The Threat of Urbanization on Beetle Diversity in New Damietta City, Egypt

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Abstract: Urbanization is a global phenomenon, particularly along coastal Mediterranean Sea that represents a threat to natural ecosystem and whole biodiversity due to the reduction of natural environment with land conversion. This impact was investigated on beetle diversity at three urbanized sites in addition to natural control site in New Damietta city, Egypt for 24 successive months (2007-2009). Within each site, 20 pitfall traps were distributed systematically in grid arrangement. Overall, beetle diversity (diversity index, richness and abundance) showed a highly significant among study sites and clarified the higher species of diversity, richness and abundance in the natural control site compared to urbanized sites. Moreover, cluster analysis and ordination (DCA) differentiated between natural control site and urbanized sites, while canonical correspondence analysis (CCA) revealed seven important environmental factors from 22 factors that correlated with beetle community. This study clarified that urbanization is not only threat to beetle diversity but also on species composition and environmental characters.
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1. Introduction

Urbanization is a dominant process of land alteration, converting rural to urban land (United Nations, 2006). It occurs at different levels, and these differ in the density of humans present, the amount of the original habitat left, and often the intensity and type of management (Blair, 2004; McDonald, 2008). Urban areas, however, are not devoid of plants and animals. These areas can provide ephemeral or more permanent habitats for species, dispersal corridors or resting places for migrating organisms (Gaston et al., 2005).

The most important consequence of urbanization is wholesale transformation of the local environment, affecting it at a fundamental level by altering habitat, climate, hydrology, and primary production (Sukopp & Starfinger, 1999; Kinzig & Grove, 2001). A final daunting result will be to habitat loss, habitat fragmentation, isolation and biotic homogenization (Miller & Hobbs, 2002; McKinney, 2002 & 2006). Further, biodiversity is linked to essential environmental services in urbanized areas, including the removal of dust, the mitigation of microclimatic extremes and the modulation of humidity (Bolund & Hunhammar, 1999). The opportunity to exchange meaningful interactions with the natural world is necessary to gain public support for biodiversity conservation (Miller, 2005).

Beetles constitute a large proportion of total insect biodiversity, play a pivotal role in trophic chains and are sensitive to human activities (Purvis and Fadl, 2002; Leraut, 2003). Numerous studies on beetle assemblages in urban areas have been largely developed in the last decades especially in Europe, Japan and in United States (e.g.: Alaruikka et al., 2002; Venn et al., 2003; Magura et al., 2004, 2006, 2008 & 2010; Elek and Lovei, 2007; Gaublomme et al., 2008; Fattorini, 2011) but until now, there is lack of studying this effect in almost world. New Damietta city is a recently reclaimed and developed city along coastal Mediterranean Sea. Urbanization is the most important impact that drew its characters overall city directions. Therefore, this study aimed to detect threat of urbanization on biodiversity using beetle diversity in this city.

2. Materials and Methods

2.1. Study sites

New Damietta city is a recently reclaimed and developed city in Egypt along coastal Mediterranean Sea. Its locality is about 18 km^2 at 31°26'20.0972"N 31°42'55.6898"E. It characterized by sandy sheets and dunes, special flora and with temperate to dry climate. New Damietta is renowned for its guava farms and palm trees over its land in addition to some famous agricultural products such as tomatoes, vegetables, wheat and others. Nevertheless, salt wild herbs and shrubs such as *Inula crithmoides* (Golden samphire), *Zygophyllum aegyptium* (Ratrayt), *Alhagi graecerum* (Aquoul), *and Juncus rigidus*

(Samaar Morrr) characterize the other wild regions. The climate of the study area is typically Mediterranean, almost semi-arid. The Mediterranean climate is defined in terms of precipitation and temperature and characterized by a high seasonality summarized as long hot and dry summer season and cool, wet short rainy winter season.

