Preliminary assessment of beetle diversity in a fragmented landscape of the Ecuadorian tropical dry forest

Evaluación preliminar de la diversidad de escarabajos en un paisaje fragmentado del bosque seco tropical ecuatoriano

Stefania León-Parrales [1]
https://orcid.org/0000-0002-8111-8486
genesisleon_98@hotmail.com

Taryn Ghia [2]
https://orcid.org/0000-0001-6212-5501
tarynghia@yahoo.com

Jaime A. Salas [1,3]
https://orcid.org/0000-0003-3468-5178
jaime.salasz@ug.edu.ec

Andrea E. Narváez * [4,5]
https://orcid.org/0000-0002-5953-9233
aenarvgarc@gmail.com

*Corresponding author

1. Universidad de Guayaquil, Facultad de Ciencias Naturales, Carrera de Biología, Guayaquil, Ecuador.

2. Museo QCAZ Invertebrados, Facultad de Ciencias Exactas y Naturales, Pontificia Universidad Católica del Ecuador, Quito, Ecuador.

3. Instituto Nacional de Biodiversidad, Investigador Asociado, Quito, Ecuador.

4. Universidad Espíritu Santo-Ecuador, Km2.5 vía Samborondón, Samborondón, Ecuador.

5. Fundación Great Leaf, De las Azucenas N47-60 y Av. Eloy Alfaro Quito, Ecuador.

Abstract

Landscape alterations may affect beetle assemblages wherein sensitive species can disappear, and highly adapted species populations can increase. Beetle diversity in a restored forest and cropland was assessed in the tropical dry forest of Ecuador. Pitfall trapping and manual collection were performed in three sites: two sites with cropland and one site with secondary forest remnant. Four bait types were used to attract beetles feeding on different resources to achieve an adequate preliminary beetle assessment. This study is the first approach to characterizing the coleopteran community in the tropical dry forest of Manabí. We report 64 morphospecies associated with productive land and fragmented forests and highlight the occurrence of some resilient genera like *Canthon*, *Canthidium*, *Deltochilum* and *Euspilotus* that have successfully adapted to disturbed ecosystems; on the other hand, *Phyllophaga* and *Diabrotica* were also detected mainly in the crop landscape. Overall, present a baseline of the beetle assemblage composition in a secondary forest and cropland, and provide relevant information for further assessment of land use change in the region.

Resumen

Las alteraciones del paisaje pueden afectar los ensambles de escarabajos donde las especies sensibles pueden desaparecer y las poblaciones de especies altamente adaptadas pueden aumentar. Se evaluó la diversidad de escarabajos en un bosque restaurado y tierras de cultivo del bosque seco tropical de Ecuador. Se realizó trampas de caída y recolección manual en tres sitios; dos sitios con tierras de cultivo y un sitio con remanente de bosque secundario. Se usaron cuatro tipos de cebo para atraer escarabajos que se alimentaban de diferentes recursos para lograr una evaluación preliminar adecuada del ensamble de escarabajos. Este estudio es la primera aproximación a la caracterización de la comunidad de coleópteros en el bosque seco tropical de Manabí. Reportamos 64 morfoespecies asociadas con tierras productivas y bosques fragmentados y destacamos la presencia de algunos géneros resilientes como *Canthon*, *Canthidium, Deltochilum* y *Euspilotus* que se han adaptado con éxito a ecosistemas perturbados; por otro lado, *Phyllophaga* y *Diabrotica* también fueron detectados principalmente en el paisaje de cultivos. En general, presentamos una línea de base de la composición de escarabajos en un bosque secundario y tierras de cultivo, y brindamos información relevante para una evaluación adicional del cambio de uso del suelo en la región.

Keywords:
Beetles, secondary forest, coprophages, insect pests, dry forest.

Palabras Clave:
Escarabajos, bosque secundario, coprófagos, plaga de insectos, bosque seco.

Introduction

The expansion of the agricultural frontier has resulted in the depletion of high-quality forests, leading to biodiversity loss and alterations in fauna composition (Carrillo et al. 2007, Murillo et al. 2016). One of the most threatened ecosystems in Ecuador is the dry forest, which occurs in continuous stretches along the coast and in isolated valleys within the Andean region (Troya 2016). This ecosystem has been subjected to human pressure, including non-sustainable agricultural practices such as weed burning, the intensive use of pesticides, and intense livestock farming (Hernandez Camacho 1992; Laurance & Bierregaard 1997, Amador & Martínez 2011). These practices have put the ecosystem at risk and threaten the survival of the species that depend on it. The Manabí province forest, which belongs to the Cordillera Chongón Colonche ecosystem, has experienced secondary succession for at least 40 years, resulting in the re-establishment of the native dry forest vegetation in abandoned croplands (Pourrt 1998). Allowing for secondary succession is of great importance to promote a healthier ecosystem through natural processes, leading to more diverse composition of flora and fauna compared to productive lands (Caamal-Maldonado & Armendariz-Yañez 2002). A case in point is Cascol town in Manabí province, situated at the center of the Ecuadorian coastal region, where landscape regeneration has been ongoing over the last four decades.

While existing biological research has primarily focused on botanical and ecological aspects of these ecosystems, there has been relatively limited investigation into insect populations (Troya 2016, Moreira & Arias 2019). Insects plays an important role in ecosystem health, meaning that changes to their population and species composition can have significant impacts. Coleopterans, a particularly abundant group of insects, serve as excellent models for studying ecosystem health. The use of coleopterans as bioindicators of ecological disturbance and forest health is based on the ability of some species to respond rapidly to environmental changes caused by anthropogenic activities (Noss 1990, Halffter 1993, Celi & Dávalos 2001, Albrecht 2003, Pearce & Venier 2006). These organisms are extremely sensitive to environmental alterations such as pollution, plant succession, and ecosystem degradation (Escobar & Chacón 2000). Landscape degradation, such as monocultures, may affect their physiological performance and ecological preferences, triggering species displacement towards healthier ecosystems, sensitive species disappearance, or an accelerated increase of highly adaptable species (Noss 1990, Wink et al. 2005). Conversely, landscape regeneration tends to foster increased insect diversity or recovery of specific groups, compared to insect communities in agricultural settings and plantations. For example, both Miss and Cuauhtemoc (2007) and Alvarado and Osorio (2020) noted an increase in the diversity of coprophagous and saproxylophagous beetles in regenerating primary and secondary forests, coinciding with vertebrate mobility and natural vegetation decomposition.

The study of beetle assemblages in farmland and secondary forests is essential for assessing ecosystem health and the dynamics of beetle communities (Muñoz et al. 2015). Furthermore, for any conservation initiative to be effective, it is necessary to have basic information of the diversity of beetles and the experimental designs applied for monitoring (Caamal-Maldonado & Armendariz-Yañez 2002). This background motivated the present work, focused on the fragmented landscape of the Cascol (Manabí province); we present preliminary information on the diversity of tropical dry forest beetles by comparing cropland and secondary forest in regeneration. This research aims to contribute to a better understanding of the beetle communities in this ecosystem to reinforce conservation efforts in the region.

Material and methods

Study sites and sampling. Field work took place in December 2020, in El Descanso community (1°44´S, 80°29´ W, 555 m of altitude) located in Cascol, Paján Municipality (Manabí province), within the Cordillera Chongón Colonche (CCHC) ecosystem in the center of the Ecuadorian coastal region (Bonifaz & Cornejo 2004). The sampling period overlapped with the beginning of the rainy season. Cascol vegetation cover is characterized by tropical dry forests; the annual rainfall in this area is 2500 mm and has an average annual temperature of 24 °C (Muñoz et al. 2015).

