

1 **Assessing the Relationship Between Vegetation Structure and Harvestmen**  
2 **Assemblage in an Amazonian Upland Forest**

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12 **Running Title:** Vegetation Structure and Harvestmen's Relationship

13

14 **Abstract**

15 1. Arthropod diversity and non-flying arthropod food web are strongly influenced by  
16 habitat components related to plant architecture and habitat structural complexity.  
17 However, we still poorly understand the relationship between arthropod diversity and the  
18 vegetation structure at different spatial scales. Here, we examined how harvestmen  
19 assemblages are distributed across six local scale habitats (trees, dead trunks, palms,  
20 bushes, herbs and litter), and along three proxies of vegetation structure (number of  
21 palms, number of trees and litter depth) at mesoscale.

22 2. We collected harvestmen using cryptic manual search in 30 permanent plots of 250 m  
23 at Reserva Ducke, Amazonas, Brazil. The 30 plots cover approximately 25 km<sup>2</sup> of upland

24 forests. At a local scale, harvestmen were most diverse and abundant on trees. The likely  
25 preference of trees by harvestmen may be related to the variety of local microhabitats  
26 offered by large trees. However, despite the strong link between number of harvestman  
27 species and individuals with large trees, only harvestmen assemblages composition were  
28 related with number of trees and with number of palms, at mesoscale.

29 3. Harvestman richness and abundance were not related with any vegetation structure  
30 predictor at mesoscale. Therefore, areas of *upland* forest in the central Amazon with large  
31 trees and palms do not harbor more harvestman species nor individuals, but are suitable  
32 to maintain different harvestmen assemblages.

33

34 **Keywords:** Amazon, Arachnida, Opiliones, community ecology, microhabitat, big trees,  
35 palms, conservation.

36

### 37 **Introduction**

38 Tropical forests occupy 11% of the earth's surface yet maintain more than 60% of its  
39 terrestrial biodiversity (Wilson, 2000). The reason that promotes such highly  
40 concentration of plant and animal diversity remains contentious (Hubbell, 2001; Novotny  
41 *et al.*, 2006), but there is compelling evidence that tropical diversity is influenced and  
42 maintained by wide environmental gradients and habitat structural heterogeneity  
43 (Gardner *et al.*, 1995; Halaj *et al.*, 2000). In the Amazon rainforest several arthropod  
44 assemblages have been characterized and related to environmental gradients. For  
45 instance, ant diversity is affected by water table depth variation (Baccaro *et al.*, 2013),  
46 ants influence termites (Pequeno & Pantoja, 2012), different environmental predictors

47 affect cockroaches simultaneously (Tarli *et al.*, 2013), and understory forest structure  
48 affect harvestmen assemblages (Tourinho *et al.*, 2014; Porto *et al.*, 2016). However, few  
49 studies investigated how non-flying arthropods are limited or affected by vegetation  
50 structure (Vasconcelos *et al.*, 2008; Donoso *et al.*, 2010) and we still poorly understand  
51 the role of vegetation structure on arthropod diversity in forested areas at different spatial  
52 scales.

53 Arachnids represent one of the most diverse groups of arthropods, and around 2%  
54 of described species occurs in the Amazon basin (Adis & Harvey, 2000). With more than  
55 6600 species described (Kury, 2016), harvestmen represent the third most diverse order  
56 of arachnids, after spiders and mites, and are well represented in the Amazon biome  
57 (Kury & Pinto-da-Rocha, 2002). Harvestmen are mostly predators and strongly affected  
58 by temperature and humidity, thus, susceptible to dehydration (Curtis & Machado, 2007).

59 Only a few studies have investigated the relationship between harvestmen species  
60 and habitat structure. It was demonstrated that harvestmen assemblages from Atlantic  
61 forest are positive related to forest quality, responding more drastically to fragmentation  
62 than most arthropods (Bragagnolo *et al.*, 2007). Proud *et al.*, (2012) suggests that in  
63 tropical forests of Costa Rica, harvestmen can use trees as refuges when disturbed, but  
64 only in sites with higher harvestmen diversity in the ground/litter microhabitat. Recent  
65 evaluation of collecting techniques also offered evidence for a relationship between  
66 number of palm trees and harvestmen assemblage composition in upland Amazonian  
67 forest (Tourinho *et al.*, 2014; Porto *et al.*, 2016). However, how vegetation structure  
68 directly or indirectly influences harvestmen assemblages remains still little understood.

