INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 11, No. 1, p. 25-35, 2017
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Spatial distribution of Hymenoptera under the rain-fed conditions of Habis valley, Northwestern Coast, Matrouh Governorate, Egypt

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Article published on July 21, 2017

Key words: Hymenoptera, Matrouh, Northwestern valleys, Biodiversity, Spatial distribution

Abstract

Valleys in the Egyptian Northwestern Coast are widely subjected to different human activities which may represent a major threat to biodiversity. Lack of studies documenting the entomofauna of these valleys was the motivator to conduct the present research which may help in the diversity conservation of the valleys. Hymenoptera composition was assessed along the valley altitude. A total of 236 individuals, about98 morphospecies,16 identified families have been recorded in both yellow pan traps and sweep net when used at mid spring 2016. The highest altitudes (>40m) represented by about 25% of total collected Hymenoptera. There was a significant positive correlation between abundance, richness of hymenopteran families and morphospecies with the altitude. Diversity was adversely decreased in a slight mode with altitude. Ordination analysis revealed the importance of braconid, eulophid, ichneumonid and pteromalid families. Cluster analysis stressed the segregation of the upstream that have wild plants from the other sampling points. Therefore, agro-developmental activities in the valley should promote the maintenance of biodiversity. This is the first contribution to study the biodiversity of Hymenoptera in Northwestern Coast valleys. More studies are required to explore the entomofauna composition of Habis valley and the other valleys as well.

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Introduction

Egyptian Northwestern Coast has about 218 valleys (wadis), most of them have direct flow to the Mediterranean Sea (Hoffet *et al.*, 2012). The topographic nature of such valleys shows different altitudes. The highest altitude is represented at the upstream and the terraces of the valley with gradual slope at the midstream till the lowest elevation at the downstream or the delta (El Bastawesy *et al.*, 2008). Egyptian Northwestern Coast has two main zones; southern zone with elevated tableland and the coastal northern one with a lot of drainage lines (valleys or wadis) flows northwardly dissecting the southern zone (Yousif *et al.,* 2013). The prevailing environmental conditions (the scarcity of water sources, soil salinity and hot summer season) at such coastal area enforced the local Bedouins to a unique agriculture style, which is referred as rain-fed agriculture at the rehabilitated valleys. The concept beyond such agriculture type is to utilize the infiltrated rainwater in the soil of mid- and down-streams to provide the domestic cultivation their barely water requirements (Sewidan,1978; El Bastawesy *et al.*, 2008). The same authors referred to the scarcity of surface (runoff) water at the Egyptian Northwestern Coast which is due to the absence of any water resources except the rainwater at the winter season and considerable amount of such water especially after heavy precipitation events is percolated deeper in the soil. In this regard, local Bedouins implement a lot of preparatory practices before cultivation. Such practices include construction of water harvesting systems (dykes, cisterns and reservoirs), enlargement the midstream width of the valley, removing great areas of wild vegetation and expansion of olive and/or fig grooves (Imamand Sawaby, 2013). Such practices are unfortunately considered as one of the main causes for biodiversity deterioration through converting natural landscapes to fulfill human demands (Kolo *et al.*, 2011). Accordingly, such deteriorating situation should cope with baseline inventory studies that may act as a helper tool for conservationists (Jennings and Tallamy, 2006; Chen *et al.*, 2009).

Biodiversity studies are carried out through nominating certain biota as representative candidates, such as birds, flowering plants and certain invertebrates (Terborgh, 1977; Tilman, 1982; King *et al.*, 1998). Last decade showed increased attention to the role of certain insect orders for tracking and assessing ecological and ecosystem changes for recovery and conservation purposes (Niemela *et al.*, 2000; Kaloyan and Joe, 2009).

Order Hymenoptera is one of the largest insect orders, including more than 7000 described species or about 25% of the total described insect species (Gauld and Bolton, 1988; Goulet and Huber, 1993), with many ecologically important species (Gauld and Bolton, 1988).The vast majority of the order are parasitoids on other insect species (Parasitica) (Wahlberg and Solbreck, 2013). The same authors found that Hymenoptera is among the 3-4 largest insect groups at high altitudes (together with Coleoptera, Diptera and Homoptera). The same authors stated that dispersal studies of Hymenoptera are mainly confined to Aculeata that are the larger hymenopterous insects. On the other hand, several studies concerned with flight trapping (Glick,1939), revealed that many species of parasitic Hymenoptera are found at high altitudes in the air.

