2022. Journal of Arachnology 50:301–307

SHORT COMMUNICATION

Lustrochernes grossus (Pseudoscorpiones: Chernetidae) associated with decaying wood in riparian cloud forests

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Abstract. We analysed the dead-wood characteristics that determine the presence of saproxylic pseudoscorpion species in remnants of riparian cloud forest. We examined 98 dead-wood pieces (70 logs and 28 stumps), and recorded tree species, decaying wood stages, presence of the pseudoscorpion *Lustrochernes grossus* (Banks, 1893) (Chernetidae) and the Bess beetle *Helicus tropicus*. In these wood samples we found 24 *L. grossus* and one chela. We recorded the highest number of individuals in *Clethra mexicana* (11), followed by *Quercus corrugata* (6) and *Liquidambar styraciflua* (6). In *Annona cherimola* and *Trema micrantha*, one chela and one female were recorded, respectively. The presence of this pseudoscorpion is likely due to its relationship with the Bess beetle, which coexists in decaying wood. The distribution of *L. grossus* in dead wood may also be influenced by tree species and stage of decay. Forest fragmentation and the extraction of firewood from the remnant riparian fragments of cloud forest are factors that could jeopardize the saproxylic pseudoscorpion species and other arthropod diversity associated with decaying wood in this threatened ecosystem.

Keywords: Pseudoscorpions, dead wood, saproxylic, Veracruz

https://doi.org/10.1636/JoA-S-21-032

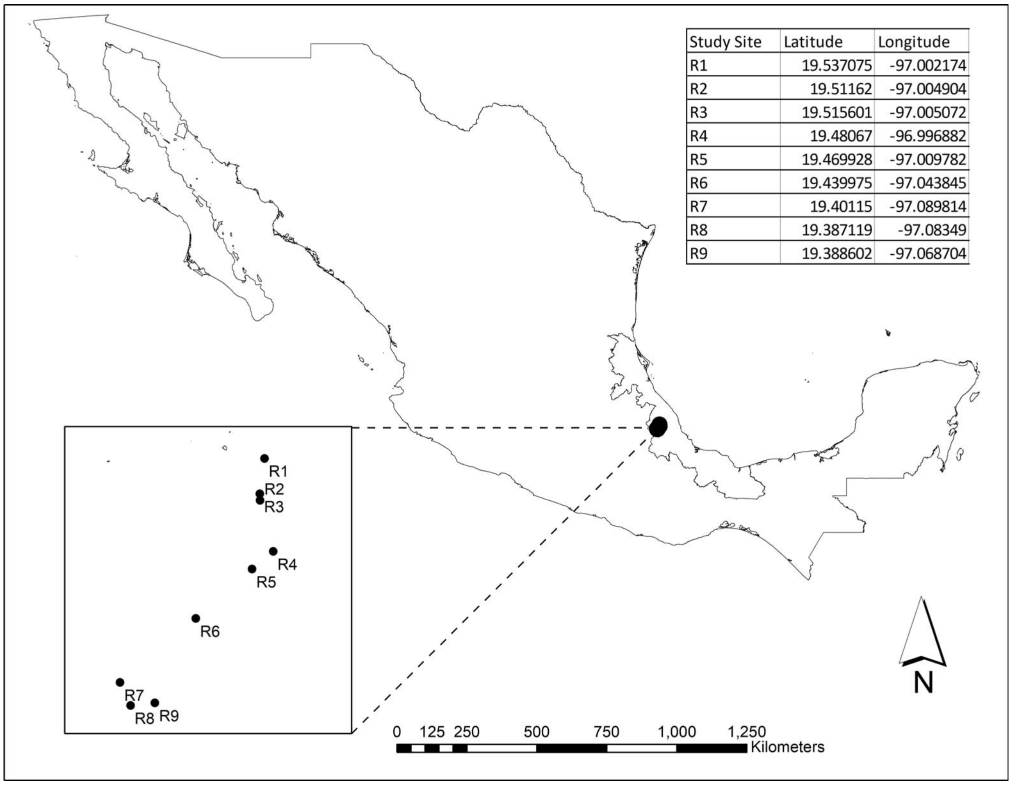
Decaying wood is a microhabitat for a wide species richness of saproxylic (dead wood dependent) organisms which are vital for the maintenance and functionality of forests because they contribute to the nutrient recycling process (Ulyshen 2018a). Species richness and composition of saproxylic biota vary depending on the stage of decay, which determines the coexistence of species in different trophic guilds colonising this environment (Ulyshen 2018a). Pseudoscorpions are small arachnids (2–12 mm) associated with damp and cryptic habitats such as forests, caves, and the intertidal zone (Weygoldt 1969). Pseudoscorpions have been recorded in the bark of living and dead trees, tree hollows, between cracks, under rocks and in forest litter (Weygoldt 1969; Muchmore 1990; Hernández-Corral et al. 2018). However, there is scarce information about pseudoscorpions associated with decaying wood, in spite of the fact that it is a relatively stable environment, with little variation in temperature and humidity (Castillo & Reyes-Castillo 2003). In particular, no study has evaluated the ecological patterns that determine the presence of saproxylic pseudoscorpions inhabiting decaying wood in Mexico.

