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Diversity of Scolytinae (Coleoptera: Curculionidae) in different landscapes in northern Brazil

Diversidade de Scolytinae (Coleoptera: Curculionidae) em diferentes paisagens no norte do Brasil

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Abstract

A survey of beetle assemblages of the subfamily Scolytinae was conducted in habitat gradients ranging from primary to secondary forests, cocoa plantations, and pastures in the Amazonian biome. Sampling was carried out in 2015, during February/March (rainy season), June (intermediary season), and September/October (dry season). A total of 4,534 Scolytinae were captured, comprising four genera and nine species. The most abundant species were *Xyleborus affinis* and *Xyleborus volvulus*, representing approximately 34% and 31% of the total abundance, respectively. Species of Scolytinae in general showed seasonality and greater abundance and richness in regions with greater coverage of plant litter.

Keywords: Amazon, biodiversity studies, habitat preference, insects.

Resumo

Assembleias de besouros da subfamília Scolytinae foram estudadas em gradientes de habitats que variam de floresta primária a secundária, plantações de cacau e pastagens no bioma Amazônia. A amostragem foi realizada durante o ano de 2015, nos meses de fevereiro/março (estação chuvosa), junho (estação intermediária) e setembro/outubro (estação seca). Um total de 4.534 Scolytinae foi capturado, compreendendo quatro gêneros e nove espécies. As espécies mais abundantes foram *Xyleborus affinis* e *Xyleborus volvulus*, representando aproximadamente 34% e 31% da abundância total, respectivamente. As espécies de Scolytinae em geral mostraram sazonalidade e maior abundância e riqueza em regiões com maior cobertura de serapilheira.

Palavras-chave: Amazônia, estudos de biodiversidade, preferência de habitat, insetos.

Introduction

The Amazon biome is a unique area; it holds the world's largest rainforest and is considered a biodiversity hotspot. It is also important for carbon storage and regional/global regulation of the hydrological cycles and climate (Fernandes, 2009). However, human action has caused, directly or indirectly, the reduction and loss of biodiversity (Cajaiba *et al*., 2015; Cajaiba and Silva, 2017) due to changes in the natural ecological processes and the emergence of new combinations of species, mainly by habitat transformation, fragmentation,

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and damage (Marques *et al*., 2002). Several factors have been identified including the suppression of natural habitats, ecosystem fragmentation, overexploitation of natural resources, climate change, and introduction of alien species. This biodiversity loss threatens the sustainability of the region, with a consequent reduction of environmental services such as pest control, nutrient cycling, and maintenance of soil structure (Cajaiba and Silva, 2015; Valiente-Banuet *et al*., 2015).

Predicting the ecological consequences of land-use/ land-cover changes is, therefore, a subject of great scientific and political interest in order to support strategic options for sustainable development, land-use planning, and natural resource management (Turner *et al*., 2007). In this context, ecological assessment and monitoring are important tools to support effective management of ecosystems and natural resources, and the use of pertinent indicators is crucial to measure and evaluate the status and trends of target environmental systems (Cajaiba and Silva, 2014).

Beetles have characteristics that qualify them as appropriate for ecological studies (Carlton and Robinson, 1998; Didham *et al*., 1998; Cajaiba and Silva, 2015) and for monitoring different compartments of the ecosystem (Marinoni, 2001). Several studies suggest that beetles are strongly associated with habitat structure and factors associated with microclimates (Schwarzkopf and Rylands, 1989; Bishop *et al*., 2009) that can be altered by anthropic activities. For example, beetles respond to environmental disorder, soil depth, local humidity, temperature, soil pH, and pollution (Pearce *et al*., 2003; Kaiser *et al*., 2009; Garcia *et al*., 2010; Negro *et al*., 2010; Vasquez-Velez *et al*., 2010). Beetles have also been shown to indicate successful management and restoration of habitats (Jacobs *et al*., 2010; Paoletti *et al*., 2010; Gomez, 2010).

Beetles of the subfamily Scolytinae (Coleoptera: Curculionidae), with more than 6,000 described species, constitute one of the largest groups of Coleoptera (Eroğlu *et al*., 2005; Sarikaya and Avci, 2011). These beetles, commonly known as bark and ambrosia beetles, colonize living and dead trees (Gandhi *et al*., 2010), with some species causing widespread mortality of coniferous and deciduous trees in forests (Oliver and Mannion, 2001; Gandhi *et al*., 2010). In general, bark beetle larvae feed on the phloem of their host trees, whereas ambrosia beetle larvae feed on the symbiotic fungus inoculated by the mother beetles when they bore into the xylem of their host trees (Rabaglia *et al*., 2006). These insects are well-known forest pests and also play an important role in wood degradation (Gray, 1972). In the Amazon biome, these beetles were also found to attack several forest and fruit trees (Abreu, 1992; Barbosa, 1994; Dall'Oglio and Peres-Filho, 1997; Abreu *et al*., 2012).

