Phlebotomine Sand Flies (Diptera: Psychodidae) of the Palestinian West Bank: Potential Vectors of Leishmaniasis

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ABSTRACT Two forms of leishmaniasis are endemic to the Jenin district in the northern region of the West Bank. Visceral leishmaniasis (VL), caused by *Leishmania infantum,* mainly affects infants. Cutaneous leishmaniasis (CL) affects a broader age group and is probably caused by *L. tropica.* Although the Jenin district is the most important focus of leishmaniasis in the West Bank, the sand fly fauna of the area has never been studied in a systematic manner. We collected base-line data on sand fly species, their distribution, and their feeding preferences to facilitate risk assessments for contracting leishmaniasis. Light traps, sticky traps, insecticide knockdown collections, aspirator, and human-landing collections were used. A total of 4,082 sand flies was collected in foci of confidence limits and/or VL between June and December 1998. Nine *Phlebotomus* species representing seven subgenera were identified: *P.* (*Larroussius) perfiliewi transcaucasicus* Perfil'ev, *P.* (*La.*) *tobbi* Adler & Theodor, *P.* (*La.*) *mascitti canaaniticus* Adler & Theodor, *P.* (*La.*) *mascitti mascitti* Grassi, *P.* (*La.*) *syriacus* Adler & Theodor, *P.* (*Phlebotomus*) *papatasi* Scopoli, *P.* (*Synphlebotomus*) s.p., *P.* (*Paraphlebotomus*) *sergenti* Parrot, *P.* (*Par.*) *jacusieli* Theodor, *P.* (*Adlerius*) *halepensis* Theodor. Two other *Phlebotomus* subspecies, *P.* (*La.*) *major major* Annandale, *P.* (*La .*) *neglectus* Tonnoir, require confirmation. In addition, four species of the closely related genus, *Sergentomyia* were also found: *S.* (*Sergentomyia*) *theodori* Parrot, *S. (S.) fallax* Parrot, *S.* (*Sintonius*) *tiberiadis* Adler, Theodor & Lourie, *S.* (*Sin.*) *christophersi* Sinton. Among five species of sand flies collected on human bait, *P. papatasi* constituted ≈90% followed by *P. major syriacus* (8%) and *P. mascitti* (2%). Sand fly human-biting activity occurred through the night and it was highest between 2400 and 0300 hours. *P. papatasi. P. perfiliewi*, *P, major* and *P.tobbi* were the more endophilic species constituting 93% of all flies caught indoors. Seven *Phlebotomus* spp. constitute potential vectors of leishmaniasis but the most probable ones are as follows: *P. papatasi* the main human-biting species, a recognized vector of *L. major* (CL), *P. sergenti*, *L. tropica* (CL) and *P. syriacus*, *L. infantum* (VL).

KEY WORDS *Phlebotomus,* resting sites, biting activity, leishmaniasis, West Bank

IN THE PALESTINIAN West Bank, both visceral leishmaniasis (VL) and cutaneous leishmaniasis (CL) constitute growing public health problems (Arda 1983, Greenblatt et al. 1985, Klaus et al.1994, Qubain et al. 1997, Baneth et al.1998). *Leishmania major* Yakimoff & Schokhor, 1914, and *L. tropica* Wright, 1903, are the causative agents of confidence limits, whereas *L. infantum* Nicolle, 1908, infections cause VL. *L. major* infections occur in the central Jordan valley and Jericho, where they are transmitted to humans by *Phlebotomus papatasi* Scopoli sand flies inhabiting burrows of the rodent reservoir host *Psammomys obesus* Cretzschmar, 1828 (Adler and Theodor 1927, Schlein et al. 1982). In contrast, *L. tropica* is mainly found in the northern region of the West Bank (S.S.S., unpublished data). *L. tropica* infects all ages, indicating a peridomestic mode of transmission. Based on cursory survey of medical records, in the current study area there have been at least 544 CL cases in recent years (Table 1). The reservoir animals and the sand fly vectors of *L. tropica* in the region have not been identified with certainty. The suspected host is the rock hyrax (*Procavia capensis* Pallas, 1766) and the probable vector is *P. sergenti* Parrot, a species that has been implicated in other foci in the Middle East (Killick-Kendrick 1990, Al-Zahrani et al. 1988; A.W., unpublished data). Human VL caused by *L. infantum* is confined to the northern regions of the West Bank where it affects mainly young children. From 1990 through 1999, 127 VL cases were recorded in the northern West Bank. Within the study area included in the present report, there were 53 confirmed cases of human VL (Table 1) and a number of parasite strains isolated from dogs

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Table 1. Correlation between altitude and presence of sand fly species in the Jenin district

