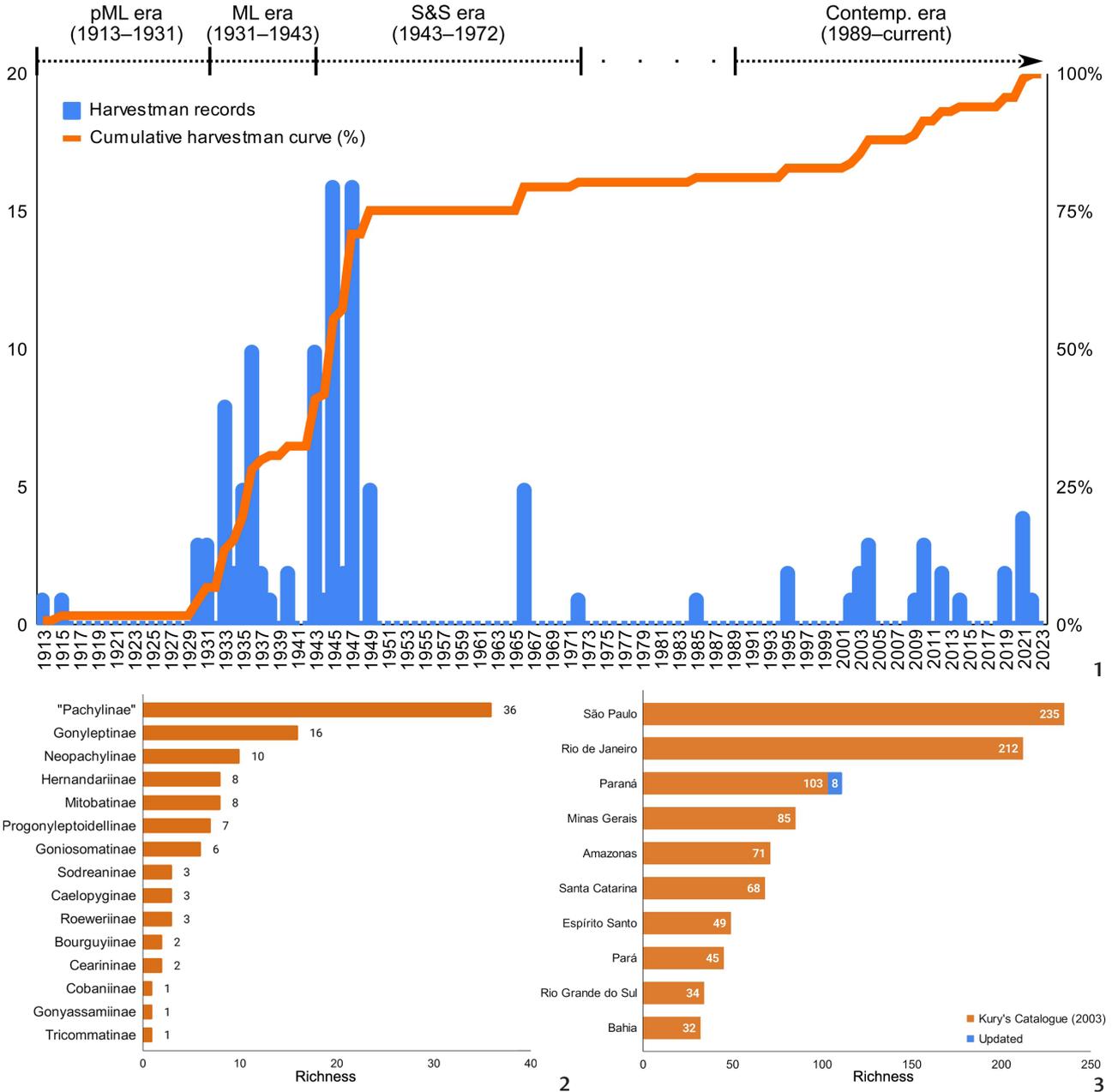
RESULTS

Checklist

A total of 1,115 records comprising 118 harvestman species occurring in the state of Paraná, distributed in five families, was compiled (Table 1, Figs 1–3). The total number of occurrence records refers to Brazil and includes the entire known geographic distribution for species recorded in Paraná. These records contain 8 additional Laniatores species when compared to those recorded in Kury's (2003a) catalogue (Fig. 3) and the full data represent 11.70% of the total Opiliones species in Brazil (see Kury 2023). Among the representatives of the suborder Eupnoi, two subfamilies (Enantiobuninae and Gagrellinae) were recorded from Neopilionidae and Sclerosomatidae respectively, while among those belonging to the suborder Laniatores, Cosmetidae, Cryptogeobiidae and Gonyleptidae were recorded, with the last family including 15 subfamilies, with “Pachylinae” being the richest, with 36 species (Fig. 2).

From the total species records, 584 refer to Paraná, covering 164 different localities in 66 of the 399 municipalities in the state (Figs 4–5). These records represent only 16.54% of the municipalities in Paraná sampled for harvestmen and are mostly concentrated in the First Plateau, making the east of the state with the highest density of records while the central and northeast regions have a scarcity of records (Figs 6–7). Of the 118 registered species, 60 are endemic to the state (Table 1) and 106 specific names have Paraná as their type locality (Table S1).

