J. Egypt. Ger. Soc. Zool., Vol. 28(E), Entomology, 189-201, Jan. 99
Rec. 2/11/98
ISSN 1110-5364
Jan., 1999

SPATIAL DISTRIBUTION OF *PHLEBOTOMUS PAPATASI* (SCOPOLI) AND *P. BERGEROTI* PARROT IN SINAI, EGYPT IN RELATION TO SOME LANDSCAPE VARIABLES.

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Running head: Spatial Distribution of Sandflies

Key words: Distribution - *P. papatasi* - *P. bergeroti* -landscape variables - Sinai - Egypt.

ABSTRACT

The spatial distribution of the leishmaniasis vector *Phlebotomus papatasi* and the suspected vector *P. bergeroti* in relation to landscape variables was studied in central and southern Sinai. The landscape variables used to characterize sandfly habitats were extracted from Landsat imagery interpretation maps and the climatic Atlas, and a digital data base was developed in a geographic information system (GIS) software. *P. papatasi* attained a wider spatial distribution in a lower altitudinal range and occurred in a wider variety of habitats as compared to *P. bergeroti* which exhibited limited distribution in a higher altitudinal range and its occurrence was dependent on specific landscape components. Both species occurred at sites of similar RH and maximum temperature. Soil type and surface coverage were the most landscape variables affecting the ecology of *P. papatasi* and *P. bergeroti*. The digital data base generated can be integrated with remote sensing information to build spatial models that can predict sandfly distribution over large areas, thus saving effort and money.

INTRODUCTION

Cutaneous leishmaniasis (CL) due to *Leishmania major* is endemic in the northeastern part of Sinai peninsula where *Phlebotomus papatasi* was the only *Phlebotomus* species collected and was found to be the vector of the pathogen in the area (Mansour *et al.*, 1991; Fryauff *et al.*, 1993). Few cases of CL were reported from central and southern parts of Sinai as well (Kamal *et al.*, 1991; El Hossary, 1998); however, the vector is yet unknown. Several sandfly species were recorded during field studies in southern Sinai (El Sawaf *et al.*, 1987), including *P. bergeroti*, a close relative of *P. papatasi*. This study also indicated that *P. papatasi* is common in northern Sinai, while *P. bergeroti* was absent. *P. bergeroti* was incriminated as the vector of zoonotic cutaneous leishmaniasis (ZCL) in many parts of its range (WHO, 1990). Hanafi *et al.* (1996) reported the first experimental infection and transmission of *L. major* by *P. bergeroti* which provides additional evidence for the possible role of this species as a vector in southern Sinai.

Despite the geographic overlap in many countries of their range, sympatric populations of *P. papatasi* and *P. bergeroti* are rarely reported (Lane and Fritz, 1986). Within these occasional areas of sympatry, *P. papatasi* occupies a lowland habitat while *P. bergeroti* is more abundant in highlands (Lewis and Büttiker, 1982). However, in a separate study in a leishmaniasis focus in Saudi Arabia Büttiker *et al.* (1982) found both species to be abundant and coexisting.

Knowledge of the geographic distribution of sandfly vectors contributes to the understanding of when, where and how humans become infected with *L. major*. Despite the few records on sandfly species composition in Sinai, our knowledge on the distribution of *P. papatasi* and *P. bergeroti* in Sinai and their habitat requirements is scanty. Accordingly, the aim of the present investigation is to study the spatial distribution of *P. papatasi* and *P. bergeroti* in relation to some landscape variables in an attempt to characterize their habitats.

MATERIAL AND METHODS

Study Area

Sinai is a 61,000 km^2 triangular peninsula. Three sections may be noted. The base of the triangle is the Mediterranean front that extends for 200 km. The central part encompasses the Tih and El-Igma Plateaus and the region of domes which includes a number of distinct hill groups. Numerous wadis drain the Central Sinai plateaus into the lower areas to the north and often support rich and diverse flora. The main part of southern Sinai is a basement-complex country with a core of granite, volcanics and metamorphic rocks. This core is outskirted with elevations ranging from 500 to 2639 m (Gebel Katherine). Wadis of various sizes are numerous among these highlands.