69 Here, we investigate the relationship between vegetation structure and a  
70 harvestmen assemblage in an *upland* forest in the Central Amazon at two different spatial  
71 scales. We investigate how harvestmen assemblages are distributed at local scale (plots of  
72 500 m<sup>2</sup> each). We also test and describe the relationship of two direct proxies of  
73 vegetation structure (number of palms and number of trees) and one indirect proxy of  
74 vegetation structure (litter depth) with the harvestmen assemblage composition at  
75 mesoscale (25 km<sup>2</sup>).

76

## 77 **Methods**

### 78 **Study area**

79 The study area is located in the central Amazon, in the Reserva Forestal Adolpho Ducke  
80 (Fig. 1), which is a 100 km<sup>2</sup> fragment of *terra firme* forest administrated and protected by  
81 the Instituto Nacional de Pesquisas da Amazônia (INPA). The vegetation is typically  
82 upland rainforest, with a diversity of trees around 1200 species (Costa et al., 2009), with  
83 a canopy height of 30-35m above the ground. Annual mean temperature is 26°C. Annual  
84 precipitation is between 1.900-2.300 mm<sup>3</sup>, and the wet season usually begins in  
85 November and lasts until May (Baccaro et al., 2008). Altitudinal variation is between 30-  
86 180 m asl.

87

### 88 **Sampling design**

89 A total of 30 plots were sampled between July and November 2014, covering an area of  
90 25 km<sup>2</sup> (Fig. 1). Collecting plots were established following the RAPELD protocol  
91 (Magnusson *et al.*, 2005). Each plot is a 250 m transect with variable width, and the

92 distance between them is 1 km. Two experienced collectors sampled every plot in a  
93 single visit for one hour. The sampling were undertaken along one meter to each side of  
94 the main line of the 250 m-long plots, totalizing 500 m<sup>2</sup> of sampled area per plot (2 x 250  
95 m). Along the survey, all harvestman found within the plot were collected. The habitat  
96 occupied by each individual was recorded at the moment of the capture, and were  
97 classified into trees, dead trunks, palms, bushes, herbs and litter. Harvestmen were  
98 collected using cryptic manual searching, which focus on specific habitats described  
99 above (Porto *et al.*, 2016). This method allows for collection of more species and  
100 individuals compared with traditional surveys (Porto *et al.*, 2016).

101

## 102 **Species data**

103 To identify harvestmen species we examined the external morphology under a  
104 stereomicroscope and compared with the original descriptions provided in the literature  
105 (Pinto-da-Rocha, 1994, 1996, 1997, 2004; Kury, 2003) type material or pictures of the  
106 type material. Nymphs and females with ambiguous morphology were excluded. In the  
107 case of groups with a very conservative external morphology and/or poorly understood  
108 taxonomy (e.g. Cosmetidae, Sclerosomatidae, Zalmoxidae) we also prepared their male  
109 genitalia to allow proper species delimitation, following Acosta *et al.*, (2007). Material is  
110 labeled and deposited in the Invertebrate collection at INPA (curator Celio Magalhães).

111

## 112 **Environmental data**

113 We tested two direct proxies of vegetation structure as habitats available for harvestmen:  
114 number of palms (NPalm) and number of trees with diameter at breast height > 30 cm

115 (DBH30); and litter depth (Litter) as an indirect proxy of vegetation structure. The  
116 number of trees, palms and litter depth were obtained from the data repository of the  
117 PPBio program ([ppbio.inpa.gov.br](http://ppbio.inpa.gov.br)). Within plots, all trees with diameter at breast height  
118 > 30 cm (DBH30) in 1 ha (40 m x 250 m) were mapped, and their diameters at 1.30 m  
119 (DBH) measured (Castilho et al., 2006). The same protocol was used to count and map  
120 the palm trees within plots. At every 5 m along the long axis of the plots, a measurement  
121 of litter depth was taken. Measurements consisted of forcing a stick of 0.5 cm in diameter  
122 into the litter until it reached the soil and noting the distance in cm between the top piece  
123 of litter and the soil. In addition, we also measured the diameter at breast high of trees  
124 with harvestmen during the sampling surveys.