Urbanization is one of the main characters in the recently reclaimed cities. Briefly, the combined effects of the multiple elements of urbanization have led to the reduction, alteration and fragmentation of the rural habitat. Three urbanized study sites in addition to natural control one were chosen and coordinated using a hand-held GPS (Garmin, GPS III plus). Natural control site is laid at E 31º 39' 46.8"and N 31º 27' 20.6". Three urbanized sites were determined; Urban1 at E 31º 40' 10.4"and N 31º 27'23", while the other sites were inside the city; Urban2 at E 31º 40' 45"and N 31º 26'20.3" and the third site, Urban3 at E 31º 40' 37.6"and N 31º 26' 28.8". These urbanized sites represented different intensity of urbanization. Urban 1 is coastal site that characterized by exchange of the sandy soil to white, loamy soil and change in the main characters of this site, in addition to runoff water, noise and light, urbanization encompassed more than 1/2 the total land area, which contributed to the disappearance of perhaps less than 1/2 of natural habitat. The Urban 2 is residential, that includes fragments of nonurban land within surrounding urban land; with continuous increasing of correlated impact aspects such as light, workers, noise, urbanization wastes that cause heavy effect on this site and removal of its vegetation cover occurred at the end of this study. While, inside city urbanized site (Urban 3) characterized with vast area of fragmented nonurban patches within urban land, with less urbanized effect from light, water runoff, sandy soil and vegetation as in nature.

2.2. Data sampling

The sampling of beetles was conducted using pitfall trap (rounded plastic bottle 13 cm deep with an opening of 5.7cm diameter and filled one-third full of water with a little of colorless detergent). Twenty traps per site at five meter intervals in a regular distribution were fixed. Traps were closed except for 48-hours period of trapping once per month throughout the study period (2007-2009). This period of 48 hours is considered adequate to minimize depletion of the ground insects (Southwood & Henderson, 2000). The collected specimens were identified to the species level whenever possible. Occasionally only generic or even family designations were possible but even though without a name, it was ensure that each morphotype represents a separate species.

Soil samples were collected from each site for physical and chemical analysis. The portion finer than 2 mm was kept for physical and chemical analysis. Texture analysis was performed with different sieve diameters: 0.59 mm for coarse sand; 0.25 mm for medium sand; 0.063 mm for fine sand; and < 0.063 mm for silt and clay fraction. Soil moisture was estimated in each soil sample by drying at 105ºC for 72h then ignition (at 450°C for 3 h) for estimation of organic matter content. Electric conductivity (EC) and soil Hydrogen number (pH) were evaluated in 1:5 soil–water extract using electric conductivity meter and a glass electrode pH-meter, respectively (Jackson, 1962). Potassium, Sodium and Calcium of the soil extract were measured by using Flame Photometer (model Jenway PFP7) (Rowell, 1994). Moreover, calcium carbonates ($CaCO_3$) and chlorides (Cl-) were determined according to (Jackson, 1962). On the other hand, bicarbonates (H_2CO_3-) were determined in soil extract by titration against 0.1N Hydrochloride acid (HCl) using Phenolphthalein and Methyl orange as indicator respectively (Piper, 1947). Moreover, the samples of plants in each site were identified in the Botany Department, Damietta Faculty, Mansoura University. The relative vegetation cover to each plant was estimated according to the method described in the literatures (Barbour *et al.*, 1999). While the total area and barren area (m^2) were determined using standard methods.

2.3. Data analysis

Overall beetle diversity

Overall beetle diversity was expressed as species richness, abundance and Simspon diversity index. Species richness is the simplest way to describe community and regional diversity and most universally applied measure and important traits of biodiversity of which it captures much of the essence (Magurran, 1988; Sarkar & Margules, 2002) that refers to number of species in certain area. However, abundance is the kind of diversity measures that has inclusively been considered as equivalent to biodiversity per se (Peet, 1974) and referred to the sum of individuals in area. However, Simpson diversity index (D) is nearly the most tractable and statistically useful calculation (Lande, 1996):

$\lambda = \Sigma p_i^2$ $D = 1 - \lambda$ Where D is Simpson diversity index, λ is an index of dominance. p_i is the proportion of the community occupied by the i^{th} species.

All parameters of beetle diversity were calculated by PC-ORD program 4.14 (McCune & Mefford, 1999). However, analyses of variance (ANOVA) were used to test for differences.

