ASSESSING THE POTENTIAL ROLE OF BEETLES AS BIOINDICATORS IN SOUTH SINAI, EGYPT.

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ABSTRACT

A study of ground beetle (Coleoptera) Communities was conducted in south Sinai Peninsula, Egypt. Using pitfall trap we collected a total of 4183 specimens from all sites, representing 73 genera and 98 species belonging to 19 coleopterous families. Various environmental factors influencing the distribution of beetles were measured. The most important were altitude and medium sand. Overall results suggest that abundance and species richness increased as the level of elevation decreased. To determine whether sites might sort into groups based in their beetles assemblage and environmental factors, sites were ordinated by canocal correspondence analysis (CCA), and classified by two-way indicator species analysis (TWINSPAN). Ordination suggested that the distribution of beetles was somewhat influenced by altitude and medium sand size. We used the cross-taxon analysis to assess the use of different beetle families as indicators of the health and functioning of the environment (ecological and environmental indicators) or as surrogate indicators of the overall diversity or assemblage composition of other groups within an area (biodiversity indicators). Cryptophagidae and Dermestidae were highly correlated with the environment and Tenebrionidae and Anthicidae were highly correlated with overall community.

INTRODUCTION

Within the class Insecta, the beetles, order Coleoptera, constitute 40 % of all described insects. They are an extremely diverse order in terms of life histories, behaviour and ecology. Beetles occur at all trophic levels, inhabiting a multitude of terrestrial and aquatic niches (Eyre *et al.*, 1989). Beetles have also proven to be useful bioindicators for environmental monitoring and assessment (Stork 1990; Luff, 1996; Desender & Bosmans, 1998; Petit & Usher, 1998; Rodríguez, *et al.*, 1998), with their high diversity and sensitivity to environmental conditions providing a fine grained view of ecological change (Erwin, 1997 & Semida, *et al.*, 2001). Most of the

previous studies that have used beetles have focused on one or a few species, often in the family Carabidae (Lenski, 1982; Holliday, 1992; Niemela *et al.*, 1993; Beaudry *et al.*, 1997). However, few studies have examined the entire beetle assemblage (Mouna & Rutanen, 1994). Beetle species assemblages provide a useful tool for examining ecosystem processes because of their ubiquity, sensitivity to environmental change, and their range of ecological roles (Thiele, 1977; Niemela *et al.*, 1993; Muona & Rutanen, 1994; Didham *et al.*, 1996 & Didham *et al.*, 1998).

Ground beetles are excellent bioindicators of habitat perturbation (Dritschilo & Wanner, 1980; Kromp, 1989; Larsen *et. al.*, 1999; Work *et. al.*, 1998), such as nutrient enrichment, as some are sensitive to pollutants and the majority are highly selective in the habitat they occupy (Larsen *et. al.*, 1999). Most of the surveys focus on the response of the species to changing environmental conditions, such as forest fragmentation (e.g., Niemela *et al.*, 1988) or management practices (e.g., Rushton *et al.*, 1990). In addition to these studies, ground beetles have been used in studies on urban ecology (Venn, 2000), insecticides (Basedow, 1990), effects of military tanks (Mossakowski *et al.*, 1990), classification of habitat type (Eyre & Luff, 1990) and assessment of site quality (Eyre *et al.*, 1996).

McGeoch *et al.* (2002) showed that dung beetles are sensitive to habitat change, and have been suggested as potential bioindicators. The presence and activity of dung beetle adults are conditioned by many environmental factors, such as vegetation cover, soil type, temperature, and precipitation (Barkhouse & Ridsdill-Smith, 1986). Moreover, the presence of dung beetles is obviously related to the existence of discrete resource patches of dung in the ecosystem (Hanski & Cambefort, 1991). Dung beetles have been used in several studies to investigate the effects of environmental change on forest diversity and structure (Howden & Nealis, 1975; Nummeline & Hanski, 1989; Klein, 1989; Halffter & Favila, 1993; Kremen *et al.*, 1993; Davis, 1993).

MATERIAL AND METHODS

The Study Area

The southern mountainous part of Sinai covers about 7000 km², and contains several wadis characterized by different climatic conditions. Ten sites arranged in three different altitudinal gradients were selected to sample beetle fauna: El-Mafareq (120 masl), Sahab (950 masl), and St. Catherine (1620-1730 masl) (Wadi El-Arbaaein and Wadi El-Talaa).

Vegetation

The plant cover in the studied areas was recorded as presence and absence data (Table 1).

Sampling methods

Adult beetles had been collected by using pitfall traps over a period of one year. Ten sites were chosen to represent three different localities. In each site, 20 pitfall traps were fixed, traps were arranged in four rows, except in Wadi El-Talaa site they were arranged in three rows only; with 5m intervals between lines and among traps. Traps were left open for two successive days, starting from early morning, each month. The captured beetles were identified and counted in the laboratory.

Environmental variables

Soil characters (Table 2) were measured at the different study sites in South Sinai. Organic matter, moisture, pH values, and electric conductivity were measured according to Wilde *et al.* 1979. Moreover soil texture was determined for each site.

Data analysis

Beetle species richness, mean abundance and evenness were calculated using the PC-ORD program for Windows version 4.14 (McCune & Mefford, 1999). Differences in beetles mean abundances, richness and evenness per plot between sites were compared using one-way analysis of variance (ANOVA) (Zar, 1999) using the SPSS for Windows 12 statistical software package (SPSS, Inc. 1996).