Nine transects of 200 m long were established in three sampling sites (three transects per site) covering an approximately 30 ha total area: two inorganic corn croplands and one secondary forest (Fig. 1). Agrochemicals are used for pest control and fertilization in the cropland; however, during the entire survey no chemical compounds were applied. The forested area has been through a regeneration process for about four decades. Transects were separated between each other by 20 m and were all placed in the center of the property to avoid edge effects. 20 pitfall traps were placed per transect, every 10 m, and were checked every day. Traps remained active for one month. Three types of bait were used to attract beetles based on their feeding preferences: The first week no bait was used as a control setting, the second week decomposing fish was used to attract necrophagous beetles, the third week decaying fruit was used for saprophagous beetles, and cow excrement was used for coprophagous beetles the fourth week. We also performed active search (manual collection) for beetles hidden under stones, in leaves, flowers, tree branches, shrubs and decaying dry trunks for complementary diversity inventory. Specimens were collected in Ziplock bags with 75% alcohol, labeled and transferred for processing and identification. In the laboratory, a Motic SMZ–171 stereomicroscope, taxonomic keys, and the reference collection of the QCAZI museum were used for specimen identification to the most specific taxonomic level possible within the scope of the study (Erwin 1991, Borror et al. 1992, Morón 1997, Martínez 2005, Reyes & Morón 2005). All specimens collected were identified to family and catalogued as morphospecies, and when possible, specimens
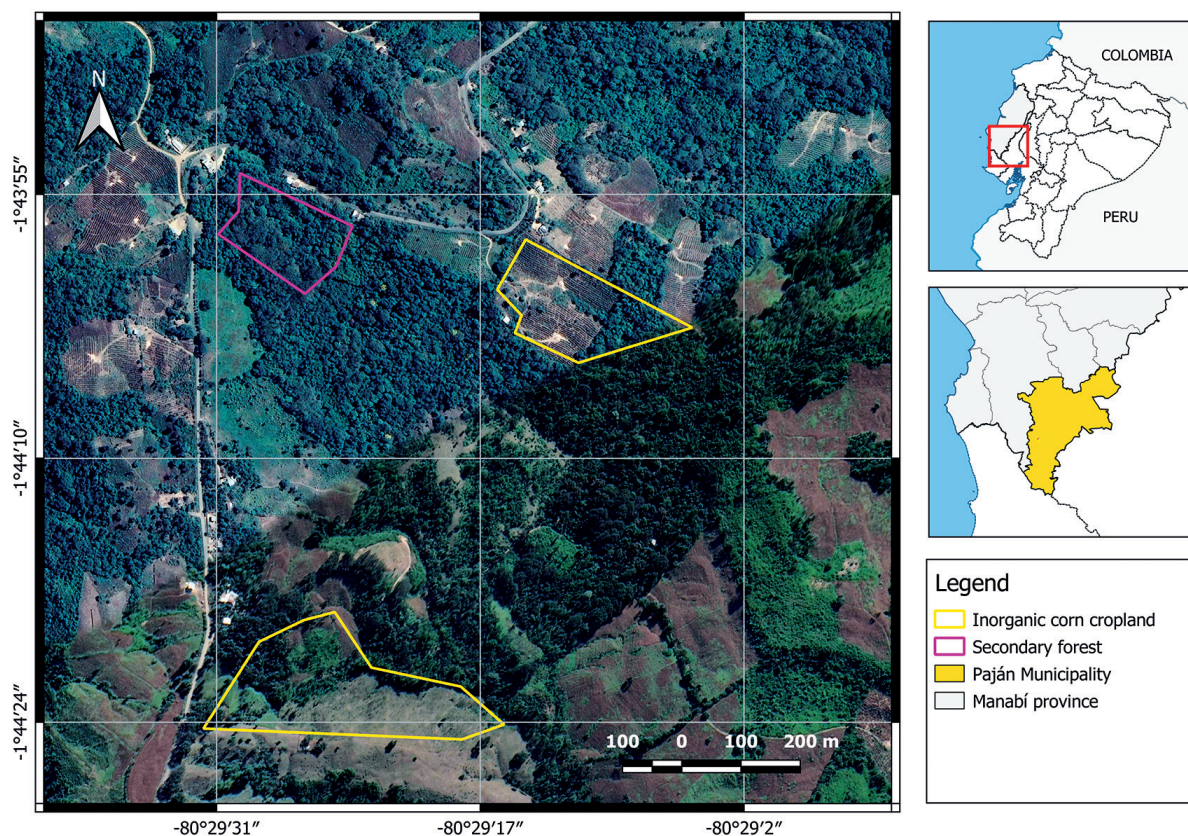
Figure 1. Study area in El Descanso, Manabí, Ecuador. The croplands and secondary forests where the beetle assemblages were evaluated are shown.

were identified to genus. The specimens were collected under the Ministry of the Environment, Water and Ecological Transition permit MAAE-ARSFC-2020-0879 and reference specimens were deposited in the dry collection of the Museum of Invertebrates at Pontificia Universidad Católica del Ecuador (QCAZI) (Appendix 1).

Sampling effort estimation. To establish the representativeness of the sampling, morphospecies accumulation curves and sample coverage analysis was used at each site and for each type of bait, using the number of pitfall traps as sampling unit, with the non-parametric estimator CHAO 1 (Colwell et al. 2012, Chao et al. 2014, Chao et al. 2016). Additionally, a sampling completeness analysis (sample coverage) was performed, which calculates the proportion of the individuals' richness, by using the iNEXTLA program (Chao & Jost 2012).

Alpha diversity. We estimated the relative abundance of morphospecies per site. The Simpson index 1-D (λ) was used to calculate the probability that randomly collected individuals are of the same morphospecies. This index ranges between 0 and 1, where values close to 0 represent greater dominance and less diversity, and values close to 1 represent less dominance and greater diversity. Also, Shannon index (H') was used to calculate the diversity per site. The value obtained ranges between 0 and 5; where 1 is considered a low diversity site and above 3 corresponds to high diversity (Magurran 1988).

Beta Diversity. Taking into consideration morphospecies variation between sites, a multivariate cluster analysis was performed to estimate beta diversity using the distance coefficients of Bray–Curtis, contemplating the number of individuals per species collected (Moreno 2001). A two-way permutational multivariate analysis of variance (PERMANOVA) was used to test community structure differences within sites (secondary forest and cropland) and between bait categories, based on Bray-Curtis's dissimilarity distance. A multidimensional scaling analysis was utilized to visualize the dissimilarity described. Both diversity index and comparative analysis were performed using Past V. 0.4 software (Hammer 2001).

Results

Morphospecies richness and diversity. We collected 4788 beetles of 64 morphospecies classified within 15 families. 254 individuals came from manual collections belonging to 28 morphospecies, 21 of which were also found in the pitfall traps (Table 1).

The morphospecies accumulation curve almost reached the estimate asymptotic phase in the secondary forest for all bait types. According to the CHAO 1 criteria, 100% of collection efficiency was observed using fish and fruit baits, 87.5% with excrement and 91.1 with no bait in the secondary forest, where the maximum number of species expected was 24 (Fig. 2). In agroecosystem, the maximum number of species expected was 15; accor-

Table 1. Abundance of coleopteran species collected in secondary forest (SF) and two cropland sites (Ca and Cb). We also report the abundance of coleopterans according to the bait type where the taxa were observed: Excrement (E), Decomposing fruit (F), Decomposing fish (FS), Control (C), and manual collections (MC) and the total relative importance (RI) of each group.

