Structure of the beetle fauna (Insecta: Coleoptera) in forest remnants of western Puerto Rico[1,2]

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ABSTRACT

We studied the richness and abundance of beetle families in two successional forest fragments located in close proximity on the campus of the University of Puerto Rico at Mayagüez (UPRM), western Puerto Rico. The study period extended from April to December 2005 and included nine monthly repetitions of quantitative samples using necrophilous, pitfall, and light traps. A total of 30 beetle families—48% of the families reported on the Island—and 38,126 individuals were obtained. The among-site variation was low, as both sites were dominated by beetles belonging to the families Curculionidae, Nitidulidae, Staphylinidae, Scarabaeidae, and Hydrophilidae (in order of abundance). These families represent a range of feeding habits and jointly constituted more than 93% of the samples. The light traps were most effective in maximizing the sampled beetle diversity. The abundance of most groups was correlated with the seasonal changes in climate and resource availability, and peaked in the middle of the rainy season in August. In summary, the forest fragments of the UPRM campus harbor a surprisingly diverse and temporally dynamic beetle fauna. More wide-ranging assessments of coleopteran communities residing in successional forests in Puerto Rico are needed to characterize and preserve these valuable habitats.

Key words: beetles, biodiversity, quantitative sampling, succession, urban forest

RESUMEN

Estructura de la fauna de escarabajos (Insecta: Coleoptera) en bosques remanentes del oeste de Puerto Rico

Se estudió la riqueza y abundancia de familias de escarabajos en dos fragmentos de bosques sucesionales en localidades cercanas en el campus

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de la Universidad de Puerto Rico, Recinto de Mayagüez (UPRM), en el oeste de Puerto Rico. El periodo de estudio se extendió de abril a diciembre de 2005, e incluyó nueve repeticiones mensuales de muestreos cuantitativos usando trampas necrófilas, de caída y de luz. Se obtuvo un total de 30 familias de escarabajos—48% de las familias reportadas para la Isla—y 38,126 individuos. La variación entre sitios fue baja, ya que en ambos sitios dominaron escarabajos pertenecientes a las familias Curculionidae, Nitidulidae, Staphylinidae, Scarabaeidae, e Hydrophilidae (en orden de abundancia). Estas familias representan un rango amplio de hábitos alimenticios y en conjunto constituyeron más del 93% de las muestras. Las trampas de luz fueron las más efectivas para obtener la mayor diversidad muestreada de escarabajos. La abundancia de la mayoría de los grupos se correlacionó con los cambios estacionales climáticos y la disponibilidad de recursos, y llegó a su máximo a mediados de la época lluviosa en agosto. En resumen, los fragmentos de bosque del campus UPRM albergan una fauna de escarabajos sorprendentemente diversa y dinámica. Se requiere de evaluaciones más amplias de las comunidades de coleópteros residentes en bosques sucesionales de Puerto Rico para caracterizar y preservar estos hábitats valiosos.

Palabras clave: escarabajos, biodiversidad, muestreo cuantitativo, sucesión, bosque urbano

INTRODUCTION

Puerto Rican forests suffered dramatically during the first half of the 20th century because of intense agricultural practices and increased pressures from the human population. However, during the past 50 years—concomitant with the transformation to an industrial economy (Grau et al., 2003)—large portions of former agricultural lands have been abandoned, thus enabling plant succession and the establishment of significant areas with fragmented secondary forests (Aide et al., 1995; Thomlinson et al., 1996; Helmer et al., 2002; Barberena-Arias and Aide, 2003). Such forest fragments are known to serve as important refuges for a remaining fraction of the original biological diversity (Escobar and Chacón de Ulloa, 2000; Quintero and Roslin, 2005).

Beetles (Insecta: Coleoptera) are the most diverse lineage of organisms worldwide and represent a major component of ecosystems in terms of biomass, species richness, and ecological roles (Didham et al., 1998; García and Chacón de Ulloa, 2005; Noriega et al., 2007). Because of their diversity and responsiveness, beetles are well suited as indicators of the ecological conditions of forest fragments (Marinoni and Ganho, 2003, 2006; Paquin, 2008). Yet studies of beetle diversity in Puerto Rico have been hindered in part by the incomplete knowledge of the Island's insect fauna (Leng and Mutchler, 1914a, 1914b; Wolcott, 1923, 1936a, 1936b, 1948; Maldonado-Capriles and Navarro, 1967; Martorell, 1976; Medina et al., 2003). In the most recent review of the insects of Puerto Rico, Maldonado-Capriles (1996) reported nearly 1,100 species of Coleoptera, thus suggesting that the actual number of species may be twice as high. Reliable data on the distribution and natural history of Puerto Rican beetles are rare, and typically limited to species with economic relevance (Wolcott, 1948; Martorell, 1976). Together these factors have hampered the use of beetles as indicators of the quality of forest fragments in Puerto Rico.

