INVESTIGATIONS INTO PHLEBOTOMINE SANDFLIES IN NAIROBI AREA

ROSEBELLA ORANGI MARANGA B.Sc. (NAIROBI)

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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ROSEBELLA, O. MARANGA

This thesis has been submitted for examination with our approval as supervisors.

1. Dr. L.W. Irungu, Department of Zoology
   University of Nairobi

22.8.90

DR. L. W. IRUNGU

2. Dr. M.J. Mutinga, International Centre for Insect Physiology and Ecology (ICIPE)

Sept. 27th, 1990

DR. MUTUKU J. MUTINGA

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ABSTRACT

Studies were commenced to collect and identify the phlebotomine sandflies found in Nairobi. The studies were also aimed at determining their numbers as well as assessing the effects of seasonal changes on the sandfly population. Four trapping methods viz. light traps, sticky traps, aspiration and human baits were employed.

Using the entomological keys of Kirk and Lewis (1951) and a pictorial key developed by Mutinga for Kenyan sandflies, 8 species and one undescribed species were recorded over a period of 6 months. The identified species included Phlebotomus guggisbergi, Phlebotomus rodhaini, Sergentomyia adleri, Sergentomyia squamipleuris, Sergentomyia clydei, Sergentomyia teesdalei, Sergentomyia harveyi and Sergentomyia bedfordi and undescribed species. The undescribed species was the most abundant among the collected sandflies whereas S. adleri was the least in abundance.

Most of the sandfly species trapped showed seasonal prevalence. The sandflies occurred in large numbers at the onset of the rains. The sandfly population decreased drastically however, during the heavy rains. The seasonal variation in numbers was closely related to the weather conditions.

Stepwise regression realized a formula that could be used to predict the number of sandflies of a particular species that one expects to catch at any given time. Detailed results are discussed elsewhere in this thesis.

The sandflies were found in termite mounds, animal burrows, caves and dugouts some of which were near human habitations. Most of the sandflies were collected from termite mounds and animal burrows. The sandflies also showed prevalence for micro-habitats.

The results of these studies have demonstrated clearly that Nairobi has a number of sandfly species some of which are potential vectors of leishmaniasis. For example, S. clydei is a suspected vector of lizard leishmaniasis in Kenya and it readily bites man. Phlebotomus guggisbergi a cave dweller, readily bites man inflicting a lot of pain. The vectorial capacity of this species needs to be investigated. More work needs to be done so as to identify the unknown species and also to reveal its vectoral potential.

CHAPTER 1

1.0 INTRODUCTION

Sandflies are haematophagus insects a fact which makes them important medical vectors. Species in the genera, *Phlebotomus*, *Sergentomyia* and *Lutzomyia* suck blood from vertebrates. The genus *Phlebotomus* occurs only in the old world, especially in the southern parts of the northern temperate areas and the tropics. *Sergentomyia* species are also restricted to the old world, being especially common in the Indian subregion, Africa and Central Asia. *Lutzomyia* species occur in the new world especially in the forested areas of Central and Southern America.

Inspite of their small size, sandflies cause severe irritation due to their bites. Sandflies are crepuscular in their biting habits, but they are mainly nocturnal. However, they will readily bite during the day in dark rooms, latrines and dark corners.

Sandflies are the known vectors of leishmaniases caused by different species of the genus *Leishmania*. There are six species of *Leishmania* infecting man (Molyneux and Ashford, 1983). These are *L. aethiopica*, *L. donovani*, *L. major*, *L. tropica*, *L. braziliensis* and *L. mexicana*.

Four of these six species of *Leishmania* occur in Kenya. They are, *L. donovani*, *L. aethiopica*, *L. major*, and *L. tropica*. *Leishmania major* has been isolated from rodents (Chance *et al.*, 1978 and Githure *et el.*, 1984, Mutinga & Ngoka (1983).