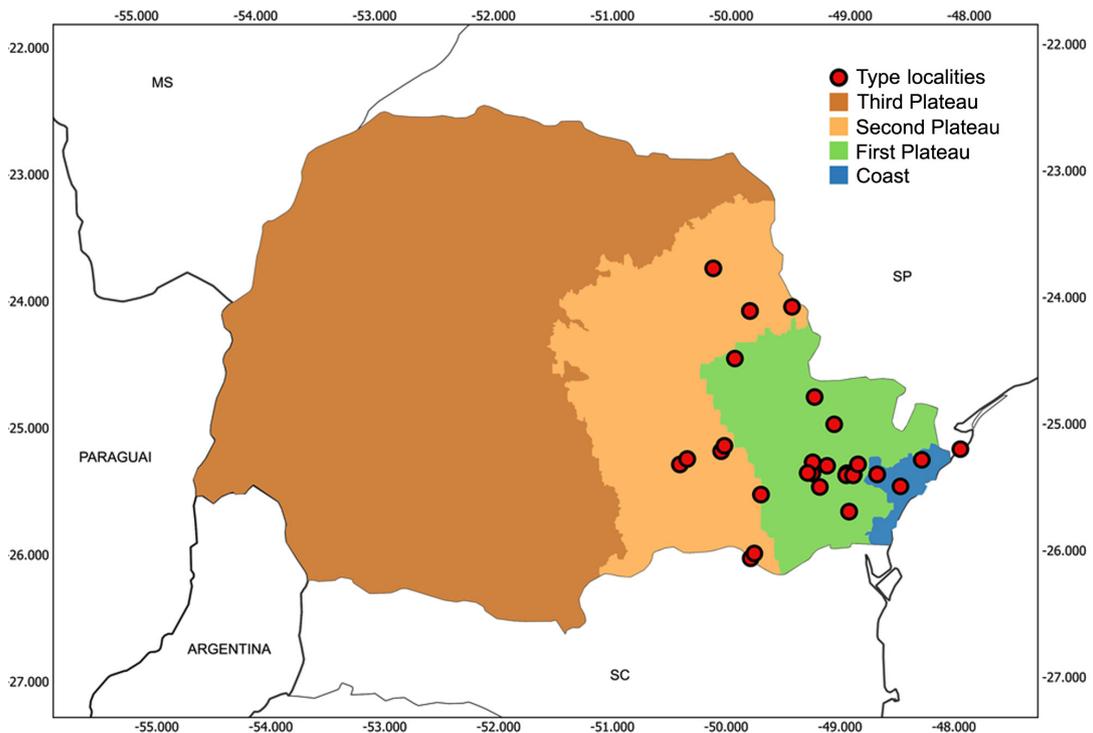
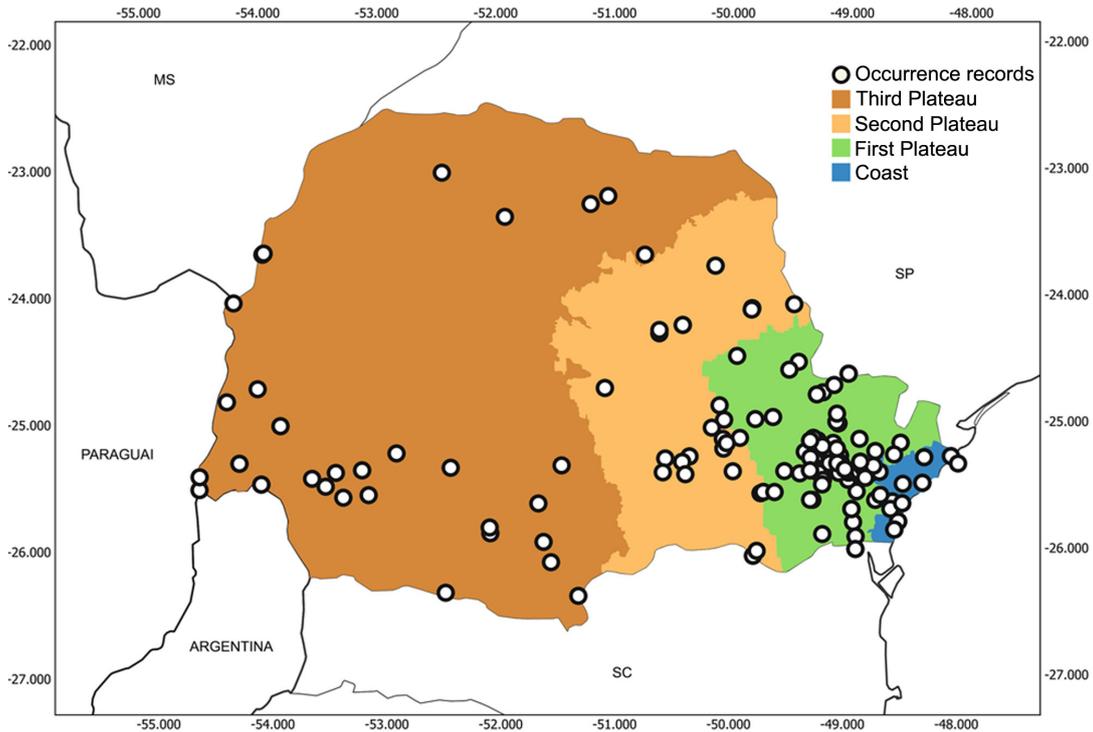
It was not possible to georeferencing the localities of “Serra Azul”, “San Ignacio”, “Km 77, road to Joinville”, “Fronreira Paraná-Santa Catarina”, “Iguaçu”, “Salto do Paraíba” and “Passagem” due to lack of information provided in the source data to ensure the accuracy of these sites. In addition, records with mention only to the state (i.e., Paraná) name were also not georeferenced due to lack of precision. A few species occurrence records were not listed in the Table 1, due to taxonomic inconsistencies, no bona fide record found, hence they are pending further research to confirm their occurrence in the state, i.e., the gonyleptids *Mischoonyx*