Grouping and ordination analysis

Cluster analysis is a grouping technique for classifying numerical data using similarity indices between localities and sites within localities depending up on the similarity distances between groups and plotted using the Hierarchical Cluster analysis. Detrended Correspondence Analysis (DCA) is an eigen analysis-based ordination technique derived from correspondence analysis (Hill and Gauch, 1980). Detrended correspondence analysis (DCA), an indirect gradient analysis technique, plots sites against axes based on species composition and abundance (ter Braak, 1994). Sites that are more similar in environmental conditions are depicted as being closer together in the diagram. However, Canonical Correspondence Analysis (CCA) is a multivariate method, which relates the community species composition to environmental variables. Its results were displayed as a CCA tri-plot of species, sample habitats and environmental variables and the axes of the ordination were constrained to optimize their linear relationships to the environmental variables. Longer the line (and more parallel) is with an axis, the more important that variable (s) is for structuring the beetle species composition. A permutation test with 1000 iterations was performed to test for significance of the species and the environmental variables. Grouping and ordination analysis was carried out by PAST V. 1.92 software running on Windows® XP. (Hammer et al., 2001).

3. Results

3.1. Overall beetle diversity

In total, 702 individuals of 46 different beetle species belonging to 15 families (Table 1) were collected from different sites throughout the study period. The most specious family was Tenebrionidae (34%) among the collected families of Coleoptera. There are highly significant differences among Coleoptera families in their species number during study period ($F_{(14, 95)} = 9.7$, P< 0.0001) in addition to significant differences among study sites ($F_{(3, 95)}$ = 5.09, P< 0.004). Also, beetle species exhibited a spatially significant difference in species richness among different study sites ($F_{(3, 95)}$ = 5.09, P< 0.0001). Where, Control site (33 species in 15 families) had the highest value of the spatial variation in species richness; while, urbanized site (Urban 2) was the lowest one (11species in five families) (Table 1).

Table1: Spatial variation in species richness (number of species), abundance, and Simpson diversity of beetle assemblages at different sites of the study area and different families of Coleoptera during 2007-2009, at New Damietta City, Egypt.

Family	Control site	Urban 1	Urban 2	Urban 3	Total
Anthicidae	1 (30)	1 (6)	0	1 (1)	1(37)
Buprestidae	0	0	0	2 (3)	1(3)
Carabidae	6 (97)	3(20)	4 (65)	5 (66)	9(248)
Cerambycidae	1(3)	0	0	0	1(3)
Coccinellidae	2 (2)	0	0	0	1(1)
Cryptophagidae	0	0	0	1(2)	1 (2)
Curculionidae	4 (13)	1(3)	0	2 (4)	5(20)
Elateridae	1(2)	0	0	0	1 (2)
Histeridae	1(one)	1(7)	0	0	1(8)
Meloidae	1(8)	0	0	1 (4)	1(12)
Mycetophagidae	0	0	1 (3)	0	1(3)
Nititulidae	0	0	0	1 (1)	1(1)
Scarabaeidae	3(23)	1(5)	0	2 (7)	5(35)
Staphylinidae	3 (28)	3 (120)	2 (13)	0	3 (161)
Tenebrionidae	11(108)	4 (13)	3 (5)	9 (44)	16 (170)
Species richness & abundance	34 (316)	14 (174)	11 (86)	24 (133)	47 (706)
Simpson diversity	0.93	0.76	0.74	0.86	0.94

Spatial variation in species richness ($F_{(3, 95)}$ = 5.09, p< 0.004); Species richness variation among beetle families ($F_{(14, 95)}$ = 9.7, p < 0.0001); spatial variation in abundance ($F_{(3, 95)}$ = 4.3, p< 0.01); spatial variation in Simpson diversity ($F_{(3, 95)}$ = 15.3, p< 0.0001). Number before brackets refers to the species richness, while that between brackets refers to abundance.

Moreover, table (1) indicates the spatial variation in abundance of beetle species with a highly significant difference among the different study sites ($F_{(3, 95)}$ = 4.3, P< 0.01). Abundance was greater in the control site, while the minimum was at Urban 2 (Table 1). Beetle diversity among the study sites was significantly different ($F_{(3, 95)} = 15.3$, $P< 0.0001$), where control site had the highest Simpson diversity index and Urban 1and 2 were the minimum sites (Table 1). On the other hand, through the time of the study the species number at control site increased more than impacted sites (Figure 1).