In this study, the presence of pseudoscorpions associated with decaying wood in Mexican cloud forests was assessed. This ecosystem is threatened due to human activities and currently occupies less than 1% of land area in Mexico (Gual-Díaz & Rendón-Correa 2014). Cloud forests have a fragmented distribution represented by riparian vegetation, being reservoirs of biodiversity (Williams-Linera et al. 2002). However, biodiversity in this ecosystem could be threatened due to reduced size and connectivity of forest fragments (Komonen & Müller 2018), affecting the diversity and distribution of saproxylic species, particularly pseudoscorpions, which have a limited capacity for movement because they depend on other organisms for their dispersal by means of phoretic associations (Villegas-Guzmán & Pérez 2005; Castillo & Villegas-Guzmán 2016; Krajčovičová et al. 2018). We assessed the relationship of pseudoscorpions with dead-wood characteristics (tree species, position, diameter classes and stage of wood decay). The accompanying fauna was also determined to find the possible means of colonisation of decaying wood by pseudoscorpions.

Fieldwork was carried out in November and December 2015, in nine remnants of riparian vegetation of cloud forest in the La Antigua basin, central Veracruz, Mexico (Fig. 1). A total of 98 dead-wood pieces (70 logs and 28 stumps) were selected. Each dead-wood piece was examined by dissection using a hunting axe (Ramírez-Hernández et al. 2019) during 1 h (98 h sampling effort in total). The specimens were collected using entomological forceps and deposited in vials containing 70% ethyl alcohol.

The following dead-wood characteristics were recorded (Ramírez-Hernández et al. 2019): (1) tree species; (2) position, either fallen (log) or standing (stump) decaying wood; (3) diameter class: diameter ranges were grouped as follows: DC1 $<$ 50 cm, DC2 50–100 cm, DC3 100–150 cm; and (4) decomposition stage, determined using a personal knife and with observations in the field. Following the method proposed by Franc et al. (2007) four decomposition categories were defined: D1, wood was hard and presented resistance to penetration with the knife, bark with moss firmly attached to the stem; D2, soft bark partly loose but the inner wood still hard to penetrate with the knife; D3, soft and wet wood, inner wood still hard to penetrate, the knife was able to penetrate the wood (1–5 cm), with an increase of moss and fungus presence; D4, bark loose and mostly gone, the knife penetrated the wood with no resistance for more than 5 cm, wood is easily broken by hand or exhibits a high level of decomposition and water accumulation with fungus. Higher soil moisture was commonly present.

The pseudoscorpions were processed using the technique discussed by Hoff (1949) modified by Wirth & Marston (1968) and they were identified to species level. They were measured according to Chamberlin (1931) and Benedict & Malcolm (1979). Specimens were deposited in the Colección de Acarología de la Escuela Nacional de



Study Site	Latitude	Longitude
R1	19.537075	-97.002174
R2	19.51162	-97.004904
R3	19.515601	-97.005072
R4	19.48067	-96.996882
R5	19.469928	-97.009782
R6	19.439975	-97.043845
R7	19.40115	-97.089814
R8	19.387119	-97.08349
R9	19.388602	-97.068704

Figure 1.—Distribution and geographic coordinates of the nine riparian remnants (R) of cloud forest studied in central Veracruz, Mexico.