Leishmaniasis is an important public health problem in several parts of the world occurring mainly in tropical and subtropical Africa, Mediterranean basin, parts of South America, Central and Eastern Asia. The disease occurs in two main forms namely, cutaneous leishmaniasis (CL) and visceral leishmaniasis (VL). Cutaneous leishmaniasis may be restricted to the skin producing a chronic ulcer or it may be concentrated in the mucous membranes which are gradually eroded producing a disfiguring and often fatal condition known as espundia. *Leishmania aethiopica* *L. major* and *L. tropica* cause various forms of cutaneous leishmaniases. *Leishmania donovani* causes visceral leishmaniasis (Kala-azar). The *Leishmania* parasites attack internal organs such as the liver, spleen and lymph glands which may enormously enlarge. *Leishmania braziliensis* and *L. mexicana* cause cutaneous leishmaniasis in South America.

Doerr and Taussing (1909) showed for the first time that *Phlebotomus papatasi* transmits sandfly fever. Other researchers have since confirmed this observation.

Whittingham and Rook (1923) later showed that the infection is transmitted hereditarily to the progeny of an infected P. papatasi. Perfil'ev (1968) later confirmed that P. papatasi transmitted the disease. The disease occurs in the southern part of palearctic region and extends up the Nile and into India, West Pakistan, Middle East into the Sudan (Duckhouse and Lewis, 1980, Nasir, 1984). A condition which clinically resembles sandfly fever has been reported from the Gambia (Bertram, et al., 1958).

The virus of yellow fever has been isolated from Phlebotomus spp. in Uganda (Smithburn, et al., 1949). However, it was difficult to say whether this observation indicated merely an accidental infection or the possibility that Phlebotomus may play some part in the natural history of yellow fever.

Bartonellosis is another disease transmitted by sandflies. The causative agent is Bartonella baciliformis. This organism produces either one or both of the syndromes known as Oroyo fever and Verruga peruana. Sometimes the name carrion disease is used to designate these two syndromes collectively. This disease is transmitted by Phlebotomus spp. (Hertig, 1948) and the disease appears to be limited in

P. rodhaini and P. alexandri. Gemetchu et al. (1974) postulated that P. orientalis was the vector of Kala-azar in the Northwestern part of Ethiopia. Ashford et al. (1973) sampled sandflies in the Belessa area of Ethiopia at 1,800 m altitude by hand capture in animal burrows, rock cracks and tree holes as well as man-bait capture. Phlebotomus martini, P. duboscqi and P. rodhaini were caught in porcupine holes but in small numbers. Sergentomyia heischi and P. orientalis were also recorded.

Gemetchu et al. (1976) recorded P. orientalis, P. heischi and P. sergenti and 9 Sergentomyia species from Southwestern Ethiopia. From their collections using sticky and light traps during the 1973-1974 period, (Gemetchu et al., 1977) found that P. orientalis was present in Humera during the dry season (December-May) but reached a peak in May-June. Ashford (1974) recorded several Phlebotomus species from southwestern part of Ethiopia, viz: P. longipes and P. pedifer (both of which have been incriminated as vectors of CL in Ethiopia), P. sergenti (in dry country), P. saevus, P. bergeroti, P. duboscqi, P. rodhaini and S. heischi. Phlebotomus longipes has been incriminated as a vector of CL (Lemma et al., 1969) and (Ashford et al., 1973). Phlebotomus pedifer has been shown to distribution to the Andean cordillera in Peru. Bartonellosis is unknown in Kenya.

Yao et al. (1938) showed that the embryos of Wuchereria bancrofti undergo development in Phlebotomus spp., but these sandflies have never been seriously suspected as vectors of filariasis. Sandflies have also been known to transmit trypanosomes (Wallace and Hertig, 1968; Anderson and Ayala, 1968).

The resting places of sandflies include crevices in trees, rocks and walls, drains, caves, dug-outs, banks of streams, animal burrows and termite hills, amongst heaps of dump soil, cracks and fissures in the soil. Different species of sandflies are associated with different habitats. For example, Sergentomvia mirabilis occurs typically in caves while sergentomvia adleri and Sergentomvia affinis have been found mainly on or near rocky areas.