From this point, Hymenoptera lends itself as a good sensitive indicator under different conditions. By the diversity of its members as parasites, predators, pollinators, herbivores and nutrient cycling, the Hymenoptera as a group plays a fundamental role in the ecosystem functions (Smith *et al.*, 2012). In this regard also, the domain theme that should be highlighted here is the high sensitivity of the hymenopteran parasitoid wasps (braconids, ichneumonids and chalcidoids) to the habitat changes due to their high degree of specialization and their higher rank in the trophic webs (Wharton, 1993; Shaw and Hochberg, 2001). A lot of publications supported the role of insect members as good habitat change indicators (La Salle and Gauld, 1993; Niemela *et al.*, 2000; Pohl *et al.*, 2007; Niklas and Gotmark, 2008).

Elevational (altitude) changes of the Egyptian Northwestern Coast may significantly exhibit their impact on insect diversity. In this concern, Rahbeck (1995) and Grytnes and Vetaas (2002) gave substantial evidences for the impact of elevational gradients on the richness of the examined species. This hypothesis is confirmed by the influence of diversity on several lepidopterous families (Holloway, 1987; Hollowayand Nielsen, 1999).

The lack of such studies at the Egyptian Northwestern valleys was the main motivator to conduct the current research as the first contribution aims to use Hymenoptera as a taxonomic group to provide a summary analysis on the relation between the distributions of its members with the different altitudes of Habis valley. This will consequently contribute to a better general understanding of the entomofaunal diversity in the intended valley.

Materials and methods

Field study

Habis valley (Northwestern Coast, Egypt) extends for more than 1650 m (31.38- 31.39 lat.) with gentle dipping to the north. Geographical location of the valley is represented in Fig. 1.