Altitude (m) sand fly species	100–199	200–299	300–399	400–499
P. papatasi	28	30	87	1
P. perfiliewi	117	42	82	13
P. major	38	45	155	6
P. tobbi	28	62	132	3
P. sergenti	24	6	8	1
P. mascittii	3	6	17	—
P. jacusieli	1	1	—	—
P. halepensis	—	1	—	—
P. (Synphlebotomus) sp.	—	—	—	1
S. theodori	380	196	125	23
S. tiberiadis	9	—	—	—
S. fallax	1	1	—	—
S. christophersi	—	—	1	—
Total	626	390	607	48

120 sticky trap nights were used on three different occasions at each altitude.

were identified as *L. infantum* (Abdeen et al. 2002). *P. syriacus* Adler & Theodor, *P. perfiliewi* Parrot, and *P. tobbi* Adler & Theodor have been implicated as competent vectors of VL in various foci in the Mediterranean basin (Killick-Kendrick 1990).

The current study is intended to augment our knowledge of the phlebotomine fauna in the Jenin district by identifying the sand fly species, assessing their tendency to bite humans and determining their relative abundance in the disease foci during different times of the year.

Materials and Methods

Study Area. Field studies were conducted in the Jenin district (32° 20′ N, 35° 8′ E), West Bank, Palestinian Authority (Fig 1). The district covers an area of 592 km^2 with altitude ranging between 90 and 750 m above sea level. The Jenin district may be divided into three major climatic zones. The central highlands are 400–650 m above sea level and receive 400–600 mm rain annually (Fig. 1, zone II). These form the watershed line and separate the eastern and western slopes. The drier and warmer eastern slopes are located west of the Jordan valley and rise steeply toward the Central highlands. These receive very little precipitation (Fig. 1, zone III) To the west are the somewhat cooler, more humid slopes of 100–400 m (Fig. 1, zone I). A total of 195,300 persons living in 96 localities inhabit the district (Palestinian Central Bureau of Statistics 1998). The inhabitants work mainly in agriculture, and domestic animals such as sheep, goats, and poultry are abundant. Houses are built of concrete and stone with the more affluent residents frequently building in suburban areas, where most leishmaniasis cases occur.

Meteorological Data. Data on relative humidity, wind velocity, and temperature were obtained from two meteorological stations located in Jenin and in Tubas. The district receives rainfall between mid-October and the end of April, with a peak during January and February (Applied Research Institute 1996). Rainfall varies significantly from 778 mm in the west to 286 mm in the southeast (Fig 1), with mean annual

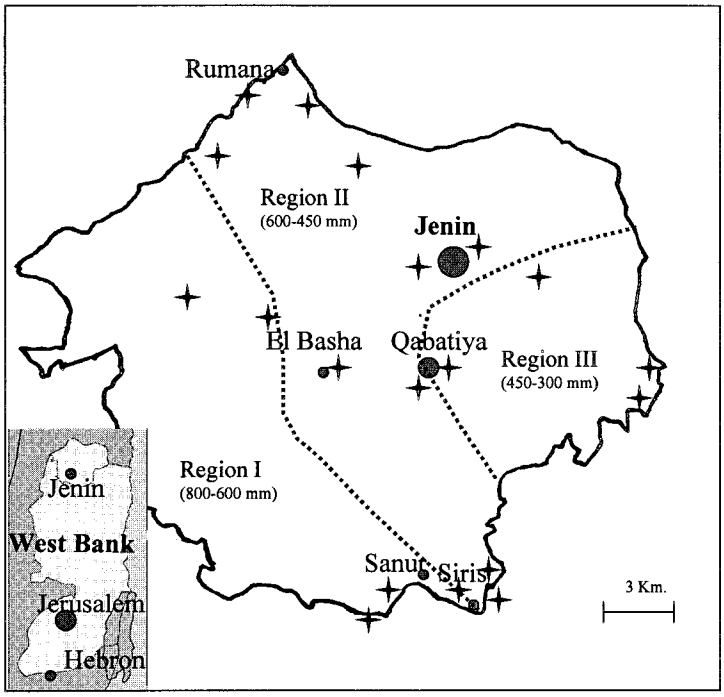

Fig. 1. Area of Jenin showing principal towns and localities where sand fly trapping was done. Dashed lines separate clines of precipitation separating the district into three regions.