125

## 126 **Data analysis**

127 We generated two data matrices: one for the local scale analysis, using the habitats  
128 recorded at the moment of the capture (trees, dead trunks, palms, bushes, herbs and litter)  
129 as objects and species as columns, and another matrix for the mesoscale analysis using  
130 plots as objects and species as columns.

131 For species richness we used the total number of species collected per plot, for  
132 abundance we used the total number of individuals sampled per plot. We compared the  
133 number of species and abundance per plot (local scale) between each habitat predictor  
134 using analysis of variance ANOVA. Tukey's Honest Significance Difference method was  
135 used to compute the 95% confidence interval for each factor. Residual analyses were  
136 used to investigate model assumptions.

137 For the mesoscale analysis, species composition per plot was summarized in a  
138 single multivariate axis using Non-metric Multidimensional Scaling NMDS, based on  
139 Bray-Curtis dissimilarity distances of the original abundance matrix. To evaluate the  
140 effect of vegetation structure on the harvestmen assemblage, we performed multiple  
141 regressions for each dependent variables against the independent variables, as follows:  
142 NMDS axis =  $a+b(\text{Palms})+b(\text{DBH30})+b(\text{Litter})$ , richness =  
143  $a+b(\text{Palms})+b(\text{DBH30})+b(\text{Litter})$ , and abundance =  $a+b(\text{Palms})+b(\text{DBH30})+b(\text{Litter})$ .  
144 Partial regression plots were generated to show the relationships between variables. All  
145 three independent variables showed low correlation ( $r < 0.3$ ).

146

## 147 **Results**

148 A total of 689 adult harvestmen were collected, representing 27 species and 12 families  
149 (Table 1). The most abundant families were Cosmetidae (37.44% of total abundance) and  
150 Sclerosomatidae (22.78% of total abundance). The most common species were  
151 *Eucynortella duapunctata* (183 individuals), *Caluga* sp. 1 (83 individuals) and *Cynorta*  
152 sp. 1 (75 individuals). Abundance per plot ranged from nine to 54, with a mean of 22.96  
153 individuals. Richness per plot varied between four to 13, with a mean of 7.93 species.

154 With 85.18% of species and 38.89% of individuals sampled, trees harbored the  
155 most diverse and abundant harvestman assemblage (ANOVA  $F_{5,174} = 15.16$ ,  $P < 0.001$   
156 and  $F_{5,175} = 55.13$ ,  $P < 0.001$  respectively) (Figs. 2-3). The second most diverse habitat  
157 was herbs, while the third most abundant habitat was litter, but no strong effects were  
158 detected among other habitats. Bushes were the less diverse and harbors fewer

159 harvestmen. Richness and abundance for the six habitats evaluated are summarized in  
160 table 2.

161 Smaller Stygnidae such as *Verrucastynus hoeferscovitorum* and *Ricstygnus* sp. 1  
162 showed preference for the litter habitat, occasionally going on short herbs. Gonyleptids  
163 species of *Discocyrtus* showed habitat segregation, with individuals of *Discocyrtus*  
164 *carvalhoi* occurring only on live trees, and individuals of *Discocyrtus* sp. 1 occurring on  
165 fallen dead trunks. The two Escadabiidae collected were found on large trees with  
166 corrugated bark. All individuals of the Fissiphalliidae collected in our study, *Fissiphallius*  
167 *martensi*, were detected on trees with corrugated bark. As something unusual, we found  
168 one specimen of *Brasilogovea microphaga* climbing on a tree, which represents the first  
169 record of climbing behavior for a Cyphophthalmi.

170 The number of trees with diameter at breast height > 30 cm varied between 87 to  
171 128 per plot (mean = 105.2). Conversely, the number of palms showed a wider range,  
172 varying between 97 to 448 palm trees per plot (mean = 269.7). The litter depth also  
173 varied largely between plots, ranging from only 1.31 to 4.18 cm (mean = 2.3 cm).