The coastal lands of the Gulfs of Suez and Aqaba are very different from one another. At the coast of the Gulf of Suez, a wide gently sloping plane extends from the coast to the foot hills of the mountains of the south and central Sinai. The Gulf of Aqaba coastal plane on the other hand, is either totally lacking or very narrow.

The peninsula of Sinai exhibits a variety of climatic features influencing habitat types. Rainfall is generally higher along the Mediterranean coast then it decreases inlandward. The mountains of the south seem to intercept some orthographic precipitation; snow may occur on high peaks. Annual relative humidity (RH) decreases gradually from 80% to 40% along a north-northeast transect with a unique low RH island around the high mountains of Saint Katherine. Fog and dew may provide additional moisture resources that are of special significance. Annual means of air temperature ranges between 35°C and 25°C, while that of minimum air temperature ranges between 17.5°C and 12.5°C.

Sandfly Collection Sites

Field surveys were carried out in 15 sampling sites covering both central and southern Sinai. The sites were chosen to provide, as possible, homogenous spatial coverage and to account for the diversity of habitats. However, the harsh topographic features, inaccessibility and presence of landmines influenced our geographic coverage of the peninsula.

Sandfly Collection and Habitat Characterization

Entomological surveys were carried out between 1996 and 1997 during the period of peak sandfly activity (June to September; Fryauff *et al.*, 1993). Sand flies were trapped using oiled paper traps held with wooden sticks and placed 15-20 cm above the soil. Fifty traps were set at each site between 18.00 h and 19.00 h and collected the next morning. Sandflies were cleared by immersion in chloral hydrate and phenol (1:1 w/v) for 48 h. All specimens were mounted in Puri's medium, after separating the head and body to allow for detailed morphological examination. Differentiation between *P. papatasi* and *P. bergeroti* was based on morphological characters described by Lane and Fritz (1986).

Sandfly habitats were characterized based on the following landscape variables: altitude, soil type, surface coverage and annual means of daily relative humidity; precipitation; maximum and minimum air temperatures. In the field, sampling sites were georeferenced using a hand-held GPS (GPS 12XL personal navigator, GARMIN Europe LTD) and altitudes were determined onsite using hand-held altimeter. To identify soil types and surface coverages spatially associated with sandfly collection sites, geographic locations of those sites were overlain on Landsat imagery interpretation maps, scale 1: 250,000 (Remote Sensing Center, Academy of Scientific Research and Technology, Cairo, Egypt, 1980) so the required information were extracted. Similar operations were done to obtain meteorological information from corresponding maps (Climatic Atlas of Egypt, Egyptian Meteorological Authority, 1996). A digital data base was then developed in Arc Info, a geographic information system (GIS) software (PC version). Two thematic data layers were built in the GIS through digitizing first, the study area boundary, and second the geographic locations of collection sites. The coverages were registered to the Universal Transverse Mercator projection (UTM). Non-spatial (attribute) data such as sandfly species, altitude, soil type .....etc. were attached to the point coverage of collection sites.

RESULTS

Spatial Distribution of Sandflies

The data base developed in the GIS was used to generate a digitl map of the spatial distribution of sandflies in the study area (Figure 1). Collection data shown in Fig. 1 indicated that *P. papatasi* is more widely distributed over the study area as compared to *P. bergeroti* which was limited between latitudes 28° 41` and 28° 49`, where it clustered at the south west part of the peninsula within an average distance of 15 km. Both species were absent south of latitude 28 ° 16`.