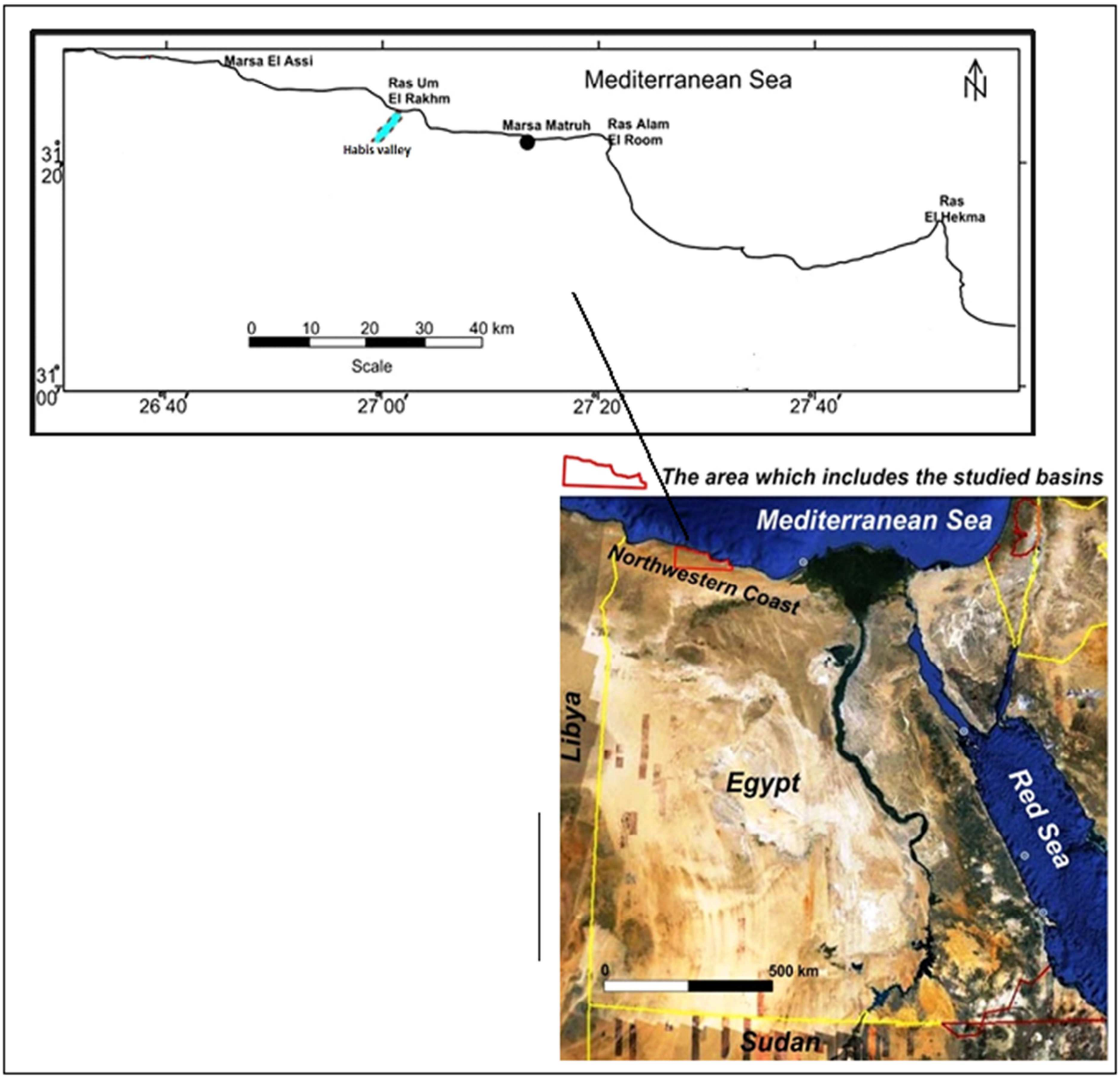

Fig. 1. Location of Habis valley within the Northwestern Coast of Egypt.

The study area is dominated by sub-arid climatic conditions. It is characterized by a rainy unstable winter with average annual precipitation of 100 mm and a stable warm dry summer. The drainage basin of the valley has some agricultural activities represented by olive and fig trees beside the perennial herbs those are scattered all over the valley. Sampling was conducted at the end of April 2016 that represents the mid-spring season. This is the time of plant flowering and is characterized by the highest activity of hymenopterous insects. Twelve sampling sites were established at approximately 150 m latitudinal intervals along the valley. Sampling points started from the highest point (48.00 m alt.) in the upstream going down north towards the downstream (5.80 m alt.). At each sampling point alongside the valley, a yellow pan trap was set at 1.0-1.5 m height. The traps were filled with water containing some detergent droplets to allow insects to sink and drown quickly. The traps were emptied after 48 hours. On the other hand, sweep net was used at each sampling point. The collected insects were pooled and kept in 75% ethanol. Samples of Hymenoptera were identified to the family level using (Grissell and Schauff, 1990; Goulet and Huber, 1993; Noyes, 2016).

Data analysis

In order to know how Hymenoptera order is distributed along the valley, mapping of abundance (number of individuals), richness (number of taxa) of both families and morphospecies were done through using R 3.2.2<www.r-project.org>, vegan package (Oksanen *et al.*, 2016). In addition, Shannon index was used to assess the diversity since it provides more information about community composition than richness; it also take the relative abundances into account.

This was followed by mapping the values of Shannon index at each sampling point all over the valley. This was undergone with the same package in R.

To investigate the impact of elevation on the composition of Hymenoptera along the valley, linear regression was used to explore the abundance, diversity and the presence of family and morphospecies richness gradient with altitude. SPSS PASW Statistics ver. 18 has been used to run the regression analysis. Dissimilarity matrix using Jaccard dissimilarity (Legendre and Legendre, 1998) was calculated based on abundance data with the function vegdist from the vegan package in R.

Principle Component Analysis (PCA) was used for ordination analysis. Ordination analysis scores multivariate data in Euclidean space along two principle axes where similar data points are placed close to each other in the ordination space. Hellinger pre-transformation was undergone on the family data after Legendre and Gallagher (2001). This transformation allowed the use of ordination methods such as PCA which is Euclidean-based, with community composition data containing manyzeros. Calculations were performed using the vegan package in R.

Results

Hymenoptera distribution

Data illustrated in Table (1) referred the distribution percentages of hymenopteran families, morphospecies and individuals throughout the different altitudes of Habis valley.

The coastal plain of the valley extends in a parallel line to the Mediterranean shoreline and shows the lowest altitudes (less than 6 m).

Table 1. Site specificity by taxa in Habis valley.

