DIVERSITY AND SPATIAL DISTRIBUTION OF GROUND AND TIGER BEETLES (CARABIDAE, COLEOPTERA) IN THE SINAI PENINSULA, EGYPT.

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INTRODUCTION

Several works on carabid beetle faunas in natural habitats and agricultural ecosystems have appeared in the last 30 years (Thieke, 1977). However such analyses of carabid fauna were carried out in typically temperate and boreal regions and there have been only few studies performed in the Mediterranean area (Comandini and Taglianti, 1990). There is no such investigation for Sinai Peninsula that marked by a wide range of habitats with respect to its position among Africa, Asia and Europe; and its place within the arid transitional zone between Palaearctic and Afrotropical zones. For this reason the present work was carried out to investigate the back history, composition, diversity, affinities and spatial distribution of carabid fauna in Sinai. The author hope that such work makes the data on carabid fauna of Sinai as a whole is accessible to specialists in the fields of taxonomy, ecology, conservation biology, evolution etc.

HISTORICAL REVIEW

The present knowledge of the ground and tiger beetle fauna of the Sinai Peninsula goes back to the nineteen century, where the fauna was explored by many contributors. The most important works are summarized in figure 1.

It is known that during his big journey in Orient (1820-1825) C.G. Ehrenberg, accompanied by F. W. Hemprich, surveyed most of Sinai, particularly in El-Tor and captured a set of new beetle species, briefly described by Klug (1832) in the Symbolaes Physicae. These various species are preserved in Berlin Museum. The Klug's publication includes 11 carabid species from Sinai.

Toward 1865, began the explorations of Capt. H. S. Palmer, who was accompanied, in the beginning, by the naturalist Drake whose collection of beetles made the object of the work of Crotch (1869). Most of these beetles, including the types, are currently deposited in the collection of the Museum of Cambridge, and some in the Sharp collection.

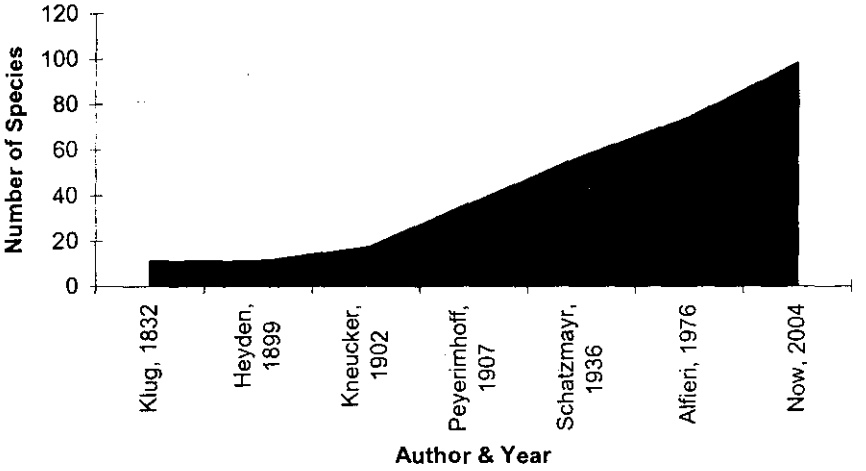


Fig. 1: Summary of carabid diversity in Sinai recorded from 1832 to 2004

J. K. Lord was sent in a scientific mission by the Government Khedivial; shortly after his return, the beetles collected by him had been published in a list by F. Walker (1871) comprising some in the Sinai Peninsula, other in Lower Egypt and in the western side of the Red Sea. These specimens were preserved mostly in the School of Medicine Museum in Cairo, but were largely destroyed after then. Some of them had been left primitively between the collections of H. W. Bâtes and the D. Sharp, these two entomologists intended to publish the rectifications that Walker's list included, after the death of H. W. Bâtes, nearly all these materials were scattered.

In 1898, Professor A. Koenig (from Bonn) crossed Sinai to Ghaza passing through the holly places. Although he was especially ornithologist, he collected a large number of beetles that were published by L. Heyden in 1899. These insects are currently deposited in the Koenig and Heyden collections.

At the beginning of twentieth century, during March and April 1902, the botanist A. Kneucker visited the western part of the Sinai Peninsula and returned with various insects. The beetles have been determined by L. Ganglbauer, and published later in 1922 by Kneucker who recorded 17 carabid species from Sinai.

Peyerimhoff (1907) collected (37 species), almost the double of the already recorded before. This can be explained by the fact that Drake, Lord, Koenig, and Kneucker were not entomologists, and may be also because Peyerimhoff had the opportunity to explore the wandering side of the peninsula (Central Sinai, at El Tih Plateau).

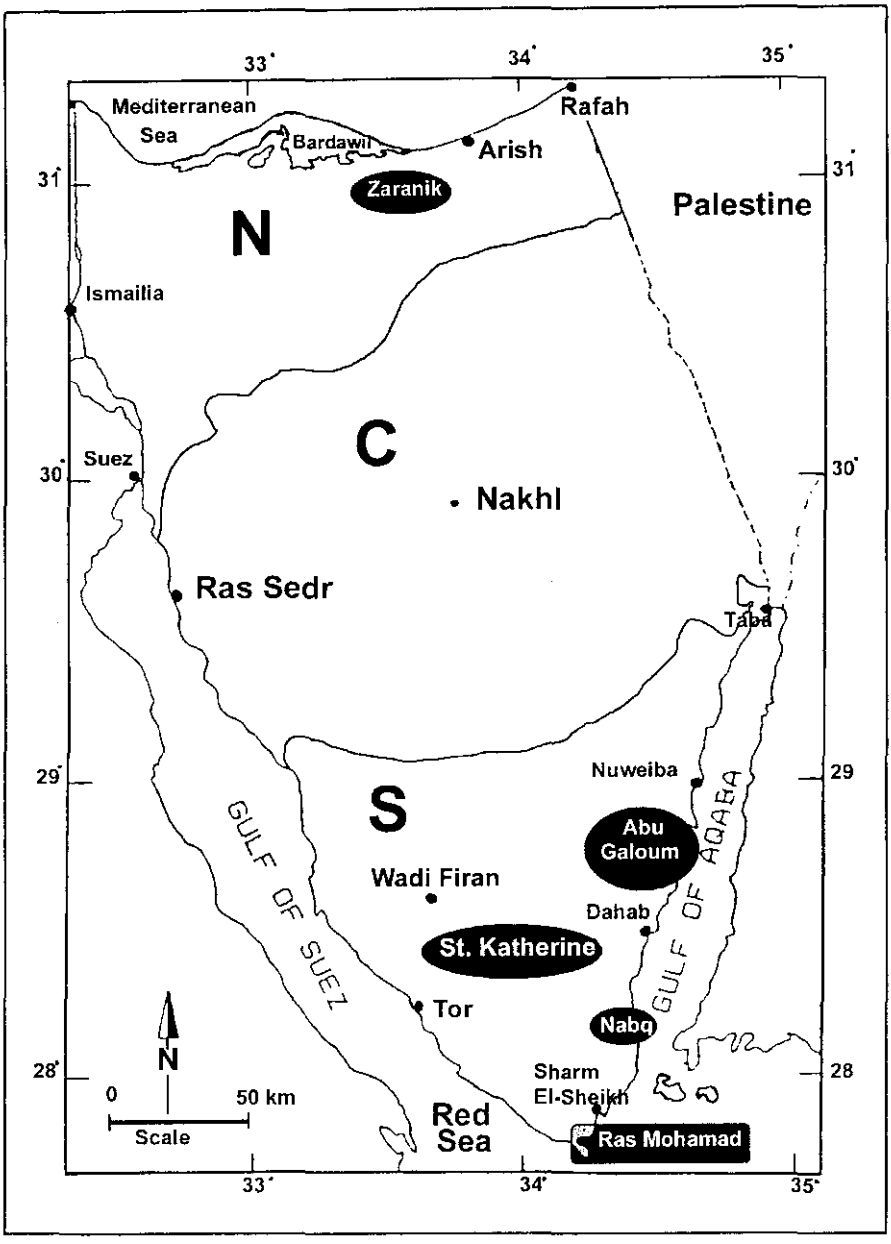
The carabid fauna in Sinai was incompletely explored until 1936 when Schatzmayr published his contribution that included the first complete and comprehensive revision of the ground beetles which were collected from different habitats and areas in Egypt including Sinai. His work gave a complete picture to the Egyptian (including Sinai) fauna at that time. He recorded 57 species from Sinai and also described 4 new taxa.