Ciencias Biológicas. We also collected saproxylic beetles (Coleoptera) associated with decaying wood as accompanying fauna, and individuals were identified to species by taxonomists (see Acknowledgments). Saproxylic beetles were deposited in the Colección Entomológica, Instituto de Ecología, A. C. (IEXA) in Xalapa, Veracruz (Mexico).

Of the 98 dead-wood pieces examined, we found arthropods inhabiting 74. We found pseudoscorpions inhabiting 19 (23.4%) of them. We collected a total of 24 pseudoscorpions and one chela (eight males, 14 females, one tritonymph and one deutonymph) belonging to *Lustrochernes grossus* (Banks, 1893) (Chernetidae). Specimens were found inhabiting 14 logs and five stumps that belong to five tree species (Table 1).

The tree species with the highest number of pseudoscorpions recorded was *C. mexicana* with 11 specimens, of which adults and nymphs were found (Tables 1, 2). This species was also represented by more samples than any of the other 10 tree species. The tree species with the lowest number of individuals were *A. cherimola* and *T. micrantha*, with one chela and one female collected, respectively. None were found in wood samples from 6 species (Table 2). Pseudoscorpions were found in all decomposition stages. The highest number of *L. grossus* (12 individuals) were found in eight logs and one stump at decay stage D2, which was also the most frequently collected decay stage. The fewest *L. grossus* were found in D3 (one log with one individual). The percentage of samples in which one or more *L. grossus* was found (Table 3) was highest for stage D4. *L. grossus* was more abundant (14) in trunks with a diameter less than 50 cm (DC1), while only four arachnids were found in trunks 100–150 cm in diameter.

The same pattern was found for saproxylic beetle diversity in Mexican cloud forest (Ramírez-Hernández et al. 2019). Previous studies have documented that *L. grossus* is associated with the bark and decaying wood of *Pinus* sp. (Muchmore 1991) and other tree species of the Fabaceae family (Córdova-Tabares & Villegas-Guzmán 2013). Studies in temperate forests indicate that tree species is one of the main factors determining the spatial segregation of the saproxylic entomofauna (Ramírez-Hernández et al. 2014) due to the physical characteristics of each type of wood, such as the degree of hardness and the capacity of some tree species to maintain higher humidity during the decomposition process. These two physical characteristics of decaying wood determine the time of degradation; for example, *Q. corrugata* takes more than five years to degrade (Forman 1995), although *Q. corrugata* maintains a high diversity of saproxylic arthropods. Ramírez-Hernández et al. (2019) observed that *C. mexicana* supports a more dynamic saproxylic community over time. This dynamism has probably made it possible to collect more specimens of saproxylic pseudoscorpions associated with this tree species.

A total of 45 species of saproxylic beetles were recorded. The most abundant beetle species was *Heliscus tropicus* (Percheron, 1835) (Passalidae), found inhabiting 33 dead-wood pieces (25 logs and eight stumps) with a total of 163 individuals (130 in logs and 33 in stumps). It was most abundant in logs at the D2 decomposition stage of *C. mexicana* (52 individuals) as occurred with *L. grossus*. The two species were found sharing the same logs on nine occasions (Table 1). Several species of the genus *Lustrochernes* Beier, 1932 are phoretically associated with passalids (Aguiar & Bührnheim 1998). In particular, *L. grossus* has been reported associated with Bess beetles below the elytra, as well as Elateridae (Villegas-Guzmán & Reyes-Castillo 2012; Córdova-Tabares & Villegas-Guzmán 2013; Villegas-Guzmán et al. 2016), performing passive phoresy (Athias-Binche 1994). In this study, *H. tropicus* was found coexisting with *L. grossus* in various dead-wood pieces. *Helicus tropicus* is a key species in decaying wood because they perforate galleries, thus facilitating the entry of insects, fungi and bacteria that contribute to the wood degradation process (Ulyshen 2018b; Ramírez-Hernández et al. 2019). In light of these results, we assume that saproxylic pseudoscorpions reach the decaying wood in two possible ways: (1) by themselves, since they