With this study we will reduce the aforementioned knowledge gap by characterizing the structure of the beetle fauna of forest remnants located on the premises of the University of Puerto Rico at Mayagüez (UPRM). The results are relevant in terms of their ecological as well as educational implications in light of the great potential of urban forests as primary tools for teaching about structure and functional interactions in nature (Simmons, 1998; Morello and Rodríguez, 2001; Wheeler, 2008).

MATERIALS AND METHODS

Study sites

The beetle fauna was sampled in two forest fragments separated by a distance of 1.4 km (Figure 1). These fragments are part of the UPRM

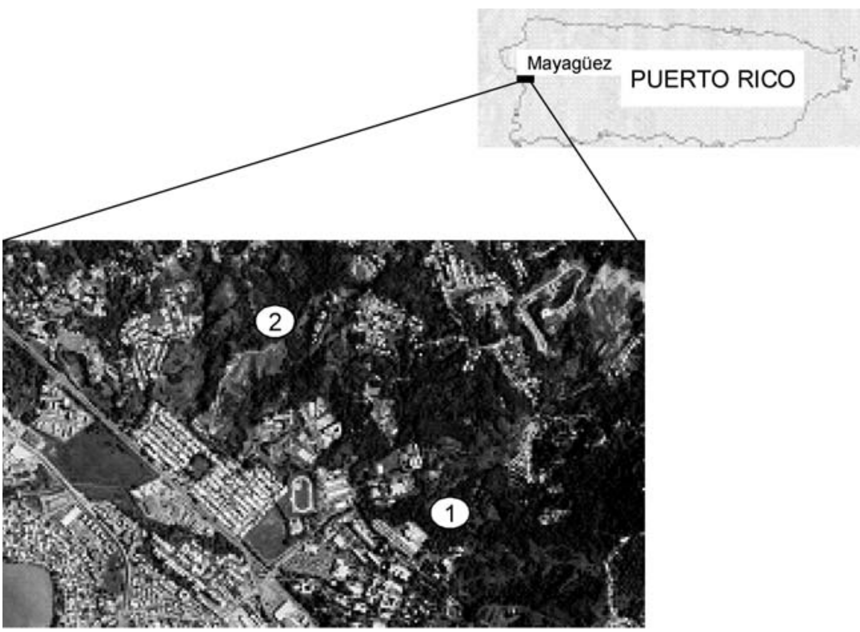


FIGURE 1. Geographic location of UPRM Campus forest fragments used for sampling beetles: (1) fragment between new Biology Building and Mayagüez Zoo; and (2) Finca Laboratorio Alzamora.

campus located in the municipality of Mayagüez, near the midpoint along the western coast of Puerto Rico (N 18°12', W 67°08'). Average temperatures at midday vary from 29 to 35° C and the average annual rainfall is > 1400 mm, with a marked dry season from January to March (information provided by the Meteorological Station of the Department of Marine Sciences, UPRM).

Site 1 is situated between the new Biology Building and the Mayagüez Zoo (N 18°12'48", W 67°08'16"), with an approximate elevation of 20 m above sea level. Site 2 is located at the Finca Laboratorio Alzamora (N 18°13'20", W 67°08'40"), at approximately 50 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.

The following plant families dominate the forest vegetation (canopy height ~30 m, high abundance of climbers and epiphytes): Amaranthaceae, Anacardiaceae, Annonaceae, Arecaceae, Bombacaceae, Bignoniaceae, Euphorbiaceae, Fabaceae, Meliaceae, Moraceae, Musaceae, Poaceae, Rubiaceae, and Sterculiaceae. The adjacent successional areas are primarily characterized by shrubs and pioneer tree species in the Melastomataceae and Rubiaceae (canopy height ~15 m or less). The pastures are used for cattle and include some isolated tall trees.