Forty years later, Alfieri (1976) published his great faunistic work on Egyptian Coleoptera, including the carabids. He reported 74 species and subspecies inhabiting Sinai; one of them was described for the first time. Besides, he synonymized many species and gave corrections to many wrongly recorded species.

In the last 28 years, important additions to carabid fauna have been collected through different sporadic expeditions to different localities in Sinai and more information was added to the fauna. Only two studies were published in 2001 including the carabid of Sinai as apart of the work; the first study was carried out by El-Moursy *et al.*, on the insect fauna of Zaranik Protectorate at North and included 10 carabid species; while the second work was conducted by Semida *et al.*, on the beetle diversity at South, included 11 species.

STUDY AREA

Sinai Peninsula is not only famous for its peculiar holly heritage, but also for its wondering desert and wadis, as well as its situation between two continents, Africa and Asia. This situation makes it as a corridor for many animals to extend their geographical range between Africa and Asia. So many biodiversity changes occurred and still occurring through this corridor.



Map 1: Sinai Peninsula with its three geomorphological parts and the protected areas.

Sinai Peninsula (Map 1) covers an area of 61.000 km2. It is continuous with the Asiatic continent for a distance of over 200 km between Rafah on the Mediterranean Sea in the north and the head of the Gulf of Aqaba in the south. It takes the form of an inverted triangle resting on the Mediterranean Sea, with the

head-down, splitting the head of the Red Sea into two, the Gulfs of Suez and Aqaba. To the North Sinai is surrounded by the Mediterranean Sea, to the West by the Gulf of Suez, to the South by the Red Sea, and to the East by the Gulf of Aqaba and Palastine.

The core of the peninsula is situated near its southern end. The western coast, on the Gulf of Suez is mostly an alluvial plain with a little vegetation. The coastal area on the Gulf of Aqaba is also very dry, but the limited vegetation has a much stronger tropical flavor. Sinai is separated from mainland of Egypt by the Suez Canal and the Gulf of Suez.

The greater part of the peninsula is drained through Wadi El Arish (310 km long) that northwardly flowing from Central Sinai to reach the Mediterranean Sea at El-Arish. The wadi is the largest stream in Sinai, presenting one third of the whole area of the peninsula (Saaid, 1990).

Sinai Peninsula is biogeographically rather complex area including:

I- Northern part is the coastal area on the Mediterranean Sea; it is a Saharo-Sindian area with strong Mediterranean realms, and is a broad tract of sand dunes some of which attain heights of over 100 m asl. The Mediterranean Coastal desert of Sinai receives less rainfall in contrast to the Western Mediterranean Coastal desert of Egypt (Osborn and Helmy, 1980). The most important protected area in the north is Zaranik Protectorate that established on the lake Bardawil, near to El Arish city, covering an area of 240 km^2. The main habitats of this area are sand dunes, wet lands, salty marches and sea shore.

II- Central part is the best developed Saharo-Sindian habitat in Sinai. This part is considered as a high plateau of Cretaceous, Ecocene, and Miocene limestones, which forms the tableland of El Tih Plateau (700-900 m asl.) and southward still higher plateau, Gebel Egma (1,620 m). Northern limits of the plateau are marked by a series of prominent mesas, ranging from 370- to 1,094-m elevation, between which extend dunes and plains of the northern desert (Osborn and Helmy, 1980).

III- Southern part is a mountainous region, and it is classified as a very arid region. It consists of an intricate complex of high and very rugged igneous and metamorphic mountains. The highest peaks of this part are Gebels: Catherine (2,641 m asl.), Umm Shomer (2,586 m), Musa (2,228 m), and Serbal (2, 070 m). The mountains are dissected by numerous wadis with bare rocky floors. The drainage of the wadis is toward the east into the Gulf of Aqaba, and westward, over the broad

sandy plain of Qaa into the Gulf of Suez. There is a great deal of water draining down the wadis; sometimes there are violent and destructive flash floods, but under normal circumstances most of the water is underground, occasionally surfacing to produce short sections of freely flowing permanent water. Sparse vegetation occurs everywhere, but the wet areas are particularly rich with plants and consequently with fauna. The southern part of Sinai probably has a great biodiversity. A large section (40 %) of the area has been declared as National Parks; namely Ras Mohammad (200 km2, 75 km2 of them is land and 125 is aquatic), Nabq, Abu Galloum, and St. Catherine (49,000 km2, with altitude 1600 m asl.).

MATERIAL AND METHODS

A critical examination of all previously published data was carried out to determine the number of recorded species and their distribution throughout Sinai. All specimens, of carabid beetles of Sinai, preserved at different National Collections and available up to June 2004 were examined.

An extensive detailed survey was conducted at many sites covering different types of habitats in Sinai since 1992 till 2004. Collecting was by hand, sweeping nets, pitfall traps and light traps. Material collected during this work was preserved in the author's collection at Entomology Department, Faculty of Science, Cairo University, Egypt.

