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ARTÍCULO:

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A structured inventory of harvestmen (Arachnida, Opiliones) at Juruti River plateau, State of Pará, Brazil

Ricardo Pinto-da-Rocha & Alexandre B. Bonaldo

Abstract:

The first structured inventory of harvestmen in the Brazilian Amazon Rain Forest was carried out at Juruti municipality, Pará State. The sampling protocol was done in three plots of (1 ha each) non-flooded upland forest, on the Juruti River plateau, nearly 60 km from the right margin of the Amazon river, and one plot in a floodplain forest area, at the Amazon river margin. To ensure assessment of the majority of potential habitats, seven collecting techniques were used, resulting in 466 individuals from 28 species. Each upland site provided 16-18 species. Flooded forest habitat was undersampled, and only five species were recorded. From the seven collecting methods employed, litter manual sorting resulted in the highest number of species per sample, and beating tray the highest ratio of individuals per sample. These two collection techniques, along with nocturnal ground search, were the most effective sampling techniques for a protocol for collecting harvestmen in this site.

Key words: Amazonian Rain Forest, Diversity, Inventory, Opiliones, Sampling protocol

Un inventario estructurado de los Opiliones (Arachnida) del altiplano del Río Juruti, Estado de Pará, Brasil

Resumen:

El primer inventario estructurado de Opiliones en la Selva Amazónica fue realizado en Juruti, Estado de Pará, Brazil. El método de muestreo se aplicó en cuatro áreas (cada una con 1 ha de extensión), tres en un bosque de tierra firme no inundado, en el altiplano del Río Juruti, a 60 km de la margen derecha del Río Amazonas, y una en un área de bosque de inundación, en la margen del Río Amazonas. Fueron utilizadas siete técnicas de muestreo para abarcar la mayor parte de los hábitats, obteniéndose 466 especimenes de 28 especies. En cada área de tierra firme se detectaron entre 16 y 18 especies. El hábitat del bosque de inundación fue poco muestreada y solamente cinco especies fueron registradas. Dentro de todos los métodos empleados, la colecta manual de suelo registró el mayor número de especies y el paraguas entomológico registró el mayor número de especimenes por muestra. Estas dos técnicas de muestreo, en conjunto con la búsqueda nocturna en suelo, fueron las metodologías más efectivas para el trabajo de colecta en este lugar.

Palabras clave: Selva Amazónica, Diversidad, Inventario, Opiliones, Método de muestreo.

Introduction

Harvestmen (Opiliones) are represented by more than 6000 described species (Hallan, 2005), and comprise the third most diverse order of Arachnida, reaching maximum richness in the Neotropical Region, especially in the humid forests of Brazil (Curtis & Machado, in press). They occur in superficial soil layers, leaf litter, under bark, on vegetation, and even in the canopy, from the equator zone to near the poles. Harvestmen are very susceptible to dehydration, and their need for moist habitats is probably a significant ecological factor that limits their occurrence in xeric environments (Curtis & Machado, in press).

The Harvestmen diversity pattern in the Neotropical Region is still little known, both on regional and local scales. The most intensely studied area in the neotropics is the Brazilian Atlantic Rainforest in southeastern, where the twentieth century specialist worked and where the major collections are located (Pinto-da-Rocha, 1999). Studies in the systematics and biogeography of Atlantic Rainforest Opiliones demonstrated that species of the order are extremely useful in reconstructing the complex history of this biome (Pinto-da-Rocha *et al.*, 2005). Recent structured inventories in São Paulo State showed that species richness comparisons among areas and environments can bring important insights to help land management decisions and environmental impact analyses, since both the abundance and species richness of these animals are susceptible to the loss of environmental quality as well as habitat fragmentation (Bragagnolo et al., unpublished data.).

The Amazon region as a whole is extremely poorly known concerning Opiliones taxonomic composition, distribution and species richness. Present knowledge on Amazon Opiliones was summarized by Kury & Pinto-da-Rocha (2002), who listed 173 species known from the Brazilian, Peruvian and Colombian Amazonia. This list can be compared with the species list from São Paulo State (232 species), an area much smaller than the Amazonia, but which has been extensively sampled since the beginning of the last century. For the two major Brazilian Amazonia states, Amazonas and Pará, only 94 and 59 species have been documented respectively (Kury, 2003). However, based on previous experience in determining material from localities near to the city of Manaus, and on data produced from Museu Paraense Emilio Goeldi by recent inventory projects on both Central and Oriental Amazon, we believe that actual species richness in these regions will be between three to five times higher than what is presently known.