Sampling techniques and scheme

The beetle fauna was sampled quantitatively during a period of nine months extending from April to December 2005. Three sampling methods were used: (1) A series of modified, slightly smaller versions of the permanent necrophilous insect trap "NTP-80" (Morón and Terrón, 1984) were constructed. Each of six traps of this type was baited with rotten sardines, and six additional traps were baited with a mixture of banana and mango fruits, topped off with concentrated vanilla extract. (2) Six modified pitfall traps were built by using 900-ml plastic containers, each with a centrally positioned film roll case hanging from an L-shaped wire attached to the rim. The cases were perforated and filled with 25 g of human excrement. Both types of traps (1 and 2) were buried to form a smooth transition with the surrounding soil. The pitfall traps were furnished with an overhanging cover for protection against rainfall and other disturbances. (3) Commercially available UV and black light traps, operated with 12-V power sources (Coleman Powermate 400 W)[6], were positioned approximately 2 m above the ground to sample insects flying at night (i.e., from 06:00 pm to 10:00 pm). At each site one UV light trap and one black light trap were separated by 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 insect preservation. No light traps were activated during periods of full moon.

Additional insect specimens were captured from time to time by manually revising a range of accessible substrates (leaf litter, tree trunks, vertebrate excrement). These non-quantitative samples were not included in the statistical analyses.

A total of 20 traps (12 + 6 + 2) were operated at each site (× 2) for a period of nine months (× 9), resulting in 360 individual sampling events. For each month the necrophilous traps and light traps were run during a ten-day period and checked at the midpoint of that period in order to replace the evaporated liquid. The pitfall traps were removed after 48 hours. The 18 buried traps (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

The sampled beetle specimens were transferred into smaller vials with 70% ethanol and properly labeled (Villareal et al., 2004). Subsequently they were sorted according to perceived morphotypes and identified to family level (Lawrence et al., 1999; Solís, 2002; Triplehorn and Johnson, 2005; Marshall, 2006). The identifications were validated through comparison with specimens housed in the UPRM insect collection (Franz and Yusseff-Vanegas, 2009). The UPRM collection is also the permanent location for all specimen vouchers of this study.

The samples were separated for analysis by study site, month, and method of capture. Family richness was taken as the number of families represented per site and month sampled. The abundance (= total number of specimens) per family was determined. The beetle diversity was also assessed by using the Shannon-Wiener (H') and Simpson (1-λ) indices at the family level, as implemented in the PRIMER 5.0 software package (Clarke and Warwick, 2001), and by following recommendations by Pielou (1984) and Magurrán (1989). To facilitate further interpretation of the results, the families were pooled together according to

[6]Trade names in this publication are used only to provide specific information. Mention of a trade name does not constitute a warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

their predominant feeding habits (Hammond and Lawrence, 1989; Lawrence and Britton, 1994; Hutcheson and Kimberley, 1999).

Data on temperature, rainfall and relative humidity throughout the sampling period were provided by the UPRM Meteorological Station.

RESULTS

Overall diversity and temporal variation

Twenty-seven beetle families were captured by using the three quantitative trapping methods. Qualitative sampling yielded three additional families—Attelabidae, Coccinellidae, and Passalidae—for a total of 30 family records for the UPRM campus. At both sites the UV and black light traps produced the highest number of families, i.e., 20 and 23 families, respectively (Table 1). On the other hand, the necrophilous and pitfall traps captured only nine and 11 families per site, respectively. The taxonomic overlap was high, with 27 families sampled at both sites. Trogidae were documented only at site 1, whereas Attelabidae and Buprestidae were found only at site 2 (Table 1).

Temporal arrangement of the samples showed August to be the month with the highest number of beetle families, i.e., 19 for site 1 and 22 for site 2, respectively (Table 2). The lowest family-level diversity (12 and 13 families, respectively) was obtained during the months of October, November and December. Site 2 yielded similar or higher values of family-level diversity in seven of the nine months sampled (Figure 2). The Shannon-Wiener and Simpson indices were closely correlated at each site and over time (Table 3). Both indices indicated that November had the highest family diversity, whereas the period from May to July had the least diversity. Beetles with herbivorous, predatory, and detritivorous feeding habits were dominant in the samples in terms of family richness (Figure 3A) and overall abundance (Figure 3B).

