

## Structure of the scarab beetle fauna (Coleoptera: Scarabaeoidea) in forest remnants of western Puerto Rico

Neis J. Martínez<sup>1,2</sup>, Nico M. Franz<sup>1,3</sup> and Jaime A. Acosta<sup>1</sup>

<sup>1</sup> Department of Biology, Call Box 9000, University of Puerto Rico, Mayagüez, PR 00681 U.S.A.

<sup>2</sup> Present address: Departamento de Biología, Universidad del Atlántico, Baranquilla, Colombia.

<sup>3</sup> E-mail: [nico.franz@upr.edu](mailto:nico.franz@upr.edu)

### Abstract

MARTÍNEZ NJ, FRANZ NM, ACOSTA JA. 2009. Structure of the scarab beetle fauna (Coleoptera: Scarabaeoidea) in forest remnants of western Puerto Rico. ENTOMOTROPICA 24(1): 1-9.

We studied the richness and abundance of scarab beetle species (Coleoptera: Scarabaeoidea) in two successional forest fragments located on the campus of the University of Puerto Rico at Mayagüez (UPRM), western Puerto Rico. The sampling period extended from April to December, 2005, and included nine monthly repetitions of quantitative captures using necrophilous, pitfall, and light traps. A total of 2399 individuals pertaining to 14 species, or 36% of the Island's total scarab diversity, were caught. The spatial variation in diversity and abundance was low among sites. However, there was a significant shift in community structure between the drier season (April to June) and rainy season (September to December). The following four species constituted 92% of all captured individuals: *Canthochilum andyi* Chapin, *C. borinquensis* Matthews, *C. taino* Matthews, and *Phyllophaga vandinei* Smyth. The results underscore the important role that western Puerto Rican forest fragments play in maintaining regional scarab beetle communities, and provide a baseline for developing ecological assessment tools for these habitats.

**Additional key words:** biodiversity, quantitative sampling, succession, urban forest

### Resumen

MARTÍNEZ NJ, FRANZ NM, ACOSTA JA. 2009. Estructura de la fauna de escarabajos (Coleoptera: Scarabaeoidea) en relictos de selva en el occidente de Puerto Rico. ENTOMOTROPICA 24(1): 1-9.

Se estudió la riqueza y abundancia de especies de escarabajos (Coleoptera: Scarabaeoidea) en dos fragmentos de bosques sucesionales localizados en el campus de la Universidad de Puerto Rico, Recinto de Mayagüez (UPRM), en el oeste de Puerto Rico. El periodo de muestreo se extendió de abril a diciembre de 2005, e incluyó nueve repeticiones mensuales de capturas cuantitativas usando trampas necrófilas, de caída, y de luz. Se capturó un total de 2399 individuos pertenecientes a 14 especies, o 36% de la fauna entera de escarabajos de la Isla. La variación espacial de diversidad y abundancia entre los sitios fue baja. Sin embargo, hubo un cambio significativo en la estructura de comunidad entre la época más seca (abril hasta junio) y la época lluviosa (septiembre hasta diciembre). Las siguientes cuatro especies constituyeron el 92% de todos los individuos capturados: *Canthochilum andyi* Chapin, *C. borinquensis* Matthews, *C. taino* Matthews, y *Phyllophaga vandinei* Smyth. Los resultados subrayan el papel importante que los fragmentos de bosque del oeste de Puerto Rico juegan en el mantenimiento de las comunidades regionales de escarabajos, y proveen un punto de partida para desarrollar herramientas de evaluación ecológica para tales habitats.

**Palabras clave adicionales:** biodiversidad, muestreo cuantitativo, sucesión, bosque urbano

### Introduction

The transformation of forests into agricultural habitats, pastures, and urban settlements has had

a profound impact on the ecosystems of Puerto Rico (Aide et al. 1995; Barberena-Arias and Aide

2003). As a result, a high percentage of the island is characterized by a mosaic of forest remnants at different successional stages (Thomlinson et al. 1996). These fragments may retain a fair portion of the original biotic diversity (Escobar and Chacón 2000; Quintero and Roslin 2005; Martínez et al. 2009).

