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

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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 species 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 (18º12'48'N', 67º08'16"W), with an approximate elevation of 20 m above sea level; whereas site 2 is located on the Finca Laboratorio Alzamora (18º13'20"N, 67º08'40"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-λ) 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	*Ataenius heinekeni* Wollaston	coprophagous
		Aphodius lividus (Olivier)	coprophagous
		Ataenius sp.	coprophagous
	Scarabaeinae	*Canthochilum andyi* Chapin	coprophagous
		Canthochilum borinquensis Matthews	coprophagous
		Canthochilum taino Matthews	coprophagous
		Canthonella parca Chapin	coprophagous
Melolonthidae	Dynastinae	*Chalepides barbatus* (Fabricius)	phytophagous
		Dyscinetus picipes (Burmeister)	phytophagous
		Phileurus valgus (Olivier)	sapro-xylophagous
	Melolonthinae	*Phyllophaga citri* Smyth	phytophagous
		Phyllophaga vandinei Smyth	phytophagous
Passalidae	Passalinae	*Spasalus crenatus* (MacLeay)	xylophagous
Trogidae	Troginae	*Omorgus suberosus* (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.

	Site 1							Site 2							Total individuals
Species	**ULT**	**BLT**	**NFI**	**PFT**	**NFR**	**ASC**	**Total**	**ULT**	**BLT**	**NFI**	**PFT**	**NFR**	**ASC**	**Total**	
Ataenius heinekeni	22	6	0	0	0	1	**29**	3	6	0	0	0	0	**9**	**38**
Aphodius lividus	0	0	0	0	0	0	**0**	0	0	0	2	0	0	**2**	**2**
Ataenius sp.	4	1	0	0	0	0	**5**	2	3	0	0	0	0	**5**	**10**
Canthochillum andyi	4	11	119	330	10	9	**483**	4	9	238	367	3	36	**657**	**1140**
Canthochillum borinquensis	0	0	30	43	1	0	**74**	0	0	23	27	0	0	**50**	**124**
Canthochillum taino	3	5	45	265	6	0	**324**	0	8	173	166	2	0	**349**	**673**
Canthonella parva	0	0	0	3	0	0	**3**	0	0	2	6	0	0	**8**	**11**
Chalepides barbatus	3	3	0	0	0	0	**6**	4	2	0	0	0	0	**6**	**12**
Dyscinetus picipes	3	2	0	0	0	0	**5**	9	3	0	0	0	0	**12**	**17**
Omorgus suberosus	1	0	0	0	0	0	**1**	0	0	0	0	0	0	**0**	**1**
Phileurus valgus	2	1	0	0	0	0	**3**	7	3	0	0	0	0	**10**	**13**
Phyllophaga citri	10	12	0	0	0	0	**22**	15	19	0	0	0	6	**40**	**62**
Phyllophaga vandinei	30	89	0	0	0	0	**119**	46	48	0	0	0	0	**94**	**213**
Spasalus crenatus	0	0	0	0	0	37	**37**	0	0	0	0	0	46	**46**	**83**
Total individuals	82	130	194	641	17	47	**1111**	90	101	436	568	5	88	**1288**	**2399**
Total species	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	
Ataenius heinekeni	0	0	2	7	1	13	1	1	4	0	0	0	1	4	0	0	2	2	**38**
Aphodius lividus	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	**2**
Ataenius sp.	0	0	1	0	2	0	2	0	0	0	0	0	0	4	0	0	1	0	**10**
Canthochillum andyi	22	19	30	73	81	28	83	82	65	43	46	21	242	114	44	14	83	50	**1140**
Canthochillum borinquensis	0	2	2	4	6	0	7	14	39	0	1	2	16	14	2	1	12	2	**124**
Canthochillum taino	0	3	3	8	19	44	58	123	66	14	10	5	30	120	31	23	90	26	**673**
Canthonella parva	0	0	0	1	2	0	0	0	0	0	0	2	1	3	2	0	0	0	**11**
Chalepides barbatus	1	0	2	0	3	0	0	0	0	0	0	2	2	2	0	0	0	0	**12**
Dyscinetus picipes	0	0	3	2	0	0	0	0	0	0	5	3	4	0	0	0	0	0	**17**
Omorgus suberosus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Phileurus valgus	1	0	2	0	0	0	0	0	0	1	2	0	1	5	1	0	0	0	**13**
Phyllophaga citri	2	0	13	4	0	0	3	0	0	0	7	14	5	5	4	1	0	4	**62**
Phyllophaga vandinei	53	26	18	13	9	0	0	0	0	12	33	15	25	3	3	3	0	0	**213**
Spasalus crenatus	1	5	5	6	3	1	0	8	8	0	7	6	0	5	8	5	3	12	**83**
Total individuals	80	55	82	118	126	86	154	228	182	70	111	70	327	281	95	47	191	96	**2399**
Total species	6	5	12	9	9	4	6	5	5	4	8	9	10	12	8	6	5	6	**14**

(641 and 568 individuals, respectively), whereas the rotten fruit traps were the least productive (17 and 5 individuals, respectively). *Canthochilum 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 Decemper) 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. %
Summer			**Summer vs. Rain**		
C. andyi	47.15	47.15	*C. taino*	37.82	37.82
P. vandinei	38.93	86.08	*C. andyi*	24.15	61.98
C. taino	6.04	92.12	*P. vandinei*	21.73	83.71
Ave. similarity	**62.24**		*C. borinquensis*	5.81	89.52
			P. citri	4.06	93.59
Transition			**Ave. dissimilarity**	**62.99**	
C. andyi	70.40	70.40			
C. taino	12.55	82.95	**Summer vs. transition**		
P. vandinei	6.30	89.25	*C. andyi*	51.78	51.78
C. borinquensis	5.20	94.45	*C. taino*	21.31	73.09
Ave. similarity	**58.81**		*P. vandinei*	10.88	83.97
			C. borinquensis	4.96	88.93
Rain			*P. citri*	3.12	92.05
C. andyi	48.43	48.83	**Ave. dissimilarity**	**59.52**	
C. taino	46.50	94.63			
Ave. similarity	**61.98**		**Transition vs. Rain**		
			C. andyi	42.87	42.87
			C. taino	31.44	74.31
			P. vandinei	8.30	82.61
			C. borinquensis	6.90	89.41
			A. heinekeni	2.89	92.30
			Ave. dissimilarity	**44.72**	

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 abudance 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-specifc 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-phyllophagous 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.

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