Kirk and Lewis (1947) concluded that the survival of sandflies in some arid areas was due to their exploitation of a vast subterranean environment consisting of animal burrows and cracks in the soil in which ambient conditions of temperature (28°C) and relative humidity (approximately 100%) exist inspite of wide fluctuations above the ground. The sandflies emerge from their subterranean environment in search of food only after darkness when the temperature falls and the relative humidity is high thus providing suitable conditions for them. However, many of them find nourishment in animal burrows and in soil fissures which are inhabited by lizards, scorpions and other insects besides sandflies. The obliteration of the soil fissures annually by rains is an important factor influencing the seasonal prevalence of the sandflies. Sandflies do not readily withstand much variation in environmental conditions such as still air, darkness and constant temperature of approximately 28^{o}C and high relative humidity of approximately 100%. Unless conditions are optimal, the females of some species are unable to feed and eventually die of starvation. Theodor (1936) showed that at 30^{o}C and a relative humidity of about 40%, the mean length of life of a fed female P. papatasi was 3.5 days, while the thermal death point in a one-hour exposure was 41^{o}C. Conditions of water vapour from the atmosphere was found to be harmful as the sandflies readily became entangled and drowned in the drops of water thus formed (Theodor, 1936).

Sandflies show seasonal prevalence and in most cases exhibit a more or less marked seasonal variation in numbers. In some regions therefore, there is a well-defined sandfly season, the prevalence of the flies being restricted to a few months of the year. The seasonal variation in numbers is closely correlated with meteorological conditions and thus varies in different areas according to climate. The dominating factors being temperature, humidity rainfall and wind. In most places sandflies disappear during the heavy rains. This is so in the Sudan (Kirk and Lewis, 1940). Abyssinia (Martin, 1938) and the Belgian Congo (Wanson, 1942) and in these regions, the greatest prevalence occurred just before the rains and later, shortly after the rains. Sandflies also show diurnal prevalence. Adler and Theodor (1931) showed that it was possible to predict to an hour when certain species in the Mediterranean zone start appearing in houses. In the Sudan, a similar diurnal periodicity has been observed in P. papatasi and Sergentomyia freetownensis var magnus and in Congo, Wanson (1942) noted that Sergentomyia africanus and Sergentomyia schwetzi were predominant in daytime catches, Sergentomyia dureni and Sergentomyia squamipleuris in night-time catches.

1.1 Overall aims of the study

The aims of this study were threefold.

Firstly, to identify the phlebotomine sandflies found in Nairobi area. Secondly, to assess their abundance and thirdly, to relate the effects of seasonal changes on the sandfly population.

CHAPTER 2

2. LITERATURE REVIEW:

The study of sandflies began in Rome when Bonnani (1691) first described a sandfly as a mosquito species. Phlebotomine sandflies are widely distributed occurring in Europe, Middle East, Asia and Africa.

2.1 EUROPE:

Rioux et al. (1969) working on the sandfly fauna of France reported Sergentomyia (Sergentomyia) minuta; Phlebotomus papatasi, Phlebotomus sergenti; Phlebotomous (Adlerius), mascittii; Phlebotomus perniciosis and Phlebotomus ariasi as the vector on account of its high density in the enzootic zone in Southern France. Phlebotomus ariasi was found upto an altitude of about 1400m (Rioux et al., 1969) while P. perniciosus and P. mascittii were recorded at an altitude not exceeding 600m.

Knowledge of sandfly fauna in Italy has recently been updated by Biocca et al., (1977). The three species P. papatasi, P. mascittii and P. sergenti were found to be rare in Italy. However, P.

pernisciosus, P.perfiliewi, P. major and P. ariasi were recorded. Biocca et al., (1977) citing Adler and Theodor (1931a) indicated that in Italy, P. perniciosus was the principal vector of visceral leishmaniasis (VL) and P. perfiliewi the principal vector of cutaneous leishmaniasis (CL).

Studies by Re's (1957), who determined the spatial and seasonal distribution of sandflies in three VL endemic regions in Portugal showed that P. perniciosus was the most predominant and was associated with a lower density of P. ariasi in the Douro region and in Lisbon. Phlebotomus perniciosus was also associated with P. papatasi and P. sergenti in Guadiana watershed, Re's (1957).