Abundance of beetle families

A total of 38,126 beetles were obtained (Tables 1 and 2). The necrophilous and pitfall traps were the most productive (26,613 individuals, 69.8%), followed by the light traps (11,197 individuals, 29.4%), and finally by the various non-quantitative sampling methods (316 individuals, 0.8%). Between sites there was no significant variation in abundance (19,003 beetles and 19,123 beetles at sites 1 and 2, respectively), although site 2 yielded higher numbers of beetles with four of the six collecting methods used. At each site the necrophilous traps baited with fruit mixes were the most productive (Table 1). In the monthly arrangement, site 1 was most productive in May and August, whereas

TABLE 1.— *Numbers of 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 collections. The sequence of families is alphabetical.*

	SITE 1							SITE 2							
Family	ULT	BLT	NFI	NFR	PFT	ASC	Total	ULT	BLT	NFI	NFR	PFT	ASC	Total	Grand Total
Anthribidae[1,2]	2	0	0	0	0	0	2	1	4	0	0	4	0	9	11
Attelabidae[3]	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2
Bostrichidae[2]	3	3	0	0	0	0	6	12	5	2	0	0	0	19	25
Brentidae[2]	1	2	0	1	0	0	4	2	1	0	0	2	0	5	9
Buprestidae[3]	0	0	0	0	0	0	0	2	0	0	0	0	10	12	12
Cantharidae[3,4]	44	34	0	0	0	0	78	24	24	0	0	0	0	48	126
Carabidae[4]	82	113	0	0	6	0	201	161	158	12	21	8	17	377	578
Cerambycidae[3]	0	4	4	1	0	2	11	4	1	9	8	0	0	22	33
Chrysomelidae[3]	11	3	0	0	0	3	17	6	5	0	4	0	3	18	35
Coccinellidae[1,3,4]	0	0	0	0	0	16	16	0	0	0	0	0	19	19	35
Cleridae[4]	2	27	0	0	0	0	29	15	7	0	0	2	0	24	53
Cucujidae[1,4]	2	6	0	0	0	0	8	8	11	0	0	0	0	19	27
Curculionidae[1,3]	1,294	984	2,105	2,000	1,116	2	7,501	1,620	1,123	2,338	2,645	2,412	0	10,138	17,639
Dermestidae[1,3]	0	0	11	0	0	0	11	0	0	19	0	2	0	21	32
Dytiscidae[3,4]	320	216	0	0	0	0	536	112	58	0	0	0	0	170	706
Elateridae[3,4]	4	5	0	0	0	5	14	6	6	0	1	0	3	16	30
Histeridae[4]	0	0	237	103	39	1	380	0	2	122	61	11	1	197	577
Hydrophilidae[1]	562	278	0	0	0	14	854	228	780	0	0	0	9	1,017	1,871
Lampyridae[4]	17	13	0	0	0	0	30	10	31	0	0	0	0	41	71
Lycidae[3,4]	3	0	0	0	0	0	3	4	3	0	0	0	0	7	10

[1]detritivore.
[2]dead wood feeder.
[3]herbivore.
[4]predator (feeding habits according to Lawrence a Britton, 1994; Hutcheson and Kimberley, 1999).

TABLE 1.— *(Continued) Numbers of 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 collections. The sequence of families is alphabetical.*

	SITE 1							SITE 2							
Family	ULT	BLT	NFI	NFR	PFT	ASC	Total	ULT	BLT	NFI	NFR	PFT	ASC	Total	Grand Total
Meloidae[3]	3	6	0	0	0	0	9	8	8	0	0	0	0	16	25
Melolonthidae[3]	26	34	0	0	0	0	60	44	32	0	0	0	2	78	138
Nitidulidae[1,3]	72	124	444	3,557	1,279	76	5,552	111	17	246	669	334	8	1,385	6,937
Passalidae[2]	0	0	0	0	0	39	39	0	0	0	0	0	54	54	93
Ptiliidae[1]	0	2	0	0	0	0	2	2	1	0	0	0	0	3	5
Rhysodidae[2]	0	0	9	2	1	0	12	0	0	5	0	0	1	6	18
Scarabaeidae[1]	36	23	312	11	736	10	1,128	7	26	511	5	810	4	1,363	2,491
Staphylinidae[1,4]	362	252	631	701	500	0	2,446	589	890	928	990	581	0	3,978	6,424
Tenebrionidae[1]	15	17	9	0	6	6	53	6	15	15	15	0	8	59	112
Trogidae[1]	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Total individuals	2,862	2,146	3,762	6,376	3,683	174	19,003	2,982	3,208	4,207	4,419	4,166	141	19,123	38,126
Total families	21	20	9	8	8	11	28	23	23	11	10	10	14	29	30

[1]detritivore.
[2]dead wood feeder.
[3]herbivore.
[4]predator (feeding habits according to Lawrence a Britton, 1994; Hutcheson and Kimberley, 1999).