Structured inventories can characterize communities in terms of species abundance, species richness and complementarity. A good inventory (defined as steepness of species accumulation curves, see Longino & Colwell, 1997), provides a checklist of organisms, which can be compared between areas since the sampling techniques and sampling effort employed are standardized. In this paper we present the results of a structured inventory of Opiliones carried out in an area that has never been surveyed before, a low plateau near to the Juruti River, a tributary of the Amazon River right margin, Juruti municipality, State of Pará, Brazil. This area is scheduled for intense Bauxite mining, and the data about harvestmen diversity will be available for longterm evaluations on the environmental consequences of these mining activities. We also compared a variety of sampling protocols, specifically evaluating the efficiency and effectiveness of different techniques. This information can be used to recommend specific protocols, as a model for completing additional surveys of Opiliones from other areas in the Amazon.

Material and methods

The study area includes three plots of 1 ha each, in the dry land of the nearly 70 m high plateau rising on the right margin of the Juruti River (Terra Firme – Dense Ombrophylous Submontane Forest), and one plot in the flooded forest area (várzea or aluvial forest) near to the locality of Jurutizinho, on the right margin of the Amazon River. These are sites where major mining activities will take place and where a fluvial port for bauxite shipment will be constructed.

The annual mean precipitation in the Juruti River area is 2100mm, with a three to four months long dry season, normally from July to October. Temperature ranges from 22 to 28°C and the relative air humidity from 77%, in the dry season, to 88%, during the rainy season.

Sampling protocols were adapted from Coddington *et al.* (1991), and arachnid collections (mainly harvestmen and spiders) were undertaken between September 2 and 20, 2002, by two collectors (Alexandre Bonaldo and a technician). The sampling effort was concentrated in the three dry land 1ha plots on the Juruti plateau and one site on flooded forest (Fig.1):

DL1. 02º 36' 45"S - 56º 11' 27"W, disturbed mature forest at igarapé Mutum valley;

DL2. 02º 36' 10"S - 56º 12' 25"W, mostly undisturbed mature forest at the Igarapé Mutum valley;

DL3. 02º 33' 07"S - 56º 13' 06"W, nearly 30 yr old secondary growth forest at the Cairanga-Mutum Road;

FLO. 02º 24' 33"S / 56º 26' 10" W, Jurutizinho flooded Forest.

The dry land areas (terra firme) neighboring the Juruti River were subject the intense wood extraction in the 1970´s. The exploitation of the Pau-Rosa tree (*Aniba rosaedora* Ducke, Lauraceae), which provides an essential oil (linalool) used worldwide in perfumery (May & Barata, 2004), proved to be disastrous in the Juruti River plateau. Wood extraction, even selective, changed forest conditions, favoring the incidence of fire, which can be devastating for Amazonian forests (Williamson & Mesquita, 2001). For these reasons, the areas of easiest access are quite impoverished. The plateau itself is dominated by a nearly 30 yr old secondary growth forest, in which the most abundant trees are *Cecropia* spp. (Cecropiaceae). The mature forests, in various degrees of disturbance, are left mainly in the low valleys formed by small tributary creeks (igarapés). The flooded forests nearby the Juruti and Amazon Rivers were mostly pristine, but a certain degree of disturbance due to extensive cattle farming was observed in some areas.

The following techniques were used within each plot on dry land sites:

PIT. Pitfall traps – 30 plastic cups (500ml) with ethanol 70%, nearly 5m apart one from the other. The traps were exposed for 12 days (60 samples by plot, 180 total).

LMS. Litter manual sorting – All the litter and superficial soil layer from 1 m^2 was concentrated with the aid of a hand-sieve. Each sample was manually sorted (30 minutes maximum), using 30x20cm plastic square plates (10 samples by plot, 30 total).

BT. Beating trail – A sample is defined as the result of each hour of continuous diurnal collecting by a single collector, with a $1m^2$ beating trail (18 samples per plot, 54 total).