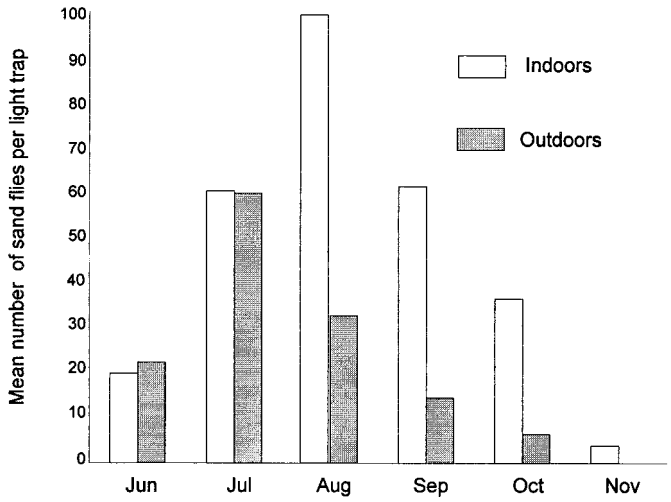

Fig. 2. Seasonal abundance of main sand fly species in Siris, Jenin district monitored using light traps every 9 d from June to November 1998.

rainfall of 528 mm. August is the warmest month with 34.2°C maximum and 21.1°C minimum temperature.

Sampling Sites. Active foci of confidence limits and VL were selected as sampling sites representative of the principal climatic zones and habitat types of the region: region I = 4, region II = 11, and region III = 4 (Fig 1).

Collection Strategy. Collections of sand flies were made over 6 mo (June to December 1998) comprising the active season of sand flies in the region. Five collection methods were used: (1) sticky traps that consisted of size A4 paper sheets coated with castor oil and stapled vertically on wooden stakes at a height of 20 cm (180 trap nights); (2) Aspirator collections were made off protected human bait both inside and outside houses (48 person-hours); (3) CDC light-traps (model 512; John W. Hock, Gainesville, FL) with small-mesh collecting bags (104 trap nights) suspended at a height of 0.5 m above ground 1 h before sunset and collected within 2 h after sunrise; and (4) insecticide spray knock-down collections were made indoors, sampling 40 houses in 10 localities during five different nights. Methods were selected based on accepted criteria for sampling leishmaniasis vectors (Perfil'ev 1968, Alexander 2000)

Processing and Identification of Sand Flies. Flies from sticky traps were removed with a needle, dipped in a 10% detergent solution, rinsed in water, dissected, and mounted in Berlese's medium (Gum Chloral Mountant–Asco, Manchester, UK) with the head ventral-side up and the remainder of the specimen placed laterally under a single coverslip. Sand flies were divided into *Phlebotomus* and *Sergentomyia* and identified to species according to published keys (Theodor 1958; Lewis 1967, 1978, 1982; Perfil'ev 1968; Lane 1986; Lane et al.1988). Identifications were verified by comparing them with mounted specimens at the entomological collection of the Department of Parasitology, Hebrew University of Jerusalem.

Sand flies were anesthetized in the freezer for 5 min, placed in a sieve, washed briefly in a 1% detergent solution, and rinsed in distilled water. Female *Phlebotomus* spp. were separated and dissected in sterile saline under a stereoscopic microscope. The gut was covered for detailed examination under phase-contrast illumination for the detection of *Leishmania* promastigotes. The head and abdomen were removed, transferred to a separate slide, and mounted in Berlese medium for identification of the species (Davies 1967, Mutinga and Odhiambo 1986).

Results

Ecological Variables. *Species Composition.* In all, 4,082 sand flies (2,036 Phlebotomus spp. and 2,046 Sergentomyia spp.) were collected from 23 localities endemic for confidence limits and/or VL. These comprised 13 *Phlebotomus* and *Sergentomyia* species: *P. (Larroussius) perfiliewi transcaucasicus* Perfil'ev, *P. (L.) tobbi* Adler & Theodor, *P. (L.) mascittii canaaniticus* Adler & Theodor, *P. (L.) mascitti mascitti* Grassi, *P. (L.) syriacus* Adler & Theodor, *P. (Phlebotomus) papatasi* Scopoli, *P. (Synphlebotomus)* sp., *P. (Paraphlebotomus) sergenti* Parrot, *P. (Par.) jacusieli* Theodor, *P. (Adlerius) halepensis* Theodor, *S. (Sergentomyia) theodori* Parrot, *S. (S.) fallax* Parrot, *S. (Sintonius) tiberiadis* Adler & Theodor, *S. (Sin.) christophersi* Sinton. *P. perfiliewi* and *P. papatasi* were the predominant *Phlebotomus* species, whereas the most abundant species over all was *S. theodori,* constituting 49.6% of all sand flies.