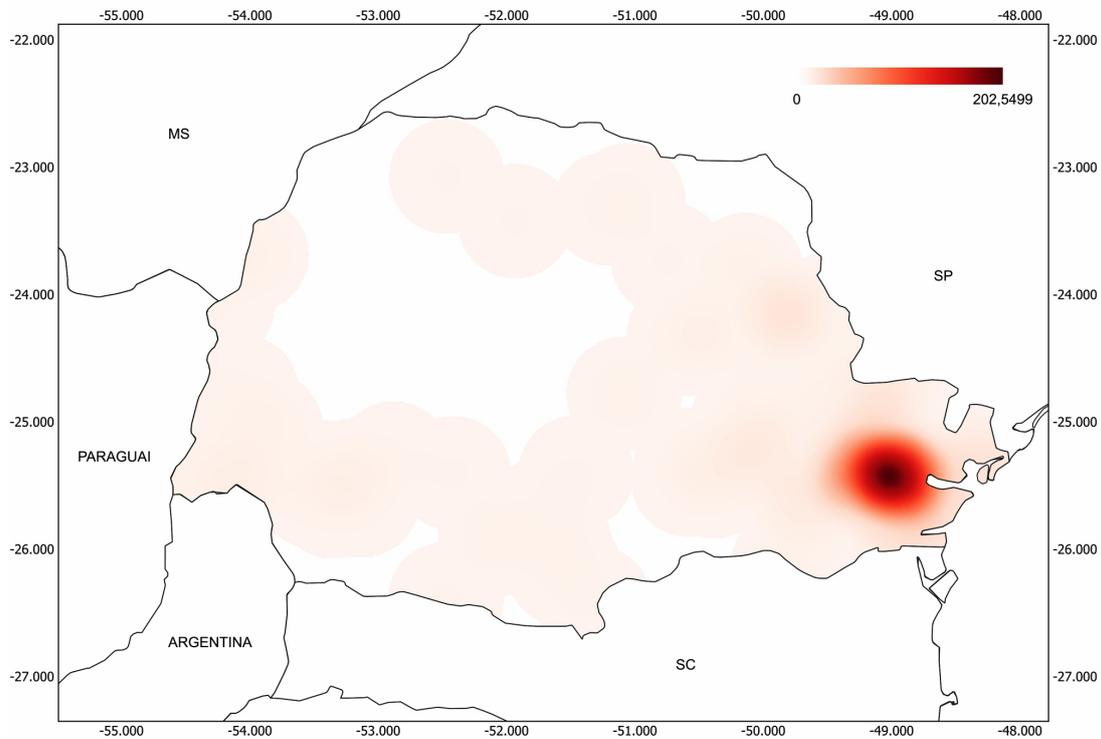
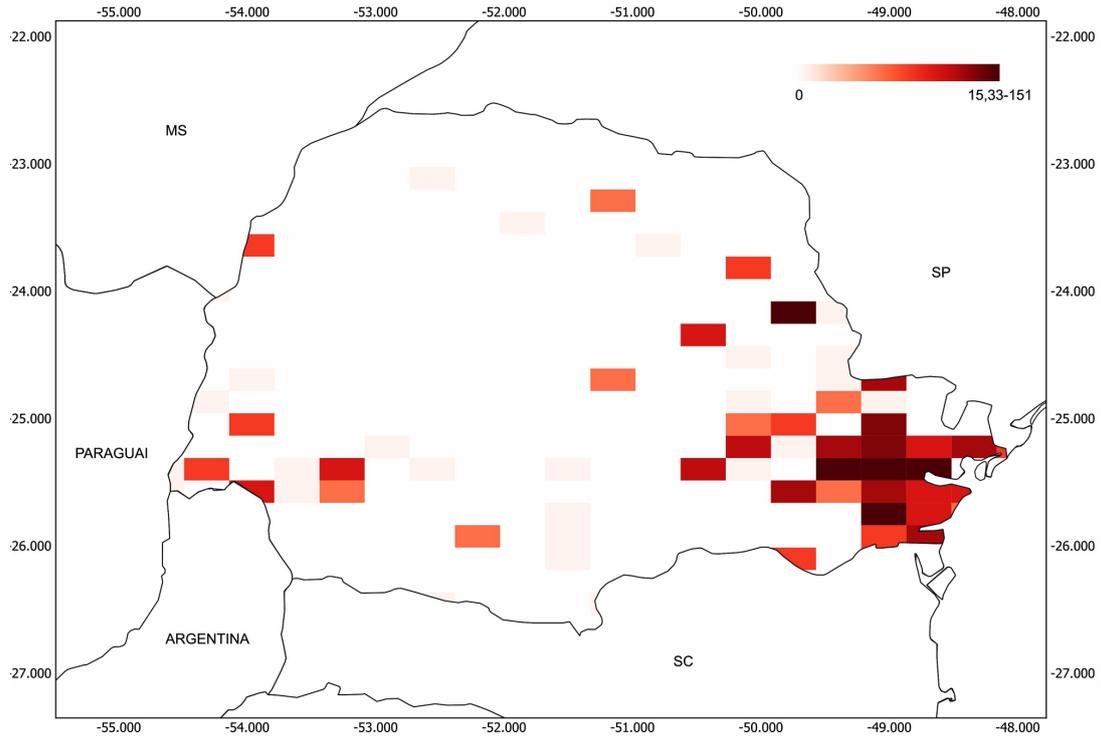
Figures 1–3. Historical records of species of Opiliones from Paraná State, Brazil based on literature: (1) number (gross) and cumulative (%) of species recorded per year; (2) number of species of the Gonyleptidae (suborder Laniatores) by subfamily; (3) comparisons of total number of Laniatores species with top ten richest states based on Kury (2003). (pML) Pre-Mello-Leitão era, (ML) Mello-Leitão era, (S&S) Soares & Soares era, (Contemp.) Contemporary era.

sulinus (Soares & Soares, 1946), *Neosadocus bufo* Mello-Leitão, 1926, *Paragonyleptes serranus* Soares, 1945, *Planiphalangodus robustus* Roewer, 1929, *Promitobates ornatus* Mello-Leitão, 1927, *Promitobates trapista* Bragagnolo & Pinto-da-Rocha,

2012, *Sadocus brasiliensis* (Soares & Soares, 1949), *Serracutisoma fritzmuelleri* DaSilva & Gnaspini, 2010 and *Triglochinnura apiaiensis* (Soares & Bauab-Vianna, 1972), and cryptogobiid *Heteromeloleptes singularis* (sic!) (Table S1).