174 The NMDS ordination axis captured 59.55% of the variation of the species  
175 composition data ( $F = 640.4$ ;  $DF = 1,433$ ;  $P < 0.001$ ). The multiple regression model,  
176 with the species composition as the response variable (NMDS Axis), explained 41.7% of  
177 the variation in the data ( $r^2 = 0.417$ ,  $P = 0.002$ ) (Fig. 4). The independent variables that  
178 contributed significantly to the model were number of palms ( $b = 0.450$ ,  $P = 0.005$ ) and  
179 number of trees with diameter above breast height > 30 cm ( $b = 0.346$ ,  $P = 0.036$ ). Litter  
180 depth did not affect species composition. Multiple regression models for richness and  
181 abundance were non-significant. Results of regression models are summarized in table 3.

182

183 **Discussion**

184 Harvestman diversity was related to local and meso scale gradients created by vegetation  
185 structure at this forest. At local scale, trees harbored the most diversity and abundant  
186 harvestman assemblages, compared with other available habitats. At meso scale number  
187 of trees and palms were the best predictors of harvestman composition, while both were  
188 not related with harvestman richness or abundance. In context, the harvestmen diversity  
189 at Reserva Ducke is comparable with recent harvestmen inventories carried out in  
190 different localities of *upland* forest across the Amazon region (Pinto-da-Rocha &  
191 Bonaldo, 2006; Bonaldo *et al.*, 2009; Tourinho *et al.*, 2014, Porto *et al.*, 2016), with  
192 number of collected species ranging between 26 to 30. Cosmetidae and Sclerosomatidae  
193 were the most abundant families, while Stygnidae and Sclerosomatidae were the most  
194 diverse groups, with five and four species collected each.

195

196 *Harvestmen diversity at local scale.*

197 Large trees can offer microhabitats such as cracks, bark pockets, bark pockets with decay,  
198 bowls in bark, stem cavities, witch broom, hollow chambers on butt of trees, among other  
199 12 tree microhabitats defined by Michel and Winter (2009), which are probably suitable  
200 for harvestmen. A total of 23 species out of 27 were found foraging on trees, indicating  
201 that trees might be one of the most important habitats for harvestmen at local scale. From  
202 these, six species were found exclusively on trees. These species were observed mainly  
203 on trees with a highly corrugated bark and big roots (locally known as *sapopemas*),  
204 suggesting that harvestmen could be using bark pockets, cracks and cavities as refuge or

205 for prey source. For instance, most individuals of Samoidae Genus 1 sp. 1 were found  
206 while foraging in tree bark pockets and cracks.

207 The use of tree bark may be related to harvestmen size. With the exception of the  
208 gonyleptids of the genus *Discocyrtus*, all species found only on trees were small (dorsal  
209 scutum length < 2.5 mm). In addition, due to their larger mass, large diameter trees  
210 provide temperature-buffering microhabitats (Brower *et al.*, 2009). This could be of  
211 benefit for some harvestmen species, especially the smaller ones that probably are more  
212 vulnerable to changes in temperature and moisture.

213 Abundance of harvestman per tree was also higher in larger trees than in smaller  
214 trees or shrubs for this assemblage. This can also be related to quantity of microhabitats  
215 available in the tree bark. In addition, large harvestman species can also take advantage  
216 of trees, as known for the cranid *Phareicranaus manauara*, which uses trees in its  
217 reproductive strategy (Colmenares & Tourinho, 2014).

218 Despite the high aggregation on trees, some harvestman species were sampled in  
219 different habitats. Species of Sclerosomatidae were more generalist, occupying almost all  
220 microhabitats, with *Caluga* sp. 1 as the only species distributed across all available local  
221 habitats. The longer lengths of legs and the high number of tarsomeres, which increase  
222 their capacity to climb and reach upper places on the vegetation, can explain this  
223 observation (Adams, 1984; Proud *et al.*, 2012). However, *Prionostemma* sp. is probably  
224 specialized in using some specific mature tree trunks that have surface color patterns  
225 similar to its body color, facilitating camouflage. From the 34 individuals collected, 32  
226 were on trees while only 2 were found in bushes and leaf litter.