A total of 511 *P. papatasi* and 148 *P. bergeroti* were collected from 12 out of the 15 study sites (Table 1). *P. papatasi* was collected from 10 sites, while *P. bergeroti* was collected only from 5 sites. Sympatric populations of *papatasi* and *bergeroti* were recorded from 3 sites only namely, Wadi Sa'al (N 28° 45` E 34°14`), Wadi Nissrine (N 28°49` E 33°30`) and Wadi El Tarr (N 28° 16` E 33° 30`). Both species were absent from Gebel Katherine (N 28° 34` E 33° 58`), Wadi Kid (N 28° 20` E 34° 11`), and Wadi Madsus (N 27° 53` E 34° 12`) in the south (Fig. 1).

P. papatasi and *P. bergeroti* were encountered from most of the studied habitats, but the former was absent in the oasis and the latter was absent from domestic sites. *P. papatasi* occurred more frequent in domestic (4/10 sites) and agricultural habitats (4/10 sites), while *P. bergeroti* was more frequent in natural biotopes (3/5 sites). The number of *P. papatasi* flies collected was generally higher in agricultural habitats (Table 1), where it reaches maximum at Nekhel (306 flies). Both *papatasi* and *bergeroti* occurred in very low numbers in the natural biotopes (1-2 flies). The numbers of *P. bergeroti* collected was generally low ranging between (1- 49 flies), however, highest numbers (80 flies) occurred at Feiran oasis. At the three sites where *P. papatasi* and *P. bergeroti* coexisted, *papatasi* outnumbered *bergeroti* at agricultural habitats (Wadi Sa'al), whereas the reverse was true at natural habitats (Wadi Nissrine and Wadi El Tarr) (Table 1).

Altitude

Data presented in Fig. 2 showed that *P. papatasi* occurred in a wide range of altitudes extending from 25 m to 850 m, while *P. bergeroti* was not found at altitudes below 475 m and above 850 m. Forty percent of *P. bergeroti* collections were made within a limited altitude range of 450 m to 475 m. The remaining 60% of collections were made equally at altitudes of 650 m, 750 m, and 850 m. On the other hand, 90% of *P. papatasi* collections were at altitudes $\leq$ 600 m (Fig. 2). Both species were not found at 250 m and at altitudes higher than 850m.

Soil Type and Surface Coverage

P. papatasi occurred on a wide range of soils and surface coverage (Table 1). In contrast, the distribution of *P. bergeroti* was spatially confined to one combination made of acid igneous soils and amphibolites surface coverage. However, neither species occurred on acid igneous soils where the surface coverage was wadi deposits or prophyritic granite nor on metamud stone soils with meta-rhylite tuffs.

Meteorological Factors

Both *P. papatasi* and *P. bergeroti* occurred at sites characterized by RH values ranging between 40% to 60%. *P. papatasi* was collected from locations receiving rainfall ranging between 15 mm to 50 mm per year where 50% of the collection was made from sites receiving 25 mm. *P. bergeroti* was collected from areas receiving rainfall ranging between 15 mm and 25 mm where 80% (4/5 sites) of collections came from sites receiving 25 mm. Maximum air temperatures at sites where both species were collected ranged between 25°C and 27.5°C. At sites where *P. papatasi* was collected, minimum air temperature ranged between 12.5°C and 17.5°C where 70% of collections were made at 12.5°C to 13.5°C. On the other hand, 80% (4/5 sites) of positive sites of *P. bergeroti* had minimum temperature of 13.5°C while in the remaining site it was 15°C.

DISCUSSION

P. papatasi attained a wider spatial distribution over the study area as compared to *P. bergeroti* which was limited to a narrow belt between N 29° 41` and N 29° 49`. Moreover, *P. papatasi* occurred in a wider variety of habitats with diverse landscape features, while the occurrence of *P. bergeroti* was dependent on specific components.