NGS. Manual nocturnal ground search – A sample is the result of each hour of continuous nocturnal collecting by a single collector on the ground and vegetation below knee-level (6 samples per plot, 18 total).

NAS. Manual nocturnal aerial search – A sample is the result of 1h of continuous nocturnal collecting by a single collector in the vegetation above knee-level (6 samples per plot, 18 total).

CS. Cryptic search – A sample is the result of each hour of continuous seeking, by a single collector, for cryptic animals under bark and logs (4 samples per plot, 9 total).

W. Winkler apparatus – A sample is collected in $1m^2$ of litter, shifted in a sieve and sorted, using Winkler apparatus bags during 6 days (10 samples per plot, 30 total).

The sampling used in the flooded forest was restricted to three of the active search methods (18 BT, 6 NGS and 6 NAS).

The observed and estimated species accumulation curves were constructed with 100 randomizations in sample adding order, using "EstimateS" ver. 7.5 Beta (Colwell, 2005). All the material was identified by Ricardo Pinto-da-Rocha. Voucher specimens were deposited in the arachnological collections of the Museu Paraense Emílio Goeldi (Belém) and Museu de Zoologia da Universidade de São Paulo (São Paulo).

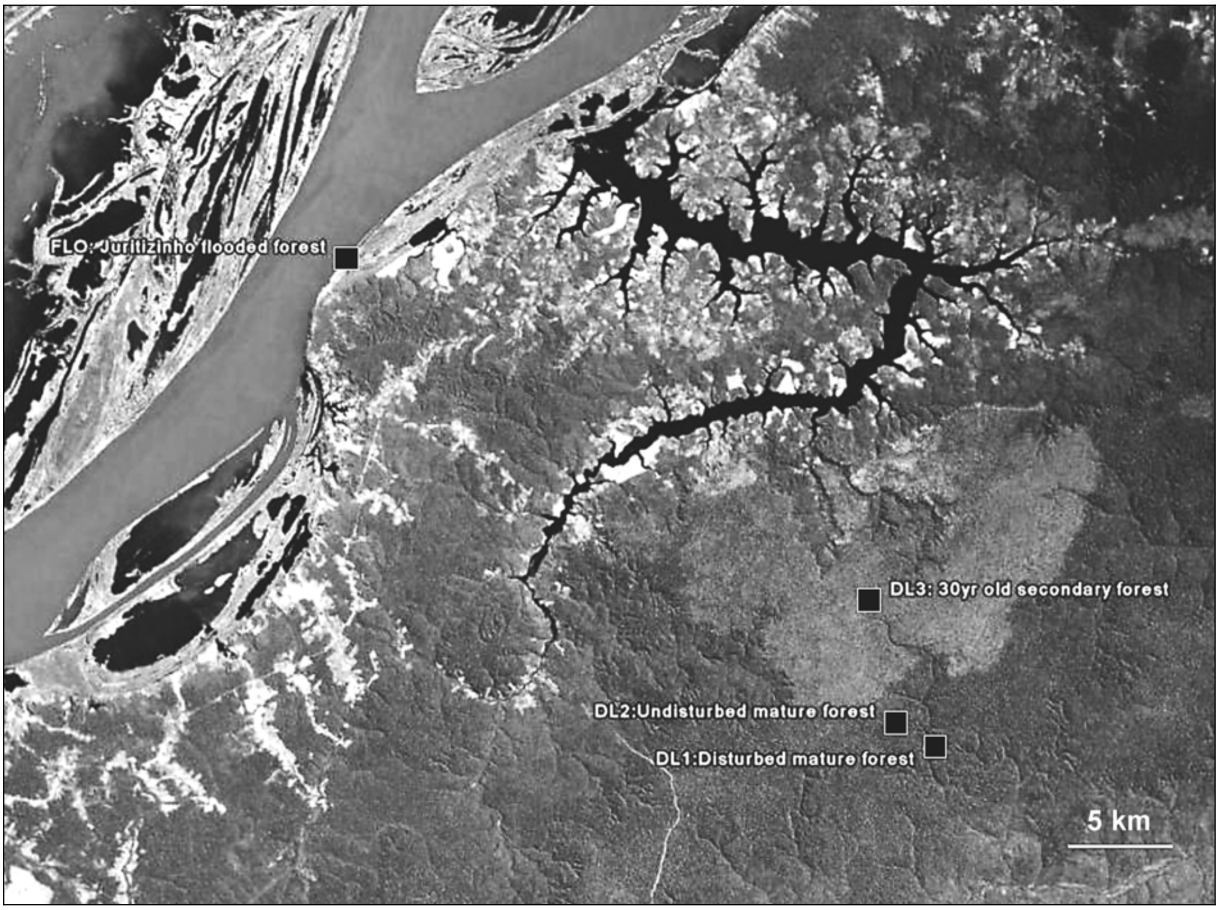


Figure 1. Location of sampled sites in Juruti, Pará, Brazil.

Results

Sampling methods

The seven methods used for sampling Opiliones in Juruti were extremely heterogeneous, in terms of both number of individuals collected and species incidence (Fig. 2, Tables I, II). Abundance ranged from 1.25 (NAS) to 6.04 (BT) specimens per sample. Method CS obtained 100 % of catching-efficiency (the ratio between the number of samples obtained and the number of those samples with at least one individual), followed by NGS (79% efficient), BT (61%), NAS (50%), LMS (46%), and W (20%). The least effective method was PIT, with only 12% catching-efficiency. Nine species were captured in only one method (six with LMS, two with BT and 1 with PIT). Each method accessed between 28 to 50% of the total Opiliones species richness in the four sampled areas (28 species).