227

228 *Relationship between vegetation structure and harvestmen assemblages.*

229 A more complex habitat can allow the co-occurrence of more harvestmen species by  
230 increasing the availability of microhabitats (Proud *et al.*, 2012). It is known that diversity  
231 and quantity of microhabitats increases with tree diameter, promoting their use by  
232 vertebrates and invertebrates and acting as predictor of biodiversity (Michel & Winter,  
233 2009). Thus, more trees with DBH above 30 cm per plot should mean more microhabitats  
234 available for all invertebrates in the study area, including harvestmen. However, our data  
235 show that either species richness or abundance at the meso scale may not be directly  
236 related with number of trees or palms. However, species composition per plot was related  
237 with vegetation structure predictors. Thus, plots with a higher number of large trees or  
238 higher number of palms may not affect the total number of species or individuals, but  
239 harbors different assemblages composition. Palm dwellers, can show lower abundances  
240 in plots with less palm trees, while trees dwellers, can be more abundant in plots with  
241 more large trees available.

242 We observed that harvestman use both faces of palm leaves for foraging, and  
243 Vasconcelos *et al.*, (1990) suggested that acaulescent palms can increase habitat  
244 complexity, as a consequence of the fallen litter trapped on their leaves. Tourinho *et al.*,  
245 (2014) and Porto *et al.*, (2016) also suggested that palms might be reflecting the overall  
246 variation of habitat structure. Thus, we can hypothesize that, at least for Reserva Ducke,  
247 more palms in a given plot would proportionally change the availability of other kinds of  
248 microhabitats, such as the ones related to trees, dead trunks and leaf-litter trapped in  
249 acaulescent palms. Consequently, plots with higher number of palms would

250 proportionally harbor more palm dwellers species. The same relation may be applied to  
251 number of trees per plot.

252 Harvestman species composition can also be affected by the increment in the  
253 numbers and abundance of generalist and vegetation dwellers, which are usually more  
254 abundant than tree and ground dwellers. For instance, *Caluga* sp. 1, *E. duapunctata*,  
255 *Prionostemma* sp. 1 and *Protimesius longipalpis*, among others, could benefit from the  
256 number of palms, but species like Samoidae Genus 1 sp. 1, Gonyleptidae spp., and  
257 Zalmoxidae *Chamaia* sp. 1, more related to trees, can be limited by the decrease of  
258 adequate microhabitats. Moreover, two of the recorded species use palms in their  
259 reproductive strategies. The stygnid *P. longipalpis* was recorded during our fieldwork  
260 using fallen palm trunks as an alternative refuge for the nymphs. In Stygnidae, at least  
261 another two species have been seen using palms leaves as a substrate to keep their  
262 clutches (Villarreal & Machado, 2011). There is also evidence that *P. manauara* and  
263 other *Phareicranaus* use fallen palm leaves and trunks to place their clutches and/or keep  
264 their nymphs (Hunter *et al.*, 2007; Proud *et al.*, 2011; Colmenares & Tourinho, 2014).

265 It is widely known that large old trees sustain countless other species, their  
266 hollows and crevices shelter many different animals and their branches and trunks are  
267 real diverse gardens (Lindenmayer & Laurance, 2016). However, they are susceptible to  
268 several threats including deforestation, logging, agriculture, drought, fire, windstorms,  
269 invasive species, the development of human infrastructure, and climate change. Across  
270 the planet old growth-forest have been cleared for human use and in the Amazon the  
271 mortality rates of large old trees are growing very fast (Lindenmayer *et al.*, 2012). Our  
272 data suggest that areas of *upland* forest in the central Amazon with a balance between

273 number of large trees and palms are suitable to maintain a comprehensive assemblage of  
274 harvestman species. Consequently, any disturbance resulting in reduction of the number  
275 of large trees will have a strong impact on harvestmen diversity, especially by limiting  
276 the occurrence of tree dwellers species. We know very little about the relationship of  
277 other non-flying arthropod and tree structure, however, our results indicate the  
278 conservation of large old trees and their global decline must be taken into consideration  
279 as a major concern to keep harvestman diversity in Amazon rainforest.