In order to explain the habitat distributions of the carabid beetles in Sinai, the species were grouped into 2 main groups:

1) Hygrophilous species: this group includes

a- Fresh water habitat (springs and streams)

b- Sea shore and Salt marshes

2) Thermophilous species that including

a- Sand dunes b- Stones and graved soil

Primer-5 software was used to illustrate the relationship between different zones or sites to changes in the carabid fauna structure, using the presence and absence data. The similarities and the grouping of communities within different sites using single-linkage cluster analysis. The cluster analyses were converted to dendrograms.

RESULTS

A- General structure of the fauna

In the present study, twenty two species of carabids were newly recorded from Sinai (marked with asterisk), 14 species of them recorded only from the Northern part, 3 species from Central part, 3 from the Southern part, and 2 species from both Northern and Southern parts (table 2).

Table (1)

	NC	DLNV	UNV	ED	WD	SP	GE
NC	0	0	0	0	0	0	0
DLNV	81.7	0	0	0	0	0	0
UNV	57.4	66.0	0	0	0	0	0
ED	67.3	72.7	59.5	0	0	0	0
WD	58.4	56.2	50.8	53.2	0	0	0
SP	75.9	75.9	51.5	67.6	45.7	0	0
GE	19.7	22.5	22.5	29.5	20	20.2	0

Similarity among different Egyptian zones. DLNV = Delta and Lower Nile Valley, ED = Eastern Desert, GE = Gebel Elba NC = North Coast, SP = Sinai Peninsula, UNV = Upper Nile Valley, WD = Western Desert.

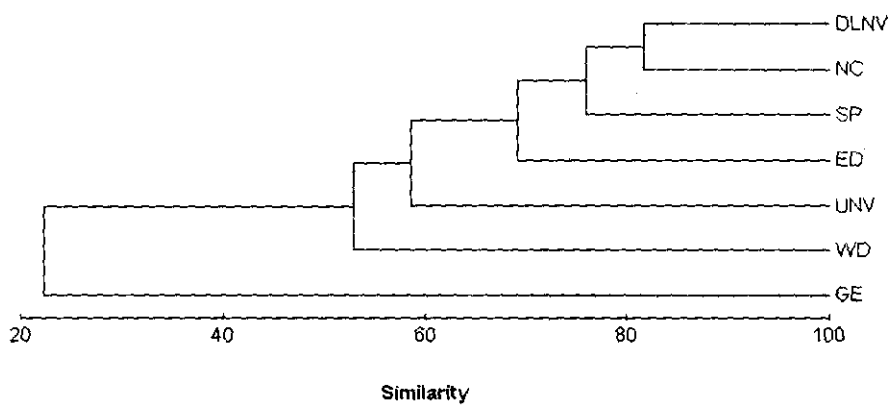


Figure 2: Dendrogram of hierarchical classification of the main Egyptian zones. DLNV = Delta and Lower Nile Valley, ED = Eastern Desert, GE = Gebel Elba NC = North Coast, SP = Sinai Peninsula, UNV = Upper Nile Valley, WD = Western Desert.

These 22 species with those reported by Alfieri (1976) form a total of 98 carabid species, belong to 52 genera under 21 tribes and 7 subfamilies, are known to reside in Sinai Peninsula (table 2). This number of species represents 45.6 % of the Egyptian carabid fauna (215 species), 18 species out of 98 are restricted only to

Sinai. In comparison with other faunas of the different zones in Egypt (tab. 1 and fig. 2), Sinai is closely similar (75.9%) to the faunas of Western North Coast of Egypt, and Nile Delta and Lower Nile Valley. Also there is similarity between Sinai and Eastern Desert (67.6). On the other side Gebel Elba and Western Desert have the lowest similarities with Sinai (20.2 and 20 respectively).

Although 52 carabid genera are present in the fauna, 18.3 % (18 spp.) of known faunal richness is accounted for by only 2 carabid genera *Bembidion* LATREILLE, and *Tachys* DEJEAN.

Spatial distribution

Carabid species appear to differ greatly in extent of their distribution in Sinai. Three species, *Amara metallescens* ZIMMERMANN, *Bembidion atlanticum megaspilum* WALKER, and *Graphipterus serrator* (FORSKAL) were found widely distributed all over the peninsula and have been recorded from the three parts of Sinai. One of the 98 species, *Carabus hemprichi* DEJEAN, was recorded from Sinai by Klug, 1832 where it has never been found again (Alfieri, 1976).

The greatest species diversity was found at Southern part (table 2), where 64 carabid species occur, while Central part has the lowest diversity. Table (2) shows that a high percentage 33.7.% (33 species) of the beetles are confined to only Southern Sinai; while 27.6% (27 species) of the species are restricted to the Northern Sinai. On the other hand Central Sinai has the lowest specific richness 3.1% (3 species).

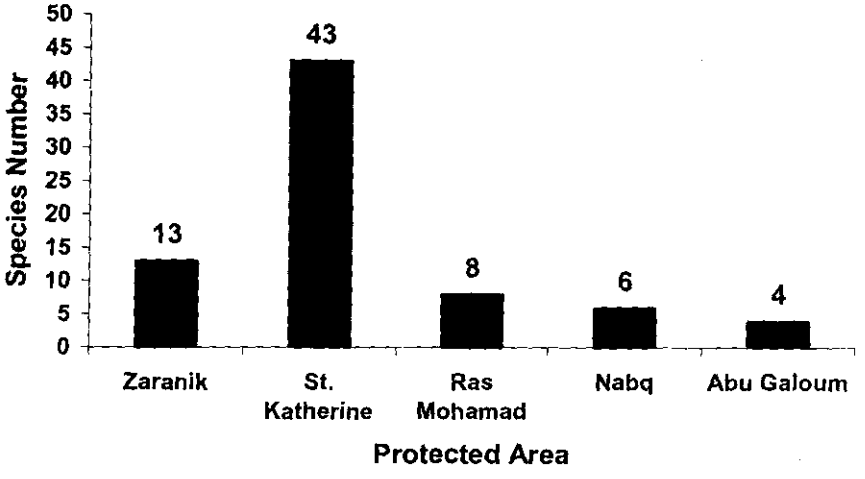


Figure 3: Species richness at different Protectorates in Sinai.

TABLE (II)

The carabid species in Sinai and their distribution in different geomorphological regions and protected areas, zoogeographical affinities and habitats.