	Methods							Sites				
	BT	CS	LMS	NAS	NGS	PIT	W	DL1	DL2	DL3	FLO	Total
EUPNOI – SCLEROSOMATIDAE												
Prionostemma sp.1	8	8	0	1	7	0	0	13	11	0	0	24
Prionostemma sp.2	0	0	0	2	2	0	0	4	0	0	0	4
Prionostemma sp.3	0	0	0	0	0	1	0	0	1	0	0	1
LANIATORES – AGORISTENIDAE												
Trinella sp.	0	1	0	0	0	2	0	0	0	3	0	3
COSMETIDAE												
Cynorta albicurvata Roewer, 1947	24	1	0	4	3	3	0	3	7	24	1	35
Cynorta variegata Roewer, 1947	1	0	0	0	0	0	0	0	0	0	1	1
Cynorta sp.	2	0	0	0	1	0	0	0	0	0	3	3
Eucynortella sp.	1	1	0	1	0	0	0	2	1	0	0	3
Metalibitia santarensis (Roewer, 1947)	1	0	0	0	0	0	0	0	0	0	1	1
Paecilaema sp.1	2	6	0	2	8	15	0	3	14	13	3	33
Paecilaema sp.2	1	0	1	0	0	0	0	1	0	1	0	2
GONYLEPTIDAE												
Huralvioides hoeferi Kury, 1995	0	0	1	0	0	0	0	0	0	1	0	1
Paraluederwaldtia caramaschii Soares & Soares, 1979	0	4	0	0	2	0	0	0	1	5	0	6
MANAOSBIIDAE												
Manaosbiidae gen.sp.1	2	18	3	0	17	3	2	9	13	23	0	45
Manaosbiidae gen.sp.2	4	1	0	0	0	0	0	1	1	3	0	5
STYGNIDAE												
Auranus parvus Mello-Leitão, 1941	0	0	1	0	0	0	0	0	1	0	0	1
Protimesius longipalpis (Roewer, 1943)	0	0	0	3	3	0	0	5	1	0	0	6
Stygnus pectinipes (Roewer, 1943)	0	7	0	2	6	0	0	5	4	6	0	15
FISSIPHALLIIDAE												
Fissiphalliius sp.n.1	179	0	3	0	0	1	0	39	83	61	0	183
Fissiphalliius sp.n.2	47	0	1	0	0	0	7	1	8	46	0	55
Fissiphalliius sp.n.3	0	0	1	0	0	0	1	0	1	1	0	2
MINUIDAE												
Minuidae gen.sp.1	0	0	4	0	0	2	4	3	2	5	0	10
ZALMOXIDAE												
Zalmoxidae gen.sp.1	0	0	6	0	1	0	1	2	1	5	0	8
Zalmoxidae gen.sp.2	0	0	2	0	0	1	1	0	2	2	0	4
Zalmoxidae gen.sp.3	0	0	1	0	1	0	0	0	1	1	0	2
Zalmoxidae gen.sp.4	0	0	7	0	0	0	2	6	0	3	0	10
Zalmoxidae gen.sp.5	0	0	1	0	0	0	0	1	0	0	0	1
Zalmoxidae gen.sp.6	0	0	1	0	0	0	2	0	0	3	0	3

Table I. Number of harvestmen species collected using seven sampling methods in four sites in Juruti region, Para State, Brazil.