The factors that influence the biodiversity of beetles are not clearly known, but the literature shows that structural complexity of vegetation and different environmental disturbances play major roles. Several studies have shown the biology, ecology, and feeding behavior of Scolytinae (Franceschi *et al*., 2005; Rabaglia *et al*., 2006; Fettig *et al*., 2007). However, there is a gap in the knowledge on the Brazilian fauna of Scolytinae, as well as that in the Amazon biome. Thus, we conducted a survey of Scolytinae assemblages, over a wide range of habitats from primary forest to secondary forests, cocoa plantations, and pastures in the Amazon biome, with the aim of supporting future research and adding information about these economically important insects. Specifically, we addressed the following questions: (i) Does the composition of Scolytinae assemblages vary among the different habitats? (ii) Does the diversity of Scolytinae in the Amazon biome differ between seasons?

Material and methods

This study was performed near the city of Uruará, state of Pará, northern Brazil (Figure 1). The territorial extension of the municipality is 10796 km² and its population encompasses circa 44789 inhabitants. The dominant land use/ land cover (LU/LC) is natural forest (69% of the area) and deforestation is concentrated mainly in the south-central part of territory and near the main roads. Extensive livestock production and the exploitation of timber at a large scale (mostly illegal) are currently considered the most serious environmental threats (Cajaiba, 2014). The studied habitats contain pertinent gradients, in terms of biophysical and ecological characteristics, for testing the response of Scolytinae communities facing the main anthropogenic drivers. These gradients encompass: Native Vegetation – NV, Early Secondary succession – ES (vegetation with five years of regeneration), Mature Secondary succession – MS (vegetation with 15 years of regeneration), Agriculture – Ag (cocoa plantations, *Theobroma cacao* L.) and Pasture for extensive livestock – Pa. The climate is classified as Aw (Köppen), hot and humid and the average annual rainfall is 2000 mm (Cajaiba *et al*., 2015).

Sampling was carried out during the year 2015, in the months of February/March (rainy season), June (final of rainy season and early dry season) and September/October (dry season). This allowed integrating eventual seasonal differences in the activity of Scolytinae. The sample points were placed at a minimum distance of 100 meters from ecotones, to ensure that most beetles captured were associated to the habitats in study. Pitfall traps with 75 mm diameter and 110 mm deep were filled with preservative liquid consisting of formalin, alcohol, water and a few drops of detergent to break the surface tension. A roof was attached to each trap to prevent rainwater from entering the trap, remaining installed for 48 h prior to collection.

In each study site (NV, MS, ES, Ag and Pa) seven sample points were placed 100 m apart. Each sample point

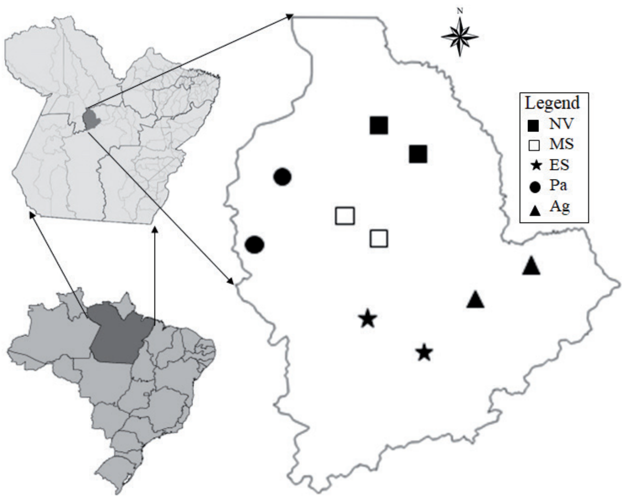

Figure 1. Location of the study area in the municipality of Uruará, state of Pará, northern Brazil with sampled habitats: Ag, Agriculture; ES, Early secondary succession; MS, Mature secondary succession; NV, Native vegetation; Pa, Pasture.

contained four pitfall traps separated by 5 meters. This protocol was applied to all areas and periods of collections, totalizing a sampling effort of 840 traps.

The Temperature-T, Humidity-H and Precipitation-P of each point were measured during the traps installation and removal with a portable weather station (model Oregon Scientific WMR200A). Data about Percentage of Exposed Soil-PES, Percentages of Leaf Litter Cover-PLC, Height of Leaf Litter-HLL were also collected. To assess the environmental complexity of each sampling site, the quadrat-section method was adopted (Campos and Hernández, 2015). Using a cross as a reference, four quadrants (northeast, northwest, southeast, southwest) were marked and, in each quadrant the following variables were measured: the HLL was measured with a ruler in 1 m × 1 m marked squares (using a PVC pipe), and the percentages of PLC and PES were measured by visual estimation using the following classes, 0-5%, 6-25%, 26-50%, 51-75%, 76-95% and 96-100% (Campos and Hernández, 2015).