Genus	Species	North	Central	South	St. Katherine	Zaranik	Ras Mohamad	Nabq	Abu Galoum	W. Isla	W. Godirate	El-Arish	El-Tor	Feiran Oasis	Katherine	ZG	Habitat	Microhabitat
Abacetus	*Quadripustulatus* (PEYRON, 1858)	1	0	1	1	0	0	0	0	1	1	0	0	0	1	P	Hyg	FEW
Acinops	*laevigatus* MENETRIES,1832	0	0	1	1	0	0	0	0	0	0	0	0	0	1	P	Therm	
Aephnidius	*rutilus** (SCHAUM, 1863)	1	0	0	0	1	0	0	0	0	0	1	0	0	0	EG	Therm	US
Amara	*metallescens* (ZIMMERMANN, 1832)	1	1	1	1	0	0	0	0	1	0	1	0	0	0	P		
Apristus	*europaeus* (MATEU, 1981)	0	0	1	1	0	0	0	0	1	0	0	0	0	0	P	Hyg	FEW
Bembidion	*aegyptiacum** DEJEAN, 1831	0	0	1	0	0	0	0	0	0	0	0	0	0	0	EG	Hyg	FEW
Bembidion	*ambiguum rugicolle** REICHE, 1865	0	1	0	0	0	0	0	0	0	0	0	0	0	0	P	Hyg	FEW
Bembidion	*atlanticum megaspilum* WALKER, 1871	1	1	1	1	0	1	0	0	0	1	0	0	1	1	P	Hyg	FEW
Bembidion	*latiplaga* CHAUDOIR, 1850	0	1	0	0	0	0	0	0	0	1	0	0	0	0	P	Hyg	FEW
Bembidion	*mixtum* SCHAUM, 1863	0	0	1	0	0	0	0	0	0	0	0	1	0	0	FP	Hyg	FEW
Bembidion	*niloticum* DEJEAN, 1831	0	1	1	1	0	0	0	0	1	0	0	1	0	0	P	Hyg	FEW
Bembidion	*praeustum* DEJEAN, 1831	0	1	1	1	0	0	0	0	0	1	0	0	1	1	P	Hyg	FEW
Bembidion	*schmidti moses* (SCHATZMAYR, 1936)	0	0	1	1	0	0	0	0	1	0	0	0	1	1	EG	Hyg	FEW
Bembidion	*varium** (OLIVIER, 1795)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	P	Hyg	FEW

Genus	Species	North	Central	South	St. Katherine	Zaranik	Ras Mohamad	Nabq	Abu Galoum	W. Isla	W. Godirate	El-Arish	El-Tor	Feiran Oasis	Katherine	ZG	Habitat	Microhabitat
Brachinus	*latipennis* PEYERIMHOFF, 1907	0	0	1	1	0	0	0	0	1	0	0	0	0	1	EG	Hyg	FEW
Broscus	*punctatus* (DEJEAN, 1828)	1	0	1	1	0	0	0	0	0	0	0	0	0	1	P	Therm	
Calathus	*mollis* (MARSHAM, 1802)	1	0	0	0	0	0	0	0	0	0	1	0	0	0	P	Hyg	
Calosoma	*chlorosticum* KLUG, 1832	1	0	0	0	0	0	0	0	0	0	0	0	0	0	FP	Therm	US
Calosoma	*olivieri* DEJEAN, 1826	0	1	1	1	0	0	0	0	0	1	0	0	0	1	FOP	Therm	US
Carabus	*hemprichi* DEJEAN, 1826	1	0	0	0	0	0	0	0	0	0	1	0	0	0	P	Therm	SD
Cephalota	*circumdata* (DEJEAN, 1822)	0	0	1	0	0	0	0	0	0	0	0	1	0	0	P	Hyg	SS
Cephalota	*litorea* (FORSKAL, 1775)	0	0	1	0	0	0	1	0	0	0	0	1	0	0	P	Hyg	SS
Cephalota	*tibialis* (DEJEAN, 1831)	1	0	0	0	1	0	0	0	0	0	0	0	0	0	EG	Hyg	SM
Chlaenius	*canariensis* DEJEAN, 1831	0	0	1	1	0	0	0	0	1	0	0	0	1	1	FP	Hyg	FEW
Chlaenius	*laeviplaga* CHAUDOIR, 1876	0	0	1	1	0	0	0	0	1	0	0	0	0	0	F	Hyg	FEW
Chlaenius	*obscurus* KLUG, 1832	0	0	1	1	0	0	0	0	1	0	0	0	0	1	FP	Hyg	FEW
Chlaenius	*spoliatus* (ROSSI, 1790)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	P	Hyg	FEW
Coryza	*beccarii sinaitica* PEYERIMHOFF, 1907	0	0	1	1	0	0	0	0	1	0	0	0	0	1	EG	Hyg	FEW
Cymindis	*andreae* MENETRIES, 1832	1	1	0	0	0	0	0	0	0	0	1	0	0	0	P	Therm	US
Cymindis	*hierichontica* REICHE, 1855	0	1	1	1	0	0	0	0	0	0	0	0	0	1	P	Therm	US
Cymindis	*laevistriata* LUCAS, 1846	0	1	1	1	0	0	0	0	1	0	0	0	0	0	NA	Therm	US
Cymindis	*setifensis** LUCAS, 1846	0	1	1	0	0	0	0	1	0	0	0	0	0	0	NA	Therm	US

Genus	Species	North	Central	South	St. Katherine	Zaranik	Ras Mohamad	Nabq	Abu Galoum	W. Isla	W. Godirate	El-Arish	El-Tor	Feiran Oasis	Katherine	ZG	Habitat	Microhabitat
Cymindis	*suturalis* DEJEAN, 1825	1	0	1	1	1	0	0	0	0	0	0	0	0	1	P	Therm	US
Daptus	*vittatus** FISCHER, 1824	1	0	0	0	0	0	0	0	0	0	0	0	0	0	P	Hyg	WS
Dicheirotrichus	*obsoletus** (DEJEAN, 1829)	0	0	1	1	0	0	0	0	1	0	0	0	0	1	P	Hyg	FEW
Dromius	*alfierii* PEYERIMHOFF, 1926	0	1	1	0	0	0	1	0	0	0	0	0	0	0	P	Therm	US
Dromius	*sellatus* MOTSCHULASKY, 1855	0	1	1	1	0	0	0	0	1	0	0	0	0	0	EG	Therm	US
Dromius	*vagepictus* FAIRMAIRE, 1875	0	1	0	0	0	0	0	0	0	0	0	0	0	0	P	Therm	US
Dyschirius	*auriculatus* WOLLASTON, 1867	0	1	0	0	0	0	0	0	0	0	0	0	0	0	P	Hyg	FEW
Dyschirius	*minutus aegyptiacus* SCHATZMAYR, 1936	0	1	0	0	0	0	0	0	0	1	0	0	0	0	EG	Hyg	FEW
Dyschirius	*schaumi** PUTZEYS, 1866	1	0	0	0	0	0	0	0	0	0	1	0	0	0	F	Hyg	
Dyschirius	*therondi* PUEL, 1929	0	1	1	1	0	0	0	0	1	1	0	0	1	1	NA	Hyg	FEW
Egadroma	*marginata* (DEJEAN, 1829)	0	1	1	1	0	1	0	0	0	1	0	0	1	1	P	Hyg	FEW
Glycia	*castanea* (KLUG, 1831)	1	0	1	1	0	0	1	1	0	0	0	0	0	1	F	Therm	US
Glycia	*ornata* (KLUG, 1831)	0	0	1	1	0	1	1	1	0	0	0	0	0	1	FP	Therm	US
Glycia	*unicolor* CHAUDOIR, 1848	1	0	1	0	0	0	0	1	0	0	1	0	0	0	F	Therm	US
Grammognatha	*euphratica* (LATREILLE & DEJEAN, 1822)	1	0	1	0	1	0	0	0	0	0	0	1	0	0	P	Hyg	SM
Graphipterus	*multiguttatus* (OLIVIER, 1790)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	EG	Therm	SD