280

### 281 **Acknowledgements**

282 José W. de Morais (INPA) helped with the transportation for the fieldwork. Isadora  
283 Williams and Willians Porto helped as field assistants. Gonzalo Giribet kindly helped  
284 with the identification of the Cyphophtalmi. The material for this study was obtained  
285 under collecting permits 39557, granted from SISBIO to the first author. This study was  
286 supported by the Coordination of Improvement of Higher Education Personnel - CAPES  
287 (PEC-PG grant #5828104 to PAC and PNPd grant #03017/09-5 to ALT), Brazilian  
288 National Council for Scientific and Technological Development – CNPq through the  
289 Brazilian Research program for Biodiversity – PPBio, National Institute of Science and  
290 Technology for Amazonian Biodiversity (INCT-CENBAM), The Program Science  
291 without borders Special Visiting Professor (CSF/PVE) and The Program Science without  
292 borders for both the Special Visiting Professor Grant (CAPES #003/2012), International  
293 Postdoctoral grant (CNPq #200972/2013-8 to ALT) and Foundation Lemann for the  
294 Lemann additional International fellowship to ALT.

295

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413 **Tables**

414

415 **Table 1.** Species collected at Reserva Ducke, and the habitats they occupied

Taxon	Dead						Total
	Trees	trunks	Palms	Bushes	Herbs	Litter	
<b>Cyphophtalmi- Neogoveidae</b>							
<i>Brasilogovea microphaga</i>	1	0	0	0	0	0	1
<b>Eupnoi-Sclerosomatidae</b>							
<i>Caluga</i> sp. 1	27	12	3	2	18	25	87
<i>Caluga</i> sp. 2	5	4	0	0	2	10	21
<i>Geaya</i> sp. 1	1	4	0	0	5	5	15
<i>Prionostemma</i> sp. 1	32	0	0	1	0	1	34

**Laniatores-Agoristenidae**

*Avima matintaperera* 10 0 0 0 2 1 13

**Laniatores-Cosmetidae**

*Eucynortella duapunctata* 17 5 53 5 81 22 183

*Cynorta* sp. 1 51 16 0 0 0 8 75

**Laniatores-Cranidae**

*Phareicranus manauara* 4 1 3 5 2 0 15

**Laniatores-Escadabiidae**

*Escadabius* sp. 1 1 0 0 0 0 0 1

*Escadabius* sp. 2 1 0 0 0 0 0 1

**Laniatores-Fissiphaliidae**

*Fissiphallius martensi* 20 0 0 0 0 0 20

**Laniatores-Gonyleptidae**

*Discocyrtus carvalhoi* 12 0 0 0 0 0 12

*Discocyrtus* sp. 1 0 5 0 0 0 0 5

**Laniatores-Manaosbiidae**

*Manaosbia* sp. 1 1 0 0 0 4 8 13

*Rhopalocranus* sp. 1 9 2 4 0 4 3 22

*Rhopalocranus rotundus* 0 0 0 0 2 0 2

*Saramacia lucasae* 8 4 0 0 2 6 20

**Laniatores-Samoidae**

*Maracaynatum* sp. 1 1 0 5 0 0 0 6

Genus 1 sp. 1 41 2 0 0 0 0 43

**Laniatores-Stygnidae**

*Verrucastygus*

*hoeferscovitorum* 0 0 0 0 0 1 1

*Protimesius longipalpis* 5 2 15 1 21 4 48

*Protimesius* sp. 1 2 1 0 0 0 0 3

*Stygus pectinipes* 13 0 7 0 5 0 25

*Ricstygnus* sp. 1 0 0 0 0 2 3 5

**Laniatores-Zalmoxidae**

<i>Chamaia</i> sp. 1	5	11	0	0	0	1	17
<i>Pirassunungoleptes</i> sp. 1	1	0	0	0	0	0	1
<b>Total</b>	268	69	90	14	150	98	<b>689</b>