Richness (S) and abundance (N) of each sampling site were measured and differences among sites were gauged using One-Way-Analysis-of-Variance (ANOVA). ANOVA was also applied to find differences in the seasonality of Scolytinae, using a Tukey's post-hoc test. The normality of the data was verified by the Shapiro-Wilk test.

The Bray-Curtis cluster analysis was applied to verify the similarity between different habitats, and UPGMA algorithm was used to draw the distance based on Bray-Curtis index. This index ranges between 0 (indicating no similarity in community composition between sites) and 1 (indicating complete overlap), and it is considered one of the most robust measures of community similarity (Magurran, 2004). The cophenetic correlation coefficient was used to verify the result significance of the cluster analysis. Multiple multivariate regressions were applied to analyze the relationship between the dependent (abundance and richness of Scolytinae) and predictive (T, H, P, PLC, HLL and PES) variables.

Results and discussion

A total of 4,534 Scolytinae, distributed in four genera and nine species, was captured. Of these, we identified 854 individuals of all species in natural vegetation (NV), eight species (1116 individuals) in mature secondary succession (MS), seven species (244 individuals) in early secondary succession (ES), four species (2,028 individuals) in agriculture (Ag), and two species (292 individuals) in pasture (Pa). The genus *Xyleborus*, with 4,514 individuals, was prevalent in all ambrosia beetle communities, comprising 99.5% of all specimens captured. The most abundant species were *Xyleborus affinis* Eichhoff 1868, with 1,526 individuals (approximately 34% of the total abundance), and *Xyleborus volvulus* Fabricius 1775, with 1,386 individuals (approximately 31% of the total abundance). *Xyleborus volvulus* was more abundant in Ag (506 individuals) and NV (300 individuals), whereas *X. affinis* was more abundant in MS (382 individuals), followed by Pa (210 individuals) and ES (58 individuals) (Table 1).

The fact that the genus *Xyleborus* presented the greatest abundance and richness is consistent with the results of several studies (Abreu *et al*., 2012; Kendra *et al*., 2011; Meurer *et al*., 2013). Although beetles of this genus may be considered beneficial, because they favor natural disbranching and contribute to degradation of wood waste in reforested areas, some species may cause high negative economic impacts, damaging large amounts of fresh-cut or stored wood (Wood, 1982; Meurer *et al*., 2013).

The species *X. affinis* and *X. volvulus* were the most abundant in all studied habitats, corroborating the results of Meurer *et al*. (2013). *X. affinis*, considered one of the most aggressive ambrosia beetle species in Brazil and other tropical regions (Beaver, 1976; Meurer *et al*., 2013), is abundant above the Tropic of Capricorn (Meurer *et al*., 2013). Beaver (1976), in a study conducted in a native forest of Mato Grosso, stressed the importance of *X. affinis* in the area, noting that the wetter the region, the better was the adaptation. According to this author, *X. affinis* apparently has no preference for hosts and may attack a wide range of plants, including herbs and lianas. The strong dominance of *X. affinis* can be explained by interspecific competition, considering that fast-growing species are more destructive and reduce the resources available for other plant species (Abreu *et al*., 1997).

The Scolytinae species richness varied significantly among the study sites ($F_{4,415} = 223.1$, $p < 0.0001$). The av-

Table 1. Species of Scolytinae collected in different habitats and their abundance in different seasons in the municipality of Uruará, state of Pará, northern Brazil. Ag, Agriculture; ES, Early secondary succession; MS, Mature secondary succession; NV, Native vegetation; Pa, Pasture. The letters R, I and D following the vegetation types correspond to the rainy, intermediary and dry seasons, respectively.

Species	NV			MS			ES			Ag			Pa		
	R	I	D	R	I	D	R	I	D	R	I	D	R	I	D
Xyleborus volvulus	104	196	32	144	116	24	34	20	18	260	246	110	34	38	10
Xyleborus affinis	74	130	38	210	156	16	38	20	18	250	238	128	110	90	10
Xyleborus ferrugineus	32	64	16	58	64	18	24	0	2	156	136	48	0	0	0
Xyleborus sp.1	14	38	30	72	56	8	18	8	0	134	132	38	0	0	0
Xyleborus sp.2	18	12	24	58	42	8	12	0	0	70	82	0	0	0	0
Xyleborus sp.3	8	6	8	24	30	6	18	10	0	0	0	0	0	0	0
Xylosandrus sp.	0	4	0	0	2	0	4	0	0	0	0	0	0	0	0
Coccotrypes sp.	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypothenemus sp.	2	2	0	2	2	0	0	0	0	0	0	0	0	0	0

erage species richness was significantly higher in NV and Ag ($p < 0.01$) than in the other habitats. The second largest species richness was observed in MS ($p < 0.05$). The lowest species richness was found in Pa ($p < 0.05$) (Figure 2a). The Scolytinae abundance also varied significantly among the study sites ($F_{4,415} = 123.8$, $p < 0.0001$). The mean abundance was significantly higher in Ag ($p < 0.01$) than in the other sites. The second largest mean abundance rate was observed in MS ($p < 0.05$) (Figure 2b).