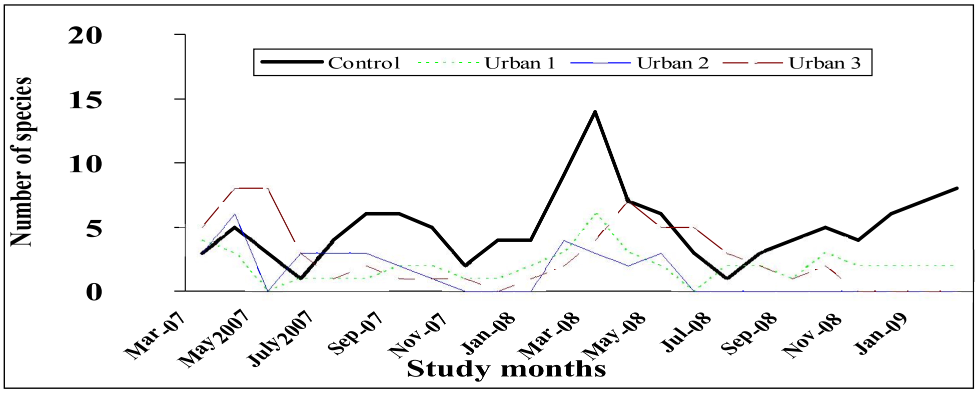

Figure 1: Temporal species richness of beetle assemblages at different sites of study area throughout study period.

3.2. Grouping and ordination analysis

As shown in Figure (2), there were clear differences in beetle composition between control site and three urbanized sites. The Hierarchical Cluster analysis of beetle species revealed three distinct groups by second divisions. Control site separated far away from the three urbanized sites at the first phase, while the second phase clustered the two urbanized sites 2 and 3 away from the third site (Urban 1). Also, Figure (3) clarified the Detrended Correspondence Analysis (DCA) that spread out the different study sites along axis 1 (Eigen-value= 0.738) and axis 2 (Eigen-value= 0.197) dependent upon their beetle composition. The axis 1 differentiated urbanized sites 2 and 3 in positive part far away from the control site and urbanized site 1 (negative part). While the axis 2 separated urbanized site 3 and control site on the upper side and both urbanized sites 1 and 2 on the lower side.

3.3. CCA Analysis on the beetles Community

Table (2) displays the results of the environmental variables in the CCA. The first axis was positively correlated with plant species richness and negatively correlated with coarse sand content of the soil. While, the second axis was positively correlated with barren area and negatively correlated with the percentage of soil moisture followed by calcium carbonates ($CaCO_3$). Since the first two axes explained only 29% of the beetle community, the third axis was plotted "Figure 4a". The third axis was positively correlated with total organic matter and negatively correlated with soil Hydrogen number (pH) Figure "4b". The first four axes explained 64.6% of the beetle fauna. The permutation results created a Trace value of 1.614 and Trace p-value of 0.49; species were not linearly related to the environmental variables.

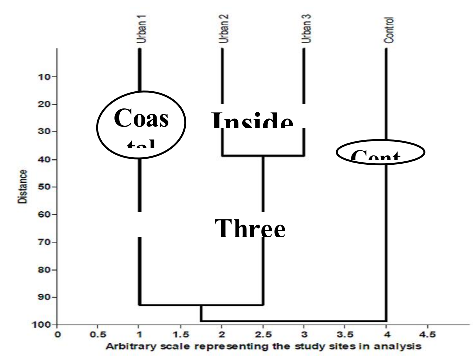

Figure 2: Hierarchical Cluster analysis of Euclidian coefficient using linkage method (Ward's Algorithm) grouping sites depending up on the similarity distances.