Figures 4–5. Maps with records of species of Opiliones from Paraná State, Brazil, based on literature: (1) all occurrence records; (2) type localities.



Figures 6–7. Heatmaps of 15th classes with density of literature records of species of Opiliones from Paran State, Brazil: (6) geohash density map with the equal count (quartile); (7) graduated density map with continuous mode.

Table 1. Species list, plateau (PLAT), endemism (ENDE) and type-localities (TYLO) of Opiliones from Paraná, Brazil. Plateau identified by “1”, “2” or “3” = First, Second or Third Plateau or by Littoral Zone when only found in the coast of the state. “?” = non-georeferenced data. “*” = Positive record for endemism and type-localities on the state (only for valid specific names).

Taxa/Species	PLAT	ENDE	TYLO
Eupnoi			
Neopilionidae			
Enantiobuninae			
<i>Thrasychiroides brasiliicus</i> Soares & Soares, 1947	1	*	*
Sclerosomatidae			
Gagrellinae			
<i>Abaetetuba citrina</i> (Pocock, 1903)	3		
<i>Abaetetuba plaumanni</i> (Roewer, 1953)	3		
<i>Garleppa insperata</i> Soares, 1972			
<i>Holcobunus iguassuensis</i> Mello-Leitão, 1935	3	*	**
<i>Jussara avati</i> Kury & Tourinho-Davis, 2003	1	*	*
<i>Pectenobunus ruricola</i> (Mello-Leitão, 1933)	2,3		*
Laniatores			
Cosmetidae			
Cosmetinae			
<i>Gnidia holmbergii</i> (Sørensen, 1884)	?		
Cryptogeobiidae			
<i>Bissulla singularis</i> (Soares & Soares, 1949)	1	*	*
<i>Pseudopachylus eximius</i> (Mello-Leitão, 1936)	1		*
<i>Tibangara fuscomaculata</i> (Soares & Soares, 1947)	1	*	*
Gonyleptidae			
Bourguyiinae			
<i>Bourguyia albiornata</i> Mello-Leitão, 1923	2		*
<i>Bourguyia trochanteralis</i> (Roewer, 1930)	1		
Caelopyginae			
<i>Ampheres leucopheus</i> (Mello-Leitão, 1922)	1		
<i>Pristocnemus pustulatus</i> Koch, 1839	1		
<i>Thereza speciosa</i> (Roewer, 1913)	1		*
Cearininae			
<i>Parapachyloides uncinatus</i> (Sørensen, 1879)	?		
<i>Liogonyleptoides inermis</i> (Mello-Leitão, 1922)	1		
Cobaniinae			
<i>Cobania validissima</i> (Mello-Leitão, 1933)	2	*	*
Goniosomatinae			
<i>Serracutisoma banhadoae</i> (Soares & Soares, 1947)	1	*	*
<i>Serracutisoma gnaspini</i> DaSilva, 2014	1		
<i>Serracutisoma guaricana</i> DaSilva & Gnaspini, 2010	1	*	*
<i>Serracutisoma inerme</i> (Mello-Leitão, 1927)	1		*
<i>Serracutisoma molle</i> (Mello-Leitão, 1933)	1, 2, 3		*
<i>Serracutisoma thalassinum</i> (Simon, 1879)	1		*
Gonyassamiinae			
<i>Acanthopachylopsis spectabilis</i> Soares & Soares, 1949	1	*	*
Gonyleptinae			
		Continues	