TABLE 2.— *Seasonal abundance of beetle families sampled monthly and with quantitative methods at sites 1 and 2 of the UPRM Campus during the period of April to December, 2005. The sequence of families is determined by their overall abundance.*

	SITE 1										SITE 2										
Family	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Grand total
Curculionidae	82	405	934	1,707	1,419	698	916	659	679	7,499	458	1,008	1,388	1,073	1,645	1,455	937	1,132	1,042	10,138	17,637
Nitidulidae	414	2,292	1,188	229	561	222	395	126	49	5,476	147	267	117	170	231	123	175	97	50	1,377	6,853
Staphylinidae	64	267	242	426	618	366	139	163	161	2,446	63	187	127	592	913	369	231	1,189	37	3,671	6,117
Scarabaeidae	5	34	18	113	11	153	142	316	182	974	67	55	26	279	237	194	23	191	8	1,080	2,054
Hydrophilidae	11	28	15	4	138	15	138	477	14	840	0	0	9	5	219	1	7	697	61	999	1,839
Dytiscidae	6	35	19	15	86	45	165	139	26	536	6	4	9	6	6	1	7	122	0	161	697
Histeridae	1	6	1	8	17	63	26	9	14	145	1	8	2	48	53	24	3	15	6	160	305
Carabidae	2	41	43	29	26	19	19	1	12	192	0	11	13	23	72	57	88	45	51	360	552
Melolonthidae	26	7	18	5	3	0	1	0	0	60	6	24	11	9	12	6	4	0	4	76	136
Cantharidae	5	2	6	7	25	15	7	2	9	78	7	0	4	4	16	5	1	4	7	48	126
Tenebrionidae	0	0	4	8	14	11	0	4	6	47	0	12	0	0	2	1	0	9	0	24	71
Lampyridae	5	3	6	4	5	0	0	7	0	30	2	2	2	2	14	7	7	3	2	41	71
Cleridae	0	0	2	14	1	3	0	0	0	20	2	3	0	1	7	0	2	0	0	15	35
Dermestidae	0	4	0	0	5	2	0	0	0	11	3	2	4	3	5	4	0	0	0	21	32
Cerambycidae	0	0	2	0	2	1	1	3	0	9	3	8	5	1	0	3	1	1	0	22	31
Chrysomelidae	2	1	3	3	5	0	0	0	0	14	2	8	3	1	0	0	1	0	0	15	29
Cucujidae	0	0	0	0	0	0	0	0	8	8	3	0	0	0	0	0	0	1	6	10	18
Bostrichidae	4	0	0	0	0	2	0	0	0	6	4	2	0	3	2	0	0	0	8	19	25
Meloidae	0	5	0	0	0	0	4	0	0	9	0	0	0	0	3	5	0	8	0	16	25
Elateridae	1	2	0	2	4	0	0	0	0	9	0	2	0	1	4	0	2	4	0	13	22
Rhysodidae	1	0	4	0	4	3	0	0	0	12	0	0	0	0	2	3	0	0	0	5	17
Anthribidae	0	0	0	0	0	0	0	0	2	2	0	0	4	0	2	1	0	0	2	9	11
Lycidae	0	0	2	0	0	1	0	0	0	3	0	0	4	0	1	1	0	1	0	7	10
Brentidae	2	1	0	0	1	0	0	0	0	4	1	0	0	0	4	0	0	0	0	5	9
Ptiliidae	0	0	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	1	2	3	5

TABLE 2.— *(Continued) Seasonal abundance of beetle families sampled monthly and with quantitative methods at sites 1 and 2 of the UPRM Campus during the period of April to December, 2005. The sequence of families is determined by their overall abundance.*

	SITE 1										SITE 2										
Family	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Grand total
Buprestidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	2
Trogidae	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Total individuals	631	3,133	2,508	2,574	2,945	1,619	1,953	1,908	1,162	18,433	775	1,603	1,728	2,221	3,452	2,260	1,489	3,520	1,249	18,297	36,730
Total families	16	16	18	15	19	16	12	13	12	26	16	16	16	17	22	18	15	17	13	26	27