Classification

Two-way indicator species analysis (TWINSPAN) was performed using the statistical package PC-ORD for Windows version 4.14 (McCune & Mefford, 1999) using the following settings: maximum number of indicators per division = 5; maximum level of division = 3; minimum group size per division = 6; and maximum number of the species in the final table = 50. Classification by TWINSPAN was stopped at the third level, so that the size of the sites would demonstrate ecological meaning.

Ordination was used in part to check whether the classification by TWINSPAN adequately reflected the invertebrate species gradient composition in the data and also to detect the relations between environmental factors and the composition of the invertebrate communities.

TABLE (1)

The vegetation of the studied sites in South Sinai

Species	Family	CA1	CA2	CA3	SA1	SA2	SA3	MA1	MA2	MA3	TA
Acacia raddiana Savi	Leguminosae	0	0	0	0	0	0	1	1	0	0
Achillea fragrantissima (Forssk.) Sch.-Bip.	Compositae	1	1	0	0	0	0	0	0	0	1
Alkanna orientalis (L.) Boiss.	Boraginaceae	1	1	0	0	0	0	0	0	0	0
Almond		0	0	1	0	0	0	0	0	0	0
Apple		0	0	1	0	0	0	0	0	0	0
Apricot		0	0	1	0	0	0	0	0	0	0
Artemisia inculta Del.	Compositae	1	1	0	0	0	0	0	0	0	0
Asclepias sinaica (Boiss.) Muschl.	Asclepiadaceae	1	1	0	0	0	0	0	0	0	1
Ballota undulata (Fresen.) Benth.	Labiatae	1	1	0	0	0	0	0	0	0	0
Dat palm "young"		0	0	0	0	0	0	1	1	0	0
Diplotaxis harra (Forssk.) Boiss.	Cruciferae	1	1	0	0	0	0	0	0	0	0
Echinopis glaberrimus Dc.	Compositae	1	1	0	0	0	0	0	0	0	0
Fagonia mollis Del.	Zygophyllaceae	1	1	0	0	0	0	0	0	0	0
Fig		0	0	1	0	0	0	0	0	0	0
Mentha longifolia (L.)	Labiatae	1	1	0	0	0	0	0	0	0	1
Onopordum ambiguum Fresen.	Compositae	1	1	0	0	0	0	0	0	0	0
Origanum syriacum L.	Labiatae	1	1	0	0	0	0	0	0	0	1
Peganum harmala L.	Zygophyllaceae	1	1	0	0	0	0	0	0	0	1
Phlomis aurea Decne.	Labiatae	1	1	0	0	0	0	0	0	0	0
Pomegranate		0	0	1	0	0	0	0	0	0	0
Retama raetam (Forssk.)	Leguminosae	0	0	0	0	0	0	1	1	0	0
Salvia spinosa L.	Labiatae	1	1	0	0	0	0	0	0	0	1
Stachys aegyptiaca Pers.	Labiatae	1	1	0	0	0	0	0	0	0	1
Tamarix nilotica (Ehrenb.) Bge	Tamaricaceae	0	0	0	1	0	0	0	0	1	0
Tanacetum santolinoides Dc.	Compositae	1	1	0	0	0	0	0	0	0	0
Verbascum sinaiticum Benth.	Scrophulariaceae	1	1	0	0	0	0	0	0	0	0
Vine		0	0	0	0	1	0	0	0	0	0
Zilla spinosa (L.) Prantl.	Cruciferae	1	1	0	0	0	0	0	0	0	0
Zizyphus spinachristi (L.) Willd.	Rhamnaceae	0	0	0	0	0	0	1	1	0	0
Zygophyllum simplex L.	Zygophyllaceae	0	0	0	0	0	0	1	1	0	0
Gazwarina		0	0	0	1	0	0	0	0	0	0

CA1, CA2, and CA3: the three sites at Wadi El-Arbaeein in St. Catherine; MA1, MA2 and MA3: the three sites in El-Mafareq; TA: the site in Wadi El-Talaa in St. Catherine.

TABLE (II)
The Environmental variables at studied sites in South Sinai

Variable	TA	CA1	CA2	CA3	SA1	SA2	SA3	MA1	MA2	MA3
Elevation	1640	1620	1640	1730	950	950	950	120	120	120
pH	9	8	8	8	8	8	8	8	8	8
Conductivity (micromhos)	550	543	549	579	303	303	303	33	33	33
Organic Matter (%)	733	724	732	772	404	404	403	44	44	44
Moisture (%)	430	425	430	453	238	238	238	28	28	28
Gravel (%)	571	564	571	602	315	315	315	35	35	35
Coarse Sand (%)	578	571	578	609	319	319	319	36	36	36
Medium Sand (%)	526	520	526	555	291	291	290	33	33	33
Fine Sand (%)	558	552	558	589	308	308	308	34	34	34
Silt + Clay (%)	554	547	554	584	306	306	306	34	34	34

CA1, CA2, and CA3: the three sites at Wadi El-Arbaaein in St. Catherine; MA1, MA2 and MA3: the three sites in El-Mafareq; TA: the site in Wadi El-Talaa in St. Catherine; SA1, SA2, and SA3: the three sites in Sahab.

Ordination

The CCA was done in the forward selection mode of the CANOCO program (ter Braak, 1987), and the significance of each variable was tested in a sequential fashion using a Monte-Carlo simulation algorithm before it was added to the final model. All variables that were significant at $p<0.05$ were included in the final model. The environmental variables were log-transformed to compress high values and spread low values by expressing the value as order of magnitude (McCune, & Grace, 2002).