Taxa/Species	PLAT	ENDE	TYLO
<i>Acanthogonyleptes editus</i> (Roewer, 1943)	1	*	*
<i>Geraeocormobius anomalus</i> (Mello-Leitão, 1931)	2	*	*
<i>Geraeocormobius armatus</i> (Roewer, 1913)	1, 2		*
<i>Geraeocormobius granulatus</i> (Mello-Leitão, 1937)	1		*
<i>Geraeocormobius rohri</i> (Mello-Leitão, 1933)	1, 2, 3		*
<i>Geraeocormobius sylvorum</i> Holmberg, 1887	2, 3		*
<i>Gonyleptes auricola</i> (Mello-Leitão, 1924)	1, 2		*
<i>Gonyleptes horridus</i> Kirby, 1819	2		*
<i>Guascaleptes serratus</i> (Roewer, 1913)	1		*
<i>Megapachylus grandis</i> Roewer, 1913	1, 2		*
<i>Mischonyx anomalus</i> (Mello-Leitão, 1936)	1	*	*
<i>Mischonyx squalidus</i> Bertkau, 1880	1	*	
<i>Neosadocus maximus</i> (Giltay, 1928)	?	*	
<i>Neosadocus robustus</i> (Mello-Leitão, 1936)	1	*	*
<i>Progonyleptoides castaneus</i> (Roewer, 1943)	?	*	*
<i>Tupacarana gofferjei</i> Soares & Soares, 1947	1	*	*
Hernandariinae			
<i>Acrogonyleptes exochus</i> (Mello-Leitão, 1931)	1, 2, 3		*
<i>Acrogonyleptes granulatus</i> (Soares, 1966)	1		*
<i>Acrogonyleptes spinifrons</i> Roewer, 1917	1, 3		
<i>Hernandaria armatifrons</i> (Roewer, 1917)	2, 3		
<i>Hernandaria heloisae</i> (Soares, 1945)	1, 2		*
<i>Hernandaria setulosa</i> (Mello-Leitão, 1933)	2	*	*
<i>Hernandaria una</i> (Mello-Leitão, 1927)	1, 3		
<i>Pseudotrogulus trotskyi</i> DaSilva & Pinto-da-Rocha, 2010	Littoral	*	*
Mitobatinae			
<i>Discocyrtoides pinorum</i> Kury, 2019	1	*	*
<i>Longiperna insperata</i> (Soares & Soares, 1947)	1		*
<i>Neoancistrotus intermedius</i> (Mello-Leitão, 1936)	Littoral	*	*
<i>Neoancistrotus nigroides</i> (Soares & Soares, 1947)	1	*	*
<i>Promitobates difficilis</i> (Mello-Leitão, 1931)	1		
<i>Promitobates hatschbachi</i> Soares, 1945	1, 2		*
<i>Promitobates nigripes</i> (Mello-Leitão, 1935)	1, 3		
<i>Promitobates viridigranulatus</i> (Soares & Soares, 1946)	1		*
Neopachylinae			
<i>Krateromaspis dilatata</i> (Sørensen, 1884)	3		
<i>Neopachylus herteli</i> Soares & Soares, 1945	2	*	*
<i>Neopachylus imaguirei</i> Soares & Soares, 1947	1, 2	*	*
<i>Neopachylus incertus</i> (Mello-Leitão, 1935)	1, 2		*
<i>Neopachylus mamillosus</i> Roewer, 1915	2	*	*
<i>Neopachylus marginatus</i> (Mello-Leitão, 1931)	1, 2		*
<i>Opisthoplatus elegantulus</i> (Mello-Leitão, 1939)	3		
<i>Opisthoplatus prospicius</i> (Holmberg, 1876)	1, 3		
<i>Opisthoplatus vegetus</i> (Canals, 1939)	3		
<i>Senu leonardosi</i> (Mello-Leitão, 1935)	1	*	*
“Pachylinae”			
<i>Discocyrtus banhado</i> Kury, 2003	1	*	*
<i>Discocyrtus brevifemur</i> Soares & Soares, 1947	1	*	*
<i>Discocyrtus catharinensis</i> (Mello-Leitão, 1923)	1		*
<i>Discocyrtus dubius</i> Soares, 1945	1	*	*
<i>Discocyrtus guarana</i> Piza Jr., 1940	2	*	*
		Continues	

Taxa/Species	PLAT	ENDE	TYLO
<i>Discocyrtus heteracanthus</i> Mello-Leitão, 1936	1, 2	*	*
<i>Discocyrtus langei</i> Mello-Leitão, 1936	2	*	*
<i>Discocyrtus simplex</i> Soares, 1943	1	*	*
<i>Discocyrtus spinifemur</i> Soares, 1945	1	*	*
<i>Discocyrtus subinermis</i> Mello-Leitão, 1936	1, 2	*	*
<i>Eopachylus ignotus</i> Mello-Leitão, 1931	1		
<i>Eusarcus catharinensis</i> (Mello-Leitão, 1927)	1	*	*
<i>Eusarcus dubitatus</i> (Soares & Soares, 1945)	2	*	*
<i>Eusarcus dubius</i> Soares, 1943	1	*	*
<i>Eusarcus hastatus</i> Sørensen, 1884	3		
<i>Eusarcus pulcherrimus</i> (Soares, 1966)	1		*
<i>Goodnightiella impar</i> Soares & Soares, 1945	?		*
<i>Guaraniticus flavimaculatus</i> Soares & Soares, 1947	1	*	*
<i>Guaraniticus lesserti</i> Mello-Leitão, 1933	1, 2	*	*
<i>Guaraniticus nigrosulcatus</i> (Mello-Leitão, 1937)	1, 2	*	*
<i>Guaraniticus tetracalcar</i> Soares & Soares, 1945	?	*	*
<i>Gyndesoides dispar</i> Mello-Leitão, 1933	2	*	*
<i>Iguassua humilis</i> Mello-Leitão, 1935	?	*	*
<i>Kuryella melanoacantha</i> (Soares & Soares, 1947)	1	*	*
<i>Kuryella xanthoacantha</i> (Soares & Soares, 1947)	1	*	*
<i>Mangaratiba angulispinosus</i> (Soares, 1966)	1	*	*
<i>Metalycomedes secundus</i> Soares & Soares, 1947	1	*	*
<i>Ogloblinia argenteopilosa</i> (Mello-Leitão, 1935)	1		*
<i>Ogloblinia loretoensis</i> Canals, 1933	1, 2, 3		
<i>Ogloblinia pulchra</i> Pinto-da-Rocha & Soares, 1995	1	*	*
<i>Paraprosontes inermis</i> Soares & Soares, 1947	2	*	*
<i>Pseudoacrogaphinotus simplex</i> Soares, 1966	1	*	*
<i>Pseudogyndesoides bariguiensis</i> Soares, 1945	1	*	*
<i>Triglochinura langei</i> (Soares & Soares, 1949)	1	*	*
<i>Uropachylus nasutus</i> Soares & Soares, 1947	1	*	*
<i>Uropachylus ypiranga</i> (Mello-Leitão, 1922)	2		*
Progonyleptoidellinae			
<i>Cadeadoius niger</i> (Mello-Leitão, 1935)	1		*
<i>Deltigalus curvispina</i> (Perty, 1833)	1		*
<i>Gonyleptooides albipunctatus</i> (Roewer, 1943)	?	*	*
<i>Gonyleptooides marumbiensis</i> Soares, 1945	1	*	*
<i>Heliella singularis</i> Soares, 1945	1	*	*
<i>Iguaepia gengnageli</i> (Soares & Soares, 1949)	1	*	*
<i>Iguaepia melanocephala</i> Mello-Leitão, 1935	1		*
Roeweriinae			
<i>Bunopachylus armatissimus</i> (Roewer, 1913)	1	*	
<i>Khazaddum inerme</i> (Soares & Soares, 1947)	1, 2		*
<i>Roeweria virescens</i> (Mello-Leitão, 1940)	1		*
Sodreaninae			
<i>Sodreana bicalcarata</i> (Mello-Leitão, 1936)	1		*
<i>Sodreana hatschbachi</i> (Soares & Soares, 1946)	1	*	*
<i>Sodreana leprevosti</i> (Soares & Soares, 1947)	1		
Tricommatinae			
<i>Tricommatulus fulvus</i> Soares, 1966	1	*	*
Total: 118 species		60	93