Beetles in the superfamily Scarabaeoidea (*sensu* Grebennikov and Scholtz 2004) are considered valuable indicators of the relative state of fragmentation and habitat degradation (García and Pardo-Locarno 2004), in part because of their diverse feeding types – including herbivory, detritivory, fungivory, saprophagy, and coprophagy – which depend on a functioning trophic structure and the availability of suitable microhabitats (Klein 1989, Escobar 1994, Medina and Kattan 1996). Scarab beetles furthermore provide important ecosystem services as primary and secondary consumers, degraders of organic matter, and food sources for other invertebrates and vertebrates (Reyes Novelo and Morón 2005). At present 16 genera and 39 species of Scarabaeoidea have been recorded for Puerto Rico (see Chapin 1935; Plank 1948; Wolcott 1948; Dechambre 1979; Chalumeau 1982, 1983, 1985). Several authors have contributed to our knowledge of the taxonomy and natural history of these species on the Island, including Wolcott (1936, 1948), Matthews (1963a, 1963b, 1965, 1966, 1969), Martorell (1976), Maldonado-Capriles (1982), Medina et al. (2003), and Evans and Smith (2005).

Here we assess the scarab beetle fauna of two forest fragments located in western Puerto Rico, on the premises of the University of Puerto Rico at Mayagüez (UPRM). We characterize the taxonomic composition and describe the spatial and temporal dynamics of the respective species. This is the first thoroughgoing study of scarab beetle communities in forest fragments of Puerto Rico. The herein presented data may lead to the development of useful tools for the ecological assessment and conservation of these ubiquitous Puerto Rican habitats (see Kohlmann et al. 2007).

## Materials and Methods

### Study Sites

The scarab beetle fauna was sampled in two western Puerto Rican forest fragments separated by a distance of 1.4 km. These fragments are part of the UPRM campus and are located in the municipality of Mayagüez, near the midpoint along the western coast of Puerto Rico. Average temperatures at midday vary from 29-35 °C and the average annual rainfall is > 1400 mm, with a marked dry season from January to March/April (information provided by the Meteorological Station of the Department of Marine Sciences, UPRM). For further detail refer to Martínez et al. (2009).

Site 1 is situated between the New Biology Building and the Mayagüez Zoo (18°12'48"N, 67°08'16"W), with an approximate elevation of 20 m above sea level; whereas site 2 is located on the Finca Laboratorio Alzamora (18°13'20"N, 67°08'40"W), at approximately 80 m above sea level. Both fragments are surrounded by streams and are somewhat distant from residential areas and university facilities. The sampling was carried out in the most preserved sections where native vegetation persists along with cultivated trees. These sections are categorized as wet subtropical forest (Figueroa Colón, 1996), and include irregular patches of secondary forest interspersed with a mosaic of cultivars, open successional areas, pastures, and adjacent human settlements.

### Sampling Techniques and Scheme

The scarab beetle fauna was sampled during the period of April to December, 2005. Three sampling methods were utilized: (1) a series of smaller versions of the permanent necrophilous insect trap "NTP-80" were constructed (Morón and Terrón 1984). Six traps of this type were provisioned each with rotten sardines; and six additional traps were provisioned with a mixture of banana and mango fruits, topped off with concentrated vanilla extract. (2) Six modified pitfall traps were fabricated using 900 ml plastic containers, each with a centrally positioned film roll case hanging from an L-shaped wire attached to the rim. These cases were perforated and

supplied with 25 g of human excrement. Both types of traps (1 and 2) were buried so as to form a smooth transition with the surrounding soil. The pitfall traps were furnished with an overhanging plastic roof for protection against rainfall and other disturbances. (3) Commercially available UV and black light traps, operated with 12 V power sources, were positioned approximately 2 m above the ground to sample scarab beetles flying at night, from 06:00 pm to 10:00 pm. At each of the two sites, one UV light trap and one black light trap were installed at a distance of approximately 300 m. The traps' containers were filled with 1.0 L of a 5:1 70% ethanol:glacial acetic acid mixture for specimen preservation. No light traps were activated during periods of full moon. Additional specimens were captured by manually revising a range of microhabitats (tree trunks, etc.). These non-quantitative samples were not included in the statistical analyses.

A total of 20 traps (12 "NTP-80" + 6 pitfall + 2 UV/black light) were operated at each site for a period of nine months, resulting in 360 individual sampling events. For each month, the necrophilous traps and light traps were run during a ten day period. The pitfall traps were removed after 48 hours. The 18 buried traps (types 1 and 2) were separated by a distance of approximately 40 m along a linear transect of fragmented forest (total length ~ 680 m).

### Sample Processing and Data Analysis

Upon emptying the traps, the captured specimens were transferred into vials with 70% ethanol and subsequently mounted, labeled, and identified to species using the following taxonomic works: Matthews (1966), Morón (1994), Stebnicka (2001, 2003, 2004, 2005, 2006), Joly and Escalona (2002), Carrillo-Ruiz and Morón (2003), Gillogly and Ivie (2005), Schuster and Cano (2005), Stebnicka and Lago (2005), and Reyes Novelo and Morón (2005). The identifications were validated through comparison with specimens housed in the UPRM insect collection (see Franz and Yusseff 2009). The UPRM insect collection is also the permanent location for all specimen vouchers of this study.