Table 1.—Distribution of *Lustrochernes grossus* and *Heliscus tropicus* associated with different tree species of decaying wood through the riparian remnant of cloud forest vegetation in central Veracruz, Mexico.
Pos: Position; Diam: Diameter class; Decay: Decomposition stage; T: Tritonymph; D: Deutonymph

Tree species	Pos	Diam	Decay	Beetle species (abundance)	*L. grossus*
Alnus acuminata Kunth 1817	Stump	DC2	D1	Carabidae: *Pachyteles mexicanus* (2)	0
	Stump	DC2	D1	No records	0
Annona chirimola Mill.	Log	DC1	D2	Carabidae: *Pachyteles mexicanus* (2) Passalidae: *Heliscus tropicus* (1), *Homalolinus* sp. 1 (1)	1 (chela)
	Log	DC2	D1	No records	0
	Log	DC2	D2	Passalidae: *Homalolinus* sp. 2 (1) Staphylinidae: *Osorius* sp. 1 (17)	0
	Log	DC2	D2	Passalidae: *Hemiphileurus dejeani* (1) Staphylinidae: *Aleocharinae* sp. 2 (1)	0
	Log	DC3	D1	Staphylinidae: *Clavilispinus* sp. 1 (3)	0
	Log	DC3	D1	No records	0
	Stump	DC2	D2	No records	0
	Stump	DC4	D1	No records	0
Clethra mexicana DC.	Log	DC1	D2	Staphylinidae: *Osorius* sp.1 (7), *Priochirus* sp. 2 (4)	0
	Log	DC1	D2	Carabidae: *Phloeoxena batesi* (1) Passalidae: *Heliscus tropicus* (42), *Hemiphileurus dejeani* (2), *Pseudacanthus aztecus* (1) Tenebrionidae: *Anaedus mexicanus* (1)	2 ♀
	Log	DC1	D2	Staphylinidae: *Priochirus* sp. 1 (1)	0
	Log	DC1	D2	Carabidae: *Elaphropus microspilus* (1) Tenebrionidae: *Arrhabaeus* sp. (2)	0
	Log	DC1	D4	Carabidae: *Euchroa lasvigas* (1), Passalidae: *Hemiphileurus dejeani* (1) Ptilodactylidae: *Ptilodactyla* sp. (1) Tenebrionidae: *Platydema maculipennis* (1)	2 ♀
	Log	DC1	D4	Passalidae: *Hemiphileurus dejeani* (1) Staphylinidae: *Homalolinus* sp. 1 (2) Tenebrionidae: *Uloma mexicana* (1)	0
	Log	DC2	D1	Leiodidae: *Agathidium* sp. (1)	0
	Log	DC2	D1	Carabidae: *Platynus acutulus* (1) Passalidae: *Heliscus tropicus* (9) Staphylinidae: *Osorius* sp. 1 (5), *Priochirus* sp. 1 (4)	1 D
	Log	DC2	D2	Carabidae: *Platynus variabilis* (1) Passalidae: *Heliscus tropicus* (2) Tenebrionidae: *Platydema maculipennis* (3)	1 T
	Log	DC2	D2	Staphylinidae: *Osorius* sp. 1 (2)	0
	Log	DC2	D2	Passalidae: *Heliscus tropicus* (8) Staphylinidae: *Belonuchus* sp. 1 (1)	1 ♂
	Log	DC2	D2	Carabidae: *Platynus variabilis* (2) Passalidae: *Heliscus tropicus* (6)	0
	Log	DC2	D4	Passalidae: *Heliscus tropicus* (1), *Hemiphileurus dejeani* (1)	0
	Log	DC2	D4	Passalidae: *Heliscus tropicus* (1), *Hemiphileurus dejeani* (1) Ptilodactylidae: *Ptilodactyla* sp. (1), Staphylinidae: *Suniocharis* sp. 2 (1)	1 ♂
	Log	DC2	D4	No records	0
	Log	DC3	D1	Carabidae: *Platynus variabilis* (1) Staphylinidae: *Priochirus* sp. 1 (3)	0
	Log	DC3	D1	Passalidae: *Heliscus tropicus* (3) Staphylinidae: *Osorius* sp. 1 (8)	0
	Stump	DC1	D1	Carabidae: *Phloeoxena batesi* (1) Passalidae: *Heliscus tropicus* (2)	0
	Stump	DC2	D1	No records	0
	Stump	DC2	D2	Passalidae: *Hemiphileurus dejeani* (1), *Homalolinus* sp. 1 (2) Tenebrionidae: *Uloma fossulata* (1), *Uloma mexicana* (1)	1 ♂
	Stump	DC3	D3	Staphylinidae: *Suniocharis* sp. 2 (1)	2 ♀

Table 1.—Continued.