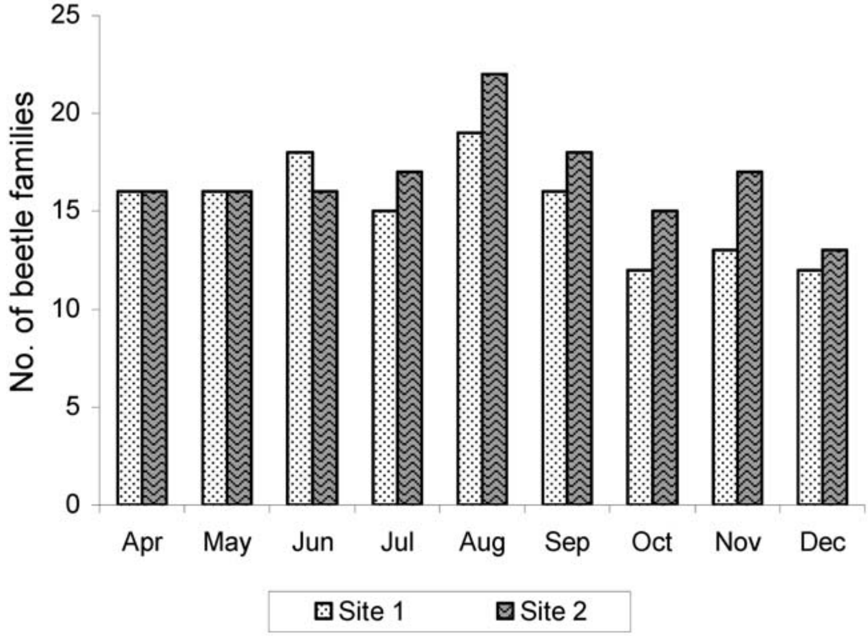


FIGURE 2. Temporal fluctuation of beetle family richness in two forest fragments of the UPRM Campus, sampled during the period of April to December, 2005.

site 2 was most productive in August and November (Table 2; Figure 4). At each site, April was the month with the lowest abundance of individuals, coinciding with the end of the dry season.

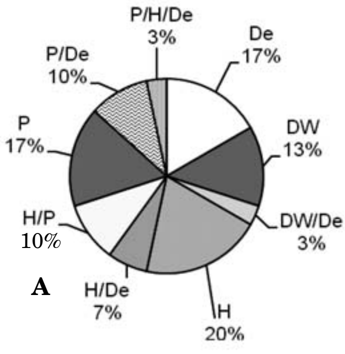
The five most numerously represented beetle families were, in order of abundance, Curculionidae (17,637 individuals), Nitidulidae (6,853 individuals), Staphylinidae (6,117 individuals), Scarabaeidae (2,054 individuals), and Hydrophilidae (1,839 individuals). In all, these families made up 94.0% of the samples obtained (Table 2; Figure 4). Nearly every other beetle sampled was a weevil (including scolytine bark beetles). Nitidulidae was the second most abundant family at site 1 (5,476 individuals), whereas Staphylinidae occupied the second position at site 2 (3,671 individuals). On the other hand, Ptillidae (five individuals), Buprestidae (two individuals, only at site 2), and Trogidae (one individual, only at site 1) were the least abundant families (Table 2).

In the temporal analysis, the abundance of Curculionidae individuals peaked in July (site 1) and August (site 2) and was lowest in April (Table 2). The Staphylinidae showed a similar distribution over the nine months sampled. This pattern was furthermore predominant in the majority of the less well represented beetle families. In contrast,

TABLE 3.—*Seasonal dynamics of Shannon-Wiener (H') and Simpson (1-λ) biodiversity indices for beetle families sampled monthly and with quantitative methods at sites 1 and 2 of the UPRM Campus during the period of April to December, 2005.*

	SITE 1		SITE 2	
Month	H'	1-λ	H'	1-λ
April	1.437	0.605	1.358	0.610
May	0.967	0.441	1.230	0.562
June	1.236	0.627	0.837	0.345
July	1.213	0.548	1.412	0.676
August	1.666	0.730	1.558	0.692
September	1.642	0.733	1.255	0.559
October	1.596	0.717	1.434	0.656
November	1.700	0.776	1.577	0.740
December	1.360	0.613	1.217	0.549
Mean ± SD	1.424 ± 0.25	0.643 ± 0.11	1.320 ± 0.22	0.599 ± 0.12

the number of Nitidulidae captured at each site was highest in May and lowest in December. The Scarabaeidae showed a diverging between-site pattern, with the highest abundance occurring in either November (site 1) or July (site 2), whereas the lowest values were recorded in either April (site 1) or December (site 2). Finally, the Hydrophilidae showed a distinctive peak in abundance in November but were much less frequent during other months; at site 2 only 22 individuals were captured during the combined periods of April-July and September-October (Table 2).