Altitude of sites (m)	48.2	40.1	32.6	28.8	27.3	26.3	18.6	17.4	11.5	5.2	5.3	5.7
Families (%)	13	13	7	7	11	11	7	10	4	4	9	3
Morphospecies (%)	12	14	8	7	10	10	7	10	5	5	8	3
Individuals (%)	16	14	5	13	14	3	6	12	3	4	8	1

Through orienting to the mid- and up- streams the higher altitude values had been recorded at the midstream area that ranged between 11 and 32 m. whereas the highest elevations had been recorded at the upstream by more than 40 m. Throughout the study area, obvious variations has been detected in the percentages of Hymenopteran families, morphospecies and individuals in terms of different altitudes. Where, the highest family percentages (13%) had been detected at the highest altitudes. Comparable observation had also been noticed for both morphospecies (12 and 14%) and individual (16 and 14%) percentages. In the same context also, the obtained data revealed that the lower the altitude values, the lower the calculated percentages.

Table 2. Pair wise dissimilarity matrix for the Jaccard incidence comparing each Hymenoptera composition at each sampling site in Habis valley.

Sites	1	2	3	4	5	6	7	8	9	10	11
2	0.50										
3	0.73	0.73									
4	0.60	0.60	0.57								
5	0.45	0.58	0.56	0.38							
6	0.45	0.58	0.56	0.38	0.22						
7	0.73	0.83	0.57	0.57	0.70	0.70					
8	0.55	0.67	0.67	0.67	0.50	0.50	0.67				
9	0.80	0.67	0.40	0.67	0.63	0.63	0.86	0.75			
10	0.80	0.80	0.67	0.40	0.63	0.63	0.86	0.75	0.80		
11	0.50	0.50	0.43	0.17	0.25	0.25	0.63	0.56	0.50	0.50	
12	0.78	0.78	0.83	0.83	0.75	0.75	1.00	0.71	0.75	0.75	0.67

That is to say, at the second altitude category that ranged between 17 and 32 meters family, morphospecies and individual percentages were of lower representation than the former ones. Where, upon considering the detected percentages at 27.3 m. elevation the representation of family, morphospecies and individual were 11, 10 and 14 %s, respectively. The lowest altitudes (<6 m.) showed the lowest percentages except for that recorded at 5.3 m that showed higher percentage values than its fellows.

The bubble maps (Fig. 2) summarized such data graphically. Geographic coordinate values had been represented at the chart axes to display the interaction between altitudes and hymenopteran families, morphospecies and individuals. It is worth to note that the bubbles diameter is proportional to the value of the represented study parameter.

The interaction between the abundance of Hymenoptera and altitude of the valley exhibited a positive correlation ($r = 0.66$, $P < 0.05$). Also, regression analysis calculations ($y = 6.94+0.57x$, $F_{reg} = 7.76$, $p < 0.05$) indicated that the number of hymenopteran population will be increased by 57% for each 100 m increase in the altitude. Comparable trend had also been stated through considering the influence of altitudes on the richness of both families and morphospecies.

In this regard, the richness of hymenopteran families showed significant positive correlation with valley altitudes ($r = 0.75$, $P < 0.05$) and regression analysis test ($y = 2.97+0.13x$, $F_{reg} = 13.09$, $p < 0.05$) confirmed that there are 13% rate of hymenopteran families increment per each 100 m increase in valley elevation. Hymenopteran morphospecies richness also showed positive correlation with valley altitude ($r = 0.77$, $P < 0.05$) and can attain 10% rate of increase for each 100 m increase in altitude according to the regression analysis calculations ($y = 2.76+0.10x$, $F_{reg} = 14.25$, $p < 0.05$). On the other hand, an intermediate negative correlation had been recorded between the diversity of Hymenoptera and altitude ($r = -0.63$, $P < 0.05$) and regression analysis ($y = 1.98 - 0.07x$, $F_{reg} = 6.39$,

$p < 0.05$) indicates that diversity will slightly decrease by rate of 7% for each 100 m increase in altitude. Such data gave an obvious indication about the impact of elevations on the distribution of order Hymenoptera along the valley.

Differences along Habis valley

To examine the dissimilarity between the various sampling points representing various elevations of the valley, a pair wise comparison was calculated using the Jaccard dissimilarity index. Table (2) showed the highest dissimilarity with the highest altitude (site 1) was in the downstream of the valley (sites 9, 10, 12). On the other hand, the highest similarity between sites occurred in the midstream between sites (5, 6) that represented by 22 dissimilarity.