According to Bray-Curtis similarity index and cluster analysis, a greater similarity was observed between NV and MS (0.77) (cophenetic correlation coefficient = 0.90) (Figure 3).

Predictive variables were significant for Scolytinae abundance ($F_{6,413} = 84.5$, $R^2 = 0.55$, $p < 0.001$) and richness ($F_{6,413} = 158.9$, $R^2 = 0.70$, $p < 0.001$). The variable HLL best explained the abundance and richness of Scolytinae (Table 2).

The fact that Ag had the highest abundance and species richness can be explained by the high HLL in these areas. On the other hand, ES and Pa are typically characterized by a relatively more open canopy with reduced occurrence of sub-forest warm and dry environment, as well as lower amounts of litter on the ground, which may explain the impoverishment observed in the Scolytinae communities. The influence of environments with greater litterfall rates

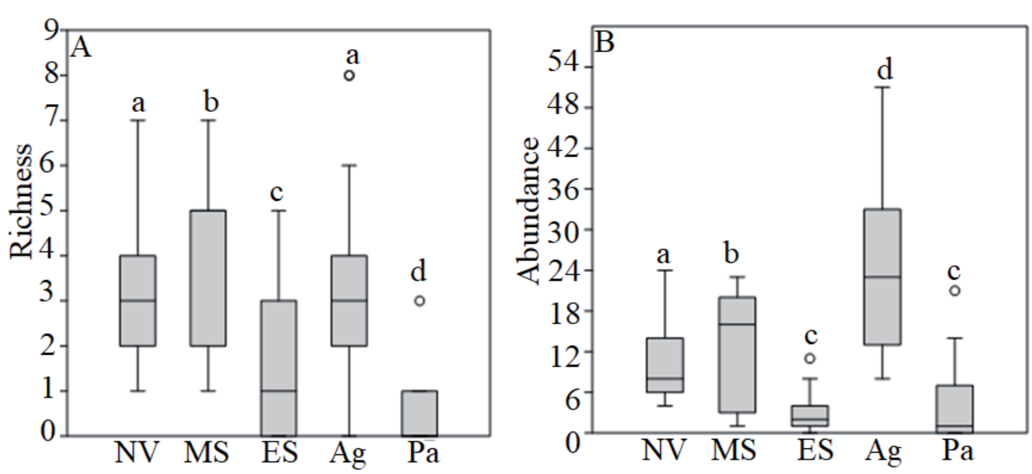

Figure 2. Box and Whisker plots expressing the differences in the projected values for (a) species richness (± SE) and (b) number of individuals (± SE) of Scolytinae in different habitats in the municipality of Uruará, state of Pará, northern Brazil. The values followed by the same letters are not significantly different according to Tukey test. Ag, Agriculture; ES, Early secondary succession; MS, Mature secondary succession; NV, Native vegetation; Pa, Pasture. Circles in the figures indicate the outliers.

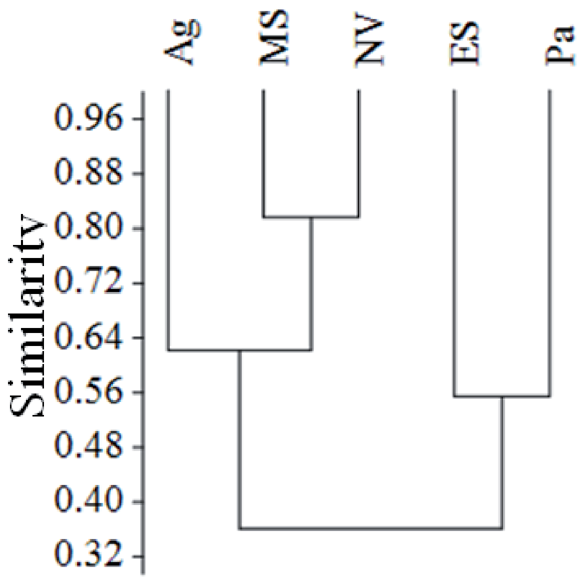

Figure 3. Bray-Curtis similarity index for the different habitats sampled (cophenetic correlation coefficient = 0.90) in the municipality of Uruará, state of Pará, northern Brazil. Ag, Agriculture; ES, Early secondary succession; MS, Mature secondary succession; NV, Native vegetation; Pa, Pasture.

on the distribution of the Scolytinae community can be confirmed by the high density of these individuals in Ag, MS, and NV. These habitats have greater amounts of material that can favor the development of vegetable debris, trunks, and broken branches, providing ideal conditions for the rapid population growth of Scolytinae species. The diversity of arthropod communities is related to the structural complexity of the habitat. More complex environments have a greater number of beetle species because of the greater supply of ecological niches for these organisms (Schaffers *et al*., 2008).