The ecologically diverse sites where *P. papatasi* was collected during the present study reflect its high ecoplasticity and ability to adapt to a whole range of environmental conditions. The limited spatial distribution of *bergeroti*, on the other hand, was expected as it has been described as a rare Afrotropical species with intrusions into the Palaearctic region (Lane and Fritz, 1986).

In the present investigation, sympatric populations of *papatasi* and *bergeroti* were encountered more frequently (3/5 sites) than previously recorded (e.g. in Saudi Arabia, Lewis and Büttiker, 1982). This finding might question the general assumption made by Lane and Fritz (1986) that whereas *papatasi* and *bergeroti* occur in the same country, they rarely share the same habitat. In our collections, specimens of both species were caught on the same traps providing more evidence for their coexistence in the same habitat. The records of *P. papatasi* in the mountains of southern Sinai, either allopatric or sympatric with *bergeroti*, present new information on the pattern of its spatial distribution different from that reported by Lane and Fritz (1986) and El Sawaf *et al.* (1987).

The number of *P. papatasi* flies was highly variable and generally higher than those of *P. bergeroti*. Similar variability in *papatasi* abundance was reported in northern Sinai (Merdan *et al.*, 1992; Fryauff *et al.*, 1993), in Israel (Schlein *et al.*, 1982; Yuval, 1991), in Jordan (Jianini *et al.*, 1995) in Saudi Arabia, (Büttiker & Lewis, 1983) and north and west Africa (Abonnenc, 1972). The finding of *bergeroti* in low densities in southern Sinai was consistent with previous records in other parts of its range (Rioux *et al.*, 1975).

Although *P. papatasi* and *P. bergeroti* shared most of their altitudinal range, the former tended to prefer lower altitudes, while the latter preferred higher elevations. The same altitudinal preference pattern was described by Büttiker and Lewis, 1983 in Saudi Arabia, and Abonnenc, 1972 in north and west Africa for *P. bergeroti*. However, the altitudinal range of *P. bergeroti* in Sinai was lower than that recorded elsewhere.

Soil type and surface coverage appeared to be the most important landscape variable affecting the ecology of *P. papatasi* and *P. bergeroti* in the study area, although they influenced both species in different ways. These variables did not limit the distribution of *P. papatasi* but appeared to model its abundance which was greatest on alluvials with coarse gravel and boulders. Lower numbers of *P. papatasi* flies, however, was recorded in sandy, stony soils and from limestone plateaus. These findings corroborate a previous report by Büttiker and Lewis (1983) in Saudi Arabia. In contrast, *P. bergeroti* was spatially associated to specific soil and surface coverage (acid igneous/amphibolites) indicating its high sensitivity to abiotic factors of its habitats. Such catholic spatial association between *bergeroti* and specific landscape features, regardless of habitat type, may be also related to strict microhabitat requirements for larval breeding by this species. In fact, soil type and conditions are critical elements in the ecology of sandflies as they constitute breeding and resting sites for the flies and habitats for reservoir animals. Soil texture (Saf'yanova, 1979: 13,14) and humidity (Artemiev, 1983) are among the important factors influencing sandfly ecology. Büttiker and Lewis (1979) highlighted that soil type, organic matter and moisture contents affect the distribution of gerbil burrows which provide daytime shelters for sandflies. Similar observations were also stated by Birely (1989) indicating the profound effect of soil type and conditions on the distribution and abundance of both sandflies and rodents.

P. papatasi and *P. bergeroti* occurred in sites of similar RH and maximum temperature ranges, while the former was found over wider ranges of minimum temperature and rainfall. This is mainly due to the limited spatial pattern of *bergeroti* which confined it to such a narrow range of meteorological variation. Although our data suggests a possible effect of minimum temperature and rainfall on the distribution of *P. papatasi* and *P. bergeroti*, the influence of meteorological factors was generally limited. This may be due to the fact that the actual atmospheric conditions do not reflect those prevailing in the microhabitats of sandfly activities (e.g. daytime resting sites, fly-host contact sites) (Büttiker and Lewis, 1983).