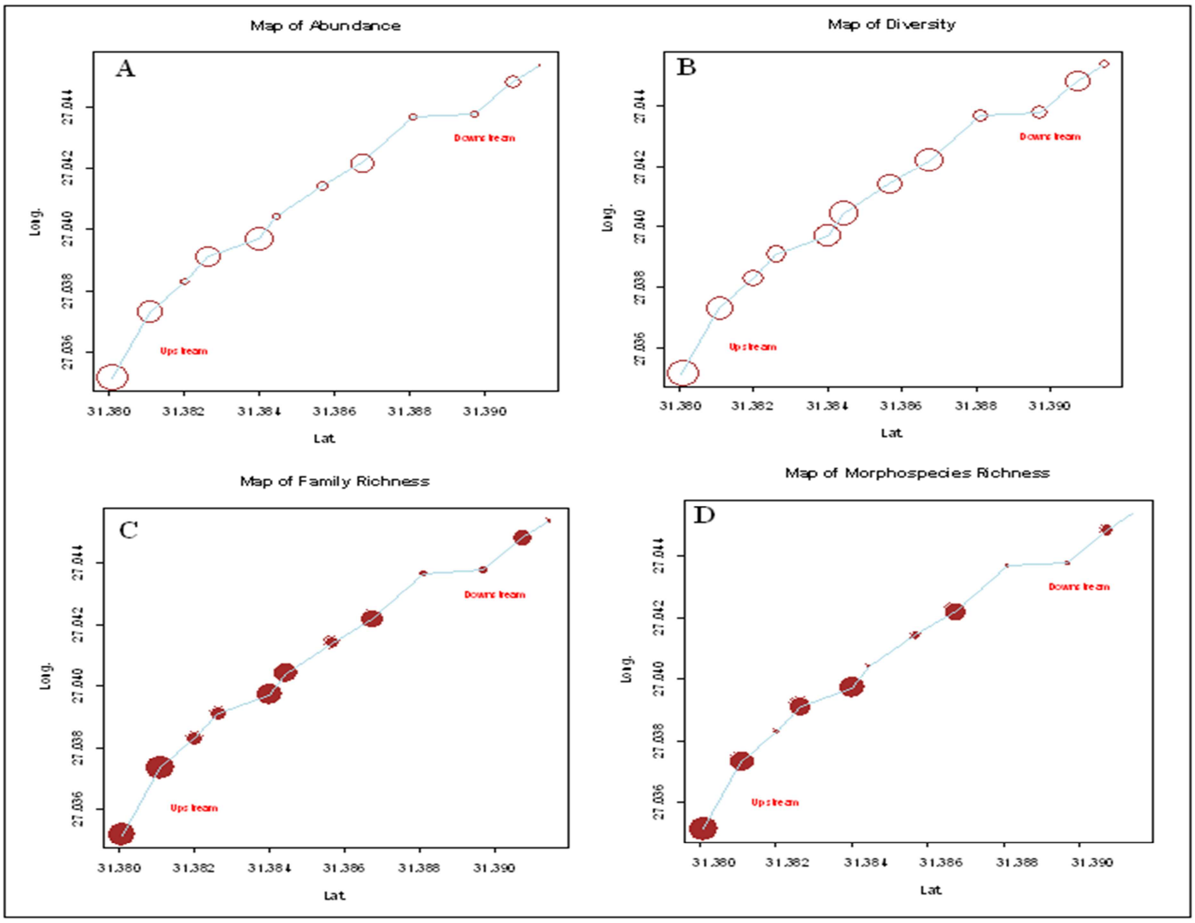

Fig. 2. Effect of different altitudes of Habis valley on Hymenopteran distribution.

The PCA biplot (Fig. 3) displays the circle of equilibrium contribution. Its radius is equal to $\sqrt{d/p}$, where d is the number of axes represented in the biplot (2 axes) and p is the number of dimensions of the PCA space (the number of families). The radius of the circle represents the length of a vector which expresses a variable that contributes equally to all the dimensions in the PCA space. Therefore, it is clear those families Braconidae, Ichneumonidae (Ichneumonoidea), Eulophidae and Pteromalidae (Chalcidoidae) are dominating other hymenopteran families. Other families (Bethylidae, Chalcididae, Crabronidae, Diapriidae, Encyrtidae, Eupelmidae, Eurytomidae, Formicidae, Mymaridae, Scelionidae, Tiphiidae, Torymidae) are grouped closer to the center, because they are present together in most of the sites. It is noteworthy that downstream sites (9, 10, 12) are somehow impoverished with no families are so close to them.