Genus	Species	North	Central	South	St. Katherine	Zaranik	Ras Mohamad	Nabq	Abu Galoum	W. Isla	W. Godirate	El-Arish	El-Tor	Feiran Oasis	Katherine	ZG	Habitat	Microhabitat
Graphipterus	*serrator* (FORSKAL, 1775)	1	1	1	1	1	0	0	0	1	0	0	0	0	0	P	Therm	SD
Habrodera	*nilotica* (DEJEAN, 1825)	0	0	1	1	0	0	0	0	1	0	0	0	0	0	F	Hyg	FEW
Harpalus	*tenebrosus* (DEJEAN, 1829)	0	0	1	1	0	0	0	0	0	0	0	0	1	0	P	Therm	US
Helenaea	*torretassoi* SCHATZMAYR & KOCH, 1934	0	0	1	0	0	0	0	0	0	0	0	1	0	0	EG	Hyg	SM
Heteracantha	*depressa* BRULLE, 1834	1	0	1	1	0	0	0	0	1	0	1	0	0	0	P	Therm	US
Laemostenus	*quadricollis* REDTENBACK, 1843	0	0	1	1	0	0	0	0	0	0	0	0	0	1	P	Hyg	FEW
Lebia	*arcuata* REICHENBACK, 1855	1	0	1	1	0	0	0	0	1	0	0	0	0	1	P	Therm	US
Licinus	*aegyptiacus** DEJEAN, 1826	1	0	0	0	0	0	0	0	0	0	0	0	0	0	P	Therm	
Limnastis	*sinaiticus* SCHATZMAYR, 1936	1	0	1	1	0	0	0	0	1	0	0	0	0	0	EG	Hyg	FEW
Lophyra	*flexuosa* (FABRICIUS, 1787)	0	1	1	0	0	0	1	0	0	1	0	0	0	0	P	Hyg	FEW
Lophyridia	*aulica* (DEJEAN, 1831)	1	0	1	0	1	0	1	0	0	0	0	1	0	0	FOP	Hyg	SS
Lophyridia	*littoralis aulicoides* (SAHLBERG, 1913)	0	0	1	0	0	0	0	0	0	0	0	1	0	0	P	Hyg	SM
Microlestes	*abeillei brisouti** HOLDHAUS, 1912	0	1	0	0	0	0	0	0	0	0	0	0	0	0	P	Hyg	FEW
Microlestes	*flavipes** MOTSCHULSKY, 1859	0	0	1	1	0	0	0	0	0	0	0	0	0	1	FP	Hyg	FEW
Microlestes	*luctuosus* HOLDHAUS, 1904	0	1	0	0	0	0	0	0	0	1	0	0	0	0	P	Hyg	FEW
Microlestes	*sinaiticus* ALFIERI, 1976	0	1	0	0	0	0	0	0	0	1	0	0	0	0	EG	Hyg	FEW

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Microlestes	*vittipennis* SAHLBERG, 1908	0	1	0	0	0	0	0	0	0	1	0	0	0	0	P	Hyg	FEW
Myriochile	*melancholica** (FABRICIUS, 1798)	1	0	0	0	0	0	0	0	0	0	1	0	0	0	FP	Hyg	SM
Orthotrichus	*cymindioides* (DEJEAN, 1831)	0	0	1	1	0	1	0	0	0	0	0	0	1	0	P	Therm	US
Paussus	*thomsoni** REICHE	1	0	0	0	1	0	0	0	0	0	0	0	0	0	P	Therm	AN
Perileptus	*stierlini* PUTZEYS, 1870	0	1	1	1	0	1	0	0	1	1	0	0	0	0	F	Hyg	FEW
Pheropsophus	*africanus* (DEJEAN, 1825)	0	1	1	1	0	1	0	0	1	1	0	0	1	0	F	Hyg	FEW
Pogonus	*chalceus** (MARSHAM, 1802)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	P	Hyg	SS
Pogonus	*glivipes* DEJEAN, 1828	1	0	1	0	1	0	0	0	0	0	0	0	0	0	FP	Hyg	SM
Pterostichus	*berytensis* REICHE & SAULCY, 1845	0	0	1	0	0	0	0	0	0	0	0	0	0	0	P	Therm	
Pterostichus	*wollastoni* WOLLASTON, 1845	0	1	1	1	0	0	0	0	0	0	0	0	1	0	FP	Therm	
Scarites	*aethiopicus* BANNINGER, 1933	0	0	1	1	0	0	0	0	1	0	0	0	1	1	FP	Hyg	FEW
Scarites	*buparius** (FORSTER, 1771)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	P	Hyg	
Scarites	*eurytus** (FISCHER, 1829)	1	0	0	0	0	0	0	0	0	0	1	0	0	0	FP	Hyg	
Scarites	*guineensis* DEJEAN, 1831	1	0	0	0	1	0	0	0	0	0	0	0	0	0	FP	Hyg	SM
Scarites	*subcylindricus* CHAUDOIR, 1843	1	0	1	0	0	0	0	0	0	0	1	1	0	0	FP	Hyg	SM
Singilis	*filicornis* PEYERIMHOFF, 1907	0	1	1	0	0	0	0	0	0	0	0	0	0	0	EG	Therm	US