Based on the results of the present study, it appears that *P. papatasi* occurs more frequent in domestic and agricultural habitats in a lower altitudinal range where it is less sensitive to underlying geomorphological factors. On the other hand, *P. bergeroti* occurs more frequent in natural habitats in a higher altitudinal range where specific geomorphological conditions are met. In conclusion, analysis of the spatial patterns of *P. papatasi* and *P. bergeroti* in relation to landscape variables allowed the identification of abiotic factors characterizing their habitats. These factors were variable and complex in case of *papatasi* but more definable for *bergeroti*. This has led to the identification of a specific soil/surface coverage combination that could be used as a "landscape predictor" for mapping the distribution of *P. bergeroti*. The digital data base generated during the present study can be integrated with remote sensing information to build spatial models that can predict sand fly distribution and/or disease over large areas, thus saving time, effort and money.

ACKNOWLDGEMENTS

This work was supported by the Research and Training Center on Vectors of Diseases (RTC). The authors are indebted to Professor Bahira M. El Sawaf and Professor Magdi G. Shehata for their interest and support to this study. Thanks are also due to the RTC field team for their technical assistance. The authors acknowledge the technical inputs of Mr. El Sayed A. Hermas, National Authority for Remote Sensing, in building the GIS data base.

REFERENCES

ABONNENC, E. (1972). Les phlébotomes de la region ethiopienne (Diptera: Psychodidae). **Memoires de l'Office de la Recherche Scientifique et Technique Outre-Mer, 55:** 1-289.

ARTEMIEV, M.M. (1983). Sandflies (Diptera, Phlebotominae) of Afghanistan. Communication 2.

Distribution in relation to landscape. **Medskaya Parazitologia, 61:** 25-33.

BIRELY, M.H. (1989). Guidelines for forecasting the vector-borne disease implications of water resources development. Panel of Experts on Environmental Management for Vector Control (PEEM Newsletter), VBC/89.6.

BÜTTIKER, W. & LEWIS, D.J. (1979). Further notes on the Phlebotomines (Diptera, Psychodidae) of the Yemen Arab Republic. **Fauna of Saudi Arabia, 1:** 368-372.

BÜTTIKER, W. & LEWIS, D.J. (1983). Some ecological aspects of Saudi Arabian Phlebotomine sandflies. **Fauna of Saudi Arabia, 5:** 479-528.

BÜTTIKER, W.; Al-AYED, I.H.; ALWABIL, A.H.; ASSALHY, H.S.; RASHED, A.M. & SHAREEFI, O.M. (1982). A preliminary study on leishmaniasis in two areas of the Asir Region. **Fauna of Saudi Arabia, 4:** 509-519.

EL HOSSARY, S.I. (1998). Sandflies distribution in Sinai. Ph. D. Thesis. Department of Entomology, Faculty of Science, Ain Shams University.

El SAWAF, B.M.; SHOUKRY, A.; EL SAID, S.; LANE, R.P.; KENAWY, M.A.; BEIER, J.C. & ABDEL SATTAR, S. (1987). Sand fly species composition along an altitudinal transect in southern Sinai, Egypt. **Annales de Parasitologie Humaine et Comparée, 62:** 467-473.

FRYAUFF, D.J.; MODI, G.B.; MANSOUR, N.S.; KREUTZER, R.D.; SOLIMAN, S. & YOUSSEF, F.G. (1993). Epidemiology of cutaneous leishmaniasis at a focus monitored by the Multinational Force and Observers in the northeastern Sinai desert of Egypt. **American Journal of Tropical Medicine and Hygiene, 54:** 598-607.

HANAFI, H.A.; EL SAWAF, B.M.; FRYAUFF, D.J.; MODI, G.B. & PRESLEY, S.M. (1996). Experimental infection and transmission of *Leishmania major* by laboratory-reared *Phlebotomus bergeroti* Parrot. **American Journal of Tropical Medicine and Hygiene, 54:** 644-646.