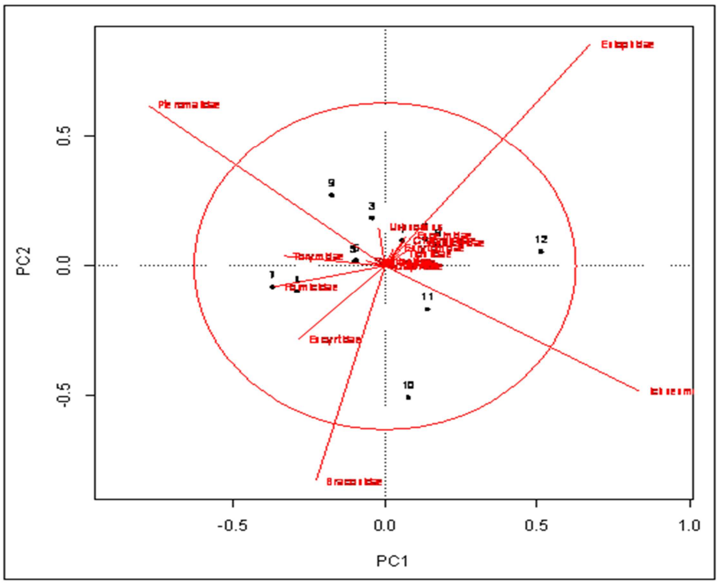

Fig. 3. PCA biplots of the Hellinger-transformed Hymenoptera families data.

Following the ordination analysis, PC was then examined for the relationship with the number of families at each site using hierarchical clustering (Fig. 4). It could be fruitful to compare a cluster analysis and ordination since it helps to confirm or explain the differences between groups of sites.

It is clear that the upstream sites (1, 2) are drawn separately. The dendrogram on the plot reveals that upstream sites are correlated with the midstream sites (4, 5, 6). On the other hand, downstream sites are grouped together and correlated to the other groups.

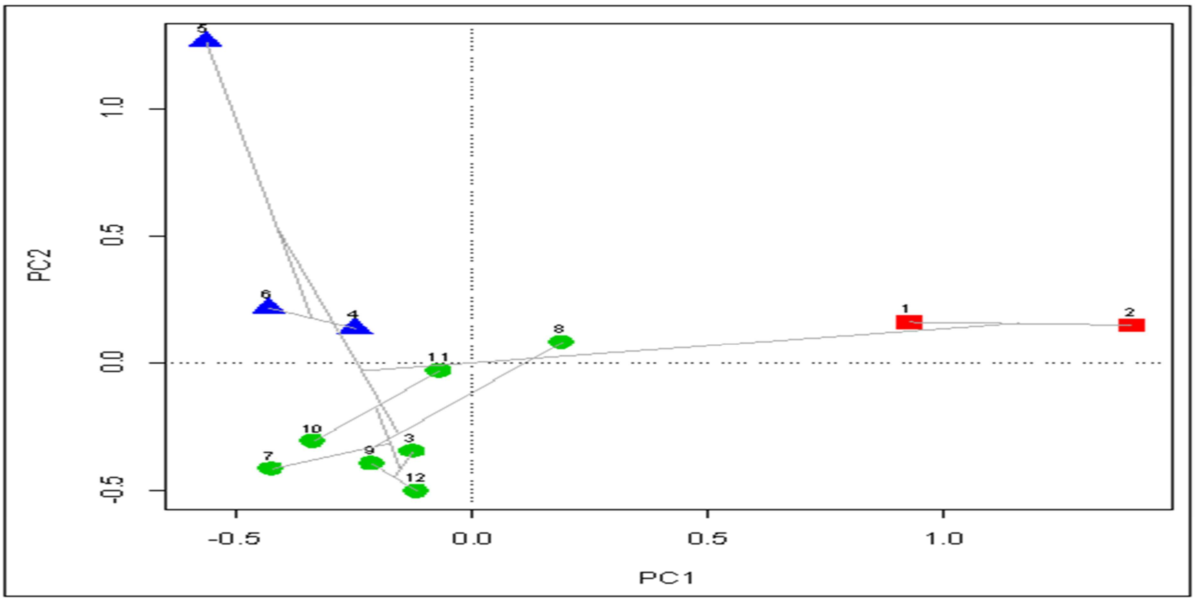

Fig. 4. PCA biplot of Hymenoptera families in Habis valley with overlaid clustering results.