Yasaroal (1965) listed some of the species of sandflies previously recorded in Turkey by different authors viz. P. papatasi, P. perniciosus, P. sergenti, P. caucascus, P. alexandri, P. perfiliewi, P. tobbi, P. laroussei, P. major, P. chinensis var. *simici* and Sergentomyia minutus var parrot. Both VL and CL occur in Turkey (Yasaroal, 1965).

In the USSR, P. chinensis has been shown to be the vector of VL (Cun-Sjun, 1955) but this species has disappeared in recent years following the intensive use of Dichloro-Diphnenyl-Trichloroethane (DDT) in house-spraying. Dolmatova and Demina (1971) have listed P. chinensis and P. kandlekii as vectors of VL in the USSR.

Zoonotic cutaneous leishmaniasis (ZCL) caused by L. major and the anthroponotic type L. tropica mainly transmitted by P. sergenti have been reported from the USSR, Safyanova (1977a). Phlebotomus papatasi is the principal vector of ZCL in the ancient valleys and oases, Safyanova (1977c) while Phlebotomus andrejevi is the main vector of ZCL in the foothills and sandy desert landscapes.

Zivkovic et al.(1973) surveyed 37 localities in Macedonia of which 37 were found to shelter sandflies and they recorded the following species viz. P. papatasi, P. perfiliew, P. major, P. tobbi and P. chinensis group. Zivkovic and Miscevic (1972a) collected five species of sandflies viz. P. papatasi, P. major, P. perfeliewi, P. tobbi and Phlebotomus siimici in the Nis region of South-east Serbia in Yugoslavia.

2.2 MIDDLE EAST

Cutaneous leishmaniasis has been reported from Israel particularly the settlements in the Arava, Negev and along the Western show of the dead sea. However, first recorded cases of leishmaniasis came from Revivim (Katzenellenbogen, 1947) and Yotvata (Katzenellenbogen and Confino, 1964). There is also a leishmaniasis endemic area near Jericho which has been studied thoroughly for many years (Huntem Uller, 1914; Adler and Theodor, 1925; Naggan et al., 1970; Shclein et al., 1982b). The common vector species found in the Negev, Central Arava and along the dead sea is Phlebotomus papatasi. The other sandfly species include P. sergenti, P. alexandri, Sergentomyia antennata, S. africana asiatica, S. tiberiadis, S. fallax, S. squamipleuris and S. clydei (Schlein et al., 1984).

In Iraq, leishmaniasis was once almost unknown but the work of Sukkar (1978) has shown it to be widespread and very common. The only man-biting sandfly in Iraq is P. papatasi. Kala-azar, presumably due to L. donovani has been reported for the first time from Afghanistan (Singh et al., 1982). The varied sandfly fauna found in

Afghanistan has been well documented by Artemiev 1982) and Javadian et al., (1982).

2.3 ASIA

Leishmaniasis is widespread in the Indian sub-continent. A study carried out in the Bihar state in India showed that after a lapse of about 15 years, VL has become prevalent, the number of VL cases increasing to 70,000 between January and August 1977 (Thakur et al., 1981), with 21 out of 31 districts being affected (Sanyal et al., 1979). Phlebotomus argentipes was collected from huts where VL was prevalent (Thakur et al., 1981).

2.4 AFRICA

Studies on leishmaniasis in countries of North Africa have been well documented from the early days until present. Dedet (1979) showed that the incidence of VL in Algeria was 497 cases during the period of 1965-1974 giving a mean annual incidence of 0.34 cases per 100,000 inhabitants. In Morocco, only 34 cases were detected during 1957-1974 giving a mean annual incidence of 0.01 cases per 100,000 inhabitants and a mean annual incidence of 0.24 cases per 100,000 inhabitants in Tunisia. Visceral leishmaniasis (VL) is endemic mainly in the humid and sub-humid areas of the North-east of Algeria and Tunisia but less endemic in Tunisian semi-arid areas (Dedet, 1979). Cutaneous leishmaniasis (CL) is endemic in the steppe fringe north of the Sahara and the two infections have been shown to be epidemiologically and geographically distinct (Dedet, 1979).