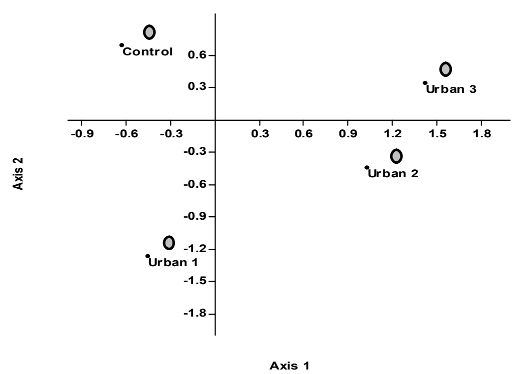

Figure 3: Detrended Correspondence Analysis (DCA) ordination study sites on axes 1 and 2 as classified by cluster analysis.

Table 2: CCA results of the three axes for the environmental variables. Bold numbers represent the most important variable for that axis.

				Continuous CCA results			
CCA term	Axis 1	Axis 2	Axis3	CCA term	Axis 1	Axis 2	Axis3
Coarse sand	-0.9539605	-0.449176	0.0585506	Soil moisture %	-0.411545	-0.953828	-0.103557
Medium sand	0.80524	-0.448428	0.347918	Electric conductivity of soil	-0.674766	-0.08225	0.622265
Fine sand	-0.483462	0.757001	-0.452191	Barren area	0.389389	0.95661	-0.24606
Clay\silt	-0.417392	0.834999	-0.249507	Site area m^2	-0.61399	0.6697	-0.04823
CaCo3%	-0.12346	-0.950445	0.460143	Vegetation cover	0.611339	-0.194352	-0.584633
H_2CO_3%	-0.482441	-0.886019	-0.222075	Plant richness	0.952132	-0.031678	-0.08066
Cl%	-0.759827	0.505559	-0.0424174	*Halocnemum strobilaceum*	-0.59992	0.619401	0.141016
Na+%	-0.795768	0.380673	0.128799	*Tamarix tetragyae*	0.928449	0.322685	-0.215188
Mg+2%	0.39548	0.597663	0.68574	*Inula crithmoides*	0.259161	-0.907972	0.0747404
pH	-0.58051	-0.256046	-0.829438	*Zygophyllum aegypteium*	0.59886	0.09217	-0.698049
Total Organic Matter %	0.420362	0.527713	0.813336	*phragmites australis*	0.826239	0.366724	-0.420263

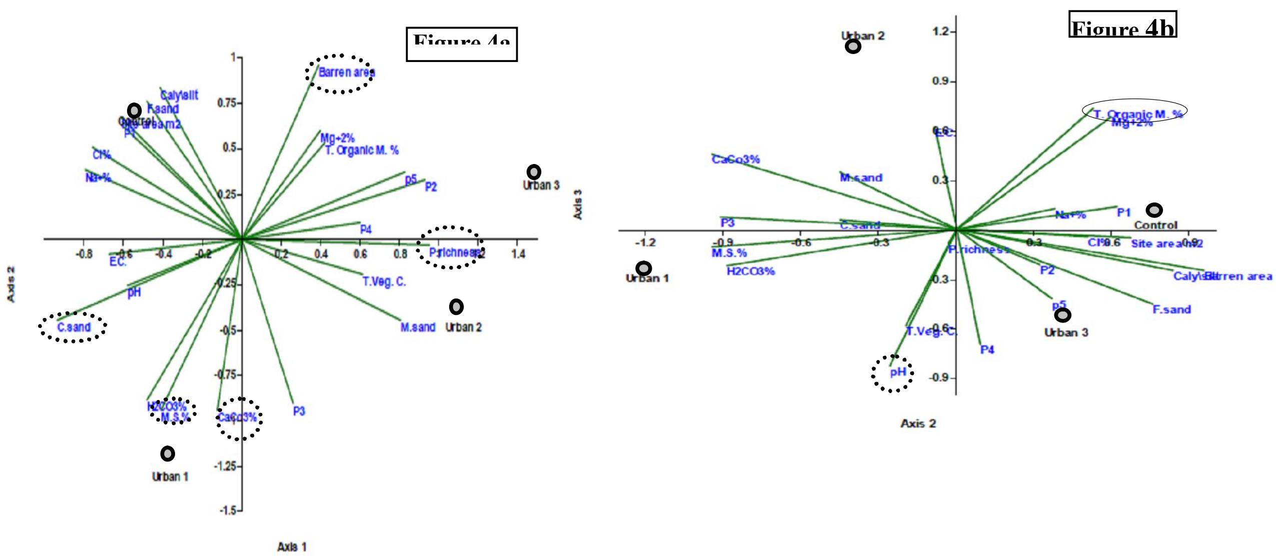

Figure 4: Canonical Correspondence Analysis (CCA) results* for the environmental variables, a) Axis 1 and 2 b) Axis 2 and 3. *Longer the line (and more parallel) is with an axis, the more important that variable(s) is for structuring the beetles species composition.