416

417

418 **Table 2.** Distribution of harvestmen across sampled habitat at Reserva Ducke. NSS =  
 419 number of species sampled only on a given habitat

420

	<b>Richness</b>	<b>%</b>	<b>Abundance</b>	<b>%</b>	<b>NSS</b>
Trees	23	85.18	268	38.89	6
Dead trunks	13	48.14	69	10.01	1
Palms	7	25.92	90	13.06	0
Bushes	5	18.51	14	2.03	0
Herbs	12	44.44	150	21.77	0
Litter	14	51.85	98	14.22	1

421

422

423

424 **Table 3.** Multiple regression models for species composition (NMDS Axis), richness and  
 425 abundance

426

<b>Response</b>	<b>Predictor</b>	<b>Coefficient</b>	<b>Standard Error</b>	<b>t</b>	<b>P</b>	<b>model R<sup>2</sup></b>
NMDS Axis	Intercept	-2.11	0.763	-2.766	0.01	0.417
	Npalms	0.003	0.001	3.064	<b>0.005</b>	
	DBH30	0.015	0.007	2.164	<b>0.039</b>	
	Litter	-0.002	0.001	-1.631	0.114	
Richness	Intercept	10.036	4.654	2.157	0.04	0.014
	Npalms	-0.002	0.007	-0.39	0.699	
	DBH30	-0.001	0.044	-0.264	0.794	
	Litter	-0.001	0.008	-0.055	0.956	

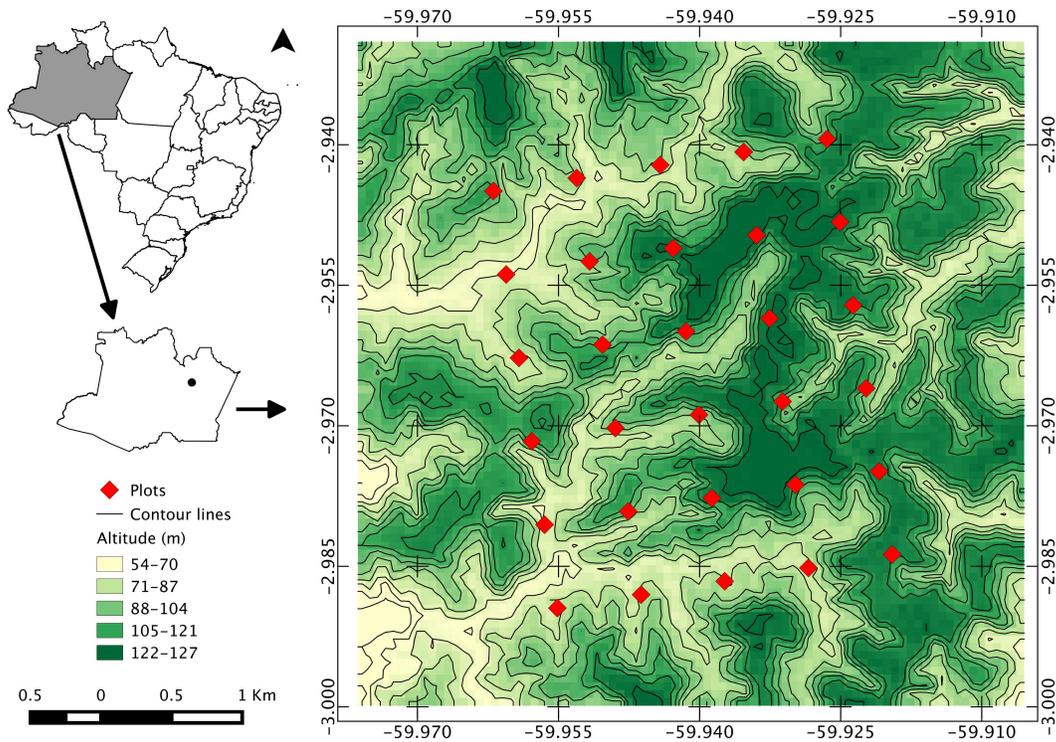
Abundance	Intercept	64.141	15.51	4.135	0.001	0.245
	Npalms	-0.036	0.024	-1.502	0.145	
	DBH30	-0.21	0.147	-1.428	0.165	
	Litter	-0.039	0.028	-1.389	0.176	