Dedet et al. (1973) presented an inventory of sandfly fauna recorded during epidemiological investigations in Visceral leishmanisis (VL) and Cutaneous leishmaniasis (CL) foci in Algeria during 1973. These workers recorded the following species; P. papatasi, P. sergenti, P. alexandri, P. perniciosus, P. perfiliewi. P, ariasi, Phlebotomus chabaudi, Phlebotomus longicuspis and Phlebotomus chadlii and five Sergentomyia species viz. S. minuta parroti, S. fallax, S. antennata, S. clydei and S. christophersi.

In Morocco, P. papatasi, P. sergenti, P. longicuspis, P. alexandri, P. perniciosus and P ariasi have been recorded (Bailly et al., 1971), indicating P. longicuspis as the vector of VL and P. papatasi as the vector of CL in North Africa.

In Tunisia, the sandfly species has been shown to be composed of _P. perniciosus, S. minuta parroti, P. papatasi, P. perfiliewi, P. longicuspis, P. sergenti, P. longeroni, P. chabaudi_ and _S. fallax_ (Dancesco _et al_. (1968); Croset (1969); Chadli _et al_. (1970 a, b and c); and Rioux _et al_. (1978) confirmed the existence of _S. antennata_ in Tunisia.

Cases of VL have been reported from Central Africa as well. The first case of VL in Chad was reported by Bouillez (1916). The second case of VL was reported much later by (Bellon, 1952). During the period 1972-1973, 16 cases of VL were detected at the central hospital of N'Djamena as reported by (Meyer, 1974).

Pirame and Becquet (1958) reported seven cases of CL in Chad. Sirol _et al_., (1971) diagonised six cases of muco-cutaneous leishmaniasis during the period 1969-1971. _Phlebotomus orientalis_ has been shown to be the major vector of VL in Chad (Lewis and Hitchcock, 1968), and _Phlebotomus duboscqi_ as the vector of CL (Lariviere _et al_., 1961).

Visceral leishmaniasis has been scantily recorded in the western part of tropical Africa, while CL has been shown to be widespread. Herve (1937), recorded cases of CL at Garoua in Cameroon. Rageau (1951) reported 326 cases of CL from Garoua and Fort Foureau during the period 1936-1946.

Rageau (1951) was the first to report on the sandfly fauna in the Cameroun. He examined a collection of 1,366 sandflies collected from six provinces and was able to identify 16 species and varieties. Phlebotomus duboscqi (hitherto shown as P. roubaudi) and Phlebotomus rodhaini (hitherto described by the author as Phlebotomus grenieri were the only representatives of genus Phlebotomus, the remaining species belonged to Sergentomyia including Sergentomyia schwetzi and S. clydei which were shown to be anthropophilic. Rageau (1951) suspected P. duboscqi as the probable vector of CL in Northern Cameroun following a similar suspicion by (Parrot and Gougis, 1943) in Niger.

Visceral leishmaniasis has never been reported from Mali whereas CL is well known in various parts of the country for example Kayes, Bamako, Gao, Segou, Mopti and Sikasso (Imperto and Diakite, 1969).

Abonnenc and Lariviere (1959) compiled the available records of the distribution of 24 sandflies of which 23 were species and varieties of

Sergentomyia and _P._ _duboscqi_ as the only representative of the genus _Phlebotomus_. Lariviere _et al._, (1961) incriminated _P._ _duboscqi_ as the vector of CL on epidemiological grounds.

From a recent sandfly survey covering the Senegal river valley in Mali, Mauritania and Senegal, Dedet _et al._, (1980a) reported _P._ _duboscqi_ captured from rodent burrows by adhesive paper traps.