In order to characterize the species community structure and its temporal changes, the samples

were separated according to study site, month, and method of capture. Species richness (S) and Margalef's richness index (d) were computed with the software program PRIMER, version 5.0 (Clarke and Warwick 2001). The species diversity was furthermore estimated via the Fisher, Shannon-Wiener (H') and Simpson (1- ) indices, and the equity or uniformity was calculated using the Pielou (J') index (Moreno 2001; Villarreal et al. 2004) as implemented in PRIMER. Among-site and seasonal variations in species composition were computed in a one-way ANOSIM analysis of similarity (Clarke and Warwick 2001). Finally, the occurrence of seasonal abundance effects was assessed using only those species that contributed more than 10% to the overall abundance, via the percentage similarity routine SIMPER, performed with PRIMER.

## Results

### Species Richness

We captured a total of 14 species of scarab beetles pertaining to 10 genera and 4 families (Table 1). Of these, only the passalid *Spasalus crenatus* (MacLeay) was not captured with any of the passive traps. *Chanthochilum* Chapin was the most diverse genus (with three species), followed by *Ataenius* Harold and *Phyllophaga* Harris (each with two species). The light traps yielded the highest numbers of species at each site (i.e., 8-10 species per type and site), whereas the necrophilous and pitfall traps were less successful, capturing only 2-5 species (Table 2). Each site yielded 13 species, 12 of which were shared among sites. *Omorgus suberosus* (Fabricius) was only collected at site 1, whereas *Aphodius lividus* (Olivier) was limited to site 2. The Margalef species richness was slightly higher at site 2 (6.89) in comparison with site 1 (5.89), showing a trend that was supported by the other indices for species richness, with the exception of the Pielou index of equity (Table 4). The greatest species richness was observed in the months of June (12 species, site 1) and August (12 species, site 2), coinciding with the transition to the rainy season in Puerto Rico (Table 3).

**Table 1.** List of Scarabaeoidea species captured in the forest fragments of the University of Puerto Rico at Mayagüez, April to December, 2005.

Family	Subfamily	Genus and species	Feeding habit
Scarabaeidae	Aphodiinae	<i>Ataenius heinekeni</i> Wollaston	coprophagous
		<i>Aphodius lividus</i> (Olivier)	coprophagous
		<i>Ataenius</i> sp.	coprophagous
	Scarabaeinae	<i>Canthochilum andyi</i> Chapin	coprophagous
		<i>Canthochilum borinquensis</i> Matthews	coprophagous
		<i>Canthochilum taino</i> Matthews	coprophagous
		<i>Canthonella parca</i> Chapin	coprophagous
Melolonthidae	Dynastinae	<i>Chalepides barbatus</i> (Fabricius)	phytophagous
		<i>Dyscinetus picipes</i> (Burmeister)	phytophagous
		<i>Phileurus valgus</i> (Olivier)	sapro-xylophagous
	Melolonthinae	<i>Phyllophaga citri</i> Smyth	phytophagous
		<i>Phyllophaga vandinei</i> Smyth	phytophagous
Passalidae	Passalinae	<i>Spasalus crenatus</i> (MacLeay)	xylophagous
Trogidae	Troginae	<i>Omorgus suberosus</i> (Fabricius)	necrophagous

**Table 2.** Numbers of scarab beetles sampled at sites 1 and 2 of the UPRM campus separated by sampling method. ULT = ultraviolet light trap; BLT = black light trap; NFI = necrophilous trap with fish; NFR = necrophilous trap with fruits; PFT = pitfall trap with human excrement; ASC = additional sporadic captures. The sequence of species is alphabetical.