Abbreviations: **BT.** Beating trail; **CS.** Cryptic search; **LMS.** Litter manual sorting; **NAS.** Manual nocturnal aerial search; **NGS.** Manual nocturnal ground search; **PIT.** Pitfall traps; **W.** Winkler apparatus. **DL1.** Disturbed dry land mature forest at igarapé Mutum valley; **DL2.** Mostly undisturbed dry land mature forest at igarapé Mutum valley; **DL3** . Nearly 30 yr old second growth forest at Cairanga-Mutum Road **FLO.** Jurutizinho Flooded forest (várzea) at right margin of Amazon River.

	BT	CS	LMS	NAS	NGS	PIT	W	DL1	DL2	DL3	FLO	TOTAL
Total samples	72	12	30	24	24	180	30	114	114	114	30	372
Valid samples	45	12	14	12	19	22	7	33	41	53	4	131
Species	12	9	14	7	11	8	8	16	18	18	5	28
Abundance	272	47	33	15	51	28	20	98	153	206	9	466
Abundance / valid samples	6	3.9	2.4	1.2	2.7	1.3	2.9	3	3.7	3.9	2.2	3.6
Singletons	4	4	8	2	3	3	3	4	9	4	3	8
Doubletons	3	0	1	3	2	2	3	3	2	1	0	2

Table II. Number of harvestmen and estimated species richness (including standard deviation) obtained with seven sampling methods in four sites in Juruti region, Para State, Brazil.

Abbreviations: **BT** = beating trail; **CS** = cryptic search; **LMS** = litter manual sorting; **NAS** = manual nocturnal aerial search; **NGS** = manual nocturnal ground search; **PIT** = pitfall traps; **W** = winkler apparatus; **DL1** - disturbed dry land mature forest at igarapé Mutum valley; **DL2** - mostly undisturbed dry land mature forest at igarapé Mutum valley; **DL3** - nearly 30 yr old second growth forest at Cairanga-Mutum Road; **FLO** – Jurutizinho Flooded forest (várzea) at right margin of Amazon River.

Another important factor to be considered when structuring a sampling protocol is the relationships between the sampling effort (e.g., time) for each method and the resulting productivity. The majority of the methods used produced samples based on one hour of collecting, with the exception of PIT (10 min to one person assemble or unassembled each pit-fall trap), and LMS (1m^2 sorted in 30 min). In Juruti, at each set of 10 samples, both NAS and BT produced six species, NGS and CS obtained nearly eight species and LMS acquired twelve species.

On the other hand, if cost of processing samples is calculated as the number of individuals collected per sample, BT and CS are the most effective, with 6 and 3.9 individuals per sample, respectively. These numbers indicated that it is necessary to employ several sampling methods to obtain a representative assemblage of actual species richness. Using LMS with an additional method (CS, BT or NGS) resulted in sampling 78% of the observed species richness. However, the most effective combination of three methods was LMS, BT and NGS, which obtained 96% of species richness.

Species richness and abundance

The sampling effort in all four sampled areas resulted in 466 individuals, belonging to nine families and 28 species (**Table I**). The richest families were Cosmetidae (seven species) and Zalmoxidae (six species). The remaining families were represented by one to three species, and representatives of Cyphophthalmi were not recorded. Five species were the most commonly collected: *Fissiphalliius* sp.1 (41% of the total catch), *Fissiphalliius* sp.2 (10.7%), *Cynorta albicurvata* (7.8%), *Paecilaema* sp. 1 (7.4%) and *Prionostemma* sp.1 (5.4%) (**Table I**).