Species Abundance. Fluctuations in abundance of sand flies were followed in one village using CDC light traps inside and outside houses for 36 trap-nights every 9 d, from June to December 1998. Of the nine species collected, five occurred every month: *P. perfiliewi, P. tobbi, P. papatasi, P. major,* and *S. theodori. P. papatasi, P. tobbi,* and *S. theodori* appear to reach a peak during

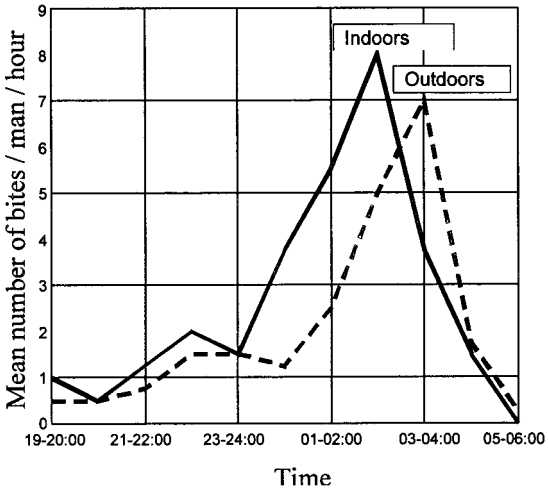

Fig. 3. Nocturnal activity patterns of sand flies determined by human biting collections indoors and outdoors. Catches comprised 90% *P. papatasi*, 8% *P. major syriacus*, and 2% *P. mascitti*.

the driest months (July), whereas *P. perfiliewi* numbers peaked in August. Numbers of all sand fly species dropped markedly in November (Fig. 2) and no sand flies were found in the area after the commencement of winter rains.

The importance of temperature, relative humidity, and wind velocity for sand fly nocturnal activity can be inferred by comparing these climatic parameters to success in sand fly catches. The months in which sand flies were most abundant were July and August characterized by high humidity (50–60%), high temperatures (24–26°C) and very little wind (generally ($0.3 < ms^{-1}$) (Data obtained from the Meterological Services).

Abundance at Different Altitudes. All the sand fly species including the suspected *Leishmania* vectors, were much more abundant below 400 m than above it (Table 1).

Biological Variables. *Resting Sites.* To identify diurnal resting sites, sand fly collections were made intermittently throughout the study period by both insecticide knockdown collections and aspirators in houses. The preferred resting sites were the corners between walls and ceilings in bedrooms and bathrooms. The most abundant species caught by knockdown and aspiration was *P. papatasi* yielding 65 fles (80%) and 10 (67%) of the catch, respectively. Other species found were *P. perfiliewi, P. tobbi, P. major, P. mascitti, P. sergenti,* and *S. theodori.*

Biting Cycle. The nocturnal human biting activity of sand flies indoors and outdoors is shown in Fig. 3. Peak activity was found to be between midnight and sunrise. *P. papatasi* was the chief human-biting species, accounting for some 90% of all sand flies caught on human bait (Fig 4). Other potential vectors, *P. syriacus* and *P. perfiliewi* (VL), were abundant but less attracted to humans (Fig. 4).

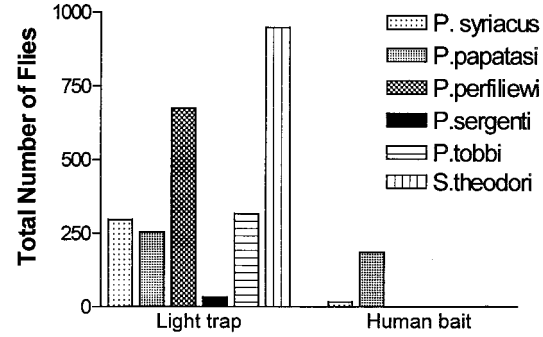

Fig. 4. Relative efficiency of light traps versus human bait for collecting different sand fly species.

Abundance Inside and Outside Houses. P. papatasi. P. perfiliewi, P, major, and *P. tobbi* were the more abundant species inside houses constituting 93% of all flies caught indoors. These same species were also the most common species collected outdoors comprising 96% of the catch (Table 2).

Attraction of Sand Flies to Animal Sheds. Collection of sand flies from sheep and goat sheds in Siris village was carried out for nine light-trap-nights during October and November. Six sand fly species were collected: 154 *P. major* (=45%), 123 *P. tobbi* (=36%), and 44 *P. perfiliewi* (=13%). Other species were found in small numbers. The number of sand flies attracted to the sheds must have been very large judging from the average of 38 caught per light trap.

Sex Ratios. The total number of males caught by all methods combined was higher than that of females (2,498 ♂ : 1,371 ♀ = 1.82). The male/female sex ratios for different species were substantially different: *P. papatasi* = 1.13 (n = 353). In contrast, P. *perfiliewi* = 0.55 (n = 727), *P. tobbi* = 0.41 (n = 349), *P. sergenti* = 0.48 (n = 40). For *Sergentomyia* species, the value for *S. theodori* was 0.51 (n = 2023).