Tree species	Pos	Diam	Decay	Beetle species (abundance)	*L. grossus*
Heliocarpus americanus L.	Log	DC1	D1	No records	0
Liquidambar styraciflua var. mexicana Oerst.	Log	DC1	D1	Passalidae: *Heliscus tropicus* (1)	0
	Log	DC1	D1	No records	0
	Log	DC1	D1	Staphylinidae: *Clavilispinus* sp. 1 (1)	0
	Log	DC1	D1	Passalidae: *Proculejus* sp. (7) Staphylinidae: *Osorius* sp. 1 (4), *Priochirus* sp. 1 (2)	1 ♀
	Log	DC1	D2	Passalidae: *Heliscus tropicus* (7) Staphylinidae: *Priochirus* sp. 2 (2)	0
	Log	DC1	D2	Carabidae: *Platynus variabilis* (1) Staphylinidae: *Osorius* sp. 1 (3)	0
	Log	DC1	D2	Passalidae: *Heliscus tropicus* (10) Staphylinidae: *Osorius* sp. 1 (22), *Priochirus* sp. 2 (6)	0
	Log	DC1	D2	Carabidae: *Platynus variabilis* (1) Leiodidae: *Agathidium* sp. (1) Staphylinidae: *Osorius* sp. 1 (1)	0
	Log	DC1	D2	Passalidae: *Heliscus tropicus* (2) Staphylinidae: *Priochirus* sp. 1 (8)	0
	Log	DC1	D3	Passalidae: *Heliscus tropicus* (3), Staphylinidae: *Osorius* sp.1 (3), *Priochirus* sp. 1 (2)	0
	Log	DC1	D4	Passalidae: *Heliscus tropicus* (1) Staphylinidae: *Aleocharinae* sp. 3 (1), *Suniocharis* sp. 1 (1)	2 ♀
	Log	DC1	D4	No records	0
	Log	DC2	D1	No records	0
	Log	DC2	D2	Passalidae: *Heliscus tropicus* (15) Staphylinidae: *Clavilispinus* sp. 1 (1)	0
	Log	DC2	D2	Carabidae: *Pachyteles mexicanus* (5) Passalidae: *Heliscus tropicus* (1), Staphylinidae: *Osorius* sp. 1 (9)	0
	Log	DC2	D3	Passalidae: *Heliscus tropicus* (4)	0
	Log	DC3	D2	No records	1 ♂
	Log	DC4	D2	Passalidae: *Heliscus tropicus* (1)	0
	Stump	DC1	D4	No records	0
	Stump	DC2	D4	Passalidae: *Heliscus tropicus* (1)	0
	Stump	DC2	D4	Carabidae: *Pachyteles mexicanus* (1) Passalidae: *Homalolinus* sp.1 (1) Tenebrionidae: *Diceroderes mexicanus* (3), *Uloma mexicana* (1) Zopheridae: *Verodes asperatus* (1)	1 ♂
	Stump	DC2	D4	No records	0
	Stump	DC3	D1	No records	0
	Stump	DC3	D2	Passalidae: *Pseudacanthus aztecus* (1)	0
	Stump	DC4	D1	Passalidae: *Heliscus tropicus* (2) Staphylinidae: *Leptochirus* sp. 1 (1)	1 ♂
Lonchocarpus guatemalensis Benth.	Log	DC1	D4	Carabidae: *Elaphropus microspilus* (1) Scarabaeidae (Rutelinae): *Macraspis chrysis* (2) Passalidae: *Proculejus* sp. (1)	0
	Log	DC2	D1	Passalidae: *Heliscus tropicus* (1)	0
Quercus corrugata Hook	Log	DC1	D1	Passalidae: *Proculejus* sp. (1)	0
	Log	DC1	D1	Carabidae: *Elaphropus microspilus* (1)	0
	Log	DC1	D1	Carabidae: *Clinidium mexicanum* (2) Passalidae: *Homalolinus* sp. 2 (1) Staphylinidae: *Clavilispinus* sp. 1 (1), *Neoxantholinus* sp. 1 (1)	0
	Log	DC1	D1	Carabidae: *Platynus variabilis* (1), Staphylinidae: *Priochirus* sp. 1 (1)	0
	Log	DC1	D1	Passalidae: *Heliscus tropicus* (2) Staphylinidae: *Misantlius* sp. 1 (2)	0
	Log	DC1	D2	Carabidae: *Platynus amplicollis* (1) Passalidae: *Heliscus tropicus* (1) Staphylinidae: *Osorius* sp. 1 (2)	1 ♀