We must stress, however, that these rankings are strongly related to the collecting methods used and to the unequal number of samples obtained with each method. For methods accessing the intermediate forest stratum, BT obtained a dominance of 66% (*Fissiphalliius* sp.1), although NAS presented a high evenness. Among the methods that accessed soil and litter fauna, PIT showed the highest dominance (53% for *Paecilaema* sp.1), whereas NGS presented an intermediary value (33% for Manaosbiidae sp.1) and LMS the lowest dominance (21% for Zalmoxidae sp.4).

The number of samples was the same in the three dry land areas (124 samples per area), but only 30 samples were obtained in the flooded forest. The number of valid samples (with at least one adult specimen) was unequal among the flooded forest site (13.3%) and dry land plots (26-42%). From the 28 species recorded, 16 occurred in DL1, 18 each in DL2 and DL3, and 5 in the flooded forest site. The three dry land forest areas are similar regarding species richness, while taxonomic composition varied among sites. Nine species occurred only in dry land forest sites, and six occurred in only two of these sites (**Table 1**). Sites DL2, DL3 and FLO contained three exclusive species each. Unfortunately, due to the small number of samples in the flooded forest in relation to the dry land forest plots, and the lack of sample replication for the former, we cannot directly compare the Opiliones communities of these two environments in terms of diversity and endemism.

Discussion

The structured inventory, using seven sampling methods obtained 28 harvestmen species in Juruti. Unfortunately, this species richness cannot be compared with other regions in the Amazon forest, as it is the very first structured inventory generated in the region. The sole Amazonian locality in which sampling efforts of harvestmen was high is the Adolfo Ducke Forest

Reserve, Manaus municipality, State of Amazonas. This is 100 Km^2 of dry land forest, where 21 Opiliones species have been recorded so far (Kury & Pinto-da-Rocha 2002). Based on this material, nine harvestmen species were named (Höfer & Beck 1995; Adis *et al.*, 2002; Kury & Pinto-da-Rocha 2002). In both the Ducke Reserve and Juruti, the richest families were Zalmoxidae and Cosmetidae.

However, further comparisons were not possible as many of the Ducke Reserve samples were obtained opportunistically. Several southeast Atlantic RainForest sites (see Pinto-da-Rocha *et al.*, 2005) are much better known than those from the Amazon, having from 17 to 63 species recorded in each (median - 29 spp.). Probably, those southeast Atlantic RainForest sites with less than 30 species recorded, are under-sampled or extremely impoverished by human activities (C. Bragagnolo, pers. comm.). Nevertheless, the data of only one structured inventory has been published until now, by Bragagnolo & Pinto-da-Rocha (2003), who accomplished 83 h of continuous manual nocturnal search (either free or bounded by a 30 m transect) at Serra dos Órgãos National Park, State of Rio de Janeiro. These authors obtained 52 of the 63 species known to occur in this National Park. In Juruti, 48 h of night hand-searching was done, resulting in 31 valid samples and 12 species recorded. Comparing the two localities at the same sampling effort (31 h), it is possible to speculate that the Serra dos Órgãos National Park contains almost three times as many species as the study area (35 spp).

Nevertheless, we should stress that the nocturnal Amazonian collecting was divided into "ground" and "aerial" seeking, which was not undertaken in Bragagnolo & Pinto-da-Rocha´s (2003) study. Therefore, it is impossible to be precise on the time spent in each kind of search there. These data suggest that the Amazonian Opiliones fauna is less diverse than in the Coastal Atlantic Forest, but future work would be required to substantiate this claim. The mature and secondary growth dry land Amazonian forests show little altitudinal variation, a very high canopy (30-50 meters), and a sparse intermediate stratum. The Atlantic Rain Forest areas, in contrast, exhibit a high altitudinal gradient, lower canopies (20-30 meters), and the intermediate stratum tends to be dense. These remarkable differences could be responsible for putatively higher effectiveness of manual nocturnal-sampling in the Atlantic Forest and maybe high diversity.