Based on our data the Marumbi region is one of the hottest spots in South America for diversity of Opiliones, this region includes Pico do Marumbi State Park and nearby areas, such as the famous localities of the railroad stations Banhado and Cadeado in the municipalities of Quatro Barras and Arapoti, respectively, which are not included in that state park (Table 2).

The collectors of harvestmen in Paraná

Roewer's initial report on harvestmen from Paraná dates to the early 20th century, wherein he mentioned species like *Weyhia armata* Roewer, 1913, now known as *Geraeocormobius armatus* (Roewer, 1913), and *Neopachylus mamillosus* Roewer, 1915 both observed in localities such as Paranaguá and Rio Negro (Roewer 1913, 1915). Following a brief hiatus, in the 1930's, nearly two decades of recurrent records of harvestmen for the state began, reaching its peak in 1945 and 1947 with 16 reported species each year (e.g., Soares 1945, Soares and Soares 1947b). By the early 1950s, 75% of the currently known fauna of Opiliones found in Paraná had been recorded. The remaining 25% were registered after a subsequent surge in Opiliones publications between 1950 and 1966, with the remaining entries scattered between 1966 and the present (Fig. 1).

DISCUSSION

Checklist

The obtained results with the species checklist and type localities, as well as many records from Paraná, were already expected, as they reflect the known impact by the collection effort of a group of researchers such as Gerdt Hatschbach and Sussumo Imaguire, in the Marumbi region as part of the Serra do Mar chain mountain, First Plateau of Paraná. These collectors, among others, are considered members of a group of mountaineers named Marumbinistas (see Alves 2008). The contribution of these pioneers in the state of Paraná was expanded from the 1990s, mainly through the studies of the specialist researcher in Opiliones, Ricardo Pinto-da-Rocha (e.g., Pinto-da-Rocha 1993, Pinto-da-Rocha and Bragagnolo 2011, Pinto-da-Rocha et al. 2012). Many harvestmen are endemic to the state and a large amount have not been recorded after their original descriptions, which can be explained in part by the fact that they may represent rare species. Another source of difficulty in studying this rich assemblage of arachnids in Paraná is the taxonomic instability, which, when combined with profusion of nomina and incomplete data available in the

Table 2. Top ten oversampled and undersampled municipalities based on number of Opiliones species from Paraná, Brazil. Municipalities with no record are omitted.

Municipality	Number of species	% of S of PR	Number of records ^A
Oversampled			
Quatro Barras	41	34.7	75
Morretes	36	30.5	108
Curitiba	28	23.7	46
Arapoti	16	13.6	16
Guaratuba	15	12.7	32
Tijucas do Sul	14	11.9	22
Antonina	13	11.0	13
Bocaiúva do Sul	13	11.0	16
Guaraqueçaba	10	8.5	18
Fazenda Rio Grande	10	8.5	11
Piraquara ^B	10	8.5	12
São José dos Pinhais	10	8.5	16
Undersampled			
Bituruna	1	0.8	1
Boa Vista da Aparecida	1	0.8	1
Carambé	1	0.8	1
Castro	1	0.8	1
Clevelândia	1	0.8	1
Cruz Machado	1	0.8	1
Cruzeiro do Iguaçu	1	0.8	1
Espigão Alto do Iguaçu	1	0.8	1
General Carneiro	1	0.8	1
Guarapuava	1	0.8	1
Ibiporã	1	0.8	1
Lapa	1	0.8	1
Londrina	1	0.8	1
Maringá	1	0.8	1
Nova Prata do Iguaçu	1	0.8	1
Pinhão	1	0.8	1
Santa Helena	1	0.8	1
São Jerônimo da Serra	1	0.8	1
Sengés	1	0.8	1
Toledo	1	0.8	1

^A Updated from Catalogue of Laniatores of Kury (2003); ^B Records that only mentioned “Piraquara” are most likely related to the locality of railroad station Banhado in Quatro Barras municipality.

literature, leads to many misconceptions and mistakes. For instance, Rubim et al. (2023) recently published a putative new record to *Opisthoplatus vegetus* (Canals, 1939), based on primary data on Opiliones from the protected areas of Iguaçu National Park and Bela Vista Biological Refuge, but it was first recorded to the same locality by Nogueira et al. (2019) few years earlier as *Discocyrtus vegetus* Canals, 1939. Similar issues arise with localities, some of which represent

lost names, have an ambiguous name with numerous homonyms (e.g., Pinheirinho) and changed their administrative boundaries. This last factor has a significant impact and is mainly due to the formation of new municipalities because of the division of larger and older municipalities. This is true for the best-known locality for harvestmen in Paraná, the railroad station Banhado, which was historically considered in the municipality of Piraquara, but now, since 1961, belongs to the municipality of Quatro Barras (L.R. Caramori et al., unpublished data). As a result, Piraquara becomes one of the poorest sampled areas in the state rather than the richest (Table 2).