The sex ratio also showed a seasonal change. In June, the male/female ratio for *P. papatasi* was 1.4 with the males out numbering the females. During July, August, and September, the balance shifted in favor of females till in October they dominated (ratio = 0.4). For *P. major*, a different situation prevailed with fe-

Table 2. *Phlebotomus* spp. caught in and around houses of CL and VL patients

Species	Inside houses of leishmaniasis patients	Around houses in leishmaniasis foci	Total
P. papatasi	93	252	345
P. perfiliewi	61	628	689
P. tobbi	46	193	239
P. major	60	141	201
P. sergenti	16	33	49
P. mascitti	3	9	12
P. jacusieli	1	4	5
P. (Synphlebotomus)	0	2	2
P. halepensis	0	1	1
Total	280	1263	1,543

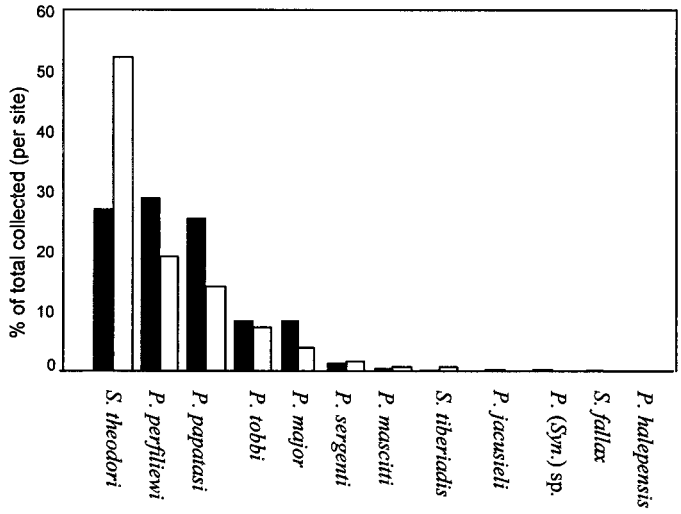

Fig. 5. Relative abundance of different sand fly species inside (shaded bars) and outside (empty bars) houses. Pooled data from human bait and sticky trap collections at different sites.

males more plentiful throughout the collection period (ratio = 0.3).

Physiological Status. More than 50% of the *P. papatasi* females caught indoors were blood fed or gravid. More gravid or freshly fed females of *Phlebotomus* spp. (30%) were collected indoors than outdoors. In animal sheds, ≈28% of *P. syriacus* females were found freshly fed, and no gravid female of any species was caught.

Productivity of Trapping Methods. Light traps were used to monitor the seasonal abundance of sand flies (Fig. 2) and sticky traps were used to collect flies not attracted by light. The total number of flies caught using light traps was 2,559 flies (108 trap-nights) comprising 11 species. On sticky traps, 1,185 flies were caught comprising 10 species in (57 trap-nights). Traps in animal sheds caught the highest number of flies, the maximum number being 264 sand flies in one trap placed alongside a stone-built house in the vilage of Beit Qad.

Dissections for Parasites. No *Leishmania* parasites were found in 923 female *Phlebotomus* spp. Dissections included *P. perfiliewi* (410), *P. tobbi* (225), *P syriacus* (175), *P. papatasi* (90), *P. sergenti* (18), *P. mascittii* (15), and *P. jacusieli* (2).

Discussion

Here we report the results of a preliminery study of leishmaniasis vectors in the Palestinian West Bank. Different sampling methods were applied throughout the summer season in different habitats. Collections methodologies, habitats and locations were selected to be diverse to sample as many of the different sand fly species as possible. Thus, results should be viewed mainly as a documentation of the species present in the Jenin District. However, valuable additional data were gleaned from the collections and presented here because of its epidemiological importance.

Ecological Variables. *Abundance of Sand Flies and Species Composition in Different Habitats.* Although comparative population densities cannot be inferred, substantial differences were found in both relative abundance and species composition of sand flies in peridomestic habitats (13 species, nine *Phlebotomus* spp. constituting 65% of all collected sand flies, and four *Sergentomyia* spp.) and agricultural or uncultivated areas (five species, one *Sergentomya* spp. constituting 92% of all collected sand flies and four *Phlebotomus* spp.). These observations are in accord with previous findings that *Sergentomyia* spp. are more adapted to open and dry habitats while *Phlebotomus* spp. prefer peridomestic areas (Quate 1964, Lane et al.1988). It is possible that peridomestic habitats have more breeding sites due to presence of moist soil and organic matter as well as diurnal resting sites in animal sheds, human dwellings, wells, and caves.

Peak abundance indoors occurred early in the season while numbers caught outdoors were still relatively low. Hence, in the earlier part of the season there is a greater risk of being bitten inside houses than outside. A similar situation has been reported in confidence limits foci in Saudi Arabia (Al-Zahrani et al. 1997). Of the sand fly species found indoors only *P. papatasi* can be considered truly endophillic since its numbers comprised 33% of flies caught indoors, although in total it only represented 22% of the catch. Previous studies on the biting activity of *P. papatasi* in Egypt and Iraq have demonstrated that the species was most active around midnight (Mohsen 1983, El-Said et al. 1986). We found the peak biting activity by human landing sampling around 0230 and 0330 hours for indoors and outdoors, respectively.