With respect to the seasonality of Scolytinae, of the nine species sampled, six (approximately 67%) were available in the three periods surveyed. *Hypothenemus* sp. was collected only in the rain season, whereas *Xylosandrus* sp. and *Coccotrypes* sp. were exclusive to the intermediary season (Table 1). A statistically significant difference in abundance was noted among the sampling seasons ($F_{2,41}$ = 81.76, $p < 0.001$), but no differences were noted between the averages of the rainy and intermediary seasons ($p > 0.05$). The dry season showed lower abundance, being statistically shorter than the other seasons ($p < 0.001$) (Figure 4a). Species richness also showed differences between the sampling seasons ($F_{2,41}$ = 21.53, $p < 0.001$). No differences were noted between the averages of the rainy and intermediary seasons ($p > 0.05$), but the dry season showed lower species richness, being statistically shorter than the other seasons ($p < 0.001$) (Figure 4b).

The abundance and richness of Scolytinae tended to show a seasonal distribution in a year, with less number of individuals and species occurring during the dry season than during the heavy rainfall season. This significant difference in the population of Scolytinae throughout the year was also observed by Flechtmann *et al*. (2001). According to Wood (1982), temperature and humidity are the two most important factors in the micro-climate of the galleries of Scolytinae species. Those belonging to the genus *Xyleborus*, in particular, reduced the growth of fungi they feed on. However, additional studies are needed to understand the extent of these changes, especially in light of the potential effects of climate change (Maveety *et al*., 2014). Seasonal variations in diversity and composition emphasize the influence of phenology on survey timing in studying Scolytinae/habitat associations. Moreover, seasonal information on Scolytinae beetle is essential to understand the relevant ecological processes and, thus, the related management aspects. Asynchronous seasonal cycles may contribute to the reduction of interspecific competition among Scolytinae.

Our study should be complemented by ecological and behavioral studies to understand and assess the preservation status of the habitats considered (Brown, 1997). Eco-

Table 2. Multivariate regressions between environmental variables and ecological indices (abundance and richness) of Scolytinae collected in the municipality of Uruará, state of Pará, northern Brazil. H, Humidity; HLL, Height of Leaf Litter; P, Precipitation; PES, Percentage of Exposed Soil; PLC, Percentages of Leaf Litter Cover; T, Temperature.

Variables	Abundance				Richness			
	Coeff. (± SE)	T	P	R2	Coeff. (± SE)	T	p	R2
T	-0.718 (±0.37)	-1.92	0.53	0.12	0.135 (±0.04)	2.72	0.001	0.24
H	-0.050 (±0.05)	-0.88	0.05	0.12	0.074 (±0.00)	9.83	0.001	0.28
P	0.032 (±0.00)	5.89	0.37	0.08	-0.002 (±0.01)	-3.79	0.0001	0.04
HLL	6.750 (±0.43)	15.35	0.001	0.35	0.776 (±0.05)	13.28	0.000	0.44
PLC	-0.130 (±0.02)	-5.39	0.001	0.17	0.020 (±0.01)	6.40	0.001	0.41
PES	0.964 (±0.22)	4.23	0.01	0.18	0.333 (±0.03)	11.02	0.001	0.25

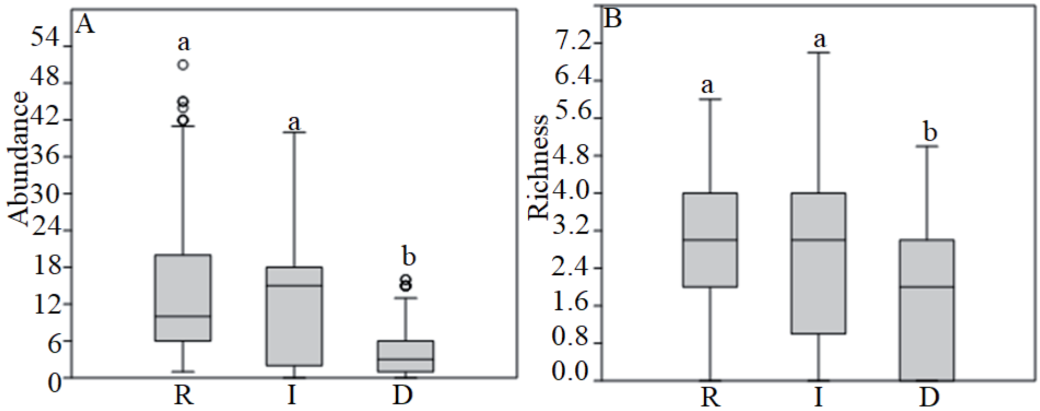

Figure 4. Scolytinae community in different periods of sampling in the municipality of Uruará, state of Pará, northern Brazil: (a) number of individuals (± SE) and (b) number of species (± SE). The values followed by the same letters are not significantly different according to Tukey test. D: Dry; I: Intermediary; R: Rain. Circles in the figures indicate outliers.

logical assessment and monitoring are important procedures to ensure effective management of ecosystems and natural resources. The use of indicators of ecosystem integrity is considered crucial to measure and assess the status and trends of target environmental systems (Kandziora *et al*., 2013).