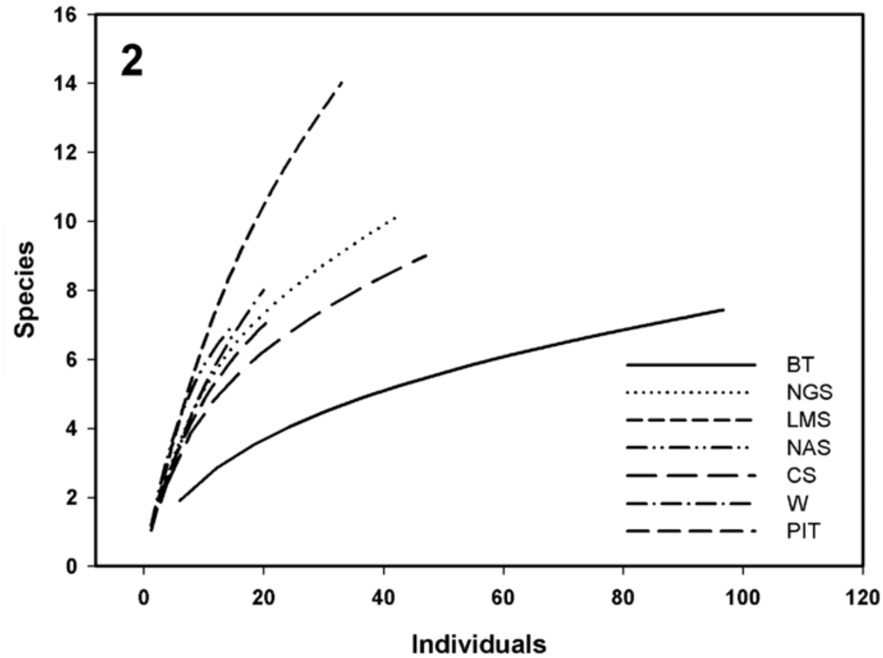
The Juruti inventory was carried out in four different sites, with species richness ranging from 5 to 18 species per site. Among the different dry land conservation stages, represented by the three dry land plots on the plateau, species richness showed a low variation (16–18 spp.).This fact alone could justify preservation measures to protect the dry land forest in all conservation stages, including secondary growth forest. In contrast to the dry land plots, the flooded forest presented only five species, three of which exclusive to this site.

Harvestmen living in the flooded forest may have unusual natural histories. In the blackwater inundation forest of Central Amazonia, an area with a cycle of flooding similar to that occurring in the "várzea", some harvestmen move to the trunk/canopy region prior to flooding where they pass 5-7 months duration of an aquatic phase (Friebe & Adis, 1983). For these reasons it would be very interesting to determine the exact differences between the taxonomic composition and other diversity patterns of dry land and flooded forests. However, the number of total and valid samples (those with at least one adult specimen) was low, and any comparison is impossible at the present stage.

Regarding abundance, again only NGS and NAS are comparable to the free search and transect search employed during the sole structured inventory available for a Neotropical area, the Serra dos Órgãos National Park (Bragagnolo & Pinto-da-Rocha, 2003). In Juruti, from 1.2 to 2.6 individuals per sample were obtained, contrasting with the results in the Serra dos Órgãos, in which a much larger abundance was verified, from 13 to 18 individuals per sample. The abundance was greater in the secondary growth forest plot (DL3 – 206 individuals) than in the older areas (DL1 – 98; DL2 – 153; see Fig. 3). This fact could be related to higher vegetal productivity (Guariguata & Orstestag, 2001) and, maybe, to higher prey availability. Unfortunately, the number of dry land sampled sites was low, restricting solid conclusions. A study with a larger number of replicates per treatment, before the start of mining activity in the Juruti plateau region, is necessary in order to understand Opiliones abundance patterns in different dry land sites and to compare species richness and similarity among dry land and flooded forests, the most impoverished vegetation type in the Amazon Forest (Williamson & Mesquita, 2001). Our base-line data provides a starting point for future surveys.

Since our sampling methods failed to collect enough species to reach an asymptote in the species accumulations curves, we are unable to predict the minimal time or number of samples that should be employed for a complete inventory. However, clearly more time is required, and the site should be visited more than once to capture phenological differences that may exist for some of the species (Curtis & Machado, in press), and to account for the interaction between season and site characteristics (e.g., moistures regimes will affect plant productivity that could influence on distribution of harvestmen species).