Species	Site 1							Site 2							Total individuals
	ULT	BLT	NFI	PFT	NFR	ASC	Total	ULT	BLT	NFI	PFT	NFR	ASC	Total	
<i>Ataenius heinekeni</i>	22	6	0	0	0	1	29	3	6	0	0	0	0	9	38
<i>Aphodius lividus</i>	0	0	0	0	0	0	0	0	0	0	2	0	0	2	2
<i>Ataenius</i> sp.	4	1	0	0	0	0	5	2	3	0	0	0	0	5	10
<i>Canthochillum andyi</i>	4	11	119	330	10	9	483	4	9	238	367	3	36	657	1140
<i>Canthochillum borinquensis</i>	0	0	30	43	1	0	74	0	0	23	27	0	0	50	124
<i>Canthochillum taino</i>	3	5	45	265	6	0	324	0	8	173	166	2	0	349	673
<i>Canthonella parva</i>	0	0	0	3	0	0	3	0	0	2	6	0	0	8	11
<i>Chalepides barbatus</i>	3	3	0	0	0	0	6	4	2	0	0	0	0	6	12
<i>Dyscinetus picipes</i>	3	2	0	0	0	0	5	9	3	0	0	0	0	12	17
<i>Omorgus suberosus</i>	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1
<i>Phileurus valgus</i>	2	1	0	0	0	0	3	7	3	0	0	0	0	10	13
<i>Phyllophaga citri</i>	10	12	0	0	0	0	22	15	19	0	0	0	6	40	62
<i>Phyllophaga vandinei</i>	30	89	0	0	0	0	119	46	48	0	0	0	0	94	213
<i>Spasalus crenatus</i>	0	0	0	0	0	37	37	0	0	0	0	0	46	46	83
<b>Total individuals</b>	82	130	194	641	17	47	1111	90	101	436	568	5	88	1288	2399
<b>Total species</b>	10	9	3	4	3	3	13	8	9	4	5	2	2	13	14

**Species Abundance**

The sampling efforts resulted in 2399 specimens of Scarabaeoidea, of which 2264 specimens (94.4%) were captured with the three types of passive traps

(Table 2). The numbers of individuals captured per site were similar (1064 specimens at site 1 versus 1200 specimens at site 2). The pitfall traps with human excrement were the most productive

**Table 3.** Seasonal abundance of scarab beetle species sampled monthly at sites 1 and 2 of the UPRM campus during the period of April to December, 2005. The sequence of species is alphabetical.

Species	Site 1										Site 2										Total
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
<i>Ataenius heinekeni</i>	0	0	2	7	1	13	1	1	4	0	0	0	1	4	0	0	2	2	<b>38</b>		
<i>Aphodius lividus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	<b>2</b>		
<i>Ataenius</i> sp.	0	0	1	0	2	0	2	0	0	0	0	0	4	0	0	1	0	<b>10</b>			
<i>Canthochillum andyi</i>	22	19	30	73	81	28	83	82	65	43	46	21	242	114	44	14	83	50	<b>1140</b>		
<i>Canthochillum borinquensis</i>	0	2	2	4	6	0	7	14	39	0	1	2	16	14	2	1	12	2	<b>124</b>		
<i>Canthochillum taino</i>	0	3	3	8	19	44	58	123	66	14	10	5	30	120	31	23	90	26	<b>673</b>		
<i>Canthonella parva</i>	0	0	0	1	2	0	0	0	0	0	0	2	1	3	2	0	0	0	<b>11</b>		
<i>Chalepides barbatus</i>	1	0	2	0	3	0	0	0	0	0	0	2	2	2	0	0	0	0	<b>12</b>		
<i>Dyscinetus picipes</i>	0	0	3	2	0	0	0	0	0	0	5	3	4	0	0	0	0	0	<b>17</b>		
<i>Omorgus suberosus</i>	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<b>1</b>		
<i>Phileurus valgus</i>	1	0	2	0	0	0	0	0	0	1	2	0	1	5	1	0	0	0	<b>13</b>		
<i>Phyllophaga citri</i>	2	0	13	4	0	0	3	0	0	0	7	14	5	5	4	1	0	4	<b>62</b>		
<i>Phyllophaga vandinei</i>	53	26	18	13	9	0	0	0	0	12	33	15	25	3	3	3	0	0	<b>213</b>		
<i>Spasalus crenatus</i>	1	5	5	6	3	1	0	8	8	0	7	6	0	5	8	5	3	12	<b>83</b>		
Total individuals	80	55	82	118	126	86	154	228	182	70	111	70	327	281	95	47	191	96	<b>2399</b>		
Total species	6	5	12	9	9	4	6	5	5	4	8	9	10	12	8	6	5	6	<b>14</b>		

(641 and 568 individuals, respectively), whereas the rotten fruit traps were the least productive (17 and 5 individuals, respectively). *Canthochillum andyi* Chapin (1095 individuals) and *C. taino* Matthews (673 individuals) were the most abundant species. On the other hand, *A. lividus* (2 individuals) and *O. suberosus* (1 individual) were rare. Four species of scarab beetles – *C. andyi* (47.9%), *C. borinquensis* Matthews (5.4%), *C. taino* (29.5%), and *Phyllophaga vandinei* Smyth (9.3%) – accounted for 92% of all individuals captured.