References

ABREU, R.L.S. 1992. Estudos sobre a ocorrência de Scolytidae e Platypodidae em madeiras da Amazônia. *Acta Amazonica,* **22**(3):413-420. https://doi.org/10.1590/1809-43921992223420

ABREU, R.L.S.; FONSECA, C.R.; MARQUES, E.N. 1997. Análise das principais espécies de Scolytidae coletadas em floresta primária no estado do Amazonas. *Anais da Sociedade Entomológica do Brasil*, **26**(3):527-35. https://doi.org/10.1590/S0301-80591997000300016

ABREU, R.L.S.; RIBEIRO, G.A.; VIANEZ, B.F.; SALES-CAMPOS, C. 2012. Insects of the subfamily Scolytinae (Insecta: Coleoptera, Curculionidae) collected with pitfall and ethanol traps in primary forests of Central Amazonia. *Psyche*, **2012**(1):1-8. https://doi.org/10.1155/2012/480520

BARBOSA, M.G.V. 1994. *Contribuição ao conhecimento da Coleopterofauna visitante de cupuaçu (*Theobroma grandiflorum *[Willdenow ex Sprengel]) Schumman em um bairro de Manaus, Amazonas.* Manaus, AM. Dissertação de Mestrado, INPA/FUA.

BEAVER, R.A. 1976. Biological studies of Brazilian Scolytidae and Platypodidae (Coleoptera).V. The tribe *Xyleborini*. *Journal of Applied Entomology*, **80**(1-4):15-30. https://doi.org/10.1111/j.1439-0418.1976.tb03293.x

BISHOP, D.J.; MAJKA, C.G.; BONDRUP-NIELSEN, S.; PECK, S.B. 2009. Dead-wood and saproxylic beetle diversity in naturally disturbed and managed spruce forests in Nova Scotia. *Zookeys*, **22**(17):309-340. https://doi.org/10.3897/zookeys.22.144

BROWN, K.S. 1997. Diversity, disturbance, and sustainable use of Neotropical forests: insects as indicators for conservation monitoring. *Journal Insect of Conservation*, **1**(1):25-42. https://doi.org/10.1023/A:1018422807610

CAJAIBA, R.L. 2014. Morcegos (Mammalia, Chiroptera) em cavernas no município de Uruará, Pará, norte do Brasil. *Biota Amazônia*, **4**(1):81-86. https://doi.org/10.18561/2179-5746/biotaamazonia.v4n1p81-86

CAJAIBA, R.L.; PERICO, E.; CABRAL, J.A.; SANTOS, M. 2015. Assessing the Potential Role of Ground Beetles (Coleoptera) as Ecological Indicators in Tropical Ecosystems: A Review. *In:* C. STACK (Ed.), *Beetles: Biodiversity, Ecology and Role in the Environment*. 1ª ed., New York, Nova Science Publishers, p. 51-84.

CAJAIBA, R.L.; SILVA, W.B. 2017. Diversidade e sazonalidade de Cydnidae (Insecta: Hemiptera: Heteroptera) em diferentes ecossistemas no estado do Pará, norte do Brasil. *Revista Brasileira de Biociências*, **15**(1):32-37.

CAJAIBA, R.L.; SILVA, W.B. 2014. Mirmecofauna (Hymenoptera, Formicidae) em fragmento florestal urbano no município de Uruará-PA. *Enciclopédia Biosfera*, **10**(18):2226-2238.

CAJAIBA, R.L.; SILVA, W.B. 2015. Abundância e Diversidade de Coleópteros de Solo em Fragmentos de Capoeira ao Entorno da Zona Urbana do Município de Uruará-PA, Brasil. *EntomoBrasilis*, **8**(1):30-37. https://doi.org/10.12741/ebrasilis.v8i1.414

CAMPOS, R.C.; HERNÁNDEZ, M.I.M. 2015. Changes in the dynamics of functional groups in communities of dung beetles in Atlantic forest fragments adjacent to transgenic maize crops. *Ecological Indicators*, **49**(9):216-227. https://doi.org/10.1016/j.ecolind.2014.09.043

CARLTON, C.E.; ROBINSON, H.W. 1998. Diversity of litter-dwelling beetles in the Ouachita highlands of Arkansas, USA (Insecta: Coleoptera). *Biodiversity and Conservation*, **7**(12):1589-1605. https://doi.org/10.1023/A:1008840427909

DALL'OGLIO, O.T.; PERES FILHO, O. 1997. Levantamento e flutuação populacional de coleobrocas em plantios homogêneos de seringueira em Itiquira-MT, Brasil. *Scientia Forestalis*, **51**(1):45-58.