Indicator species analysis

The analysis of indicator species by Dufrene and Legendre's (1997) method provided a simple, intuitive solution for identifying which species might serve as indicators of a particular environmental condition. This method calculated the proportional abundance of a particular species in a particular group, relative to the abundance of that species in all groups. Then, the method calculated the relative abundance of a certain species in a certain group and calculated the proportional frequency of the species in each group. These percentages were regarded as representations of the faithfulness or constancy of presence within a particular group. The two proportions were then multiplied to yield a percentage, which was used as an indicator value for each species in each group. Because the component terms are multiplied, both indicator criteria must be high for the overall indicator value to be high. The highest indicator value for a given species across group is saved as a summary of the overall indicator value (IV) of that species and evaluated

by the Monte Carlo method, with randomly reassigned SUs (sample units) to groups taking place 1000 times. The probability of a type I error occurring was the proportion of times that the IV from the randomized data set equals or exceeds the IV from the actual data set. The null hypothesis is that IV is no larger than would be expected by chance (McCune & Grace, 2002).

Cross-taxon congruence

An ordination of the plots for each taxon was created using results from these analyses. Cross-taxon analysis involved the estimation of the influence of each taxon on the overall combined environmental variables (McKenzie *et al.*, 2000). Databases of plants, soil variables and Levy pole variables were used and were combined to create the environmental variables matrix. Using Pearson product-moment correlation, the relationship between each pair of taxa was calculated. By doing this, it was possible to derive similarity matrices for each data sub-set, as well as for the combined environmental variables dataset. These matrices were represented as linear similarity vectors. This correlation matrix was converted to a dissimilarity matrix. The minimum spanning tree was superimposed in order to indicate the nearest-neighbour in ordination space.

RESULTS AND DISCUSSION

Trends in Richness, Abundance and Evenness

A total of 98 species (Table 3) were collected and identified from 4183 beetle specimens during the study period. The highest values (38 and 33) were recorded in MA1 and MA3 from (948 and 551 specimens) followed by MA2 (31 species from 1557 specimens) and the lowest values (10 species) was shown by SA2 from (28 specimens). The evenness value ranged from 0.882 in the CA1 site to 0.411 in the MA1 site, with a mean value of 0.697. (Figures 1a, 1b & 1c).

One-way ANOVA's revealed significant differences in beetle species richness and mean abundance between the three sites (MA 1, MA 2 and MA 3) and both the four sites (CA 1, CA 2, CA 3 and TA) and the three sites (MA 1, MA 2 and MA 3) for the pitfall trap method ($P < 0.01$). But there was no significant difference between the last two groups. One-way ANOVA's showed no significant differences in beetle species evenness between the 10 sites.

TABLE (III)

Beetle families and species collected from different study sites in South Sinai

Family	Genus	Species	TA	CA1	CA2	CA3	SA1	SA2	SA3	MA1	MA2	MA3
Anthicidae	*Anthelephila*	sp.	1	4	2	8	1	1	34	0	0	0
Anthicidae	*Anthicus*	*crinitus*	0	0	0	0	2	0	48	5	20	1
Anthicidae	*Endomia*	*bivitatta bivitatta*	0	0	0	0	4	0	47	3	3	10
Anthicidae	*Mecynotarsus*	*bison*	1	0	0	0	0	1	0	2	20	3
Anthicidae	*Mecynotarsus*	*semicinctus*	1	1	0	1	0	0	0	339	1063	34
Anthicidae	*Stricticollis*	*modestus*	6	0	0	0	0	0	0	29	88	2
Cantharidae	*Dasytiscus*	sp.	2	0	0	0	0	0	0	0	0	0
Carabidae	*Agonum*	*nigrum*	0	0	0	0	0	0	0	0	1	0
Carabidae	*Bembidion*	*atlanticum megaspilum*	51	0	0	0	0	0	0	0	0	0
Carabidae	*Bembidion*	*schmidti moses*	32	0	0	0	0	0	0	0	0	0
Carabidae	*Brachinus*	*latipennis*	54	0	0	0	0	0	0	0	0	0
Carabidae	*Calosoma*	*olivieri*	2	5	3	3	0	0	1	0	1	0
Carabidae	*Chlaenius*	*canariensis*	17	0	0	0	0	0	0	0	0	0
Carabidae	*Chlaenius*	*obscurus*	44	0	0	0	0	0	0	0	0	0
Carabidae	*Cymindis*	*setifensis*	0	5	8	34	3	0	3	2	1	2
Carabidae	*Egadroma*	*marginata*	13	0	0	0	0	0	0	0	0	0
Carabidae	*Glycia*	*castanea*	0	5	7	3	0	0	0	1	0	0
Carabidae	*Laemostenus*	*quadricollis*	3	1	7	7	0	0	0	0	0	0
Carabidae	*Lebia*	*arcuata*	0	0	1	3	0	0	0	0	0	0
Chrysomelidae	*Aphthona*	*fuentei*	0	11	1	0	0	0	0	0	0	0
Chrysomelidae	*Chaetocnema*	*tibialis*	3	0	0	0	0	0	0	0	0	0
Chrysomelidae	*Longitarsus*	*albineus*	0	0	1	0	0	0	0	0	0	0
Chrysomelidae	*Psylliodes*	*hospes*	1	0	0	0	0	0	0	0	0	0
Coccinellidae	*Scymenus*	*iterruptus*	0	1	0	0	0	0	0	0	0	0
Cryptophagidae	*Cryptophagus*	*acutangulus*	12	3	3	15	66	10	8	0	0	0