Table 1.—Continued.

Tree species	Pos	Diam	Decay	Beetle species (abundance)	*L. grossus*
	Log	DC1	D2	Staphylinidae: *Aleocharinae* sp. 2 (1), *Suniocharis* sp.1 (1)	0
	Log	DC1	D2	Passalidae: *Homalolinus* sp.1 (1) Scarabaeidae (Rutelinae): *Parisolea pallida* (1)	0
	Log	DC1	D2	Staphylinidae: *Aleocharinae* sp. 2 (1), *Leptochirus* sp. 1 (2), *Priochirus* sp. 2 (1)	0
	Log	DC1	D2	Staphylinidae: *Leptochirus* sp. 1 (2)	0
	Log	DC1	D2	Carabidae: *Clinidium mexicanum* (1), Staphylinidae: *Aleocharinae* sp. 2 (2), *Clavilispinus* sp. 1 (1), *Clavilispinus* sp. 2 (1), *Suniocharis* sp. 1 (1) Passalidae: *Homalolinus* sp. 1 (1)	1 ♀
	Log	DC1	D2	No records	0
	Log	DC1	D2	Passalidae: *Proculejus* sp. (1)	1 ♂, 2 ♀
	Log	DC1	D3	No records	0
	Log	DC1	D3	Carabidae: *Platynus cupripennis* (1), *Platynus variabilis* (1) Passalidae: *Heliscus tropicus* (2), *Homalolinus* sp. 1 (2)	0
	Log	DC1	D4	Passalidae: *Homalolinus* sp. 2 (2)	1 ♂
	Log	DC2	D3	Staphylinidae: *Osorius* sp. 1 (2)	0
	Log	DC2	D4	Passalidae: *Hemiphileurus dejeani* (1)	0
	Log	DC2	D4	No records	0
	Log	DC2	D1	No records	0
	Log	DC3	D4	No records	0
	Stump	DC2	D2	Carabidae: *Platynus cupripennis* (1) Staphylinidae: *Leptochirus* sp. 2 (1)	0
	Stump	DC2	D2	Passalidae: *Heliscus tropicus* (1)	0
	Stump	DC3	D1	Passalidae: *Heliscus tropicus* (7), *Proculejus* sp. (2) Staphylinidae: *Leptochirus* sp. 1 (4)	0
Quercus glabrescens Benth.	Stump	DC4	D2	No records	0
Quercus oleoides Schltdl. & Cham.	Log	DC1	D4	Staphylinidae: *Euconnus* sp. (1)	0
	Stump	DC1	D2	No records	0
	Stump	DC4	D2	No records	0
	Stump	DC4	D2	No records	0
Tabebuia rosea (Bertol.) DC. (1845)	Stump	DC2	D1	Passalidae: *Heliscus tropicus* (1)	0
Trema micrantha (L.) Blume (1856)	Log	DC2	D1	Passalidae: *Odontotaenius striatopunctatus* (1) Staphylinidae: *Clavilispinus* sp. 1 (2)	0
	Log	DC2	D1	Passalidae: *Heliscus tropicus* (3)	0
	Log	DC2	D1	Staphylinidae: *Bolitogyrus* sp. 1 (1), *Sepedophilus* sp. 1 (1)	0
	Log	DC3	D1	Carabidae: *Elaphropus microspilus* (1) Passalidae: *Heliscus tropicus* (3), *Homalolinus* sp. 1 (1)	0
	Stump	DC1	D1	Staphylinidae: *Priochirus* sp. 2	0
	Stump	DC2	D1	Staphylinidae: *Clavilispinus* sp. 1 (2), *Leptochirus* sp. 1 (1), *Priochirus* sp. 2 (1)	1 ♀
	Stump	DC2	D3	Passalidae: *Heliscus tropicus* (2)	0
	Stump	DC2	D3	Carabidae: *Platynus variabilis* (3) Passalidae: *Heliscus tropicus* (2), *Homalolinus* sp.1 (1)	0
	Stump	DC3	D2	Passalidae: *Hemiphileurus dejeani* (1) Scarabaeidae (Rutelinae): *Macraspis chrysis* (1)	0