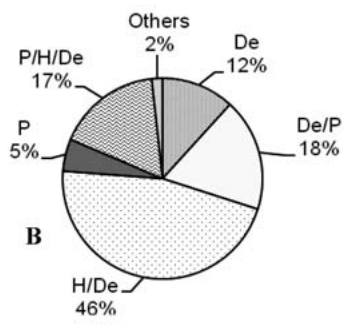


FIGURE 3. Relative frequency of primary feeding habits of beetle samples in forest fragments of the UPRM Campus: (A) richness of families; (B) overall abundance of individuals. De = detritivore; DW = dead wood feeder; H = herbivores; P = predator.

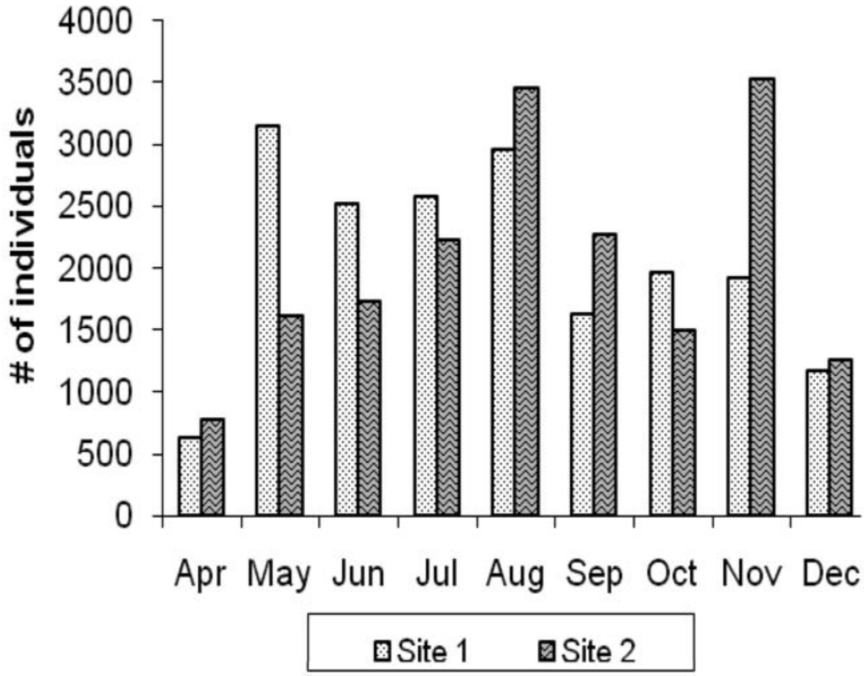


FIGURE 4. Temporal fluctuation of overall abundance of beetles in two forest fragments of the UPRM Campus, sampled during the period of April to December, 2005.

Abiotic conditions

Average temperatures during the sampling period ranged from 24° C (December) to 28° C (Figure 5). The monthly rainfall was highest in October (288.5 mm) and lowest in April (87.1 mm). Similarly, the relative humidity peaked in October (86.5%) and had its lowest values in June (78.0%, Figure 5).

DISCUSSION

The richness of beetle families documented in the UPRM forest remnants was surprisingly high, representing nearly half of the families (48.3%) reported for Puerto Rico (Wolcott, 1923, 1936a, 1948; Maldonado and Navarro, 1962) and more than 80% of the families known to attack food plants (Martorell, 1976; Medina et al., 2003). In short, these forest fragments may preserve a significant portion of Puerto Rico's beetle fauna.