TABLE (III) continued

Family	Genus	Species	TA	CA1	CA2	CA3	SA1	SA2	SA3	MA1	MA2	MA3
Cryptophagidae	*Cryptophagus*	*affinis*	0	0	0	0	0	0	0	30	4	2
Curculionidae	*Cleonus*	*hieroglyphicus*	0	0	0	0	0	0	0	1	0	0
Curculionidae	*Mogulones*	*peregriuus*	0	0	0	1	0	0	0	0	0	0
Curculionidae	*Porocleonus*	*candidus*	0	0	0	0	0	0	0	1	0	0
Curculionidae	*Sitona*	*crinitus seriesetosus*	0	0	0	0	0	0	0	0	1	1
Curculionidae	*Sitona*	sp.	0	0	2	0	0	0	0	0	0	0
Curculionidae	*Tanymecini*	sp.	0	0	0	0	0	0	0	0	0	1
Dermestidae	*Anthrenus*	*crustaceus*	0	0	0	0	0	0	0	2	0	2
Dermestidae	*Attagenus*	*trifasciatus*	0	0	0	0	0	0	0	4	1	0
Dryopidae	*Dryops*	*lurdius*	7	0	0	0	0	0	0	0	0	0
Elateridae	*Cardiophorus*	*pharaonum*	0	0	0	0	0	0	1	0	0	0
Elateridae	*Cordiophorus*	*brunneus*	0	0	0	0	0	0	0	1	0	6
Elateridae	*Drasterius*	sp.	0	0	0	0	0	0	1	0	0	0
Histeridae	*Saprinus*	*chalcites*	2	0	0	1	0	0	0	1	0	2
Histeridae	*Saprinus*	sp.	0	0	0	0	1	0	7	0	0	0
Histeridae	*Saprinus*	*sphingis*	0	0	0	0	0	0	0	9	1	15
Hydraenidae	*Ochthebius*	sp.	4	0	0	0	0	0	0	0	0	0
Lathridiidae	*Corticaria*	*fulva*	0	0	0	0	0	0	1	0	0	0
Mycetophagidae	*Typhaea*	*stercorea*	0	0	0	0	0	0	0	1	0	0
Pselaphidae	*Ctenistomorphus*	*elaniticus*	0	0	1	0	0	0	0	0	0	0
Ptinidae	*Ptinus*	*testaceus*	0	0	0	0	0	0	0	1	0	8
Scarabaeidae	*Aphodius*	*granarius*	0	2	0	112	0	0	0	0	0	0
Scarabaeidae	*Aphodius*	*lucidus*	0	0	0	0	0	0	0	0	1	0
Scarabaeidae	*Aphodius*	sp.	0	0	0	2	0	0	0	0	0	0
Scarabaeidae	*Heteronychus*	sp.	0	0	0	0	0	0	0	3	1	3
Scarabaeidae	*Netocia*	*afflicta*	0	2	0	0	0	0	0	0	0	0

TABLE (III) continued

Family	Genus	Species	TA	CA1	CA2	CA3	SA1	SA2	SA3	MA1	MA2	MA3
Scarabaeidae	*Pentodon*	*bispinosus*	0	0	0	0	0	0	0	1	1	0
Scarabaeidae	*Rhyssemodes*	*kocheri*	0	0	0	0	0	0	0	7	4	4
Scarabaeidae	*Rhyssemodes*	*orientalis*	0	1	0	36	0	0	0	0	0	0
Scarabaeidae	*Stalagmosoma*	*albella*	0	0	0	0	1	0	85	0	0	0
Staphylinidae	*Aleochara*	sp.	0	0	0	0	0	0	0	1	0	0
Staphylinidae	*Atheta*	*sordida*	0	0	0	0	0	0	0	15	15	2
Staphylinidae	*Medon*	sp.	2	0	0	0	0	0	0	0	0	0
Staphylinidae	*Pinophilus*	sp.	0	0	1	0	0	0	0	0	0	0
Staphylinidae	*Scopaeus*	*debilis*	2	0	0	0	0	0	0	0	0	0
Staphylinidae	*Trogophloeus*	sp.	0	0	1	1	0	0	0	0	0	0
Tenebrionidae	*Adelostoma*	*sulcatum sulcatum*	0	1	1	0	2	0	0	0	0	0
Tenebrionidae	*Adesmia*	*bicarinata glabrior*	0	0	0	0	0	0	0	161	87	23
Tenebrionidae	*Adesmia*	*montana*	0	0	0	0	10	2	10	0	0	0
Tenebrionidae	*Akis*	*barbara*	1	0	0	0	0	0	0	0	0	0
Tenebrionidae	*Anemia*	*aegyptiaca*	0	0	0	0	0	0	0	0	1	1
Tenebrionidae	*Anemia*	*fausti*	0	0	0	0	0	0	0	0	0	2
Tenebrionidae	*Blaps*	*schweinfurthi*	0	0	0	0	0	0	0	1	0	0
Tenebrionidae	*Curimosphena*	*villosus*	0	0	0	0	0	0	51	0	0	0
Tenebrionidae	*Gonocephalum*	*setulosum demaisoni*	0	0	0	0	3	0	0	0	1	7
Tenebrionidae	*Gonocephalum*	*soricinum*	4	0	0	0	2	0	2	4	11	22
Tenebrionidae	*Gonocephalum*	sp.	0	0	0	0	0	0	0	2	5	27
Tenebrionidae	*Leichenum*	*mulleri*	0	0	0	0	5	1	4	1	21	240
Tenebrionidae	*Leichenum*	*pulchellum*	0	0	0	0	0	0	0	2	0	2
Tenebrionidae	*Leichenum*	sp.	6	0	0	0	0	0	0	0	0	0
Tenebrionidae	*Megadasus*	*soricinum*	0	0	0	0	3	0	9	0	0	0
Tenebrionidae	*Mesostena*	*angustata*	0	0	0	0	1	6	1	17	31	12