JANINI, R., SALIBA, S. & KAMHAWI, S. (1995). Species composition of sand flies and population dynamics of *Phlebotomus papatasi* (Diptera: Psychodidae) in the southern Jordan Valley, an endemic focus of cutaneous leishmaniasis. **Journal of Medical Entomology, 32:** 822-826.

KAMAL, H, SHEHATA, M., OSMAN, A., DOHA, S., EL HOSSARY, S. & SCHNUR, L. (1991). The first confirmed isolation of *Leishmania major* from southern Sinai. Proceedings of the Annual Meeting of the American Society of Tropical Medicine and Hygiene, Boston Massachusetts.

LANE, R.P. & FRITZ, G.N. (1986). The differentiation of the leishmaniasis vector *Phlebotomus papatasi* from the suspected vector *P. bergeroti*. **Systematic Entomology, 11:** 439-445.

LEWIS, D.J. & BÜTTIKER, W. (1982). The taxonomy and distribution of Saudi Arabian Phlebotomine sandflies (Diptera: Psychodidae). **Fauna of Saudi Arabia, 4:** 353-397.

MANSOUR, N.S.; FRYAUFF, D.J.; MODI, G.B.; MIKHAEl, E.M. & YOUSSEF, F.G. (1991). Isolation and characterization of *Leishmania major* from *Phlebotomus papatasi* and military personnel in north Sinai, Egypt. **Transactions of the Royal Society of Tropical Medicine and Hygiene, 81:** 747.

MERDAN, A.I.; MORSY, T.A.; SHOUKRY, A. & WAHBA, M. (1992). Two successive years studies on *Phlebotomus papatasi* in North Sinai Governorate, Egypt. **Journal of the Egyptian Society of Parasitology, 22:** 91-100.

RIOUX, J-A., CROSET, H., LEGER, N., BENMANSOUR, N. & CADI SOUSSI, M. (1975). Présence au Maroc de *Phlebotomus bergeroti*, *Phlebotomus chabaudi*, *Phlebotomus chadlii* et *Sergentomyia christophersi*. **Annales de Parasitologie Humaine et Comparée, 50:** 493-506.

SAF'YANOVA, V. M. (1979). Relationship of leishmaniasis with sandflies. USSR Ministry of Health, Gamaleya Institute, Moscow: 20 pp.

WORLD HEALTH ORGANIZATION. (1990). Control of the leishmaniases, World Health Organization Technical Report Series, 793.

YUVAL, B. (1991). Populations of *Phlebotomus papatasi* (Diptera: Psychodidae) and the risk of *Leishmania major* transmission in three Jordan habitats. **Journal of Medical Entomology, 28:** 92-495.