Legend	
Environmental Factor	**CCA Term**
Coarse sand	C. sand
Medium sand	M.sand
Fine sand	F.sand
Soil moisture%	M.S.%
soil Hydrogen number	pH
Electric conductivity of soil	E.C.%
Total organic matter of soil%	T. Organic matter%
Plant richness	P. richness
Total vegetation cover%	T.Veg. C.
Halocnemum strobilaceum	P1
Tamarix tetragyae	P2
Inula crithmoides	P3
Zygophyllum aegypteium	P4
phragmites australis	P5

4. Discussion

Over the last century, Mediterranean ecosystems have undergone important alterations as a result of extensive changes in land-use, although the Mediterranean Basin has long been recognized as one of the biologically richest regions in the world (Blondel & Aronson, 1999). New Damietta city, Egypt is one of Mediterranean's cities that has been witnessed urban development for tourism and changes in its natural view. Beetle diversity was used to evaluate the impact of urbanization on the biodiversity in this city during this study.

In the current study, the beetle community was dominated with species of Tenebrionidae. The same finding was reported from Cyprus (Taraslia et al., 2009) and Spain (Piñero et al., 2011). This result may be explained by the microhabitats of coastal Mediterranean Sea region that characterized with sandy and arid environments (Taraslia et al., 2009; Piñero et al., 2011), high electric conductivity, organic matter (Colombini et al., 2008), and wild plant species of sand dunes. Species of the mentioned family exhibit morphological adaptations (loss of pigmentation, straight bristles, burrowing legs, winglessness) and ecophysiological adaptations (resistance to drought, and to high and largely fluctuating temperatures), which allow these very specialized species to set up permanent populations in sand dunes (Bigot et al. 1982; Ponel 1986).

Simpson and Shannon diversity measures, which are based on the assumption that the adverse effects of human activities are reflected by a reduction in richness or a change in the relative abundances of species and species assemblages, are sensitive indicators of human land use (Samways, 1989; Human & Gordon, 1997). In the current study, species richness, abundance and diversity registered their highest values at the control site in the comparing with urbanized sites. In addition, an increasing of the species number was recorded throughout the study period at the control site in the comparing to the urbanized sites. A possible explanation for these results is related to the increasing of the habitat heterogeneity, vegetation, food availability and complexity and open habitats in the natural sites more than urbanized sites, which characterized by reduction of habitat heterogeneity (Gonzalez-Megias et al., 2007; D'Amato et al., 2009).

On the other hand, the intensity of urbanization displayed gradient impacts on the species richness among the three urbanized sites. Where, low intensity (at site 3) was accompanied with high species richness throughout the study period, while low species richness was found at sites with high intensity (sites 1 & 2). The suitable explanation of this gradient is the characteristics of urbanized site (3) where large area of nonurban habitat, increasing of plant species richness that increase the suitability and heterogeneity of habitat supporting habitat for more species than the other urbanized sites. Also, Benton et al. (2003) and Gaublomme et al. (2008) were explained the same results by the difference of the correlated factors with urbanized sites such as the intensity of urbanization impact, area of remaining natural habitat, degree of heterogeneity, size of open spaces, the suitability of habitat characteristics and conditions surrounding patches such as building density.