TABLE (III) continued

Family	Genus	Species	TA	CA1	CA2	CA3	SA1	SA2	SA3	MA1	MA2	MA3
Tenebrionidae	*Mesostena*	*puncticollis*	0	1	0	0	0	0	0	0	0	0
Tenebrionidae	*Mesostena*	sp.	0	0	0	0	0	0	0	20	22	1
Tenebrionidae	*Micipsa*	*philistina*	0	0	1	0	0	0	0	0	0	0
Tenebrionidae	*Mitotagenia*	*arabs*	0	1	0	0	0	1	0	0	0	0
Tenebrionidae	*Mitotagenia*	sp.	0	0	1	0	0	0	0	0	0	0
Tenebrionidae	*Ocnera*	*major*	0	0	0	0	0	0	0	4	2	0
Tenebrionidae	*Ocnera*	*parvicollis*	0	6	0	0	0	0	0	0	0	0
Tenebrionidae	*Ocnera*	*philistina*	0	0	0	0	2	2	1	0	0	0
Tenebrionidae	*Opatroides*	*punctulatus*	2	1	0	4	17	3	59	12	0	0
Tenebrionidae	*Pimelia*	*hirtella*	0	0	0	0	0	0	0	106	41	20
Tenebrionidae	*Pimelia*	*spinulosa*	0	0	0	0	0	0	0	8	6	4
Tenebrionidae	*Proscheimus*	*arabicus*	0	0	0	0	0	0	0	0	0	8
Tenebrionidae	*Pterolasia*	*squalida*	0	0	0	0	0	0	0	18	4	3
Tenebrionidae	*Scaurus*	*carinatus*	0	0	0	0	0	0	1	0	0	0
Tenebrionidae	*Scelasodis*	*castaneus*	0	0	0	0	0	0	0	127	98	76
Tenebrionidae	*Scleron*	*multistriatum*	0	0	0	0	0	0	0	3	0	5
Tenebrionidae	*Scleron*	sp.	0	0	0	0	0	0	3	0	0	0
Tenebrionidae	*Tentyria*	sp.	0	1	0	0	0	0	0	0	0	0
Tenebrionidae	*Zophosis*	*complanata*	0	0	0	0	0	0	1	0	0	0
Tenebrionidae	*Zophosis*	*plana*	0	0	0	0	0	0	0	3	1	0
Tenebrionidae	*Zophosis*	*quadricostata*	0	0	0	0	1	1	0	0	0	0

CA1, CA2, and CA3: the three sites at Wadi El-Arbaaein in St. Catherine; MA1, MA2 and MA3: the three sites in El-Mafareq; TA: the site in Wadi El-Talaa in St. Catherine; SA1, SA2, and SA3: the three sites in Sahab.

Beetles TWINSPAN

Beetles CCA

The Two-way Indicators Species Analysis (TWINSPAN) produced three clusters groups by two divisions (Figure 2a). The first division separates the four plots (CA1, CA2, CA3 and TA); in the positive side form the rest of the plots (SA1, SA2, SA3, MA1, MA2 and MA3) which occurred in the negative side. The first division showed the beetle species *Laemostenus quadricollis* (Carabidae) as an indicators occurring in the positive side. The second division showed the beetle species *Adesmia bicarinata* (Tenebrionidae) as an indicators species separating the three plots (SA1, SA2 and SA3) in the negative side from the three plots (MA1, MA2 and MA3) in the other side.

The relation between the beetle species and the environmental variables is shown in Figure (2b). The first two axes of the CCA explained 55.4 % of the total variation, with the first axes accounting for 33.4 %. The first axes separated the three plots (MA1, MA2 and MA3) at the negative end from all the plots at the positive end. The second axes separated the three plots (SA1, SA2, and SA3) at the positive end from the other plots (CA1, CA2, CA3 and TA) at the other end. The forward-selection environmental variables of the CCA were elevation ($P < 0.002$) and medium sand % ($P < 0.002$). Both the arrows representing the two variables directed towards the four plots (CA1, CA2, CA3 and TA), with their maximum occurrence in the CA3 plot.

Beetle indicator species

The indicator species analysis showed that 21 beetle species were significantly correlated with the sites, 17 species with the Mafarq sites, with 11 indicator species were totally found in the Mafarq sites only. Two with the Catherine sites and Talaa with one of them was found only in these sites. And two indicator species with Sahab sites and also totally found in them. The beetle indicator species and their P-values are shown in (Table 4).

Agreement between taxa

Cross-taxon congruence analysis and Pearson correlation

The results of the cross-taxon analysis, illustrating how well the matrices of each family track differences in the environmental variables (environmental or ecological indicator), are shown in (Figure 3b). The correlations between the matrices of the various families and that for the environmental variables are shown

in brackets. Cryptophagidae and Dermestidae were highly significantly correlated with the environment (r = 0.78 and 0.73), followed by Anthicidae, Tenebrionidae and Staphylinidae (0.68, 0.67 and 0.50) respectively, and, lastly, both, Curculionidae and Scarabaeidae (0.43). The rest of the families showed a non significant correlation with the environmental variables.