Family	Genera	Sites			Bait				MC	Total	IR
		SF	Ca	Cb	E	F	FS	C			
Carabidae	*Calosoma* sp1		3		1	2				3	0.00063
Carabidae	*Loxandrus* sp1	5	17	18	12	13		15		40	0.00835
Carabidae	gen. sp1	1							1	1	0.00021
Cerambycidae	*Macrodontia* sp1	1							1	1	0.00021
Cerambycidae	*Neoptychodes* sp1	2							2	2	0.00042
Cerambycidae	*Neoptychodes* sp2	1							1	1	0.00021
Cerambycidae	*Stizocera* sp1	7							7	7	0.00146
Cerambycidae	*Stizocera* sp2	3							3	3	0.00063
Cerambycidae	*Trichocnemis* sp1	10							10	10	0.00209
Chrysomelidae	*Diabrotica* sp1	2	6	11				2	17	19	0.00397
Curculionidae	*Cratosomus* sp1		8	4	1	6		5		12	0.00251
Elateridae	*Conoderus* sp1	9	21	21	14	19	12	6		51	0.01065
Elateridae	*Orthostethus* sp1	3							3	3	0.00063
Elateridae	gen. sp1		2	42	2	41	1			44	0.00919
Elateridae	gen. sp2	1							1	1	0.00021
Endomychidae	gen. sp1		2					2		2	0.00042
Erotylidae	*Brachysphaenus* sp2			1				1		1	0.00021
Erotylidae	*Brachysphaenus* sp1	6	11	1	3	4	2	7	2	18	0.00376
Erotylidae	*Pselaphacus* sp1	4	2				1	1	4	6	0.00125
Histeridae	*Euspilotus* sp1	35	510	327	33	285	502	46	6	872	0.18212
Histeridae	*Omalodes* sp1	3					3			3	0.00063
Mycetophagidae	gen. sp1	1							1	1	0.00021
Nitidulidae	gen. sp1	88				88				88	0.01838
Passalidae	*Passalus* sp1	21							21	21	0.00439
Scarabaeidae	*Anomala* sp1	75	2					2	75	77	0.01608
Scarabaeidae	*Anomala* sp2			1				1		1	0.00021
Scarabaeidae	*Anomala* sp3			1			1			1	0.00021
Scarabaeidae	*Aspidolea* sp1		2	5	1		6			7	0.00146
Scarabaeidae	*Aspidolea* sp2	1					1			1	0.00021
Scarabaeidae	*Ataenius* sp1	12		1	13					13	0.00272
Scarabaeidae	*Ateuchus* sp1		6		6					6	0.00125
Scarabaeidae	*Canthidium* sp1	334	155	309	279	282	120	115	2	798	0.16667
Scarabaeidae	*Canthon* sp1	174	191	82	85	165	140	57		447	0.09336
Scarabaeidae	*Canthon* sp2	1096		2	609	182	304	3		1098	0.22932
Scarabaeidae	*Canthon* sp3	314	6	4	109	104	111			324	0.06767
Scarabaeidae	*Copris* sp1	16	1	1	17		1			18	0.00376
Scarabaeidae	*Copris* sp2	2	1	2	5					5	0.00104
Scarabaeidae	*Coprophanaeus* sp1	3	1	1		4	1			5	0.00104
Scarabaeidae	*Coprophanaeus* sp2	7				7				7	0.00146
Scarabaeidae	*Cyclocephala* sp1	4		11		4			11	15	0.00313
Scarabaeidae	*Cyclocephala* sp2		1				1			1	0.00021
Scarabaeidae	*Cyclocephala* sp3		1				1			1	0.00021
Scarabaeidae	*Cyclocephala* sp4	1						1		1	0.00021
Scarabaeidae	*Cyclocephala* sp5		31	14	1	1			43	45	0.00940
Scarabaeidae	*Enema* sp1	3							3	3	0.00063
Scarabaeidae	*Euphoria* sp1	6		1		1	3	3		7	0.00146
Scarabaeidae	*Eurysternus* sp1	24		2	25		1			26	0.00543

Family	Genera	Sites			Bait				MC	Total	IR
		SF	Ca	Cb	E	F	FS	C			
Scarabaeidae	*Genieridium* sp1	13			13					13	0.00272
Scarabaeidae	*Onthophagus* sp1	37	2		27	3	9			39	0.00815
Scarabaeidae	*Onthophagus* sp2	5	6	4	14	1				15	0.00313
Scarabaeidae	*Onthophagus* sp3	13	3	2	18					18	0.00376
Scarabaeidae	*Onthophagus* sp4	13	4	6	22	1				23	0.00480
Scarabaeidae	*Pelidnota* sp1	2							2	2	0.00042
Scarabaeidae	*Pelidnota* sp2	1							1	1	0.00021
Scarabaeidae	*Phanaeus* sp1	1	1			2				2	0.00042
Scarabaeidae	*Phileurus* sp1	1							1	1	0.00021
Scarabaeidae	*Phyllophaga* sp1	19	14	73	17	19	40	14	16	106	0.02214
Scarabaeidae	gen. sp1	4	1		4		1			5	0.00104
Scarabaeidae	*Sulcophanaeus* sp1	31			15	1	15			31	0.00647
Scarabaeidae	*Deltochilum* sp1	359	3	1	99	103	146	14	1	363	0.07581
Staphylinidae	*Paederus* sp1	35			9	12	2		12	35	0.00731
Tenebrionidae	*Mylaris* sp1	2							2	2	0.00042
Tenebrionidae	*Parepitragus* sp1	1	7	1		4		5		9	0.00188
Trogossitidae	*Temnoscheila* sp1	5							5	5	0.00104
Grand Total		2817	1022	949	1455	1354	1425	300	254	4788	

ding to the CHAO 1 criteria, 100% of collection efficiency was observed with no baits while lower efficiency was observed will all bait types: 72.9% and 77.1% with fish, 89.7% and 72.3% with fruit, and 91.7% and 96.4% with excrement Fig. 2). The sample coverage analysis showed a high percentage in secondary forest (Excrement = 99%, fruit = 98%, fish = 99%, no bait = 1%) and in both cro-

plands (Excrement = 95/97%, fruit = 97/96%, fish = 95/97%, no bait = 0.98/1%).

Overall, there was low dominance and high diversity in all sites (1-D_{sf}= 0.799; 1-D_a = 0.691; 1-D_b= 0.758). The forest had both the greatest diversity and abundance (H'$_{sf}$ = 2.207, spp $_{sf =}$ 52, N$_{sf}$ = 2817) compared to cropland (H$_a$' = 1.695, spp $_{a =}$ 31, N$_a$ = 1022; H$_b$' = 1.857, spp $_b$= 29, N$_b$ = 949).
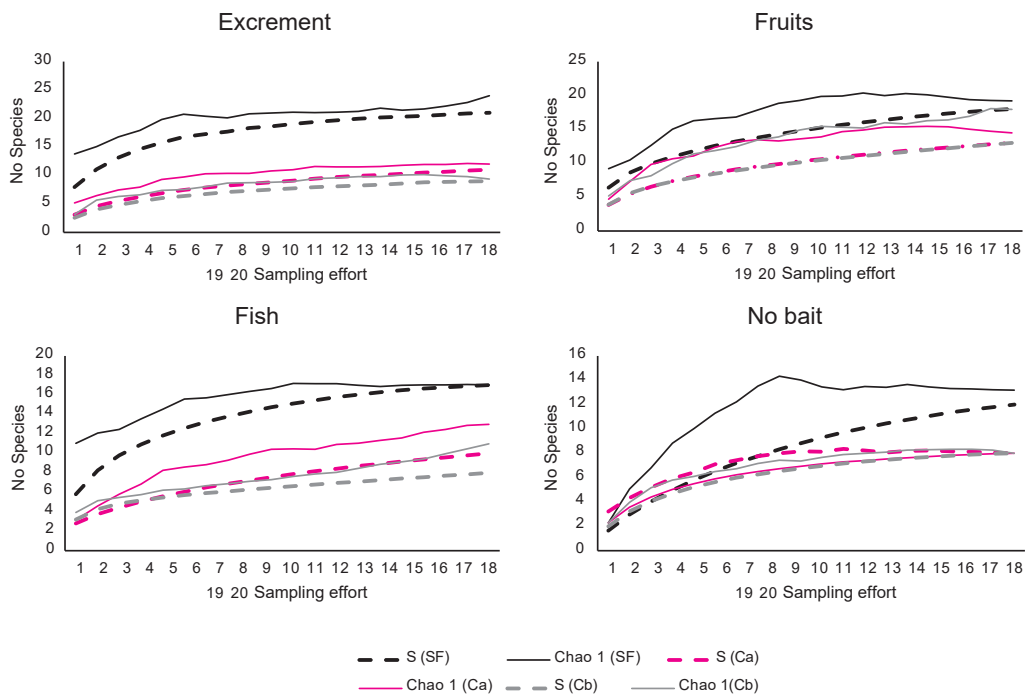