Genus	Species	North	Central	South	St. Katherine	Zaranik	Ras Mohamad	Nabq	Abu Galoum	W. Isla	W. Godirate	El-Arish	El-Tor	Feiran Oasis	Katherine	ZG	Habitat	Microhabitat
Sphodrus	*leucophthlmus* (LINNE, 1758)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	P	Therm	US
Stenolophus	*abdominalis* (GENE, 1836)	0	0	1	1	0	0	0	0	1	0	0	0	0	1	P	Hyg	FEW
Syntomus	*lateralis* (MOTSCHULSKY, 1855)	0	0	1	0	0	1	0	0	0	0	0	0	0	0	PO	Therm	US
Syrdenus	*grayi* (WOLLASTON, 1862)	1	0	1	0	1	0	0	0	0	0	0	1	0	0	P	Hyg	SM
Tachys	*curvimanus* WOLLASTON, 1854	0	1	1	1	0	0	0	0	0	1	0	0	0	1	P	Hyg	FEW
Tachys	*gilvus* SCHAUM, 1863	0	0	1	1	0	0	0	0	1	0	0	0	0	0	EG	Hyg	FEW
Tachys	*grandicollis angustatus* (DEJEAN, 1831)	0	1	1	1	0	1	0	0	1	1	0	0	1	0	NA	Hyg	FEW
Tachys	*haemorrhoidalis** (PONZA, 1805)	0	1	0	0	0	0	0	0	0	1	0	0	0	0	FP	Hyg	FEW
Tachys	*lucasi** (DUVAL, 1852)	0	1	1	0	0	0	0	0	0	1	0	0	0	0	FP	Hyg	FEW
Tachys	*priesneri** SCHATZMAYR & KOCH, 1934	1	0	0	0	0	0	0	0	0	0	0	0	0	0	FP	Hyg	FEW
Tachys	*scutellaris aegyptiacus** SCHATZMAYR & KOCH, 1934	1	0	0	0	1	0	0	0	0	0	0	0	0	0	EG	Hyg	SM
Tachys	*sinaiticus* SCHATZMAYR, 1936	0	0	1	1	0	0	0	0	1	0	0	0	0	1	EG	Hyg	FEW
Tachys	*tetraphacus* BEEL, 1895	0	0	1	0	0	0	0	0	0	0	0	1	0	0	P	Hyg	SM
Tetragonoderus	*arcuatus* DEJEAN, 1829	1	0	0	0	0	0	0	0	0	0	0	0	0	0	FOP	Hyg	

Genus	*Species*	North	Central	South	St. Katherine	Zaranik	Ras Mohamad	Nabq	Abu Galoum	W. Isla	W. Godirate	El-Arish	El-Tor	Feiran Oasis	Katherine	ZG	Habitat	Microhabitat
Thermophilum	*sexmaculatum pharaonum* (BEDEL, 1914)	1	1	0	0	1	0	0	0	0	0	0	0	0	0	FP	Therm	SD
Trichis	*maculatus** KLUG, 1831	1	0	0	0	1	0	0	0	0	0	0	0	0	0	P	Hyg	SM
Trichis	*pallida* KLUG, 1831	0	0	1	1	0	0	0	0	1	0	0	1	0	0	FP	Hyg	FEW
Zabrus	*ventricosus** ZIMMERMANN, 1831	1	0	0	0	0	0	0	0	0	0	0	0	0	0	P		

AN; Ant nests; EG: Endemic to Egypt; ES Endemic to Sinai; F: Afrotropical; FOP: Afrotropico-Oriental-Palaearctic; FP: Afrotropico-Palaearctic; FWE: Fresh water edges; Hyg: Hygrophilous species; NA: North African; P: Palaearctic; PO: Palaearctico-Oriental; SD: Sand dunes; SM: Salt marshes; SS: Sea shore; Therm: Thermophilous species; US: Under stones; ZG: Zoogeographical distribution.

Figure (3) illustrates that St. Katherine Protectorate has the highest carabid species diversity (43 species) among the different protected areas in Sinai. While Zaranik Protectorate at the Mediterranean coast inhabited with 13 species. Ras Mohammad and Nabq Protectorates have 8 and 6 species, respectively. The lowest diversity is recorded for Abu Galloum protected area (4 species).

Considering the confined diversity in each protectorate, St. Katherine also shows the highest species diversity (33 species), followed by Zaranik that was occupied by 10 species. Although 8 species were recorded from Ras Mohammad, only one species is confined to it. Nabq and Abu Galloum, on the Gulf of Aqaba, have 3 and 2 confined species respectively.

From a spatial distribution view point, El-Arish, El-Tor, Feiran Oasis, Katherine, Wadi Godirate, Wadi Isla, and Zaranik are the most 7 specious sites in Sinai. Figure 4 shows the sites clustered according to the similarities of their carabid faunas. The dendrogram at a similarity level 2.59% gives 2 groups, the first one included 4 sites (Katherine, Feiran Oasis, Wadi Godirate, and Wadi Isla) having the fresh water habitat; the second included the 3 sites (El-Arish, El-Tor and Zaranik) characterized by salt marshes and sea shore habitat. The first group of fresh water habitats at level of 30.85% similarity gives rise to two clusters, each of which with 2 sites. The 2 sites of high elevation fresh water habitat (Katherine and Wadi Isla) are linked together at 46.15% similarity, leaving the 2 sites of moderate elevation (Feiran Oasis and Wadi Godirate) completely detached. However within the salt marshes and sea shore habitats, El-Arish at 8.51% leaves the other 2 sites (El-Tor and Zaranik).

Faunal affinities

As expected (fig. 5), the Palaearctic element in the carabid fauna of Sinai is the highest (51%). Almost 7% is represented by species having widespread distributions in the Afrotropical Region, whereas the Afrotropico-Palaearctic component amounts to 18.4%. Moreover, the North African element counts 4% only. There is 9% of the fauna represents the endemic species of Egypt, despite the fact that Sinai Peninsula has its endemism (7%).

Figure 6 shows that the dominant element in the carabid fauna is Palaearctic with great effect on the different parts in Sinai. The Central part of Sinai shows a higher Palaearctic affinity (55.9 %) than that found in Northern and Southern parts (53.8% and 46.9 respectively). On the other hand, the Afrotropical component shows its lowest effect at Central part (5.9%) and its greatest effect at

Southern (9.4%). Furthermore, the Central part receive more North African element (11.8 %) than that received by Southern part (6.3), the Northern part however, has no North African components. Also the Afrotropico-Palaearctic element has its highest effect at Northern part.

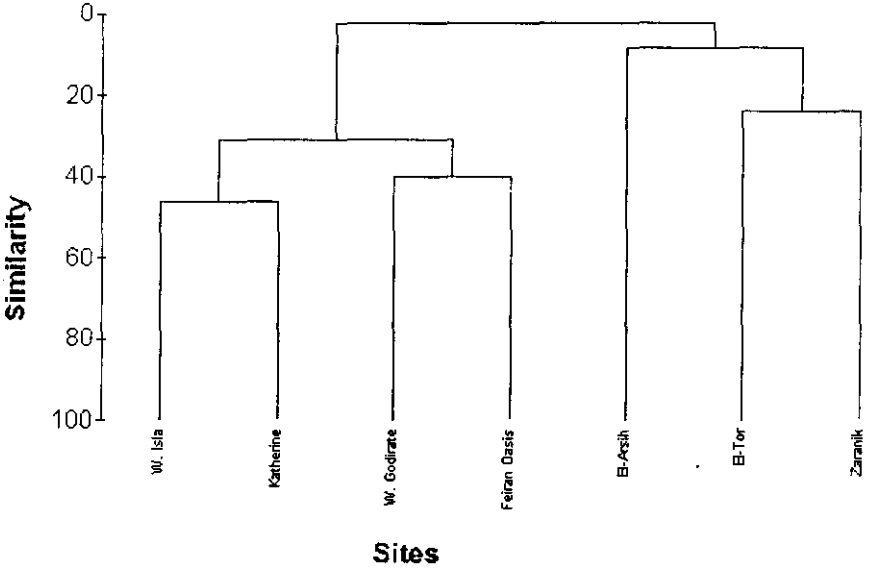

Figure 4: Dendrogram of the most specious sites in Sinai.