Figure (3a) shows how the species composition of each family acts as biodiversity indicators for the "overall community composition". The correlations between each familles and "overall community composition" are shown in brackets. Tenebrionidae showed a highly significant correlation (0.84) followed by Anthicidae (0.73) followed by moderate significant correlation for Staphylinidae and Cryptophagidae (0.59 and 0.51). Dermestidae, Scarabaeidae and Histeridae had the lowest significant correlation with the overall community (0.42, 0.41 and 0.40) respectively.

Estimated beetle species richness and abundance vary significantly among different sites, and this finding is complying with Semida, *et. al.*, 2001; but evenness did not vary significantly across the different sites, despite strong changes in community composition and structure. These results highlight the difficulties associated with relying on species richness or diversity alone to inform the assessments or the conservation priority setting process (Spector, 2001). Noss (1990) and others have pointed out that comparisons of species richness among sites may not necessarily convey much useful information about them or their relative conservation value, even for a single species. Worse still, because richness, diversity or biomass can be high in disturbed or otherwise degraded landscapes, uncritical reliance on richness could lead to unjustified levels of assessment of conservation value (Spector & Forsyth, 1998). Lower diversity, however, does not reflect a less specialized or less unique fauna in forests (Simberloff, 1999). Thus, composition of the fauna in these habitats is extremely important, and the knowledge gained from species identity and associated natural history offers deeper insights than species richness alone (Simberloff, 1999; Work *et al.*, 2004). The identity and relative importance of species within communities are a key component of the assessment, and are significantly more informative than measures such as richness or diversity (Spector, 2001).

The CCA results for beetles showed that the elevation and soil medium sand factors were the main factors maintaining the beetle composition of the Katherine sites and separate them from the other sites. The importance of soil characteristics is known to be one of the important factors that affect ground dwelling beetle communities (Jaganyi, 1998 & Semida *et. al.*, 2001). There have been numerous studies examining

the factors influencing the distribution and composition of beetles in different vegetation types, in these studies many environmental factors, such as pH, soil organic content (Luff *et al.*, 1989; McCraken, 1994), soil and litter moisture (Luff *et al.*, 1992; Sanderson *et al.*, 1995), vegetation height and development (Gardner, 1991; Gardner *et al.*, 1997), nutrient status, altitude, or grazing (Holmes *et al.*, 1993; Semida *et. al.*, 2001), were found to be important influences on ground beetles.

The cross taxon analysis indicated that assemblage composition of different beetle families tracked changes in the environment. Cryptophagidae and Dermestidae assemblages were the most highly correlated with the environment, suggesting that, out of the different beetle families we studied, these are the best ecological indicators. The reasons for their high responsiveness to differences in the environment differ though. Cryptophagids are saprophagous species and occur in haystack, vegetable refuse, fungi, stored products, mouldy plant, animal materials, and on dry sea-weed (Hinton, 1945). Dermestid beetles on the other hand, feed on a very wide variety of materials of both animal and vegetable origin. The 2 dermestid species recorded during this study (*Anthrenus crustaceus & Attagenus, trifasciatus*) are able to maintain themselves only on animal matter or materials containing animal proteins (Hinton, 1945). Thus it is not surprising that cryptophagids respond closely to the nature of the soil in the studied sites. It is probably for the same reason that dermestid beetles also exhibited reasonably high correlations with environmental factors.

The performance of the various families as biodiversity indicators is slightly different. Here, Tenebrionidae showed a highly significant correlation, followed by Anthicidae, Staphylinidae and Cryptophagidae, indicating that surveys of any one of these groups provides some indication of how the assemblages of other groups are developing.