Many of the species (names) not listed in the Table 1, hence excluded from Paraná’s Opiliones fauna, are due to drastic and rapid changes in the records status because of taxonomic instability and inconsistency. Recently, endemic genera of the Atlantic Forest have been investigated including taxonomic revisions, some of them using modern molecular-based species delimitation methods (e.g., Peres et al. 2019, Castro-Pereira et al. 2021, Gueratto et al. 2021). Therefore, database records must be constantly curated and reviewed to remain up-to-date, and therefore records must be treated with caution. Species such as *Mischonyx sulinus* (originally in *Ilhaia* Roewer, 1913), *Neosadocus bufo* and *Sodreana inscripta* (Mello-Leitão, 1939, originally combined with *Zortalia* Mello-Leitão, 1936) were recently considered junior synonyms or their occurrence in Paraná was based on misidentifications; despite of this, even recent studies and databases still cite their records for the state (e.g., Nogueira et al. 2019). The same applies for incomplete compilations or not comprehensive studies, both of which can be also biased for such limitations, leading to incorrect distributions or record status (e.g., Rubim et al. 2023). Studies involving compiled or new primary data on biodiversity must be open to scrutiny, to aim this voucher species, digital open source and mechanisms that allows replicability are strongly necessary (see Monckton et al. 2020, Bianchi and Gonçalves 2021).

In addition, the concentration of Opiliones records in the First Plateau of Paraná and in areas of Tropical Atlantic Rainforest and Araucaria Forest, reflect the higher sampling effort in these areas, and can be partially explained by the climatic conditions and temperature and humidity levels of these environments. These ecological, biological, and historical factors acting as causal explanation of richness of Opiliones has been supported by recent studies (Bragagnolo et al. 2007, DaSilva et al 2017, Nogueira et al. 2019). Coastal Atlantic Forest region of Paraná has been identified a biotic component with unique evolutionary and biogeographic

histories (DaSilva et al 2017), these aspects together with environmental conditions such as the size and integrity of forest cover as well as microclimate gradients (Andrade et al. 2022) may be main drivers of diversification and the high levels of diversity of Opiliones in this region. However, it is important to emphasize substantial sampling biases. As discussed in Oliveira et al. (2016), most records of occurrences of Brazilian biodiversity are concentrated in areas close to urban centers and with easy access, leading to the misconception that there are a higher number of species in these areas, when in fact it is a matter of lack of sampling in less accessible areas. A similar discussion occurs in Troudet et al. (2017), who show Arachnida as a highly undersampled group, while taxonomic groups with a greater social interest, such as birds, are oversampled. In short, the distribution and richness of Opiliones is strongly biased by the sampling effort from Marumbinistas and other collectors, thus pending larger sampling effort in poorly studied sites.

Gaps of knowledge

With very few exceptions in research categories other than taxonomy (e.g., Hara and Gnaspini 2003 with a study about behavior, morphology and phylogenetics), the vast majority of studies on harvestmen from Paraná focused primarily on taxonomic descriptions of new taxa (e.g., Kury 2019, DaSilva 2014, Carvalho and Kury 2021). Numerous geographic areas still lack any Opiliones records, leaving many aspects of their biology and ecology waiting to be explored. Allied to high levels of endemism, substantial body size, and high regional abundance, this scenario offers an unequalled opportunity to investigate these fascinating chelicerates.

The collectors of harvestmen in Paraná

The knowledge about Opiliones from Paraná can be arbitrarily divided into four periods: (1) pre-Mello-Leitão (1913–1931), (2) Mello-Leitão era (1931–1943), (3) Soares & Soares era (1943–1972) and (4) contemporary era (1989–current). These periods, however, often overlap, and while it's straightforward to pinpoint the beginning of each period based on publication dates, the same cannot be said for their endings. This is due to the lasting impact of these contributions, as once published, they continue to strongly influence subsequent studies.

The pre-Mello-Leitão period is characterized by contributions from non-Brazilian researchers, both collectors and authors. Undoubtedly, the most prominent was Carl-Friedrich Roewer (1881–1963, Fig. 8), a German researcher whose works were of foremost importance for the knowledge

of harvestmen around the world, describing more than a third of the species of the order at the time (see Machado et al. 2007). Roewer described *Weyhia armata* (Fig. 9), today *Geraeocormobius armatus* (Roewer, 1913), from the municipality of Paranaguá, that corresponds to the first named harvestman based on material from the state of Paraná (see Roewer 1913). Roewer continued to be active as throughout the subsequent periods (e.g., Roewer 1943).

During the Mello-Leitão period, Brazilian collectors began to make notable contributions. One such collector was Frederico Augusto Lange de Morretes (1892–1954), a distinguished artist and malacologist who amassed numerous specimens that became the basis for new species of harvestmen. These were predominantly collected from the locality of Cachoeirinha (see Mello-Leitão 1933), now part of the municipality of Arapoti. In addition to Lange de Morretes, the contribution of foreign collectors continues with Frei Tomás Borgmeier (1892–1975), a German priest who had a passion for insects and ended up founding the prestigious “Revista de Entomologia” in Rio de Janeiro. Frei Borgmeier collected many specimens of harvestmen mostly from the municipality of Rio Negro that were described as new species by Mello-Leitão (1931). Borgmeier also deserves to be recognized for his relevance in the foundations of phylogenetic systematics (Williams and Ebach 2008).