Sand fly activity was more closely related to wind velocity than to any other climatic factor. *P major* and *P. tobbi* were very sensitive even to low wind velocities while *P. papatasi* was not measurably affected by the wind velocity (range = 0.4 m/s–1.4 m/s). Although

these results cannot be tested statistically due to specific local situations and small numbers of flies, they are supported by previous findings from East Africa and Saudi Arabia (Quate 1964, Roberts 1994).

The relatively high numbers of *Sergentomyia* species collected by sticky traps from almond trees infested with aphids may reflect sugar feeding behavior because aphid honeydew was considered an important source of sugar for sand flies. However, the mechanism controlling attraction of sand flies to different plants is not known (Cameron et al. 1994). The low numbers or absence of sand flies at oak and pine forest in our study may indicate that these trees are not suitable sites for resting and breeding.

Phelobtomus papatasi is a proven vector of confidence limits caused by *L. major* in the Jordan valley and Jordan (Schlein et al. 1982, Janini et al. 1995). It was the biting sand fly species found in abundance in houses of confidence limits patients (Table 2). However, recognized reservoir hosts of *L. major* do not occur in the Jenin district which ecologically resembles foci of *L. tropica* in the West Bank and Israel where exophilic *P. sergenti* and *P.* (*Adlerius*) spp. were found infected (A.W., unpublished data). Furthermore, if the highly endophilic and anthropophagic *P. papatasi* were the vector, one would expect there to be many more cases of confidence limits, as is the case in Jericho and other localities in the lower dryer regions of the Jordan Valley where *L. major* is endemic.

We did not encounter any *L. infantum*-infected sand flies. The vector is probably peridomestic because the age distribution of patients is skewed, with 95% under the age of 5 yr (Abdeen et al. 2001). The most likely vector is *P. (La). syriacus*, a peridomestic biter that has been incriminated in transmission of *L. infantum* in other countries (Killick-Kendrick 1990). The probable vector of *L. tropica* is *P. sergenti*—a shy species that normally keeps away from human habitation and can be captured in larger numbers in caves and crevices. Relatively few *P. sergenti* were collected in this study and none were infected.

Notes on Species Found

Phlebotomus (Larroussius) perfiliewi. Lewis (1982) described three subspecies of *P. perfiliewi*, one of which, *P. perfiliewi transcaucasicus*, was found in the Jenin district. Although it is found in large numbers in different habitats, it is not a human biting sand fly and probably plays a role in transmitting parasites between reservoir animals (Adler and Theodor 1957). It is a proven vector of VL caused by *L. infantum* (Killick-Kendrick 1990).

Phelobotomus (L.) tobbi. Was collected in most localities from domestic and natural habitats. It was more abundant in animal sheds and seemed to rest inside houses during daytime. It is a suspected vector of VL in the Mediterranean region (Killick-Kendrick 1990).

Phelobotomus (L.) mascitti. Little is known about ecology of this rare species (Lewis 1982). In this study we collected 29 specimens in six localities. Two subspecies, *P. mascittii canaaniticus* Adler & Theodor and *P. mascittii* Grassi were identified (Lewis 1982).

Phelobotomus (L.) major. This is an eastern Mediterranean species, and has been recorded from Israel, Syria, the Caucasus, and Turkestan (Leger et al. 1983). Three subspecies were found in the current study: *P. major syriacus* Adler & Theodor was the most prevalent followed by *P. major major* Annandale and *P. major neglectus* Tonnoir. *P. (L.). syriacus* is a proven vector of VL in the Mediterranean (WHO 1984).

Phelobotomus (Synphlebotomus) sp. Two females and two males were collected in domestic habitats in Siris and Jadeida villages. Based on taxonomical criteria suggested by Lewis (1982), specimens are suspected to be *P. rossi* de Meillon & Lavoipierre.

Phelobotomus (Paraphlebotomus) sergenti. Forty *P. sergenti* were collected in human habitats in confidence limits foci in Jenin. This peridomestic species has a wide distribution from the Mediterranean basin through the Middle East to India and South to Yemen and the Ethiopian highlands. It is a proven vector of confidence limits caused by *L. tropica* through much of its distribution (Al-Zahrani et al. 1988, 1997; Killick-Kendrick1990). Five percent of the *P. sergenti* found in a confidence limits focus near Jerusalem were found to harbor *L. tropica* parasites. *P. sergenti* is rarely attracted to humans which explains relatively low incidence of disease despite high infection rates in flies (A.W., unpublished data).

Phelobotomus (Adlerius) halepensis. This species, with its characteristic tip of the aedeagus, was originally described from Aleppo in Syria and from Tehran. During the present survey, a single male *P. halepensis* was found in one locality namely Deir Abu Daif. It is a suspected vector of VL (Killick-Kendrick 1990).