Figure 2. Species accumulation curve considering the number of pitfall traps as sampling effort in Secondary Forest and both Cropland sites (a and b) while sampling with no bait and with three bait types (excrement, fruit, fish). Dashed indicates the actual values, and continues line indicates the values of Chao 1.

The most representative family in the secondary forest was Scarabaeidae including *Canthidium* (Erichson 1847) sp1, *Canthon* (Hoffmannsegg 1817) sp1, *Canthon* sp2, *Canthon* sp3 and *Deltochilum* (Eschscholtz 1822) sp1. On the other hand, in the cropland the most abundant groups were Histeridae, *Euspilotus* (Lewis 1907) sp1 and Scarabaeidae (*Canthidium* sp1, *Canthon* sp1) (Table 1)*. Some morphospecies were exclusively found in one type of habitat; this was the case of 28 morphospecies which occurred only in secondary forest such as Carabidae gen. sp1, *Macrodontia* (Lacordaire 1830) sp1, *Neoptychodes* (Dillon & Dillon 1941) sp1 and sp2, *Stizocera* (Audinet-Serville 1834) sp1 and sp2, *Trichocnemis* (LeConte 1851) sp1, *Orthostethus* (Lacordaire 1857) sp1, Elateridae gen. sp2, *Omalodes* (Erichson,1834) sp1, Mycetophagidae gen. sp1, Nitidulidae gen. sp1, *Passalus* (Fabricius 1792) sp1, *Aspidolea* (Bates 1888) sp2, *Ataenius* (Harold 1867) sp1, *Cyclocephala* (Dejean 1821) sp4, *Coprophanaeus* (Olsoufieff 1924) sp2, *Enema* (Hope 1837) sp1 and sp2, *Genieridium* (Vaz-de-Mello 2008) sp1, *Onthophagus* (Latreille 1802) sp1, *Pelidnota* (MacLeay 1819) sp1 and sp2, *Phileurus* (Latreille 1807) sp1, *Sulcophanaeus* (Olsoufieff 1924) sp1, *Paederus* (Fabricius 1775) sp1, *Mylaris* (Pallas 1781) sp1, *Temnoscheila*

(Westwood 1830) sp1; while 12 morphospecies such as *Calosoma* (Weber 1801) sp1, *Cratosomus* (Schoenherr 1825) sp1, Elateridae gen. sp1, Endomychidae gen. sp1, *Brachysphaenus* (Lacordaire 1842) sp2, *Anomala* (Samouelle 1819) sp2 and sp3, *Aspidolea* sp1, *Ateuchus* (Weber 1801) sp1, *Cyclocephala* sp2, sp3, and sp5 were only observed in crops (Table 1).

Bait association. Most of the morphospecies were observed in multiple bait traps; however, several were exclusive to one type of bait. *Ataenius* sp1*, Ateuchus* sp1, *Copris* (Geoffroy 1762) sp2, *Onthophagus* sp3 and *Genieridium* sp1 were observed only in excrement traps. Nitidulidae gen. sp1, *Coprophanaeus* sp2, *Cyclocephala* sp1, and *Phanaeus* (MacLeay 1819) sp1 were found in fruit exclusively. *Omalodes* sp1, *Anomala* sp3, *Aspidolea* sp2, *Cyclocephala* sp2 and sp3 were exclusive collected in fish bait traps.

Community structure. The analysis of dissimilarity shows aggregation of morphospecies based on the level of disturbance (Table 2, Fig. 3); the coleopteran composition of the secondary forest differs from the coleopteran composition of both cropland sites which are grouped within a unique cluster.

Table 2. Dissimilarity matrix based on Bray Curtis Index (Figure 3).

|	SF_T1	SF_T2	SF_T3	Ca _T1	Ca _T2	Ca _T3	Cb _T1	Cb _T2	Cb _T3
SF_T1	1	0.668	0.759	0.33	0.45	0.44	0.51	0.46	0.47
SF_T2	0.668	1	0.723	0.25	0.35	0.3	0.41	0.32	0.34
SF_T3	0.759	0.723	1	0.26	0.37	0.36	0.37	0.34	0.36
Ca_T1	0.334	0.251	0.257	1	0.74	0.74	0.57	0.66	0.6
Ca _T2	0.449	0.348	0.37	0.74	1	0.78	0.68	0.71	0.72
Ca _T3	0.443	0.305	0.362	0.74	0.78	1	0.72	0.82	0.73
Cb_T1	0.511	0.413	0.372	0.57	0.68	0.72	1	0.72	0.79
Cb _T2	0.458	0.324	0.343	0.66	0.71	0.82	0.72	1	0.83
Cb _T3	0.467	0.339	0.36	0.6	0.72	0.73	0.79	0.83	1
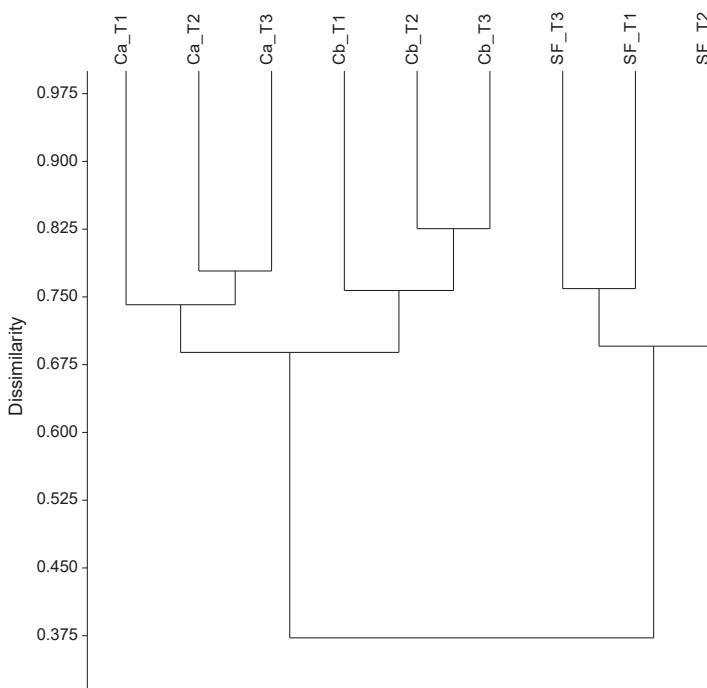
Figure 3. Dissimilarity dendrogram based on Bray Curtis index (Table 2).