Discussion

Field collection of Habis valley insects using both yellow pan traps and sweep net revealed the presence of 236 individuals of Hymenoptera, about 98 morphospecies in 16 identified families during spring 2016. Insect biodiversity inventories of the valleys and their relation to altitudinal gradients are particularly important since they represent a documentation of the current situation.

This can serve in the future for different studies regarding climate change and agricultural expansion. Such studies have been previously reported by many authors. Chen *et al*. (2009) discovered that the average range of geometrid moths had shifted 67 m upward in altitude through 40 years intervals of Geometridae (Lepidoptera) repeated taxonomic inventory in montane habitat, Borneo. Larsen (2010) reported a similar altitudinal shift (72m) of an dean dung beetles through the past 10 years and explained that it may be most likely due to the climate change.
In the present study, about quarter of the totally collected Hymenoptera, dominated by parasitoid groups (Ichneumonoidea and some Chalcidoidea) are reported at higher altitude (> 40m). Likewise, both abundance and richness of hymenopteran families and morphospecies showed increased patterns with altitude. This is greatly agreed with previous studies done by Wahlberg and Solbreck (2013) and others. Studies of parasitic wasp movements have been greatly concentrated on their short range orientation and movements in searching for their hosts (Rohani and Miramontes, 1995; French and Travis, 2001).

Both abiotic and biotic factors may play a significant role in these changes. Out of the abiotic factors, temperature is the vital attribute that responsible for deriving field scenarios of cold-blooded arthropods (their biological activities and population dynamic regulation) (Hodkinson, 2005; Vayssieres *et al*., 2008). The second abiotic factor that may play a significant role is humidity as stated by Duyck *et al.* (2004). In addition, Wahlberg and Solbreck (2013) reported that many Parasitica regularly engaged in long-distance flight high in the air. Another important factor from our point of view is the lack of human intervention in the upstream. Where, a lot of preparatory practices for cultivation occur in the mid and downstream of the valley. These practices that include enlarging the midstream width of the valley, removing great areas of wild vegetation, constructing different water harvesting systems might have a strong impact on the distribution of Hymenoptera along the valley.

Clustering and PCA in the present study revealed the discrimination of different groups of both family and sites. Different clusters of sites are represented and overlaid the dendrogram on the ordination plot. The result of this analysis have confirmed the previous output when it showed segregation of upstream sites. This has strengthened the previous explanations of higher Hymenoptera representation in the highest altitudes. PCA is not a statistical test but rather than it is a heuristic procedure aiming to represent the major features in the data through a reduced number of axes (Borcard *et al*., 2011). That's why it is called "ordination in reduced space". The same authors stated that cluster analysis looks for different discontinuities in the dataset and ordination extracts the main data trends in form of continuous axes. It is therefore mostly well adapted to analyze data from natural ecological communities, which are generally structured in gradients.

Biodiversity could be considered as a broad indicator for ecological resilience and ecosystem stability (Chumak *et al*., 2005).Studying the present status of biodiversity will help in understanding changes due to direct causes like land conversion and indirect ones such as climate change (Maveety *et al*., 2011). During this first study of its kind in the Northwestern Coast of Egypt, it was clear that the faunal composition of Hymenoptera differ along the valley. Agricultural expansion and human activities might be one of the most important reasons of lower hymenopteran diversity. This drive the attention to conduct more studies for conservation of biodiversity in the Northwestern Coast valleys.

Acknowledgement

Authors of the present work would like to express their deep thanks and gratitude to Prof. Neveen S. Gadallah, Dept. of Entomology, Faculty of Science, Cairo University, Giza, Egypt for her efforts in the samples' identification. Thanks also extend to Dr. Abdel Naser Kobisi and Mr. Hamdy Hussein (Desert Research Center) for their kind help during the field work. Dr. Abd AlSamad Abd Al Satar Aldabaa (Director of GIS unit, Desert research Center) for his efforts in all GIS work needed during the present study.

This work has been done in cooperation with Sustainable Development Center for Matrouh Resources (SDCMR), Matrouh, Egypt.

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