It is the wideness that beetle composition discriminated between the disturbed and undisturbed sites even when species were grouped into higher taxonomic levels, which may be a way of overcoming the difficulty of identifying arthropod species from poorly studied, species-rich ecosystems (Uehara-Prado et al. 2009). Throughout the current results of Hierarchical Cluster Analysis and Detrended Correspondence Analysis (DCA), natural control site, where species of *Graphipterus serrator* (Forsskål, 1775), *Daptus vittatus* Fischer von Waldheim, 1823 (Carabidae), *Phtora apicilaevis* Marseul, 1876 and *Scelosodis castaneus* Eschscholtz, 1831 (Tenebrionidae) have been registered only there, and so they separated far away the three urbanized sites. These may be due to habitat alteration and elimination of the combination of factors necessary for specialists of beetles, which caused by urbanization (Magura et al. 2004, 2008& 2010). In addition, this explanation may confirm the hypothesis that is related to the 'increasing disturbance hypothesis'(Gray, 1989).

On the other hand, the more closed relationships between the two urbanized sites 2 and 3 than the third site (Urban 1) was demonstrated in the result of cluster analysis at the second phase. Although the two axes of DCA displayed the separation among the four sites. Where, it showed the nearest similarity between urbanized sites 2 and 3 in positive part and the control site and urbanized site 1 in the negative part of the axis 1 and urbanized site 3 and control one on the upper side and urbanized 1and 2 on the lower side of the axis 2. The pattern of CCA indicated the similarity of sites distribution with the DCA ordination and cluster analysis for confirmation that sites also correlated with environmental factors. The electric conductivity, Na^+ and Cl^- ions (axis1), site area (axis1& 2) detected their characterized increasing toward control site. Also, increasing of barren area, fine sand, clay\silt (axis2), and organic matter (axis3) were indicated towards the control site and urbanized site (3), respectively. Plant species richness (axis1), presence with high relative cover of *Tamarix tetragyae* and *Phragmites australis* (axis 1) towards urbanized sites 2 and 3; coarse sand in soil (axis 1) and the relative cover of *Halocnemum strobilaceum* (axis 2) toward the control site and urbanized site1. Finally, soil moisture, calcium carbonates ($CaCO_3$), bicarbonate (H_2CO_3%) (axis 2 correlation) and soil Hydrogen number (pH) (axis 3 correlation) towards urbanized sites 1 and 2. These results revealed the causes of the clustering and ordination of sites and indicated that the similarity of some environmental factors can lead to the similarity in some species among sites. These are consistent with the view of Jana *et al.* (2005) who stated that homogeneity of environment is behind the similarity of arboreal and flying arthropods.

Also, the correlation between the species and their environment was illustrated by the three axes of CCA results, explaining 64.6% of the beetle species correlation. Seven important environmental factors from 22 factors were clearly highly correlated. The first axis was positively correlated with plant species richness and negatively correlated with coarse sand content of soil. The second axis was positively correlated with barren area and negatively correlated with the percentage of soil moisture followed by calcium carbonates ($CaCO_3$). While the third axis was positively correlated with total organic matter % and negatively correlated with soil Hydrogen number (pH). Positive and negative correlation of environmental factors with the beetle community in addition the characteristics of sites that were revealed by CCA, explained the increasing of the species richness and diversity in control site and urbanized site 3 respectively unlike other urbanized sites. The positive relationships between environmental factors and species have been documented by different studies (Hunter and Price, 1992; Vohland et al., 2006; Colombini et al. 2008; Shaban, 2009), where the increasing the variety, plenty food and surface foraging for beetle community. Oppositely, the revealed negative correlations with beetle species, which indicated their increasing toward both urbanized sites (1& 2), come co-according to the study of Liu *et al.* (2009) who stated a negative correlation with soil alkalinity and explained this result with soil alkalinity that gradually decreased, while electrical conductivity, total nitrogen, and organic matter markedly increased". The abundance of three species of beetles *Carabus hortensis*, *Pterostichus melanarius* and *Abax parallelepipedus* decreased as the $CaCO_3$ content of the soil increased as detected by Magura *et al.* (2002). While, increasing of the coarse sand particles in the soil will leading to high temperatures, and a scarcity of accessible water and nutrients for the soil as mentioned by (Ranwell, 1972).

5. Conclusion

In conclusion, urbanization has recently been the master throughout the changes of species richness, diversity and dispersal of species in many ecosystems and leads to the threats on biodiversity. Therefore, it has been necessary to refine the ecosystem case and tackle the conservation program to keep peace on other species and achieve a significant reduction in the rate of loss of biodiversity.

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