July and November presented the highest abundances of scarab specimens (327 individuals at site 2 and 228 individuals at site 1, respectively), although the seasonal patterns of abundance were generally somewhat alternating, with the period of April to June yielding lower numbers (Table 3). The numbers of *C. andyi* and *C. taino* tended to peak in July to November (with the latter species being slightly delayed). On the other hand, *Phyllophaga citri* Smyth peaked in June, and *P. vandinei* in April (site 1) and May (site 2).

### Seasonal and Spatial Effects

Comparison of the species community structure

throughout the sampling period revealed two statistically separated groupings (ANOSIM;  $R=0.66$ ;  $p=0.001$ ): one constituted by the “higher precipitation months” (September to December) and the other spanning the “summer months” (April to June). On the other hand, neither period showed significant variation with regards to the intermediate “transition months” (July to August). Furthermore, there were no significant spatial differences in scarab communities among the two sites ( $R=0.07$ ;  $p=0.26.1$ ).

According to the SIMPER analysis, three species typified the summer period, i.e., *C. andyi*, *C. taino*, and *P. vandinei* (Table 5). *Canthochillum borinquensis* was an additional typifying species for the transition period, yet neither this species nor *P. vandinei* characterized the high precipitation period. All *Canthochillum* and *Phyllophaga* species jointly differentiated the summer and high precipitation periods (Table 5). The latter period was also differentiated from the transition period by a slightly higher abundance of *Ataenius heinekeni* Wollaston.

**Table 4.** Summary of diversity indices resulting from sampling of scarab beetle species at sites 1 and 2 of the UPRM campus: total richness (S), Margalef (d), Pielou (J'), Fisher, Shannon-Wiener (H'), and Simpson (1-λ).

	S	d	J'	Fisher	H'	1- λ
Site 1	5.889	1.058	0.670	1.436	1.599	0.585
Site 2	6.889	1.241	0.637	1.647	1.707	0.608
Combined	6.389	1.150	0.653	1.542	1.653	0.596

**Table 5.** Analysis of typification and discrimination of scarab beetle species communities during three climate periods (summer: April to June; transition: July to August; rain: September to December) in the forest fragments of the UPRM campus (Ind. = individual contribution to community; Acu. = accumulated contribution to community).

Analysis of typification			Analysis of discrimination		
Climate period	Ind. %	Acu. %	Climate period	Ind. %	Acu. %
<b>Summer</b>			<b>Summer vs. Rain</b>		
<i>C. andyi</i>	47.15	47.15	<i>C. taino</i>	37.82	37.82
<i>P. vandinei</i>	38.93	86.08	<i>C. andyi</i>	24.15	61.98
<i>C. taino</i>	6.04	92.12	<i>P. vandinei</i>	21.73	83.71
<b>Ave. similarity</b>	<b>62.24</b>		<i>C. borinquensis</i>	5.81	89.52
<b>Transition</b>			<i>P. citri</i>	4.06	93.59
<i>C. andyi</i>	70.40	70.40	<b>Ave. dissimilarity</b>	<b>62.99</b>	
<i>C. taino</i>	12.55	82.95	<b>Summer vs. transition</b>		
<i>P. vandinei</i>	6.30	89.25	<i>C. andyi</i>	51.78	51.78
<i>C. borinquensis</i>	5.20	94.45	<i>C. taino</i>	21.31	73.09
<b>Ave. similarity</b>	<b>58.81</b>		<i>P. vandinei</i>	10.88	83.97
<b>Rain</b>			<i>C. borinquensis</i>	4.96	88.93
<i>C. andyi</i>	48.43	48.83	<i>P. citri</i>	3.12	92.05
<i>C. taino</i>	46.50	94.63	<b>Ave. dissimilarity</b>	<b>59.52</b>	
<b>Ave. similarity</b>	<b>61.98</b>		<b>Transition vs. Rain</b>		
			<i>C. andyi</i>	42.87	42.87
			<i>C. taino</i>	31.44	74.31
			<i>P. vandinei</i>	8.30	82.61
			<i>C. borinquensis</i>	6.90	89.41
			<i>A. heinekeni</i>	2.89	92.30
			<b>Ave. dissimilarity</b>	<b>44.72</b>	

Discussion

Our sampling effort revealed a remarkable diversity of scarab beetles inhabiting the relatively small UPRM forest fragments, or nearly 36% of the species richness documented for Puerto Rico. Most captured species were not previously reported to occur in western Puerto Rico, with the exception of *C. andyi*, *C. borinquensis*, *C. taino*, *Dyscinetus picipes* (Burmeister), and *S. crenatus* (see Wolcott

1936, 1948). The numbers of genera and species are comparable to those obtained by Lozada et al. (2004) in a less perturbed mountainous habitat in Cuba, thus underscoring the importance of the UPRM forest remnants as refuges of native scarab beetles.