The abundance of coleopterans was significantly different between sampling sites and baits ($F_{(2,8)}$ = 12.43; p < 0.001) with a higher abundance in the secondary forest than from both cropland sites (Fig. 2). Manual capture abundance also differed from the one using baits ($F_{(2)}$ = 12.39; p < 0.001). Several groups were found to feed on multiple bait resources, which shows similar composition (Fig. 4); excrement was the bait yielding the highest abundance in the forest while fruit and fish yielded the highest abundance in cropland.
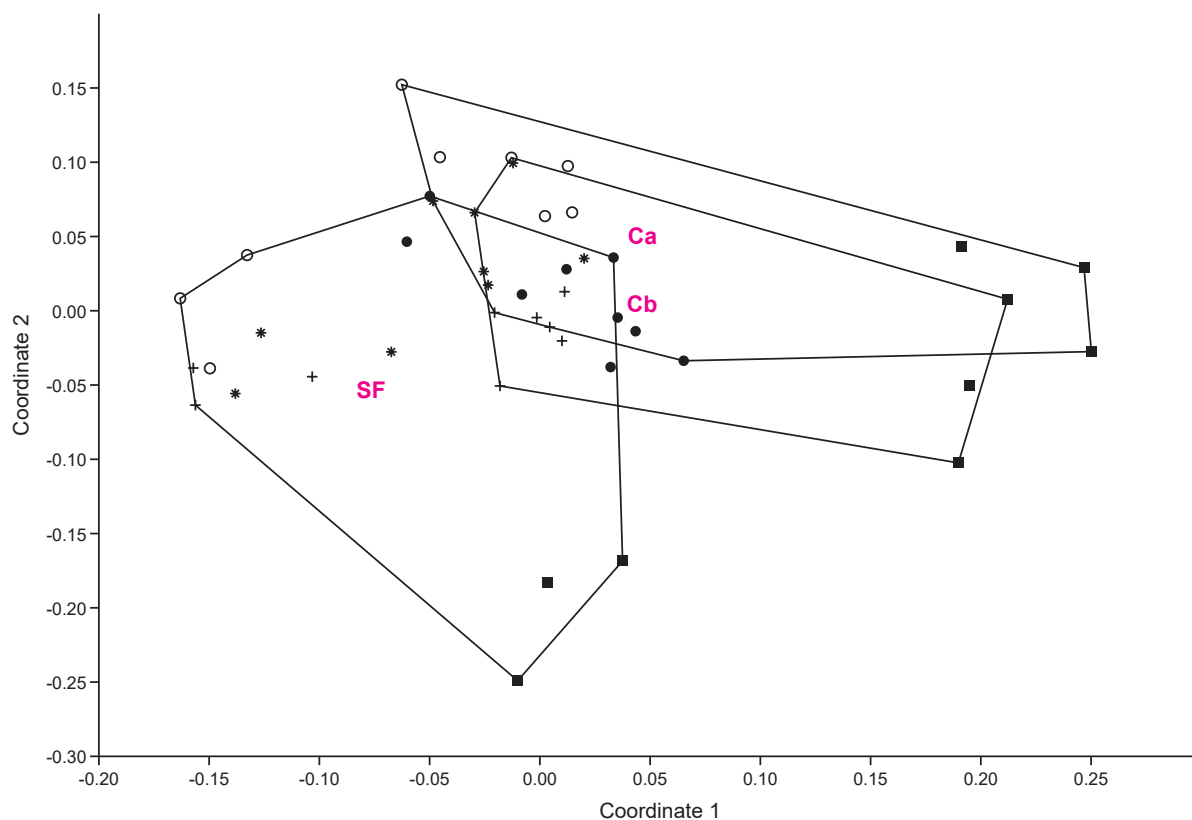
Figure 4. MDS including species abundance per site and per baits (fill square-Manual collection, plus excrement, starfruit, unfilled circle-Fish, dot-Control).

Discussion

In ecosystems exposed to alterations, whether natural or human-caused, species diversity tends to reduce as sensitive organisms disappear, and tolerant organisms abundance increases (Metcalfe 1989). However, the regenerating forests situated between altered areas, like croplands, are expected to be refuges for entomofauna and harbor higher diversity concentrations (Bihn et al. 2008, Moulatlet et al. 2021). Our study presents the first preliminary assessment of the beetle diversity in tropical dry forests of Manabí, where one of the main problems is the continuous fragmentation of vegetation cover.

We found 64 beetle morphospecies, 52 of which were found in secondary forests and 31 in croplands. *Canthon* sp2, sp3, and *Deltochilum* were dominant in secondary forests, while *Euspilotus* sp1 and *Canthidium* sp1 were dominant in croplands. *Euspilotus* and *Canthidium* are known to tolerate disturbance and have been associated with fragmented ecosystems (Escobar & Chacon 2000).

We report a representative number of beetles morphospecies in comparison with other disturbed dry forest ecosystems in the Ecuadorian coast and Andean region. For instance, Dominguez Marin-Armijos and Ruiz (2015) found six species in dry mountain shrub in Catamayo-Loja, Molina-Moreira and Arias (2019) recorded nine species, while Ramos and Sanchez (2019) discovered seven species in secondary forests of Calceta-Manabí that are characterized by dry forest vegetation; this locality is geographically closer to Cascol and has a similar topography.

In addition, Cascol has a higher diversity of beetles than similar ecosystems in Colombia and Peru. Uribe and Vallejo (2013) reported 22 species in a tropical dry forest of the Magdalena River. Andrade et al. (2017) found 31 species in farmland, disturbed riparian vegetation and native dry forest habitat in Peru.

Although the species accumulation curve and the completeness analysis suggest an efficient monitoring performed in both ecosystems, the estimators of CHAO 1 suggest that there are still morphospecies to be recorded, in both forest and crop. Complementary capture techniques, such as flight interception traps, light traps, and canopy fumigation, as well as a more extensive monitoring throughout the year should be implemented to provide a full beetle species inventory and a comprehensive analysis of the beetle community (Pedraza et al. 2010, Otavo et al. 2013).

The dissimilarity dendrogram shows differences in beetle composition between croplands and secondary forests, with greater morphospecies diversity and richness observed in the regenerated forest site. Scarabaeidae morfospecies such as *Canthidium* sp1, *Canthon* sp2, and *Deltochilum* sp1, mainly associated with excreta and decaying fish, were more abundant in the secondary forest, although not exclusive to this habitat. In general, this family is associated with better quality forest due to its significant role in organic (animal-origin) matter decomposition, indicating better quality of regenerated landscapes (Chamorro et al. 2019). Conversely, fewer morphospecies were observed in croplands, and only two morphospecies, *Euspilotus* sp1 and *Canthidium* sp1, were dominant. These genera are considered ecologically tolerant to fragmentation (Reyes Novelo et al. 2007).

We detected certain morphospecies previously reported as pests, such as *Phyllophaga* (Harris 1826) species that tend to destroy plant roots (Cueva 2014, Contreras 2019, Morocho et al. 2020). Similarly, *Diabrotica* (Chevrolat 1836) species feed on foliage, flowers, and roots causing physiological alterations and delaying crop development (Pérez et al. 2006). *Diabrotica* contains the largest number of pest species, targeting some of the most important horticultural crops on the continent (Cabrera Walsh 2005, Cabrera Walsh et al. 2020). In fact, corn and other grasses could be the most important larval hosts, which has helped this group become widespread. Although these species were expected to be found only in crops, we also found them in the secondary forest. Pests that are widely distributed are recognized for their ability to feed on multiple resources, despite their specificity (Tuda et al. 2005). This aptitude allows them to remain in the forest, where multiple resources are available, explaining the occurrence of *Diabrotic*a and *Phyllophaga* in the secondary forest.