None of the methods employed obtained more than half of the observed species richness, and the most efficient ones in both abundance and richness are CS, LMS, BT and MGS. The most used methods to catch opilionids in the Neotropical region, the nocturnal ground and aerial manual searching (Bragagnolo & Pinto-da-Rocha, 2003) recorded together only 12 species in Juruti. In one unpublished study (R. Pinto-da-Rocha, unpu-blished data) on the Parque Estadual da Cantareira (Atlantic Rain Forest, southeastern Brazil), where four techniques were employed (PIT, BT, W, and nocturnal seeking), night collecting represented 88 % of total observed richness.



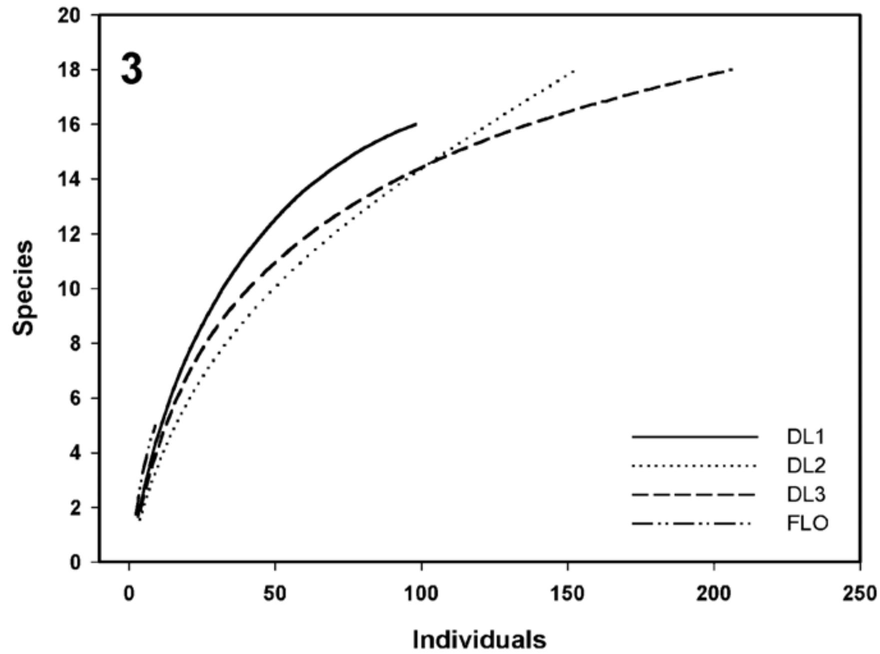


Figure 2. Observed species accumulation curve depicting harvestmen sampled with seven sampling methods in four sites in the Juruti region, Para State, Brazil. Collecting with beating trail was included just until the 100th specimen. Abbreviations: **BT.** Heating trail; **CS**. Cryptic search; **LMS**. Litter manual sorting; **NAS**. Manual nocturnal aerial search; **NGS**. Manual nocturnal ground search; **PIT**. Pitfall traps; **W**. Winkler apparatus.

Figure 3. Species accumulation curves depicting harvestmen sampled in four sites in the Juruti region, Para State, Brazil. Abbreviations: **DL1**.Disturbed dry land mature forest at igarapé Mutum valley; **DL2**. Mostly undisturbed dry land mature forest at igarapé Mutum valley; **DL3**. Nearly 30 yr old second growth forest at the Cairanga-Mutum Road; **FLO**. Jurutizinho Flooded forest (várzea) at right margin of Amazon River.

Thus, at least in Amazonia, it is necessary to employ several sampling methods in order to maximize the observed richness of the harvestmen fauna. We recommend assessing the Amazonian dry land harvestmen fauna with a sampling protocol composed of LMS, BT and NGS, to be replicated in as many areas as possible in the same region. In addition to this being the most effective combination of sampling methods, it permits a crucial time gain in the field, as sampling can be done daily (LMS and BT) and nightly (NGS). These three methods sample Opiliones from litter (LMS, NGS) and understory (BT). We do not recommend the use of PIT or W for adult harvestmen sampling, as these methods require a great deal of effort both to set traps in the field and to sort the resulting samples. In addition, the number of valid samples is the lowest among the methods employed and species composition can be achieved with other "low cost" methods (especially LMS). More important, the few species and specimens obtained with PIT could be sampled with other less time consuming and more efficient methods, as W, CS and LMS, which obtained four species in common with PIT each.

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