The two sampled sites were very similar with regards to species richness and abundance, showing no significant spatial patterns. Twelve of the 14

observed species were common at either site, which suggests that the forest fragments are sufficiently connected so as to preclude the development of different species communities. Application of various diversity indices (Table 4) shows that: (1) a small number of species tend to dominate the faunal structure throughout the year (S); (2) these species are present in somewhat similar abundance distributions (J'); and (3) many species are represented in low numbers (H'). The Shannon-Wiener values in particular resemble those of Ronqui and Lopes' (2006) study of Scarabaeoidea in a rural South American habitat.

The observed temporal shifts in community structure are most likely related to a taxon-specific interaction of life cycle and seasonality. Specifically, the melolonthine species (*Phyllophaga*) are univoltine whereas all other species are multivoltine. In addition, members of the Melolonthinae tend to *increase* in abundance during the drier months of the year when leaf production is reduced and flower and fruit production are augmented (Morón 1994; Carrillo-Ruiz and Morón 2003). Conversely, most non-melolonthine species in the sample appeared to be *limited* by low precipitation. The advent of strong rains in August coincided with an increase in captured specimens (see also Ronqui and Lopes 1996), although peaks in the abundances of *P. citri* and *P. vandinei* in the months of May and June might be similarly related to heavy rainfalls and warm temperatures. Such apparent repartitioning of food resources throughout the year may facilitate the coexistence of a higher number of scarab beetle species (Escobar and Chacón 2000).

Of the five species that dominated the community structure in the UPRM forest fragments, three species (*C. andyi*, *C. borinquensis*, and *C. taino*) are copro-necrophagous. Of these, *C. andyi* and *C. taino* showed only partially overlapping seasonal abundances. The two most common rhizophagous-phylophagous species, *P. citri* and *P. vandinei*, had similarly off-set peaks in abundance (see also Buss 2006). The relatively high abundance of *P. vandinei* during the summer months was most typical of this period.

The herein presented results demonstrate the important ecological role that western Puerto Rican forest fragments play in maintaining local scarab beetle communities. They provide a baseline for the development of related assessment tools for these ubiquitous successional habitats (Aide et al. 2005), and will hopefully contribute to an increased recognition and preservation of their dynamic insect faunas.

### Acknowledgments

The authors thank Carlos Santos and Ángel González for their support and comments provided throughout the course of this study; Miguel Morón for providing critical literature and methodological advice; and the staff and students of the Finca Laboratorio Alzamora, Mayagüez Campus, for facilitating and participating in the field work upon which this manuscript is based.

### References

- AIDE TM, ZIMMERMAN JK, HERRERA L, ROSARIO M, SERRANO M. 1995. Forest recovery in abandoned tropical pastures in Puerto Rico. For Ecol Manage 77(1-3): 77-86.
- BARBERENA-ARIAS MF, AIDE TM. 2003. Species diversity and trophic composition of litter insects during plant secondary succession. Carib J Sci 39(2): 161-169.
- BUSS E. 2006. Flight activity and relative abundance of phytophagous scarabs (Coleoptera: Scarabaeoidea) from two locations in Florida. Florida Entomol 89(1): 32-40.
- CARRILLO-RUIZ H, MORÓN MA. 2003. Fauna de coleópteros Scarabaeoidea de Cuetzalán del Progreso, Puebla, México. Acta Zool Mex 88: 87-121.
- CHALUMEAU F. 1982. Contribution à l'étude des Scarabaeoidea des Antilles (III). Nouv Rev Entomol 12(4): 321-345
- CHALUMEAU F. 1983. *Batesiana* et *Martinezia*, nouveaux genres d'Eupariini (Coleoptera: Scarabaeidae: Aphodiinae) du nouveau monde. Bull Mens Soc Linn Lyon 52: 142-153.
- CHALUMEAU F. 1985. Un Dynastinae des Antilles décrit: *Endroedianibe* Chalumeau. Bull Mens Soc Linn Lyon 54: 98-100.
- CHAPIN EA. 1935. New species of Scarabaeoidea (Coleoptera) from Puerto Rico and the Virgin Islands. J Agric Univ Puerto Rico 19(1): 67-71.