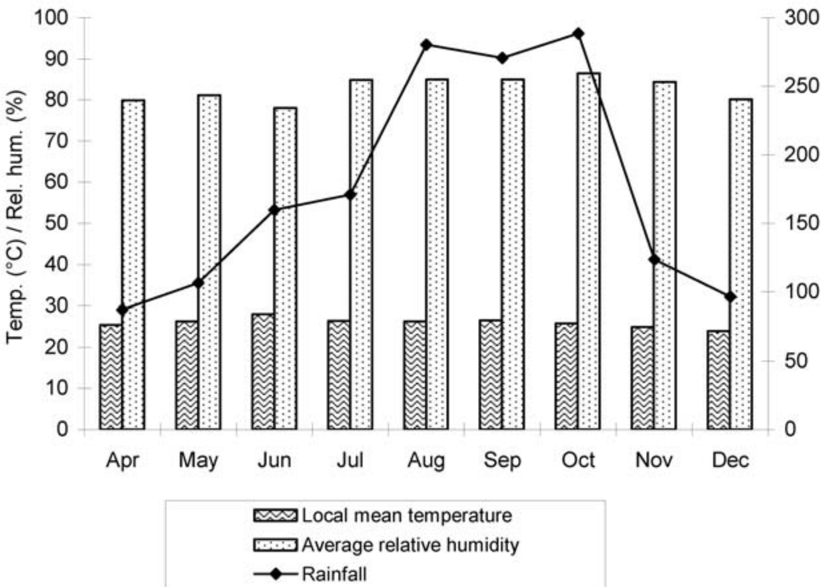


FIGURE 5. Monthly fluctuation of temperature, relative humidity, and rainfall on the UPRM Campus during the sampling period of April to December, 2005.

The between-site variation in richness was small, as would be expected in habitats that share a similar location, history of land use, plant composition, and environmental conditions. The occurrence of singleton families restricted to one site (e.g., Trogidae) is most likely a result of insufficient sampling of rare taxa rather than a function of the fragments' state of preservation. The diversity of families is similar to that observed in other Antillean forest remnants (Lozada et al., 2004) but less than that observed in continental systems (Didham et al., 1998; Ganho and Marinoni, 2003; Iannuzzi et al., 2003). The light traps captured more than 75% of the beetle families and therefore constitute the most effective method of monitoring groups occurring in virtually all microhabitats of these forests (Wolda et al., 1998).

The richness of beetle families was correlated with the rainfall patterns on the UPRM campus (which are also typical for western Puerto Rico). The highest diversity coincided with a higher precipitation in the summer months (especially in August) even though the traps are less efficient in the presence of heavy rains, and insect mortality is high as well (Pinheiro et al., 2002). Species migration, low population levels, low availability of resources, and relative inactivity possibly are factors for the lesser diversity seen during the drier months (such as April). These differences notwithstanding, the temporal variation of family richness was limited, thus suggesting that the fragmented habitats are able to sustain the beetle fauna throughout most of the year (Pinheiro et al., 2002).

Both diversity indices (Table 3) were fairly low, either because of consistent resampling of similar taxa (H') or because of a numerical predominance of a few families (1-λ). The values were nevertheless higher than those reported for forest remnants in Costa Rica (Goehring et al., 2002) and New Zealand (Hutcheson and Kimberley, 1999), thus underscoring the value of the UPRM fragments for the local fauna. The mostly balanced representation of beetles with different feeding habits (Figure 3) is further indication of a healthy diversity of plant species, trophic levels, and biological processes (Hutcheson and Kimberley, 1999; Barbarena and Aide, 2003; Barbosa et al., 2005). Other authors (Davies et al., 1997; Santos et al., 2003) have observed a similar sequence of families representing particular feeding habits, viz., Curculionidae (herbivores), Nitidulidae and others (detritivores), Carabidae and others (predators) (Table 2).

The beetle fauna of the UPRM forest fragments was numerically dominated by five families that are known for their abundance in the leaf litter and are among the 14 most diverse beetle families (Crowson, 1981). The high occurrence of weevils was due primarily to bark beetles in the subfamily Scolytinae (Oberprieler et al., 2007). These wood-feeding beetles are attracted to several volatile compounds, including ethanol, and are therefore common in many quantitative surveys (Iturre et al., 1995; Hall, 2001; Santos et al., 2003).

Different families peaked at different times during the sampling period. In particular, the high beetle numbers in May at site 1 were due largely to the family Nitidulidae, whose species feed on flowers and ripening or rotting fruits (Morón and Terrón, 1984) such as mango, which were abundant at that time. At site 2, other trees including soursop (*Annona muricata* L.), citrus trees and plantains set fruit in October and November and are likely correlates with high beetle diversity during these months. Most remaining families peaked around the middle of the rainy season when the vegetation cover, habitat diversity and food resources are increasing and seem to have a positive effect on the beetle populations (Pinheiro et al., 2002).

In summary, the forest fragments of the UPRM Campus are home to a surprisingly diverse and temporally dynamic beetle fauna. The present report lays the groundwork for more wide-ranging assessments of coleopteran communities residing in successional habitats in Puerto Rico (Aide et al., 1995). This research will hopefully lead to an increased recognition and preservation of these valuable habitats and their insufficiently known fauna (Maldonado-Capriles, 1996).

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