Groves (1970) reported on CL cases and stated VL cases have not been encountered in South West Africa (Now Namibia), but with more awareness to its diagnosis, the disease may be discovered in future. With this in mind, Grove _et al._ (1971) conducted a preliminary survey for 8 months aimed at studying the sandfly fauna with a view of detecting the potential vectors of leishmaniases. They recorded 9 species of _Sergentomyia_ group and also _P._ _rodhaini_ as well as three specimens of the "symphlebotomus" and _P._ _grovei_ (Downes, 1971); _P._ _rossi_ (De meillon and Lavoipierre, 1944), and Lewis and Ledger, 1976). _Phlebotomus_ _grovei_ is a vector of VL in Namibia (Grove, 1978).

Neither VL nor CL has been reported from the Republic of South Africa. However, phlebotomine sandflies viz; P. rossi (Lewis and Ledger, 1976) and Sergentomyia transvaalensis (Davidson, 1980) have been reported.

No case of human VL has been reported from Senegal, however, canine VL is prevalent (Ranque et al., 1971). Phlebotomus duboscqi and P. rodhaini have been reported from Senegal (Ranque, 1977). Sergentomyia clydei, S. schwetzi, S. magna, S. squamipleuris, S. dubia, S. buxtoni, S. affinis vorax, and S. adleri have also been recorded in Senegal (Dedet et al., 1978). Dedet et al., (1980a) carried out a survey in the Senegal river valley and reported the following species: Sergentomyia lesleyae, S. schwetzi, S. antennata, S. bedfordi and S. christophersi in addition to those he recorded earlier.

Phlebotomus duboscqi and Phlebotomus bergeroti as well as Sergentomyia species have been reported from Upper Volta (now Cote de Voire) (Abonnenc and Pastre, 1971).

Lewis and murphy (1965) reported the existence of P. rodhaini as the only Phlebotomus species from Gambia and Sergentomyia species which included Sergentomyia Murphyi (which belongs to the S.

schwetzi complex) and S. clydei which they suspected of biting man. Although S. schwetzi and S. clydei in the Sudan were considered as unsuitable hosts for Leishmania donovani, (Lewis and Murphy, 1965) thought that they merit further study in relation to possible animal reservoirs in the Gambia as they may behave differently.

Lewis & Mc Millan (1961) have reported on the sandfly fauna from collections made in Nigeria. The only species of Phlebotomus recorded were P. duboscqi and P. rodhaini and 13 species of Sergentomyia group.

Asimeng (1990) identified 13 species of sandflies in Northern Nigeria. Apart from Sergentomyia christophersi, which he recorded for the first time in Nigeria, the remaining twelve species which included P. rodhaini, P. duboscqi, S. antennata, S. bedfordi, S. africana, S. schwetzi, S. buxtoni, S. ingrami, S. simillima, S. affinis, S. adleri and S. clydei were all reported by Lewis and McMillan (1961).

Leishmaniases and phlebotomine sandflies are well spread in the Eastern parts of Africa. Kala-azar is endemic in the lowland areas of Ethiopia as well as Kenya and Sudan. The main endemic areas in Western Ethiopia is the Setit Humera district, where the disease is associated with an explosive increase in agricultural settlement (Fuller *et al*., 1976). There is a wide distribution of *Phlebotomus orientalis* in the Afar region of Ethiopia and all the lowlands of Ethiopia. The opportunity of widespread outbreaks of Kala-azar exists as a result of the increased immigration of non-immune people into the area (Fuller *et al*., 1976). Ashford (1974) made a list of 39 species of sandflies of which 16 belonged to the genus *Phlebotomus* and the rest were *Sergentomyia* species. Among the species recorded, 3 have been known to be vectors of VL, viz. *P. orientalis*, *P. martini* and *P. chinensis* (Ashford 1974). Lewis *et al*. (1974) described 3 new species of subgenus *Larroussius* and these were: *P. giblensis*, *P. fantalensis* and *P. aculeatus*.