DIDHAM, R.K.; HAMMOND, P.M.; LAWTON, J.H.; EGGLETON, P.; STORK, N.E. 1998. Beetles species responses to Tropical Forest fragmentation. *Ecological Monographs*, **68**(3):295-323. https://doi.org/10.1890/0012-9615(1998)068[0295:BSRTTF] 2.0.CO;2

EROĞLU, M.; ALKAN-AKINCI, H.; ÖZCAN, G.E. 2005. Kabuk böceği Salgınlarının Nedenleri ve Boyutları. *Orman ve Av Dergisi*, **5**(1):27-34.

FERNANDES, A.L. 2009. The social and environmental impacts of industrial agriculture in the Legal Amazon. *In*: Simpósio Brasileiro de Sensoriamento Remoto, XIV, Natal. *Anais*… p. 159-165.

FETTIG, C.J.; KLEPZIG, K.D.; NOWAK, J.T. 2007. The effectiveness of vegetation management practices for prevention and control of bark beetle infestations in coniferous forests of the western and southern United States. *Forest Ecology and Management*, **238**(1-3):24-53. https://doi.org/10.1016/j.foreco.2006.10.011

FLECHTMANN, C.A.H.; OTTATI, A.L.T.; BERISFORD, C.W. 2001. Ambrosia and bark beetles (Scolytidae: Coleoptera) in pine and eucalypt stands in southern Brazil. *Forest Ecology and Management*, **142**(1-