may be in the ground or litter, and having detected the trunk, they can enter through a hole, crack or fissure, and (2) through beetles that inhabit these types of microhabitats, such as Passalidae, Cerambycidae and Elateridae, establishing a phoretic relationship, and this is why their life cycles can coincide (Castillo & Villegas-Guzmán 2016).

In summary, *L. grossus* was found in decaying logs and stumps in riparian remnants of cloud forest vegetation. We found that *L. grossus* was mainly associated with *C. mexicana*, though this was also the most commonly collected type of wood in our samples. Passalids are probably playing a key role in the dispersal of pseudoscorpions, being able to colonize decaying wood. The highest number of *L. grossus* were found in wood at decomposition stage D2, the most common decay stage in our wood samples. The highest percentage of samples with associated *L. grossus* was D4, the most decayed. Comparison of stages D1, D2+D3, and D4 suggests a preference for more decayed wood, or that more decayed wood samples are older

Table 2.—Summary of the presence of *Lustrochernes grossus* in wood samples from 11 tree species.

Wood samples	Number of samples	Number of samples with pseudoscorpion(s)	Percent samples with pseudoscorpion(s)
trees w <5 samples*	11	0	0
Annona chirimola	8	1	12.5
Clethra mexicana	21	8	38.1
Liquidambar styraciflua	25	5	20.0
Liquidambar styraciflua	24	4	16.7
Trema micrantha	9	1	11.1

* *Alnus acuminata* (2), *Heliocarpus americanus* (1), *Lonchocarpus guatemalensis* (2), *Quercus glabrescens* (1), *Quercus oleoides* (4), and *Tabebuia rosea* (1)

Table 3.—Summary of the presence of *Lustrochernes grossus* in wood samples at different stages of decay. Intermediate decay levels D2 and D3 are shown separately and combined, as there were few samples at decay stage D3. See text for definitions of decay stages.

Decay Stage:	Number of samples	Number of samples With pseudoscorpion(s)	Percent samples With pseudoscorpion(s)
D1	35	4	11.4
D2	38	9	23.7
D3	8	1	12.5
(D2+D3)	(46)	(10)	(21.7)
D4	17	5	29.4

and have offered more time for colonization by beetles and pseudoscorpion. However, larger sample sizes are needed to test the significance of the associations suggested by this study. Forest fragmentation and firewood extraction may be affecting the distribution and abundance of pseudoscorpions in riparian habitats. This makes it necessary to establish management strategies that ensure the conservation of the habitat of this saproxylic fauna.

ACKNOWLEDGMENTS

We thank Ricardo de Jesús Madrigal-Chavero, Johanna Murillo-Pacheco and Xiomara Velázquez-Landa for their help during the fieldwork. We thank Nathalie Hernández-Quiroz for help with the map. We appreciate Pedro Reyes-Castillo for his invaluable support in identifying passalids. We would like to thank Oscar Francke and two anonymous reviewers for their comments and suggestions on the manuscript. We would like to thank Margaret Schroeder for help with language corrections. The research was supported by the Consejo Nacional de Ciencia y Tecnología, A.C. (CONACYT) with projects CB 2008-101542-F and CB-285962. This work was part of the postdoctoral research of Alfredo Ramírez-Hernández at INECOL, and he thanks the postdoctoral fellowship funded by CONACYT (2015-2016).

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Manuscript received 27 May 2021, revised 6 October 2021, accepted 10 October 2021.