- CLARKE KR, WARWICK RM. 2001. Change in marine communities: an approach to statistical analysis and interpretation, 2nd edition. PRIMER-E, Plymouth, United Kingdom.
- DECHAMBRE RP. 1979. Nouveaux Dynastidae Pentodontini Américains (Coleoptera: Scarabaeoidea). Rev Franç Entomol (Nouv Ser) 1(3): 101-103.
- ESCOBAR F. 1994. Excremento, coprófagos y deforestación en bosques de montaña al sur occidente de Colombia. Tesis de Pregrado, Universidad del Valle, Cali, Colombia.
- ESCOBAR F, CHACÓN P. 2000. Distribución espacial y temporal en un gradiente de sucesión de la fauna de coleópteros coprófagos (Scarabaeinae Aphodiinae) en un bosque tropical montano, Nariño-Colombia. Rev Biol Trop 48(4): 961-975.
- EVANS AV, SMITH ABT. 2005. An electronic checklist of the New World chafers (Coleoptera: Scarabaeidae: Melolonthinae), version 1. Electronically published, Ottawa, Canada. 344 p.
- FIGUEROA COLÓN JC. 1996. Phytogeographical trends, centers of high species richness and endemism, and the question of extinctions in native flora of Puerto Rico. Ann. N. Y. Acad. Sci. 776: 89-102.
- FRANZ NM, YUSSEFF VANEGAS SZ. 2009. The University of Puerto Rico at Mayagüez insect collection - then and now. Entomological News 120(49): 401-408.
- GARCÍA JC, PARDO-LOCARNO LC. 2004. Escarabajos Scarabaeinae saprófagos (Coleoptera: Scarabaeidae) en un bosque muy húmedo premontano de los Andes occidentales Colombianos. Ecol Apl 3(1,2): 59-63.
- GILGOLLY AR, IVIE MA. 2005. Provisional key to the genera of West Indian Passalidae. <http://virgin.msu.montana.edu/WestIndies/Polyphaga/Scarabaeoidea/Passalidkey.html>
- GREBENNIKOV VV, SCHOLTZ CH. 2004. The basal phylogeny of Scarabaeoidea (Insecta: Coleoptera) inferred from larval morphology. Invert Syst 18(3): 321-348.
- JOLY LJ, ESCALONA H. 2002. Revisión del género *Chalepides* Casey, 1915 (Coleoptera: Scarabaeidae: Dynastinae: Cyclocephalini). Entomotropica 17(1): 37-90.
- KLEIN B. 1989. Effects of forest fragmentation on dung and carrion beetle communities in Central Amazonia. Ecology 70(6): 1715-1725.
- KOHLMANN B, SOLÍS A, ELLE O, SOTO X, RUSSO R. 2007. Biodiversity, conservation, and hotspot atlas of Costa Rica: a dung beetle perspective. Zootaxa 1457: 1-34.
- LOZADA A, FERNÁNDEZ I, TRUJILLO M. 2004. Lista preliminar de los coleópteros (Insecta, Coleoptera) de Topes de Collantes, Trinidad, Sancti Spíritus, Cuba. Bol Soc Entomol Arag 34: 101-106.
- MALDONADO-CAPRILES J. 1982. The genus *Ataenius* (Coleoptera: Scarabaeidae) in Puerto Rico. J Agric Univ Puerto Rico 68(1): 111-112.
- MARTÍNEZ NJ, ACOSTA JA, FRANZ NM. 2009. Structure of the beetle fauna (Insecta: Coleoptera) in forest remnants of western Puerto Rico. Journal of Agriculture of the University of Puerto Rico 93(1-2): 83-100.
- MARTORELL LF. 1976. Annotated food plant catalog of the insects of Puerto Rico. University of Puerto Rico, Agricultural Experiment Station, Río Piedras, Puerto Rico. 303 p.
- MATTHEWS EG. 1963a. Observations on the ball-rolling behavior of *Canthon pilularius* (L.) (Coleoptera, Scarabaeidae). Psyche 70: 75-93.
- MATTHEWS EG. 1963b. Description of the larva and pupa of *Cathochilum histeroides* (Harold) with notes on its biology (Coleoptera: Scarabaeidae). Coleop Bull 17: 110-116.
- MATTHEWS EG. 1965. The taxonomy, geographical distribution, and feeding habits of the canthonines of Puerto Rico (Coleoptera: Scarabaeidae). Trans Am Entomol Soc 91: 431-465.
- MATTHEWS EG. 1966. A taxonomic and zoogeographic survey of the Scarabaeinae of the Antilles (Coleoptera, Scarabaeidae). Mem Am Entomol Soc 21:1-312.
- MATTHEWS EG. 1969. New data on Antillean Scarabaeinae beetles, and two new species from Hispaniola. Psyche 76: 114-125.
- MEDINA C, KATTAN G. 1996. Diversidad de coleópteros coprófagos (Scarabaeidae) de la reserva forestal de Escalerete. Céspedesia 21(68): 89-102.
- MEDINA S, MARTORELL LF, MALDONADO J. 2003. Catálogo de los nombres comunes de insectos y acarinos de importancia económica de Puerto Rico. Universidad de Puerto Rico, Estación Experimental Agrícola, Río Piedras, Puerto Rico. 149 p.
- MORENO C. 2001. Métodos para medir la biodiversidad. Manuales y Tesis Soc Entomol Arag, Vol. 1., Zaragoza. 84p.
- MORÓN MA, TERRÓN RA. 1984. Distribución altitudinal y estacional de los insectos necrófilos de la Sierra Norte de Hidalgo, México. Acta Zool Mex 3(1): 1-47.
- MORÓN MA. 1994. Fauna de Coleoptera Lamellicornia en las montañas del noreste de Hidalgo, México. Acta Zool Mex 63(1): 7-59.
- PLANK HK. 1948. Life-history, habits and control of the *Coconut rhinoceros* beetle in Puerto Rico. Bull Fed Expt Stat Mayagüez 45: 1-35.
- QUINTERO I, ROSLIN T. 2005. Rapid recovery of dung beetle communities following habitat fragmentation in Central Amazonia. Ecology 86(12): 3303-3311.
- REYES NOVELO E, MORÓN MA. 2005. Fauna de Coleoptera Melolonthidae y Passalidae de Tzucacab y Conkal, Yucatán, México. Acta Zool Mex 21(2): 15-49.