The Soares & Soares (Figs 10–11) period is the most significant for the knowledge of the Opiliones of Paraná, representing the highest number of publications containing description of new species. Their huge contribution is mainly due to the studies from Benedicto Abílio Monteiro Soares (1914–1985) and Helia Eller Monteiro Soares (1923–1999). In this period, the main collectors were part of a group of enthusiast mountaineers known as Marumbinistas. They carried out several expeditions through the Marumbi region, among them the botanist Gerdt Hatschbach (1923–2013, Fig. 12), and the brothers Sussumo Imaguire (birth and presumed death unknown) and Nobor Imaguire (1928–2020), also associated to the Federal University of Paraná. Considered one of the greatest botanists in Brazil, Hatschbach began studying insects and arachnids in 1934, building collections that were eventually donated to the Museu de História Natural Capão da Imbuia at Curitiba (Straube 2020). Imaguire is often mentioned by Soares & Soares irregularly and mistakenly with different initials of the first name or even with just the surname, leaving doubts about the collector of the specimen. Along with the Marumbinistas, Rudolf Bruno Lange (1922–2016), nephew of F. Lange de Morretes, and Carlos Nicolau Gofferjé (1922–2005) also gathered



8

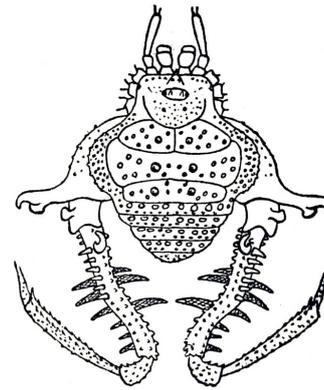


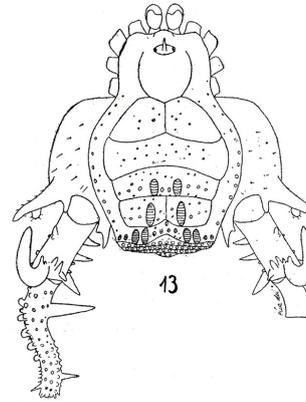
Fig. 79.

Weyhia armata n. sp. — ♂ — dorsal.

9



10



13

Fig. 13 - *Neopachylus imaguirei*, sp. n. (♂).

11



12



13

Figure 8–13. Key contributors (8, 10, 12) to the knowledge of the Opiliones from Paraná and species associated to them (9, 11, 13): (8) Carl-Friedrich Roewer unknown date (from Kraus 1963); (9) *Geraecormobius armatus*, from Roewer 1913, BHL public domain; (10) Helia Eller Monteiro Soares in 1992 (Photo courtesy by Ricardo Pinto-da-Rocha) and Benedicto Abílio Monteiro Soares ca. 1950 (Photo courtesy José Robert Pujol Luz); (11) *Neopachylus imaguirei*, from Soares & Soares 1947b, BHL CC BY-NC-SA 4.0; (12) Gerdt Hatschbach in occasion of his 89th birthday in 2012 (Photo by Irene Roiko/SMCS); (13) *Promitobates hatschbachi* (Photo by APP, specimen from Piraquara, Paraná, 2020).

many specimens during this time. According to Padre Jesus Santiago Moure in Straube (2020), R. Lange made the arachnological fauna of Paraná one of the best studied in Brazil in the 1940s. Gofferjé, on the other hand, was a medical doctor who had self-taught malacology and had assembled a private collection of more than 20,000 zoological specimens, which eventually was donated to the University of Vale do Itajaí (Straube 2020). Several species names were given to these collectors in recognition of their significant contributions, including *Neopachylus imaguirei* Soares & Soares, 1947 (Fig. 11), named after Sussumo Imaguire, *Tupacarana gofferjei* Soares & Soares, 1947, after Carlos Gofferjé (see Soares and Soares 1947a), and *Promitobates hatschbachi* Soares, 1945 (Fig. 13), which was named in honor of Gerdt Hatschbach (see Soares 1945).

Finally, in the contemporary period, we observe a predominance of Brazilian researchers and collectors. This period started with studies in the late 1980s and early 1990s by Ricardo Pinto-da-Rocha, some works in collaboration with Helia Soares in which they revised the gonyleptid genus *Ogloblinia* Canals, 1933 (see Pinto-da-Rocha and Soares 1995). Modern authors include specialists such as Adriano Brilhante Kury, Ricardo Pinto-da-Rocha and Marcio Bernardino da Silva, who are the main authors and collectors of harvestmen in this period. Pinto-da-Rocha, a native from Paraná, where he completed his first publications (Pinto-da-Rocha and Caron 1989), has amassed harvestmen knowledge across Neotropical region. Kury is headquartered in the Museu Nacional of Federal University of Rio de Janeiro and although focused on the Neotropical fauna, has conducted expeditions for harvestmen around the world. Recently, he described a new gonyleptid, *Discocyrtoides pinorum* Kury, 2019, from São José dos Pinhais municipality (see Kury 2019). Meanwhile, DaSilva, a native from São Paulo, has been working with Goniosomatinae (DaSilva and Gnaspini 2010) and among other species, described *Serracutisoma gnaspini* DaSilva, 2014, with distribution to Paraná (see DaSilva 2014).

Final remarks

The harvestmen fauna from Paraná comparatively can be considered one the best studied, particularly in the in the highland area around the Metropolitan region of state capital Curitiba, new species still are being described (Carvalho and Kury 2024) even before our newly compiled checklist is released, so it is still far from being inventoried.

This is the very first step toward to provide a full database to consolidated knowledge on Opiliones of one of the richest hotspots for these invertebrates in the world.

It undoubtedly, will help in conservation policies and future taxonomic investigations. We also encourage similar approaches on the state of art for other investigation fields such behavior, ecology, and natural history in the state, as well as to other neotropical areas.

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Competing Interests

The authors have declared that no competing interests exist.

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Supplementary material 1

Table S1. Primary data on records of Opiliones from Paraná based on literature from 1913 to 2023. It includes the first publication citing the occurrence of a specific taxon in the State, remaining records are amended and updated records from Kury's (2003) catalogue of Laniatores species.

Authors: LR Caramori, AB Kury, ÂP Pinto.

Data type: Georeferenced localities for Opiliones recorded from Paraná.

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