4- Endemism

Sinai Peninsula harbors 16 endemic species and subspecies out of 44 in Egypt. Sinai has its own 7 endemic carabid species namely: *Bembidion schmidti moses* (SCHATZMAYR), *Brachinus latipennis* PEYERIMHOFF, *Coryza beccarii sinaitica* PEYERIMHOFF, *Helenaea torretassoi* SCHATZMAYR & KOCH, *Limnastis sinaiticus* SCHATZMAYR, *Microlestes sinaiticus* ALFIERI, and *Tachys sinaiticus* SCHATZMAYR.

The highest endemism occurs at Southern part where 6 species were found, all of them inhabiting St. Katherine Protectorate. Northern and Central parts have only 1 endemic species for each, *Limnastis sinaiticus* SCHATZMAYR and *Microlestes sinaiticus* ALFIERI respectively.

Habitat aspect

Carabid beetles also differ in their ecological requirements and the range of habitats that they inhabit in Sinai. The known habitat distributions of ground beetles

in the Sinai Peninsula are shown in Table 2. No such information is yet available for 10 species, which are generally 5 hygrophilous and 5 thermophilous species.

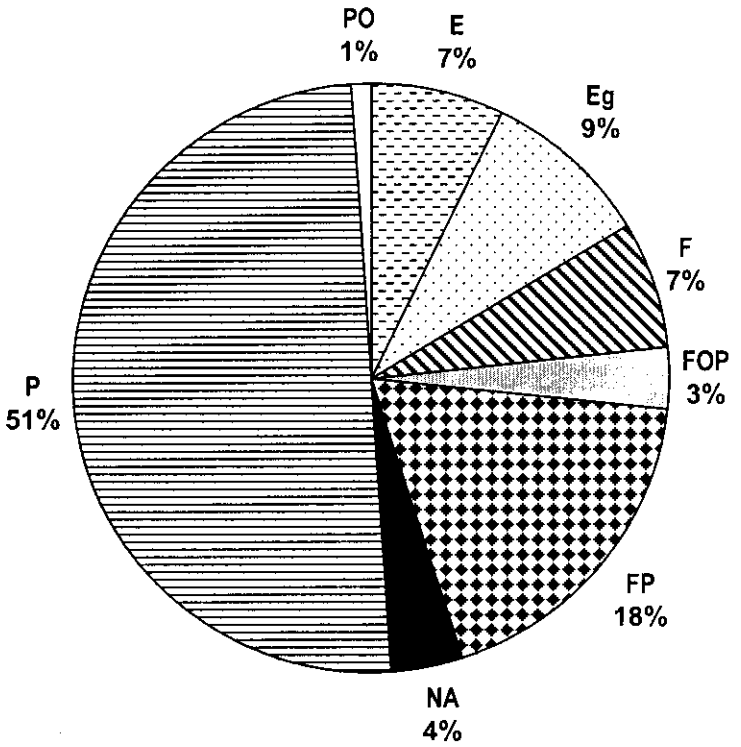

Figure 5: The faunal composition of carabid fauna and its zoogeographical affinities in Sinai Peninsula. E Endemic to Sinai; EG: Endemic to Egypt; F: Afrotropical; FOP: Afrotropico- Palaearctico-Oriental; FP: Afrotropico-Palaearctic; NA: confined to North Africa only; P: Palaearctic; PO: Palaearctico-Oriental.

Hygrophilous species

Sinai Peninsula is inhabited with 65 species belonging to the hygrophilous group (66.3 %). Forty three species of this group are known to occur near fresh water edges, like streams and springs; and 16 have a preference to sea shore and salty marshes (fig. 8).

The Southern part of the peninsula is occupied with 32 hygrophilous species that prefer the fresh water habitats (fig. 7), 27 species out of this number occur in St. Katherine Protectorate. The central part of Sinai has 20 species of fresh water habitat. On the other hand the Northern part harbors only 5 species that prefer the fresh water habitats, but no one of them occurs in Zaranik Protectorate.

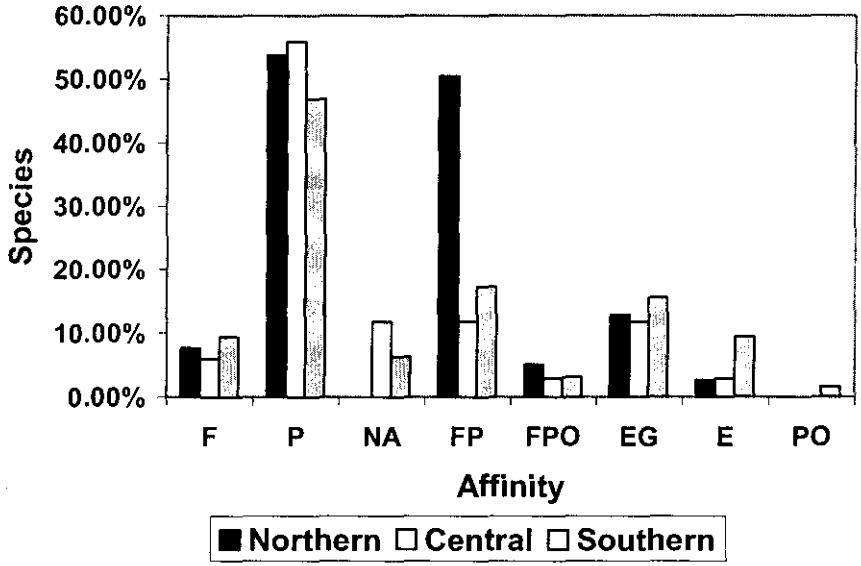

Figure 6: The affinity and faunal composition of the three geomorphological parts in Sinai. E Endemic to Sinai; EG: Endemic to Egypt; F: Afrotropical; FOP: Afrotropico-Palaearctico-Orienta; FP: Afrotropico-Palaearctic; NA: confined to North Africa only; P: Palaearctic; PO: Palaearctico-Oriental