Phelobotomus (Paraphlebotomus) jacusieli Theodor. The species was described based on a single male from northern Israel (Theodor et al. 1958). In the course of our survey, four females were caught by light traps in three different localities. It is not known to transmit leishmaniasis.

Phelobotomus (P.) papatasi. This is one of the most common and widespread of all sand fly species, occurring from Morocco and Portugal in the West to Bangladesh in the East. This species, the principal vector of *Le. Major* in the Middle East and is a proven vector in the Jordan Valley (Schlein et al. 1982, Buttiker and Lewis 1983). It is a highly anthropophilic species with peridomestic preferences. *P. papatasi* was present in the majority of sampling sites, and is undoubtedly one of the dominant species in the Jenin district.

Sergenomyia (Sergenomyia) antennata Group. Two species were collected from the Jenin district: *S. theodori* (Parrot) and *S. fallax* (Parrot). Following the taxonomy of Lewis (1973), they are differentiated according to the shape of the cibarial teeth and the pharyngeal armature. *S. theodori* is the most abundant in areas away from human habitation, constituting 49.72% of all catches.

Sergenomyia (Sintonius) christophersi Sinton. This species is distributed from sub-Saharan Africa through the Middle East and extending into Pakistan. The females are easily recognized by the presence of four long horizontal teeth with numerous denticles between them on the cibarium. Only a single female was collected around houses in Qabatiya. This species has been found in southern of Jordan (Lane et al. 1988).

Sergenomyia (Sintonius) tiberiadis Adler, Theodor & Lourie. This rare species is a small pale fly, easily distinguished from all other species of the sub-genus *Sintonius* by the characteristic curved, strap-like cibarial teeth in both males and females. Flies of this species were collected from the neighboring localities of Silat El Harthiya and El Yamun.

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References Cited

Abdeen, Z., S. Sawalha, K. Bader, O. Yousef, K. Azmi, H. Khanfar, M. Shtayeh, A. Warburg, C. L. Greenblatt, L. F. Schnur, C. L. Jaffe, and G. Baneth. 2002. Epidemiology of visceral leishmaniasis in the Jenin District, West Bank, Palestine, 1989–1998. Am. J. Trop. Med. Hyg. 66: 329–333.

Adler, S., and O. Theodor. 1927. The transmission of *Leishmania tropica* from artificially infected sand flies to man. Ann. Trop. Med. Parasitol. 21: 89–103.

Adler, S., and O. Theodor. 1957. Transmission of disease agents by Phlebotomine sand flies. Annu. Rev. Entomol. 2: 203–226.

Alexander, B. 2000. Sampling methods for phlebotomine sandflies. Med. Vet. Entomol. 14: 10–122.

Al-Zahrani, M. A., W. Peters, D. A. Evans, L. Ching Chin, V. Smith, and R. P. Lane 1988. *Phlebotomus sergenti,* a vector of *Leishmania tropica* in Saudi Arabia. Trans. R. Soc. Trop. Med. Hyg. 82: 416.

Al-Zahrani, M. A., R. P. Lane, L. Ching Chin, M. A. Asiry, and W. Peters. 1997. Biology of *Phlebotomus* sand flies (Diptera: Psychodidae) in two contrasting Leishmaniasis foci of south-west Saudi Arabia. Bull. Entomol. Res. 87: 221–230.

Arda, H. M. 1983. A report on cutaneous Leishmaniasis in the West Bank of Jordan. Jordan Med. J. 17: 57–63.

Baneth, G., G. Dank, E. Keren-Kornblatt, E. Sekeles, I. Adini, C. Eisenberger, L. Schnur, R. King, and C. L. Jaffe. 1998. Emergence of visceral Leishmaniasis in central Isreal. Am. J. Trop. Med. Hyg. 59: 722–725.

Buttiker, W., and D. J. Lewis. 1983. Insects of Saudi Arabia: some ecological aspects of Saudi Arabian Phlebotomine sand flies (Diptera: Psychodidae). Fauna Saudi Arabia 5: 479–530.

Cameron, M. M., C. Davies, J. Monje, P. Villaseca, E. Ogusuku, and A. Llanos-Cuentas. 1994. Comparative activity of Phlebotomine sand flies in different crops in the Peruvian Andes. Bull. Entomol. Res. 84: 461–467.

N. T. Davies. 1967. Leishmaniasis in the Sudan Republic 28. Anatomical studies on *Phlebotomus orientalis* Parrot and *P. papatasi* Scopoli (Diptera: Psychodidae). J. Med. Entomol. 4: 50–65.

El-Said, S., J. C. Beier, B. El Sawaf, S. Doha, and E. El Kordy. 1986. Sand flies (Diptera: Psychodidae) association with visceral leishmaniasis in El Agamy, Alexandria Governorate, Egypt. II. Field behavior. J. Med. Entomol. 6: 609–615.