We used several types of bait to understand the affinity of beetles to a particular type of food, which tends to be associated with their ecological roles and differs between taxa (Selfa & Anento 1997, Guseva & Koval 2013, Honek et al. 2013; Luna, 2015); by doing so we aimed to ensure that beetles from multiple guilds were well represented in croplands and in the secondary forest (Bogoni & Hernandez 2014). Our analysis showed coprophagous beetles as the dominant group, followed by saprophagous and necrophagous beetles. Coprophagous beetles are considered beneficial since they fulfill a cleaning function in forest areas where large amounts of excrement need to be processed to return to the soil and improve its fertility and aeration (Luzuriaga 2013). We report only one saprophagous exclusive morphospecies, Nitidulidae gen. sp1, which was found only in the secondary forest. This group feeds on decaying plant and organic matter, such as the bark of trees and decaying fruits (Pedraza et al. 2010), justifying its occurrence in the forest. However, it has also been reported as a post-harvest pest in strawberry fields (Gutiérrez et al. 2020).

During manual collections we found specimens of the families Erotylidae, Passalidae and the genus *Pelid-nota* (Scarabaeidae) in decomposing organic matter that are also considered saprophagous (Arnett et al. 2002). Some morphospecies were found in all bait types, such as *Canthidium* sp1 and *Canthon* sp1 in the forest and *Cratosomus* sp1 and *Phyllophaga* sp1 in crops. The genera *Canthidium* and *Canthon* have been considered generalists since they utilize various substrates when there is low availability of their main resource (Dominguez 2012, Sulca & Huamantinco 2016); in contrast, *Cratosomus* and *Phyllophaga* are considered harmful pests common in croplands (Isabeth et al. 2003, Pérez et al. 2008).

We also collected specimens of the following genera: *Macrodontia*, *Neoptychod*es, *Stizocera*, *Trichocnemis*, *Anomala, Conoderus* (Eschscholtz 1829)*, Orthostethus,* and Elateridae gen. sp1 and sp2. These groups use a wide spectrum of food sources, including live and decaying wood, seeds, and roots (Martínez 2000, Paucar-Cabrera 2005, Zurita-García et al. 2014). *Mycophagous* morphospecies (*Mylaris* sp1, Mycetophagidae, gen. sp1, Trogossitidae, gen. sp1 and *Phileurus* sp1) (Arnette et al. 2002) were also found.

Molina-Moreira & Arias (2019) state the need to carry out entomofauna studies in other dry forests on the Ecuadorian coast that will allow for comparisons between populations located within the forest and populations in fragmented areas. This study is the first to characterize the coleopteran community in the tropical dry forest of Manabí, reporting a significant diversity and representativity of 15 families including 64 morphospecies. This lays a foundation for future research on integrated pest management, community ecology, and disturbance assessment along the fragmented landscape of the Ecuadorian dry forest. According to Viana (1993), regenerated and remnant forests serve as refuges for wildlife that were once widely distributed in the area. Based on our initial analysis of beetle communities in regenerated forests, we suggest these patches should be protected for conservation purposes, and to prevent the possibility of insects becoming crop pests. While our work contributes valuable insights into the morphospecies composition of these forests, more detailed identification is necessary to fully understand the dynamics of the beetle community in these disturbed ecosystems, and to expand the checklist of beetle species in the Ecuadorian dry forest. Overall, these findings highlight the importance of preserving regenerated forests and continuing research efforts to better understand their ecological significance.

Literature cited

Albrecht H. 2003. Suitability of arable weeds as indicator organisms to evaluate species conservation effects of management in agricultural ecosystems. Agriculture, Ecosystems & Environment 98(1 –3): 201-211. https://doi.org/10.1016/S0167-8809(03)00081-1

Alvarado F, Osorio F. 2020. Coleópteros necrófagos, coprófagos y frugívoros en la cordillera El Merendón, Honduras. [Undergraduate thesis]. [Honduras]: Universidad Zamorano. https://bdigital.zamorano.edu/handle/11036/6814

Amador L, Martínez C. 2011. Amphibians present in four localities of the Cordillera Chongón – Colonche, Ecuador. Technical Bulletin Zoological Series10 (7): 55–68.

Andrade K, La Rosa H, Saavedra D. 2017. Preliminary list of beetles (Insecta: Coleoptera) of the sector "La Greda", Buenos Aires, Morropón, Piura (Peru). Arquivos entomolóxicos 18: 289–296.

Arnett R, Thomas M, Skelley P, Frank H. 2002. American Beetles Vol 2, Polyphaga: Scarabaeoidea through Curculionoidea. Florida: CRC Press.

Bihn J H, Verhaagh M, Brändle M, Brandl R. 2008. Do secondary forests act as refuges for old growth forest animals? Recovery of ant diversity in the Atlantic Forest of Brazil. Biological Conservation 141(3): 733–743. https://doi.org/10.1016/j.biocon.2007.12.028

Bonifaz C, Cornejo X. 2004. Flora del Bosque de Garúa (Árboles y Epífitas) de la Comuna Loma Alta, Cordillera Chongón Colonche, Provincia del Guayas. Ecuador. Guayaquil Universidad de Guayaquil/Missouri Botanical Garden/fundación Gaia.

Bogoni JA, Hernández, M. I. 2014. Attractiveness of native mammal's feces of different trophic guilds to dung beetles (Coleoptera: Scarabaeinae). Insect Science 14(1). https://doi.org/10.1093/jisesa/ieu161

Borror D, Triplehom C, Johnson N. 1992. An introduction to the study of the Insects. Philadelphia Saunders College Pub.

Carrillo R, Alarcón R, Neira M. 2007. The effects of carabid beetles (Coleoptera: Carabidae) on the arthropod fauna of wheat fields in Chile. Journal of Tropical Ecology 55(1): 101–111. https://doi.org/10.15517/rbt.v55i1.6060

Cabrera Walsh G. 2005. Diabroticina (Coleóptera: Chrysomelidae: Galerucinae) de la Argentina y el Cono Sur: una visión biogeográfica y evolutiva de su biología y la de sus enemigos naturales, en relación con la factibilidad del control biológico de las especies plagas. [Doctoral Thesis]. [Buenos Aires]: Universidad de Buenos Aires.

Cabrera Walsh G, Ávila C J, Cabrera, N, Nava D E, de Sene Pinto A and Weber D C. 2020. Biology and management of pest Diabrotica species in South America. Insects 11(7): 421. https://doi.org/10.3390/insects11070421

Caamal-Maldonado A, Armendariz-Yañez I. 2002. La Sucesión Secundaria en los Ecosistemas y Agroecosistemas Tropicales - el henequén (Agave fourcroydes) en el contexto de la diversificación. Trop. Subtrop. Agroecosystems. 1(1): 28–32. https://redalyct.org/articulo.oa?id=93911238005

Celi J, Dávalos A. 2001. Monitoring Manual. Dung beetles as indicators of environmental quality. Quito: EcoCiencia.