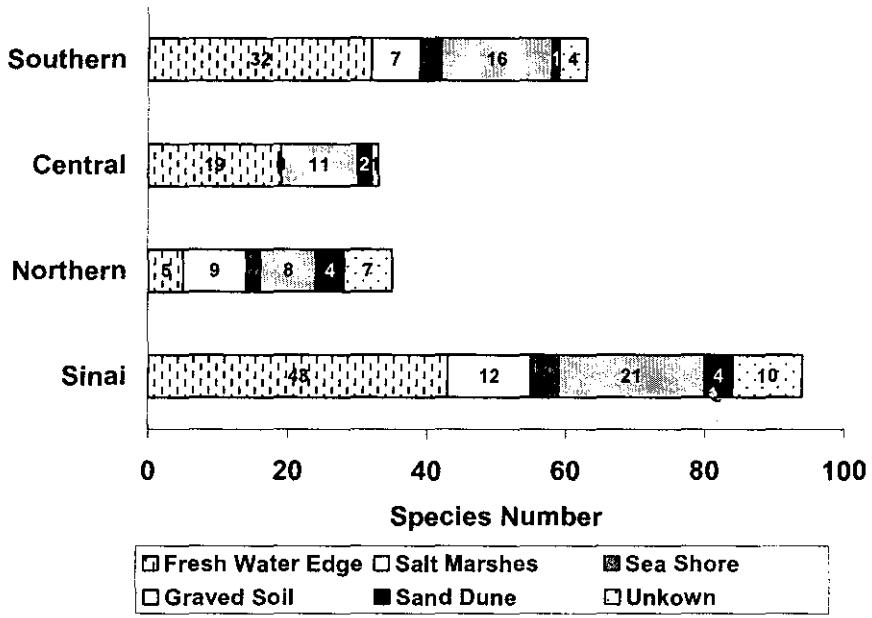

Figure 7: Distribution of carabid species among different habitats in Sinai and its different geomorphological parts.

Thermophilous species

Thirty one ground beetle species of Sinai fauna are thermophilous (fig. 7). Also the Southern part has the highest diversity (21 species), while the Northern part has 15 species, and the Central part has 13 species. As well, St. Katherine has 15 species out of 21 species that are in the Southern, while Ras Mohammad, Nabq, and Abu Galloum have 3, 3, and 4, species respectively; and there is 5 thermophilous species live in Zaranik Protectorate.

Four species out of 31 namely: *Carabus hemprichi, Graphipterus multiguttatus*, *Graphipterus serrator*, and *Thermophilum sexmaculatum pharaonum* are confined to the sand dune habitat. The four species inhabit the Northern part and only *Graphipterus serrator* extends its range of distribution to the South at St. Katherine. *Thermophilum sexmaculatum pharaonum* and *Graphipterus serrator* are only species of sandy dune that occur in Zaranik Protectorate.

Twenty one species are known to prefer the stony or gravely soil in Sinai. Sixteen species occur in Southern, 10 in Central and 8 species in Northern. Only one species *Aephnidius rutilus* (SCHAUM) prefers that habitat found in Zaranik at North, while 11 species live in St. Katherine at the South.

DISCUSSION

Sinai Peninsula, with its position at the northeast corner of Africa, forms a bridge between Asia and Africa. It also a part of the Mediterranean Basin and it embraces one biogeographic corridor that links the tropics in the south with the Palaearctic in the north, the Red Sea links the tropical seas of the Indian Ocean with the temperate Mediterranean. This geographic position had its imprint on the ethnology of inhabitants and on the geographical affinities of its carabid fauna.

The present study on the carabid beetles of Sinai revealed the increasing of carabid species from 74 to 98 species and subspecies. The landmass of Sinai laying within the transitional zone or "Sahara Desert" which separates between Afrotropical region to the south and Palaearctic region to the north (Tweedie, 1974) accordingly, the fauna showed great effects of the two regions. The fauna has high percentage of the Palaearctic effect increases at the North and Central parts of Sinai, and decreases southwardly; this is due to the long border touching Palaearctic lands at north and east-wards.

Data on carabid species from different geomorphological parts of Sinai Peninsula in Egypt indicate that major variations in carabid fauna structure occur at

spatial scales. Such variation in species composition and richness will be expected on the basis of biogeographical processes that generally operate such large spatial scales, e.g. geographical barriers, climatic differences (Dufrêne, 1990; Finn *et al.*, 1998). The ordination indicates that soil water and elevation are important factors in the distribution of carabid beetles (Eyre and Luff, 1990).

The highest richness that recoded in Southern Sinai generally is due to the high elevation. This pattern differs from that reported by many studies that consider the species richness along the elevation gradients. Most such studies have found the species richness decreases with increasing elevation (Pizzolotto and Brandmayr, 1990; Fisher, 1998; Samson *et al.*, 1997; Brühl *et. al.*, 1999; Semida *et al.*, 2001). A similar finding was found by Sanders *et al.* (2003), when studied the ant species richness in Spring Mountains, Nevada, U.S.A.

The rainfall generally increases with the elevation in many temperate and arid habitats (Brown, 1995); so many fresh water habitats are common at high lands at Southern Sinai. Accordingly many of the carabid species of Sinai show hygrophilous affinities, and large number of species known to occur at fresh waterside habitats (springs and streams), which explains the greater species diversity at Southern Sinai, especially at St. Katherine where a big deal of water occurs, where the habitat is rich with humidity and food supplies.

St. Katherine Protectorate has the highest species richness in comparison to the other Protectorates in Sinai, this is due to the biggest area that St. Katherine Protectorate occupying and also due to its high heterogeneous habitats that it includes (Semida *et. al.*, 2001).

The Central part of Sinai shows lower diversity and very low endemism or perhaps none at all as compared to Northern and Southern parts. It should be pointed out that this part of Sinai Peninsula has not been completely surveyed so that we can not provide enough and accurate picture of the real biodiversity and endemism of this part of Sinai.

SUMMARY

The carabid beetle fauna was investigated and analyzed in Sinai Peninsula for the first time through many expeditions and field trips since 1992 until 2004, in addition to a critical examination of previously published data and collected specimens. Twenty two carabid species were newly recorded from Sinai; these newly recorded species increased the known species to 98 species inhabiting different habitats in Sinai including the protected areas. Sinai Peninsula harbors 7 endemic species out of 44 in allover Egypt. The

carabid fauna was compared with the total fauna of Egypt (45.6% of Egyptian fauna) and its different geographical regions. The composition and structure of the carabid species and their spatial distribution in relationship to different geomorphological parts and different habitats was illustrated. Moreover, the fauna of protected areas were analyzed and compared to the whole fauna, these data about the biodiversity of carabid species will help the decision makers to put the management and conservation plans.

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