TABLE 1

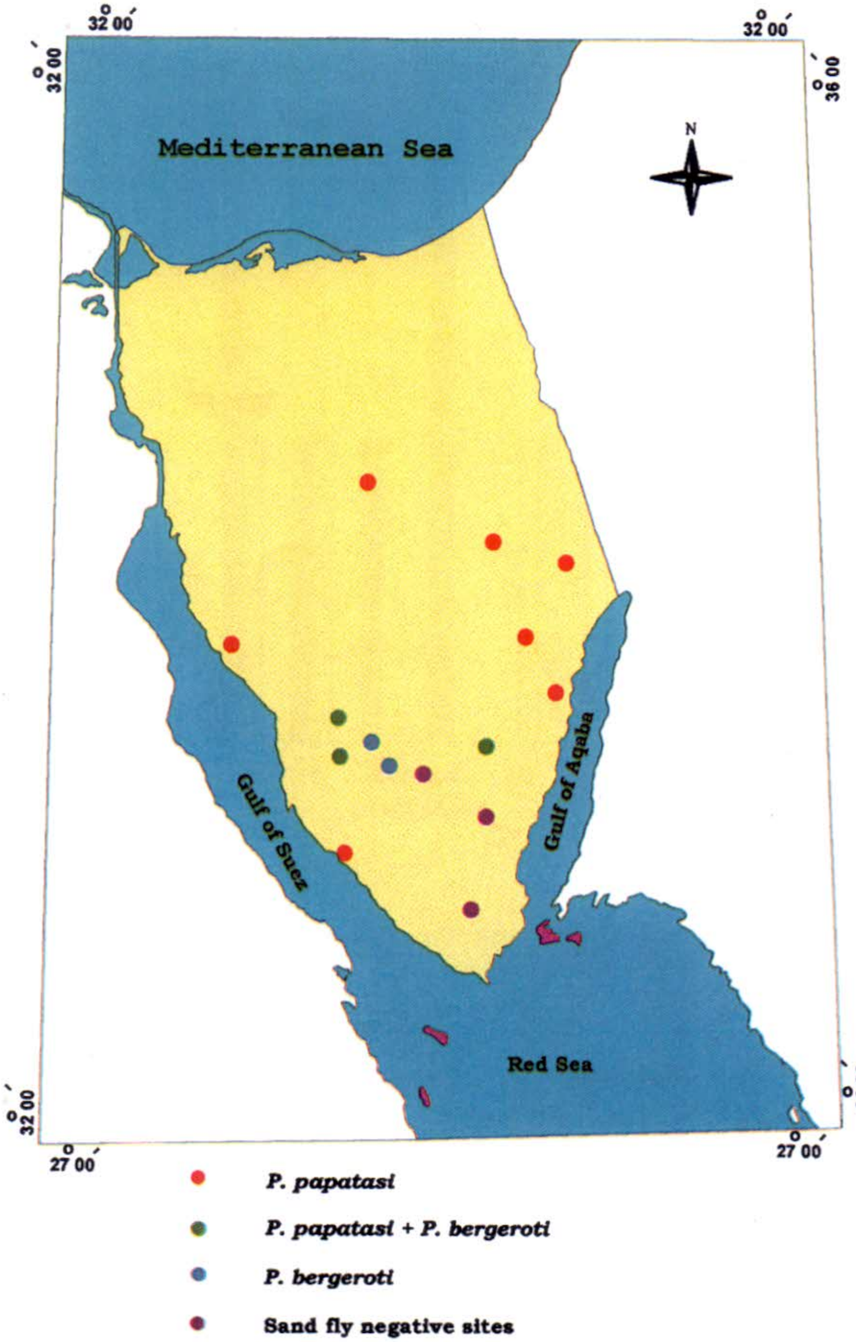
Some landscape features associated with the spatial distribution of *P. papatasi* and *P. bergeroti* in Sinai

Site ID number	Site name	Habitat type	Species	No. flies collected	Altitude (meters)	Soil type	Surface coverage
1	Nekhel	Agricultural farm	*P. papatasi*	306	450	Fixed alluvium	Coarse gravel and boulders
2	El Themed	Domestic	*P. papatasi*	35	600	Limestone	Wadi deposites/fine gravel
3	Ras el Naqab	Domestic	*P. papatasi*	1	600	Basement igneous	Coarse gravel
4	Nuweiba	Domestic	*P. papatasi*	19	25	Acid igneous	Pink granite
5	El Sheikh Atyia	Agricultural farm	*P. papatasi*	65	550	Limestone	Shale/sandstone/limestone
6	Feiran	Oasis with dense palm and olive trees	*P. bergeroti*	80	650	Acid igneous	Amphibolites
7	Wadi Ikhbar	Natural desert area	*P. bergeroti*	2	750	Acid igneous	Amphibolites
8	Wadi Sa'al	Agricultural farm	*P. papatasi* *P. bergeroti*	65 49	850	Acid igneous	Amphibolites