Tekle *et al*. (1970) using sticky papers placed near soil cracks around huts as well as man-bait capture in the Humera area, found only *S. affinis*, a non-biting sandfly. At Shelala, a locality in Setit Humera, 700M altitude (Gemetchu *et al*., 1974, 1975, & 1977) recorded the following species: *P. orientalis*, *P. papatasi*, *S. lesleyae*, *S. heischi*, be a vector of CL in Ethiopia (Ashford, 1973) Phlebotomus longipes showed seasonal prevalence, the population being highest in the wettest months and lowest at the end of the dry season. There was an increase in population in April following the rain in Mid March and early April. On the spatial distribution (Lemma et al., 1969) and (Foster, 1972b) showed that P. longipes was widespread in the highland areas of Ethiopia where CL is endemic with an attitude of 2,600M and as low as 1,600M. It was not found below 1,500M Phlebotomus pedifer was found at an altitude of 2,000M (Lemma et al., 1969). Phlebotomus longipes was found in tree holes, cracks and root cavities and was rare in houses in Ethiopia (Lemma et al., 1969) while P. pedifer was found to shelter indoors and outdoors, cracks in rocks occupied by hyraxes and also holes of large trees (Ashford et al., 1973).

Available information on leishmaniasis in Somalia is limited. Only a small outbreak of VL was reported from Somalia in 1942 (Heisch, 1954). Prior to that period, there had been no record of leishmaniasis cases.
Abonnenc (1972) working on the sandfly fauna, showed a record of P. martini collected from a hole at Shamah-Aleh by Choumara as well as P. sergenti found at 1,600M altitude. Abonnenc et al., (1959)

described a new species of P. (Larroussius) somaliensis from a female collected from a cave in Somalia.

Bray (1972), reviewing the incrimination of P. martini in Kenya, concluded that this species must be suspected as being the vector of VL in Somalia.

Both VL and CL had been reported from the Sudan since the early years of this century, VL is common in areas extending along the west bank of the Nile from Wau in the South to the borders of Kosti district in the North (Sati, 1958). Cutaneous leishmaniasis has been reported from Abu Zabad and EL Nahud in Kordofan Province (Kirk and Drew, 1938) caused by Leishmania tropica. Lewis and Kirki (1954) working on the sandfly fauna, encountered P. martini, P. duboscqi, P. alexandri, P. sergenti var. saevus, P. rodhaini and P. longipes as well as Sergentomyia species which included Sergentomyia darlingi, S. lesleyae and S. heischi.

Quate (1964) studying the sandfly fauna of the Paloich area recorded P. orientalis, P. papatasi, P. duboscqi, P. rodhani, S. heischi and S. leslayae. Dietlein (1964) working in Malakal city, collected S. squamipleuris, S. antennatus complex,

S. clydei, S. africana var. magnus, S. schwetzi, S. adleri and S. bedfordi. According to (Kirk and Lewis, 1955), P. orientalis is the major vector of VL in the Sudan. Sergentomyia clydei is widely distributed but is not a vector. The evidence of the incrimination of P. orientalis was further supported by experimental infection from human VL cases, as was reported by (McConnel, 1964). Quate (1964) studying the seasonal distribution of sandflies in the Sudan, divided sandflies into two groups, the "Seasonal species" which appeared in the dry season and "Non-seasonal species" which were present throughout the year. No sandfly species was confined only to the wet season. There were biological and taxonomic differences between the two groups. The seasonal group was composed of P. orientalis, P. papatasi, S. heischi, S. clydei and S. schewtzi. The non-seasonal group was represented by S. africanus, S. antennatus and S. squamipleuris (Quate 1964). With regard to CL, (Kirk and Lewis, 1955) believed that P. papatasi was the principal vector. Parrot and Gougis (1943) suspected P. duboscqi as the vector of CL replacing P. papatasi in the Niger region.

Wykoff et al. (1959) carried out a study on sandfly fauna of the Karamoja district in Uganda and found

P. martini, P. rodhani and some *Sergentomyia* species. More studies are needed to clarify the position of leishmaniasis and sandfly fauna in Uganda.

There are no confirmed cases of either CL and VL in both Mozambique and Tanzania.