Chamorro W, Gallo F, Delgado S. 2019. The dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) of the High Oglán Protective Forest, Pastaza, Ecuador. Biota Colombiana 20(1): 34–49. https://doi.org/10.21068/c2019.v20n01a03

Chao A, Jost L. 2012. Coverage-based rarefaction and extrapolation: standardizing samples by completeness rather than size. Ecology 93: 2533–2547. https://doi.org/10.1890/11-1952.1

Chao A., Gotelli N.J., Hsieh T.C., Sander E.L., Ma K.H., Colwell R.K., Ellison A.M. 2014. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. Ecological Monographs 84: 45–67. https://doi.org/10.1890/13-0133.1

Chao A., Ma K. H., Hsieh T.C. 2016. iNEXT (iNterpolation and EXTrapolation) Online: Software for Interpolation and Extrapolation of Species Diversity. Program and User's Guide published at http://chao.stat.nthu.edu.tw/wordpress/software_download/inext-online/

Colwell RK, Gotelli NJ, Lin SY, Mao C, Chazdon R, Longino J. 2012. Models and estimators that link the rarefaction, extrapolation and comparison of assemblies based on samples and individuals. Plant Ecology 5: 3–21. https://doi.org/10.1093/jpe/rtr044

Contreras C. 2019. Evaluación de la percepción de los agricultores maiceros sobre los daños observados en el cultivo de maíz, ocasionados por insectos plaga en la zona de Mocache [Thesis]. [Quevedo]: Universidad Técnica Estatal de Quevedo. https://repositorio.uteq.edu.ec/bitstream/43000/3628/1/T-UTEQ-0164.pdf

Cueva M. 2014. Identificación taxonómica de las especies de phyllophaga (Col.Scarabaeidae) presentes en diez cultivos de importancia económica en la provincia de Los Ríos [Thesis]. [Quito]: Universidad de las Fuerzas Armadas. http://repositorio.espe.edu.ec/bitstream/21000/9426/1/T-ESPE-002706.pdf

Dominguez D, Marin-Armijos D, Ruiz C. 2015. Structure of dung beetle communities in an altitudinal gradient of neotropical dry forest. Neotropical Entomology 44(1): 40–46. https://doi.org/10.1007/s13744-014-0261-6

Dominguez d. 2012. Ensamblaje de una comunidad de coprófagos (Coleóptera: Scarabaeinae) en un gradiente altitudinal, adaptaciones al cambio global, Cantón Catamayo – Loja. Ecuador [Thesis]. [Loja]: Universidad Católica de Loja. http://dspace.utpl.edu.ec/handle/123456789/2889

Erwin T. 1991. Natural history of the Carabids beetles at the BIOLAT Biological Station, Río Manu, Pakitza, Peru. Revista peruana de entomología 33: 1–85.

Escobar F, Chacón P. 2000. Spatial and temporal distribution in a succession gradient of the fauna of coprophagous beetles (Scarabaeinae, Aphodiinae) in a montane tropical forest, Nariño - Colombia. Journal of Tropical Ecology 48(4): 961–975. https://doi.org/10.15517/rbt.v48i4.18988

Guseva O, Koval A. 2013. Estimation of the role of predatory epigeal beetles (Coleoptera: Carabidae, Staphylinidae) in the regulation of pest population density in agroecosystems. Entomological Review 93(8): 954–961. https://doi.org/10.1134/S0013873813080034

Gutiérrez S, Elme A, Yabar E, Rogel J. 2020. Nitidúlidos (coleoptera: Nitidulidae) in strawberry fields Fragaria vescalinnaeus in the localities of Aucallama, Huaral and Supe, Barranca in Lima, Peru. Biotempo 17(1): 91–95. https://doi.org/10.31381/biotempo.v17i1.3052

Halffter G. 1993. The Scarabaeinae (Insecta: Coleoptera) an animal group for analyzing, inventorying, and monitoring biodiversity in tropical rainforest and modified landscapes. Biology International 27: 5–21.

Hammer O, Harper DAT, Ryan PD. 2001. PAST: Paleontological Statistics software package for education and data analysis. Palaeontol. Electron 4(1): 9pp.

Hernandez Camacho J. 1992. Caracterización Geográfica de Colombia. In Halffter G. editors. 1992. La Diversidad Biológica de Iberoamérica I. Mexico Acta Zoologica Mexicana. P. 45 –54.

Honek A, Martinkova Z, Jarosik V. 2013. Terrestrial beetles (Carabidae) as seed predators. Journal of Entomology 100(4): 531–544. https://doi.org/10.14411/eje.2003.081

Isabeth L, Villafaña M, Guezou N, Germosén Robineau L, Chabal F. 2003. Manual de cultivo y conservación de plantas medicinales. Tomo 3: Árboles dominicanos. Republica Dominicana: Santo Domingo Graphic Colonial.

Laurance WF, Bierregaard RO. 1997. Tropical Forest remnants: ecology, management, and conservation of fragmented communities. Chicago University of Chicago Press.

Luna J. 2015. Techniques of collection and preservation of insects. Boletín de la S.E.A. 37: 385–408.

Luzuriaga C. 2013. Escarabajos coprófagos (Coleoptera: Scarabaeidae: Scarabaeinae) como indicadores de diversidad biológica en la Estación Biológica Pindo Mirador. Pastaza-Ecuador [Thesis].[Loja]: Universidad Tecnica Particular de Loja. http://dspace.utpl.edu.ec/handle/123456789/6234

Magurran A. 1988. Ecological diversity and its measurement. Princeton University Press.

Martínez C. 2000. Escarabajos Longicornios (Coleoptera: Cerambycidae) de Colombia Biota Colombiana. 1(1):76-105.

Martínez C. 2005. Introducción a los escarabajos Carabidae (Coleoptera) de Colombia. Bogota: Alexander Von Humboldt Biological Resources Research Institute.

Metcalfe J. 1989. Biological Water Quality Assessment of Running Waters Based on Macroinvertebrate Communities: History and Present Status in Europe. Environmental Pollution 60:101–139. https://doi.org/10.1016/0269-7491(89)90223-6

Miss J, Cuauhtemoc D. 2007. Observations on saproxylophilic beetles (Insecta: Coleoptera) in Sotuta, Yucatan, Mexico. Revista Colombiana de Entomología 33(1): 77–81. https://doi.org/10.25100/socolen.v33i1.9320

Molina-Moreira N, Arias M. 2019. Inventario Preliminar de la Clase Insecta en la Reserva Ecológica Arenillas, Ecuador. Investigatio. 12: 13–48. https://doi.org/10.31095/investigatio.2019.12.2

Moreno C. 2001. Methods for measuring Biodiversity. MandT–Manuals and Thesis Aragonese Saragoza CYTED.

Morocho N, Mazón M, Ruiz J. 2020. Presencia de Phyllophaga spp. (Coleoptera: Scarabaeidae) y hongos entomopatógenos potenciales para su control biológico en sistemas agrícolas de Saraguro (Loja, Ecuador). CEDAMAZ 10(2): 51–56.

Morón M. 1997. Faunal inventories of Coleoptera: Neotropical Melolonthidae with potential as bioindicators. Giornale Italiano di Entomologia 8(46): 265–274.

Moulatlet GM, Ambriz E, Guevara J, Lopez KG, Rodes-Blanco M, Guerra-Arevalo N, Meneses P. 2021. Multi-taxa ecological responses to habitat loss and fragmentation in western Amazonia as revealed by RAPELD biodiversity surveys. Acta Amazonica 51: 234–243. https://doi.org/10.1590/1809-4392202004532

Muñoz Lopez P, Gilger M, Mazon Pilligua A. 2015. Plan de Desarrollo y ordenamiento territorial de la Parroquia Cascol Secretaria Nacional de Planificacion y Desarrollo.