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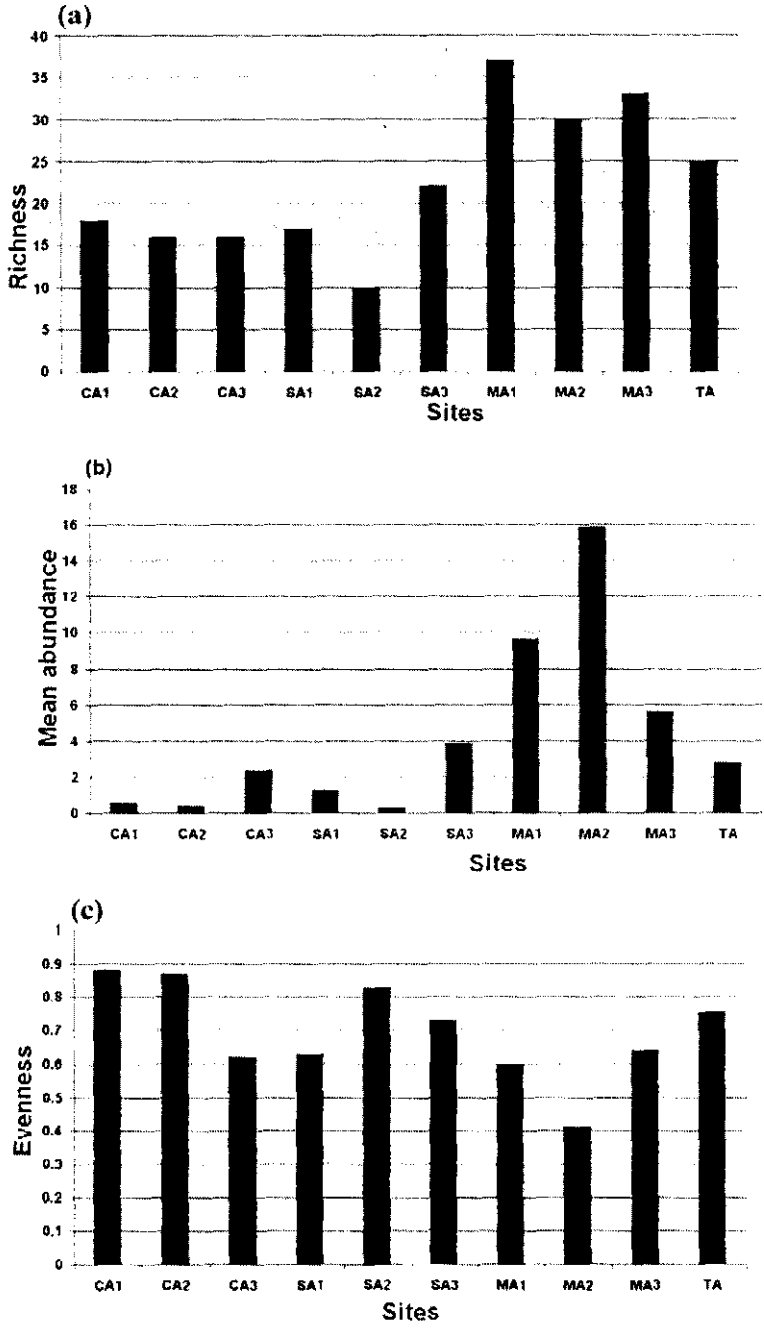

Figure 1: Beetle species richness (a), mean abundance (b) and evenness (c) in the different sites of the study area at South Sinai; Egypt.

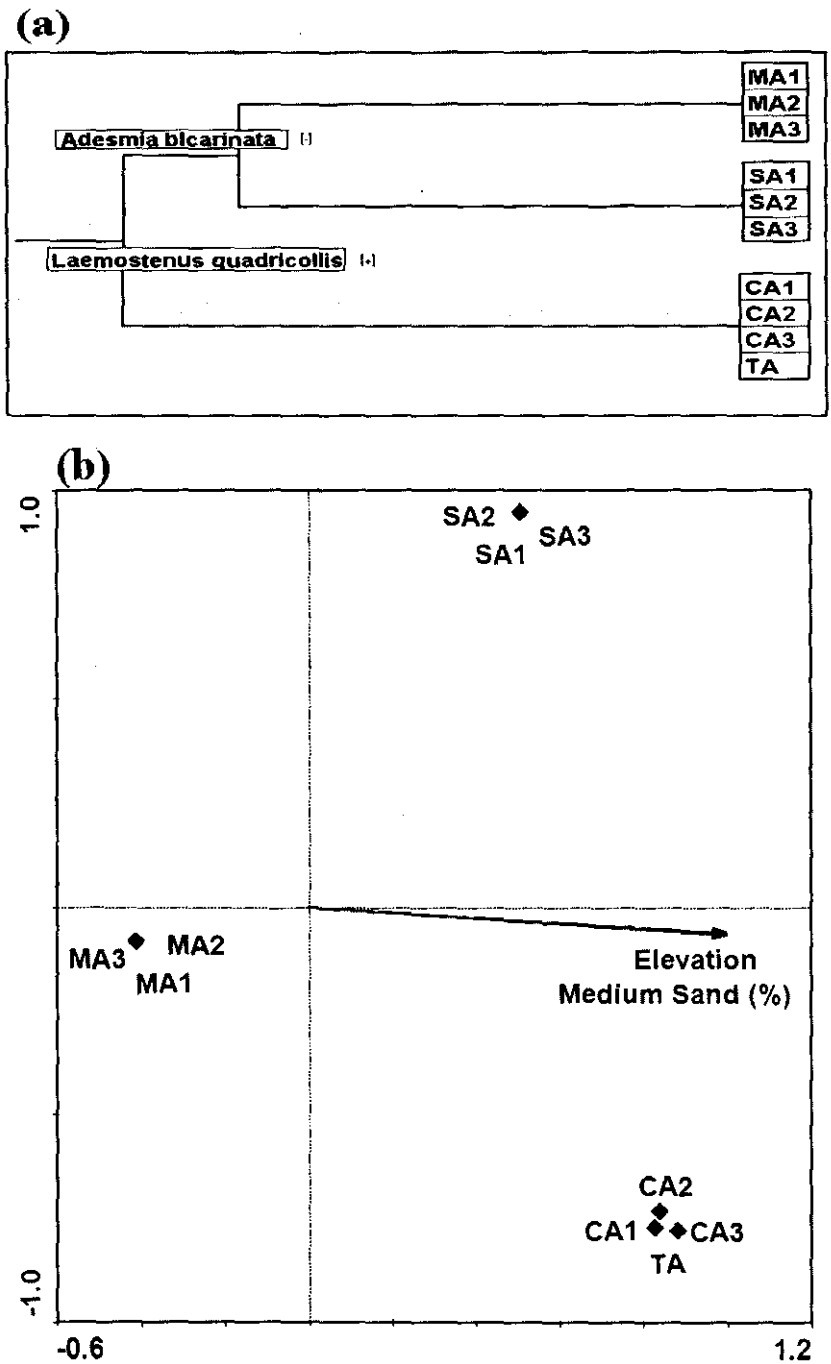

Figure 2: Beetles TWINSPAN dendograph (a) and Beetle Canocal Correspondence Analysis (CCA).