3):183-191. https://doi.org/10.1016/S0378-1127(00)00349-2
FRANCESCHI, V.R.; KROKENE, P.; KREKLING, T. 2005. Anatomical and chemical defenses of conifer bark against bark beetles and other pests. *New Phytologist*, **167**(2):353-376.
https://doi.org/10.1111/j.1469-8137.2005.01436.x
GANDHI, K.J.K.; COGNATO, A.I.; NIELSEN, D.G.; HERMS, D.A. 2010. Species Composition, Seasonal Activity, and Semiochemical Response of Native and Exotic Bark and Ambrosia Beetles (Coleoptera: Curculionidae: Scolytinae) in Northeastern Ohio. *Journal of Economic Entomology*, **103**(4):1187-1195. https://doi.org/10.1603/EC10026
GARCIA, M.; ORTEGO, F.; CASTANERA, P.; FARINOS, G.P. 2010. Effects of exposure to the toxin Cry1Ab through Bt maize fed-prey on the performance and digestive physiology of the predatory rove beetle *Atheta coriaria*. *Biological Control*, **55**(3):225-233.
https://doi.org/10.1016/j.biocontrol.2010.08.002
GOMEZ, A.D. 2010. Activity density versus biomass distribution patterns among ground-beetle species as bioindicator for conservation planning over a wide range of altitudes in Tenerife (Canary Islands). *Ecological Indicators*, **10**(6):1213-1217.
https://doi.org/10.1016/j.ecolind.2010.03.017
GRAY, B. 1972. Economic tropical forest entomology. *Annual Review of Entomology*, **17**(1):313-354.
https://doi.org/10.1146/annurev.en.17.010172.001525
JACOBS, C.T.; SCHOLTZ, C.H.; ESCOBAR, F.; DAVIS, A.L.V. 2010. How might intensification of farming influence dung beetle diversity (Coleoptera: Scarabaeidae) in Maputo Special Reserve (Mozambique)? *Journal of Insect Conservation,* **14**(4):389-399.
https://doi.org/10.1007/s10841-010-9270-x
KAISER, W.; AVENANT, N.L.; HADDAD, C.R. 2009. Assessing the ecological integrity of a grassland ecosystem: the applicability and rapidity of the SAGraSS method. *African Journal of Ecology*, **47**(3):308-317. https://doi.org/10.1111/j.1365-2028.2008.00962.x
KANDZIORA, M.; BURKHARD, B.; MÜLLER, F. 2013. Interactions of ecosystem properties, ecosystem integrity and ecosystem service indicators - a theoretical matrix exercise. *Ecological Indicators*, **28**(1):54-78. https://doi.org/10.1016/j.ecolind.2012.09.006
KENDRA, P.E.; SANCHEZ, J.S.; EPSKY, N.D.; HEATH, R.R. 2011. Diversity of Scolytinae (Coleoptera: Curculionidae) attracted to avocado, lychee, and essential oil lures. *Florida Entomologist*, **94**(2):123-130. https://doi.org/10.1653/024.094.0201
MAGURRAN, A.E. 2004. *Measuring biological diversity*. 2ª ed., Oxford, Blackwell Science Ltd., 266 p.
MARINONI, R.C. 2001. Os grupos tróficos em Coleoptera. *Revista Brasileira de Zoologia*, **18**(1):205-224.
https://doi.org/10.1590/S0101-81752001000100024
MARQUES, A.A.B.; FONTANA, C.S.; VÉLEZ, E.; BENCKE, G.A.; SCHNEIDER, M.; REIS, R.E. 2002. *Lista de Referência da Fauna Ameaçada de Extinção no Rio Grande do Sul*. Decreto nº 41.672, de 10 de junho de 2002. Porto Alegre, FZB/MCTPUCRS/PANGEA.
MAVEETY, S.A.; BROWNE, R.A.; ERWIN, T.L. 2014. Carabid beetle diversity and community composition as related to altitude and seasonality in Andean forests. *Studies on Neotropical Fauna and Environment*, **48**(3):165-174. https://doi.org/10.1080/01650521.2013.873266
MEURER, E.; BATTIROLA, L.D.; COLPANI, D.; MARQUES, M.I. 2013. Scolytinae (Coleoptera, Curculionidae) associados a diferentes fitofisionomias no Pantanal de Cáceres, Mato Grosso. *Acta Biológica Paranaense*, **42**(1):195-210. https://doi.org/10.5380/abpr.v42i1-4.35214
NEGRO, M.; ISAIA, M.; PALESTRINI, C.; SCHOENHOFER, A.; ROLANDO, A. 2010. The impact of high-altitude ski pistes on ground-dwelling arthropods in the Alps. *Biodiversity and Conservation*, **19**(7):1853-1870. https://doi.org/10.1007/s10531-010-9808-y
OLIVER, J.B.; MANNION, C.M. 2001. Ambrosia beetle (Coleoptera: Scolytidae) species attacking chestnut and captured in ethanol-baited traps in middle Tennessee. *Environmental Entomology*, **30**(5):909-918. https://doi.org/10.1603/0046-225X-30.5.909
PAOLETTI, M.G.; D'INCA, A.; TONIN, E.; TONON, S.; MIGLIORINI, C.; PETRUZZELLI, G.; PEZZAROSSA, B.; GOMIERO, T.; SOMMAGGIO, D. 2010. Soil invertebrates as bio-indicators in a natural area converted from agricultural use: the case study of Vallevecchia-Lugugnana in north-eastern Italy. *Journal of Sustainable Agriculture*, **34**(1):38-56. https://doi.org/10.1080/10440040903396698
PEARCE, J.L.; VENIER, L.A.; MCKEE, J.; PEDLAR, J.; MCKENNEY, D. 2003. Influence of habitat and microhabitat on Carabid (Coleoptera: Carabidae) assemblages in four stand types. *Canadian Entomologist*, **135**(1):337-357. https://doi.org/10.4039/n02-031
RABAGLIA, R.J.; DOLE, S.A.; COGNATO, A.I. 2006 Review of American *Xyleborina* (Coleoptera: Curculionidae: Scolytinae) occurring North of Mexico, with an illustrated key. *Annals of the Entomological Society of America*, **99**(6):1034-1056.
https://doi.org/10.1603/0013-8746(2006)99[1034:ROAXCC]2.0.CO;2
SARIKAYA, O.; AVCI, M. 2011. Bark beetle fauna (Coleoptera: Scolytinae) of the coniferous forests in the Mediterranean region of Western Turkey, with a new record for Turkish fauna. *Turkish Journal of Zoology*, **35**(1):33-47. https://doi.org/10.3906/zoo-0901-8
SCHAFFERS, A.P.; RAEMAKERS, I.P.; SÝKORA, K.V.; BRAAK, C.J.F. 2008. Arthropod assemblages are best predicted by plant species composition. *Ecology*, **89**(3):782-794. https://doi.org/10.1890/07-0361.1
SCHWARZKOPF, L.; RYLANDS, A. B. 1989. Primate species richness in relation to habitat structure in Amazonian rainforest fragments. *Biological Conservation*, **48**(1):1-12.
https://doi.org/10.1016/0006-3207(89)90055-4
TURNER, B.L.I.; LAMBIN, E.F.; REENBERG, A. 2007. The emergence of land change science for global environmental change and sustainability. *Proceedings of the National Academy of Sciences*, **104**(52):20666-20671. https://doi.org/10.1073/pnas.0704119104
VALIENTE-BANUET, A.; AIZEN, M. A.; GARCÍA, D.; GÓMEZ, J. M.; JORDANO, P. 2015. Beyond species loss: the extinction of ecological interactions in a changing world. *Functional Ecology*, **29**(3):299-307. https://doi.org/10.1111/1365-2435.12356
VASQUEZ-VELEZ, L.M.; BERMUDEZ, C.; CHACON, P.; LOZANO-ZAMBRANO, F.H. 2010. Analysis of the richness of Staphylinidae (Coleoptera) on different scales of a sub-Andean rural landscape in Colombia. *Biodiversity and Conservation*, **19**(7):1917-1931.
https://doi.org/10.1007/s10531-010-9812-2
WOOD, S.L. 1982. *The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae), a taxonomic monograph*. Provo, Brigham Young University, 1359 p.

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