Greenblatt, C. L., Y. Schlein, and L. F. Schnur. 1985. Leishmaniasis in Israel and vicinity, pp. 416–426. *In* K. P. Chang and R. S. Bray (eds.), *Leishmaniasis.* Elsevier, Amsterdam.

Janini, R., E. Saliba, S. Khoury, O. Oumeish, S. Adwan, and S. Kamhawi. 1995. Incrimination of *Phlebtomus papatasi* as vector of *Leishmania major* in the southern Jordan Valley. Med. Vet. Entomol. 9: 420–422.

Killick-Kendrick, R. 1990. Phlebotomine vectors of the leishmaniasis: a review. Med. Vet. Entomol. 4: 1–24.

Klaus, S., O. Axelrod, F. Jonas, and S. Frankenburg. 1994. Changing patterns of cutaneous leishmaniasis in Israel and neighbouring territories. Trans. R. Soc. Trop. Med. Hyg. 88: 649–650.

Lane, R. P. 1986. The sand fly of Egypt (Diptera: Phlebotominae). Bull. Br. Mus. (Nat. Hist) 52: 1–35.

Lane, R. P., S. Abdel-Hafez, and S. Kamhawi. 1988. The distribution of phlebotomine sand flies in the principal ecological zones of Jordan. Med. Vet. Entomol. 2: 237–246.

Leger, N., B. Pesson, J. Madulo-Leblond, and E. Abonnene. 1983. Sur la differentiation des femelles du sous-genre Larroussius Nitzulescu, 1931 (Diptera-Phlebotomidae) de la region Mediterraneenne. Ann. Parasitol. Hum. Comp. 58: 611–623.

Lewis, D. J. 1967. The Phlebotomine sand flies of west Pakistan (Diptera: Psychodidae). Bull. Br. Mus. (Nat. Hist) 19: 1–57.

Lewis, D. J. 1978. The Phlebotomine sand flies (Diptera: Psychodidae) of the oriental region. Bull. Br. Mus. (Nat. Hist), 37: 217–343.

Lewis, D. J. 1973. Phlebotomidae and Psychodidae (sand flies and moth-flies), pp. 155–180. *In* K.J.V. Smith (ed.), Insects and other arthropods of medical importance. The Trustees of the British Museum (Natural History), London.

Lewis, D. J. 1982. A taxonomic review of the genus Phlebotomus (Diptera: Psychodidae). Bull. Br. Mus. (Nat. Hist) 45: 121–209.

Lewis, D. J., and W. Buttiker. 1982. Insects of Saudi Arabia, Diptera: Fam. Psychodidae, Subfam. Phlebotominae. Fauna Saudi Arabia 2: 252–285.

Mohsen, Z. H. 1983. Biting activity, physiological age and vector potential of *Phlebotomus papatasi* Scopoli (Diptera: Phlebotomidae) in central Iraq. J. Biol. Sci. 14: 79–94.

Mutinga, M. J., and T. R. Odhiambo. 1986. Cutaneous Leishmaniasis in Kenya-II, studies on vector potential of *Phlebotomus Pedifer* (Diptera: Phlebotomidae) in Kenya. Insect Sci. Applic 7: 171–174.

Perfil'ev, P. P. 1968. Phlebotominae (sand flies). Translated by the Isreal Programme of Scientific Translations from 1966 original. Rehovoth, Israel.

Quate, L. W. 1964. Leishmaniasis in the Sudan Republic. 19: *Phlebotomus* sand flies of the Paloich Area in the Sudan (Diptera: Psychodidae). J. Med. Entomol. 1: 213–268.

Qubain, H. I., E. Saliba, and L. Oskam. 1997. Visceral Leishmaniasis from Bal'a, Palestine, caused by *Leishmania donovani* s.1. identified through polymerase chain reaction and restriction fragment-length polymorphism analysis. Acta Trop. 68: 121–128.

Roberts, D. M. 1994. Arabian sand flies (Diptera: Psychodidae) prefer the hottest nights? Med. Vet. Entomol 8: 194–198.

Schlein, Y., A. Warburg, L. F. Schnur, and A. E. Gunders. 1982. Leishmaniasis in the Jordan Valley II. Sand flies and transmission in the central endemic area. Trans. R. Soc. Trop. Med. Hyg. 76: 582–586.

Theodor, O. 1958. Psychodidae, Phlebotominae, pp. 1–55. *In* E. Lindner, Die Fliegen der Palaearktischen Region, vol. 9, *Psychodidae,* E. Schweizerbart'sche Verlag, Stuttgart.

(WHO) World Health Organization. 1984. The Leishmaniasis. Technical Report Series 701. WHO, Geneva.

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