Murillo-Ramos L, Ayazo R, Medina CA. 2016. Diversidad de escarabajos coprófagos (Coleoptera: Scarabaeinae) en un remanente ribereño y un fragmento de bosque húmedo tropical en Córdoba, Colombia. Ecología Austral 26(1):17–26. https://doi.org/10.25260/EA.16.26.2.0.200

Noss RF. 1990. Indicators for Monitoring Biodiversity: A Hierarchical Approach. Conservation Biology. 4(4):355–364. https://doi.org/10.1111/j.1523-1739.1990.tb00309.x

Otavo S, Parrado-Rosselli A, Ari J. 2013. Superfamily Scarabaeoidea (Insecta: Coleoptera) as a bioindicator of anthropogenic disturbance in an Amazonian national park. Journal of Tropical Ecology 61(2): 735–752. https://doi.org/10.15517/rbt.v61i2.11219

Paucar-Cabrera A. 2005. A catalog and distributional analysis of the Rutelinae (Coleoptera: Scarabaeidae) of Ecuador. Zootaxa. 948:1–92. https://doi.org/10.11646/zootaxa.948.1.1

Pearce J, Venier, L. 2006. The use of ground beetles (Coleoptera: Carabidae) and spiders (Araneae) as bioindicators of sustainable forest management: a review. Ecological Indicators 6(4): 780–793. https://doi.org/10.1016/j.ecolind.2005.03.005

Pedraza M, Márquez J, Gómez-Anaya J. 2010. Structure and composition of seasonal assemblages of beetles (Insecta: Coleoptera) from the mountain mesophile forest in Tlanchinol, Hidalgo, Mexico, collected with flight interception traps. Revista Mexicana de Biodiversidad 81(2): 437–456. https://doi.org/10.22201/ib.20078706e.2010.002.234

Pérez Domínguez JF, Romero Rosales F, Soltero Díaz L, Álvarez Zagoya R. 2006. Maize hybrids susceptibility to mexican corn rootworm (Diabrotica virgifera zeae) in Mexico. Agricultura técnica en México. 32(2):143-51.

Pérez S, Moron M, Najera M, Lopez E, and Vazquez M. 2008. Diversity analysis of the "blind hen" complex (Coleoptera: Melolonthidae) in two traditional corn production systems in the Purhépecha region, Michoacán. Acta Zoológica Mexicana 24(1): 221 –235.

Pourrt P. 1998. El Niño 1982-1983 in the light of the teachings of past events - impacts on Ecuador. Bulletin de l'Institut Français d'Études Andines 27(3): 501–515. https://doi.org/10.3406/bifea.1998.1305

Ramos J, Sánchez E. 2019. Evaluación de coleópteros como indicador ambiental en suelo en dos bosques secundarios (ESPAM MFL - Loma Seca) durante el periodo enero-abril 2019 [Thesis].[Manabi]: Escuela Superior Politécnica Agropecuaria de Manabí. http://repositorio.espam.edu.ec/handle/42000/1186

Reyes Novelo E, Delfín-González H, Morón MÁ. 2007. Copronecrophagous beetle (Coleoptera: Scarabaeidae) diversity in an agroecosystem in Yucatan, Mexico. Revista de Biología tropical 55(1): 83 –99. https://doi.org/10.15517/rbt.v55i1.6059

Reyes N, Morón M. 2005. Fauna of Coleoptera Melolonthidae and Passalidae of Tzucacab and Conkal, Yucatan, Mexico. Acta Zoológica Mexicana 21(2): 15–49. https://doi.org/10.21829/azm.2005.2121983

Selfa J, Anento J. 1997. Agricultural and forest pests. Bulletin of the Entomological Society of America 20: 75–91.

Sulca L, Huamantinco A. 2016. Seasonal variation of the beetle community Scarabaeinae (Coleoptera: Scarabaeidae) from an Amazonian flood forest in Peru. Ecología Aplicada 15(1): 47–55. https://doi.org/10.21704/rea.v15i1.582

Troya A, Bersosa F, Espinoza L. 2016. Insectos de los remanentes de bosques secos Andinos del norte de Ecuador. Ecosistemas 25(2): 79–82. https://doi.org/10.7818/ECOS.2016.25-2.10

Tuda M, Chou LY, Niyomdham C, Buranapanichpan S, Tateishi Y. 2005. Ecological factors associated with pest status in Callosobruchus (Coleoptera: Bruchidae): high host specificity of non-pests to Cajaninae (Fabaceae). Journal of Stored Products Research 41(1): 31–45. https://doi.org/10.1016/j.jspr.2003.09.003

Uribe M, Vallejo L. 2013. Carabidae y Scarabaeidae de un Bosque Tropical en el Magdalena Medio Colombiano. Boletín Científico Centro de Museos de Historia Natural. 17(2):174-196.

Viana VM. 1993. Conservação de biodiversidade de fragmentos de florestas tropicais em paisagens fe Forestas Tropicais em Paisagens Intensivamente Cultivadas. in: Fonseca GAB, Schimink M, Pinto LPS, Brito F, editors. (1993). Abordagens Interdisciplinares para Conservação da Biodiversidade e Dinamica do Uso da Terra do Novo Mundo. Anais da Conferencia Internacional "On Common Ground: Interdisciplinary Approaches to Biodiversity Conservation and Land Use Dynamics in the New World", Belo Horizonte, Brasil. Conservation International, Univ. Fed. de Minas Gerais and Univ. of Florida.

Villarreal H, Álvarez M, Córdoba S, Escobar F, Fagua G, Gast F, Mendoza H, Ospina M, Umaña A M. 2006. Manual de métodos para la elaboración de inventarios de biodiversidad. Bogota: Alexander Von Humboldt Biological Resources Research Institute.

Wink C, Guedes J, Fagundes C, Rovedder A. 2005. Soil insects as indicators of environmental quality. Journal of Agriculture and Veterinary Science 4(1): 60 –71.

Zurita-García M, Johnson P, Zaragoza-Caballero S. 2014. Biodiversidad de Elateridae (Coleoptera) en México. Revista Mexicana de Biodiversidad 85: S303-S311. https://dx.doi.org/10.7550/rmb.31749

Appendix 1. Museum numbers of the specimens collected and deposited at the Museum of Pontificia Universidad Católica del Ecuador (QCAZ).

FAMILY	Morpho species	QCAZI
Carabidae: Carabinae	*Calosoma* sp1	264670
Carabidae: Harpalinae	*Loxandrus* sp1	264676
Carabidae	sp1	264791
Elateridae: Agrypninae	*Conoderus* sp1	264685
Elateridae	sp1	264688
Scarabaeidae: Scarabaeinae	*Eurysternus* sp1	264758
Scarabaeidae: Scarabaeinae	*Onthophagus* sp1	264771
Scarabaeidae: Scarabaeinae	*Phanaeus* sp1	264794
Scarabaeidae: Scarabaeinae	*Sulcophanaeus* sp1	264783
Scarabaeidae: Dynastinae	*Cyclocephala* sp1	264766
Scarabaeidae: Dynastinae	*Cyclocephala* sp2	264724
Scarabaeidae: Dynastinae	*Cyclocephala* sp3	264725
Scarabaeidae: Melolonthinae	*Phyllophaga* sp1	264714
Scarabaeidae: Rutelinae	*Anomala* sp1	264708

Conflicto de intereses / Competing interests:

The authors declare no conflict of interest.

Rol de los autores / Authors Roles:

SL-P: Conceptualización; Investigación; Escritura - Preparación del borrador original.

TG: Investigación; Curación de datos; Redacción: revisión y edición.

JAS: Investigación; Redacción: revisión y edición.

AEN: Conceptualización; Supervisión; Investigación; Redacción: revisión y edición.

Aspectos éticos / legales; Ethics / legals:

Authors declare that they did not violate or omit ethical or legal norms in this research. This research was performed under the Ministry of the Environment, Water and Ecological Transition permit MAAE-ARSFC-2020-0879.