- RONQUI D, LOPES J. 2006. Composition and diversity of Scarabaeoidea (Coleoptera) attracted by light trap in the rural areas of Northern Paraná. *Iheringia Sér Zool* 96(1): 103-108.
- SCHUSTER J, CANO E. 2005. Clave para los géneros de los Passalidae Americanos. <http://www.museum.unl.edu/research/entomology/Guide/Scarabaeoidea/Passalidae/PassalidaeKey/>
- STEBNICKA Z. 2001. The New World species of *Ataenius* Harold, 1867. I. Revision of the *A. crenator*-group, *A. nugator*-group and *A. perforatus*-group (Coleoptera: Scarabaeidae: Aphodiinae: Eupariini). *Acta Zool Cracoviensia* 44(3): 253-283.
- STEBNICKA Z. 2003. The New World species of *Ataenius* Harold, 1867. III. Revision of the *A. imbricatus*-group sensu lato (Coleoptera: Scarabaeidae: Aphodiinae: Eupariini). *Acta Zool Cracoviensia* 46(3): 219-249.
- STEBNICKA Z. 2004. The New World species of *Ataenius* Harold, 1867. IV. Revision of the *A. strigicauda*-group (Coleoptera: Scarabaeidae: Aphodiinae: Eupariini). *Acta Zool Cracoviensia* 47(3-4): 211-228.
- STEBNICKA Z. 2005. The New World species of *Ataenius* Harold, 1867. VI. Revision of the *A. aequalis-platensis*-group (Coleoptera: Scarabaeidae: Aphodiinae: Eupariini). *Acta Zool Cracoviensia* 48B(1-2): 99-138.
- STEBNICKA Z. 2006. The New World species of *Ataenius* Harold, 1867. VII. Revision of the *A. complicatus*-group (Scarabaeidae: Aphodiinae: Eupariini). *Acta Zool Cracoviensia* 49B(1-2): 89-114.
- STEBNICKA Z, LAGO PK. 2005. The New World species of *Ataenius* Harold, 1867. V. Revision of the *A. strigatus* group (Scarabaeidae: Aphodiinae: Eupariini). *Insecta Mundi* 19(1-2): 55-83.
- THOMLINSON JR, SERRANO MI, LÓPEZ TM, AIDE TM, ZIMMERMAN JK. 1996. Land use dynamics in a post-agricultural Puerto Rican landscape. *Biotropica*, Special Issue 28: 525-536.
- VILLARREAL H, ALVARES M, CORDOBA S, ESCOBAR F, FAGUA G, GAST F, MENDOZA H, OSPINA M, UMAÑA A. 2004. Manual de métodos para el desarrollo de inventarios de biodiversidad. Programa de Inventarios de Biodiversidad, Instituto de Investigaciones de Recursos Biológicos Alexander von Humboldt, Bogotá, Colombia. 236p.
- WOLCOTT GN. 1936. Insectae Borinquenses. *J Agri Univ Puerto Rico* 20: 1-627.
- WOLCOTT GN. 1948. The insects of Puerto Rico: Coleoptera. *J Agr Univ Puerto Rico* 32(2): 225-416.