TABLE (IV)

The beetle indicator species and their indicator value in the studied sites at South Sinai.

Genus	Species	Group	Indicator value	P
Mecynotarsus	*bison*	2	81.3	0.02
Mecynotarsus	*semicinctus*	2	96.2	0.002
Stricticollis	*modestus*	2	89.8	0.04
Calosoma	*olivieri*	0	72.7	0.008
Laemostenus	*quadricollis*	0	100	0.008
Cryptophagus	*affinis*	2	100	0.02
Saprinus	*sphingis*	2	100	0.02
Heteronychus	sp.	2	100	0.02
Rhyssemodes	*kocheri*	2	100	0.02
Atheta	*sordida*	2	100	0.02
Adesmia	*bicarinata glabrior*	2	100	0.02
Adesmia	*montana*	1	100	0.02
Gonocephalum	*soricinum*	2	96.8	0.05
Gonocephalum	sp.	2	100	0.02
Mesostena	*angustata*	2	74.7	0.03
Mesostena	*sp.*	2	100	0.02
Ocnera	*leprieuri*	1	100	0.02
Pimelia	*hirtella*	2	100	0.02
Pimelia	*spimulosa*	2	100	0.02
Pterolasia	*squalida*	2	100	0.02
Scelasodis	*castaneus*	2	100	0.02

CA1	CA2	CA3	TA	SA1	SA2	SA3	MA1	MA2	MA3
0	0	0	0	1	1	1	2	2	2

CA1, CA2, and CA3: the three sites at Wadi El-Arbaaein in St. Catherine; MA1, MA2 and MA3: the three sites in El-Mafareq; TA: the site in Wadi El-Talaa in St. Catherine; SA1, SA2, and SA3: the three sites in Sahab.

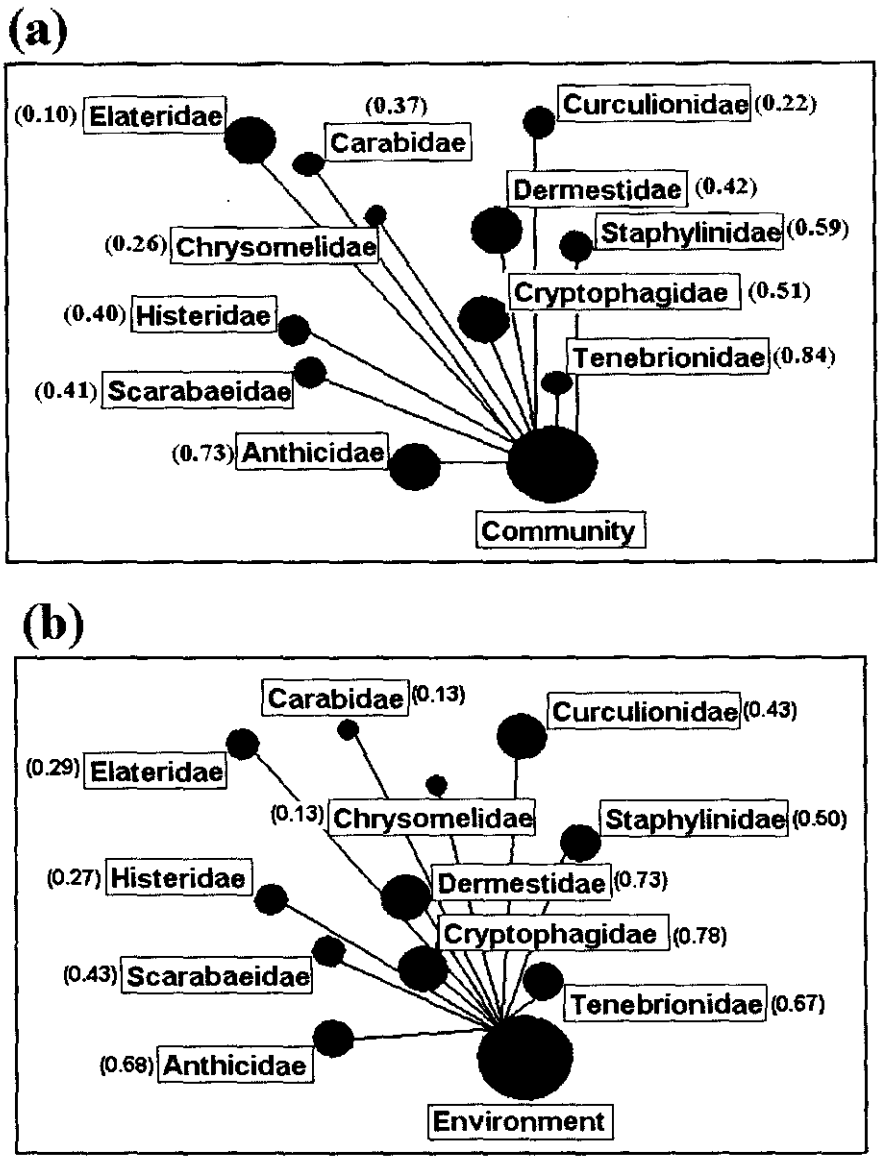

Figure 3: Beetles Cross Taxon analysis with Community (a) and Environment (b).

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