TABLE 1 (CONT'D)

Site ID number	Site name	Habitat type	Species	No. flies collected	Altitude (meters)	Soil type	Surface coverage
9	Gebel Katherine	Natural desert area	none	-	1425	Acid igneous	Wadi deposites
10	Wadi kid	Natural desert area	none	-	550	Metamud stone	Meta-rhylite tuffs
11	Wadi Nissrine	Natural desert area	*P. papatasi*	1	450	Acid igneous	Amphibolites
			P. bergeroti	7			
12	El Wadi village	Domestic	*P. papatasi*	8	25	Acid igneous alluvium	Fine gravel and sand
13	Wadi El Tarr	Natural desert area	*P. papatasi*	1	475	Acid igneous	Amphibolites
			P. bergeroti	10			
14	Wadi Gharandal	Agricultural farm	*P. papatasi*	10	75	Sandstone alluvium	Shale/marl/sandstone
15	Wadi Madsus	Natural desert area	none	-	250	Acid igneous	Prophyritic granite

Figure 1: Spatial Distribution of P. papatasi and P. bergeroti in Central and Southern Sinai, Egypt.



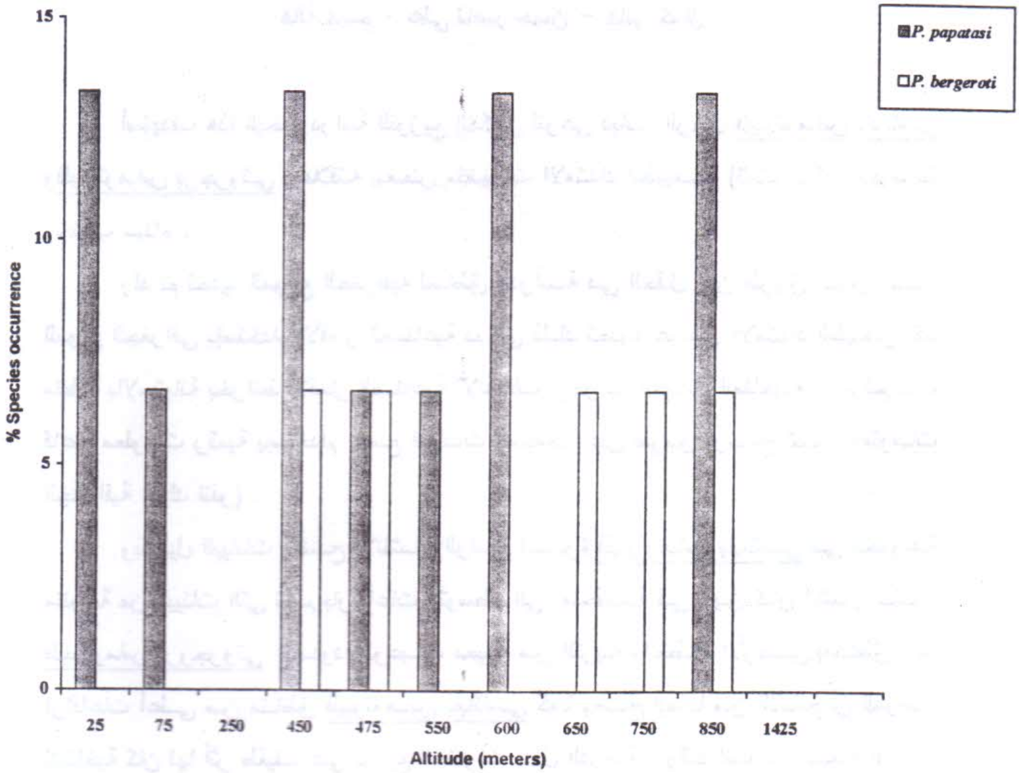


Fig. 2. Frequency distribution of *P. papatasi* and *P. bergeroti* occurrence at different altitudes.