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429 **Figures**

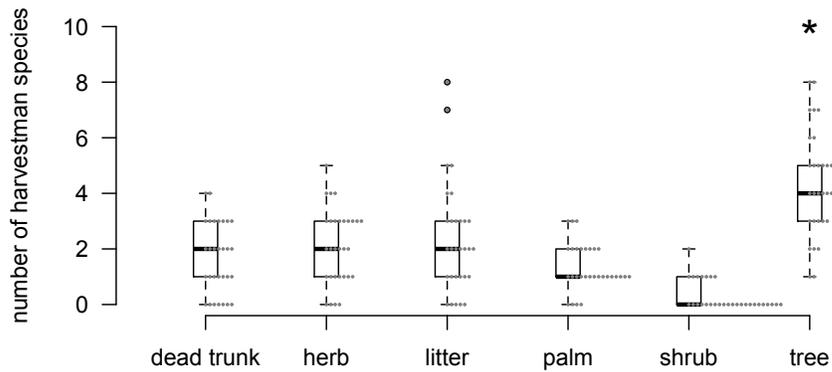
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432 **Fig. 1** Relative position of the 30 sampled plots at Reserva Forestal Adolpho Ducke.

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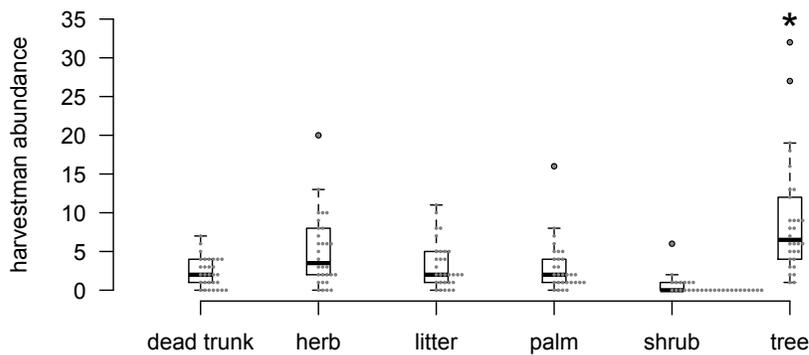
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435 **Fig. 2** Number of harvestmen species sampled per habitat. Asterisk indicates significant  
436 differences.

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440

441 **Fig. 3** Abundance of harvestmen sampled per habitat. Asterisk indicates significant  
442 differences.

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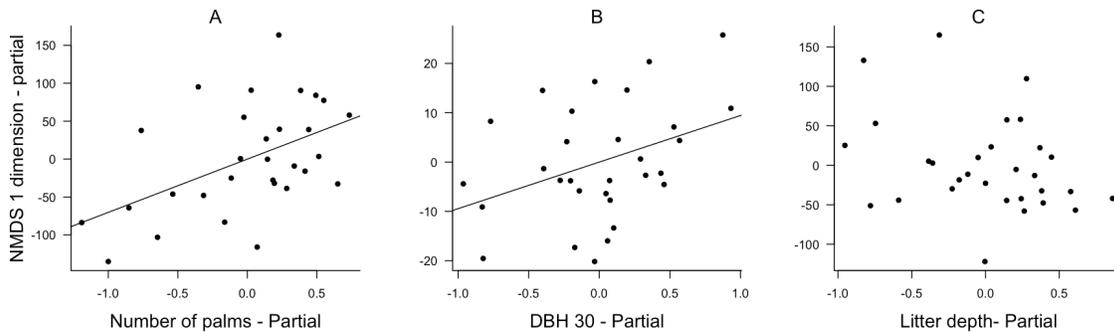
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452

453 **Fig. 4** Partial regressions of the significant effects detected on species composition  
454 (NMDS Axis) of harvestmen. a) Species composition change with the increment of  
455 number of palms ( $P = 0.005$ ), and b) number of trees with diameter at breast high  $> 30$   
456 cm ( $P = 0.034$ ), and c) species composition was not affected by litter depth ( $P > 0.1$ ).