Both visceral and cutaneous leishmaniasis are endemic in Kenya and have been intensively studied. Kala-azar was unknown in Kenya until after the world war II and it was later suggested that Kala-azar was introduced into Kenya by soldiers returning from the neighbouring countries of Sudan and Ethiopia (Anderson, 1943). However, Forbes, (1933) was the first to demonstrate parasitologically the presence of *L. donovani* in an indigenous Kenyan. Following the discovery of Kala-azar (Cole *et al.*, 1942), several cases have been reported from different parts of the country. Kala-azar occurs throughout Kenya, but most of the cases occur in areas North-east and Northwest of Nairobi, including Machakos, Kitui, Embu, Meru, Baringo, West Pokot and Turkana districts (Kager and Rees, 1983a). The continous low endemic transmission in this regions has been shown to be punctuated by intermittent epidemics. From 1973 to

1982, the number of reported cases averaged around 380 cases per year, with a range of 163 in 1973 and 1976 to 620 in 1980 (Sang and Siongok, 1984).

Manteufel (1912) was the first to show the existence of sandflies along the Kenyan Coast and since then, the number of species of sandflies known to occur in Kenya has risen steadily. Minter (1964) reported the presence of 30 species of sandflies in Kenya. According to Duckhouse and Lewis (1980) and Lewis, (1982), under the classification of Lewis et al. (1977), 38 species of sandflies occur in Kenya. Of these, 3 species, P. duboscqi (Neveu- Lemairie, 1906), P. martini (Parrot, 1936) and P. pedifer (Lewis et al., 1972) have been shown to be vectors of leishmaniases (Heisch et al., 1962; Minter, 1963; Minter and Wijers 1963; Southgate, 1964; Mutinga 1971, 1975; Mutinga and Ngoka, 1978, 1983 and Beach et al., 1984). Two species P. vansomerenae (Heisch et al., 1956) and P. celiae (Minter, 1962) have been reported as possible vectors (Southgate, 1964). One species Sergentomyia garnhami (Heisch et al., 1956) is thought to be a potential vector of visceral leishmaniasis (Mutinga, 1981; Mutinga and Odhiambo, 1982). Theodor (1931) and Sinton (1931) have described sandfly species in Kenya. Heisch and Guggisberg (1953) have also listed 20 species in Kenya.

Studies on the vectors of leishmaniasis in Kenya have been concentrated mainly on the established foci of the disease (Mutinga, 1985). However, some investigations have, to a lesser extent been extended to areas of similar climatic conditions and altitude to determine whether or not the areas have the potential for the spread of the disease (Mutinga, 1985).

Fendall (1952a) reviewed in detail visceral leishmaniasis (Kala-azar) in East Africa, including Kenya, and further gave the available records from two districts, Machakos and Kitui with a detailed account of surveys carried out in Kitui district. Heisch (1954) indicated that Kala-azar was sporadic in East Africa before the second world war, and that severe outbreaks of the disease occurred in the early 1940's. He referred to Cole, et al. (1942) and Anderson (1943) who reported that African soldiers became infected while camping North of Lake Rudolph (= Lake Turkana) in Southwest Ethiopia. Heisch (1954) reported an outbreak of a serious epidemic of Kala-azar in Kitui district which affected about 3,000 people, commencing in

1952 and reaching a peak in 1953. This epidemic was followed by a discovery of Kala-azar in Baringo district in 1955 and West Pokot in 1956 (McKinnon and Fendall, 1955; Wijers and Minter, 1962; Leewenberg et al., 1981). These two incidences led to a serious study of Kenyan sandflies in an attempt to find the vector (s) of Kala-azar in Kenya. Heisch and Guggisberg (1952) gave notes on an identification key of all sandfly species that had been found in Kenya by that time. Similarly, (Kirk and Lewis, 1952) described 3 species of sandflies in Kenya. Four years later (Heisch et al., 1956), described 6 new species from Kitui district and later Minter, (1962, 1963b) added 3 other new species from the same area. Minter (1964) reported more species that had not yet been recorded. Two more species were recorded in Kenya, P. duboscqi, (Mutinga and Ngoka, 1983), P. elgonensis (Ngoka et al., 1975) later reported as a synonym of P. aculeatus (Lewis 1982).

The males of Sergentomyia heischi (Kirk and Lewis, 1950) and Sergentomyia blossi (Kirk and Lewis, 1952) were unknown in Kenya until recently (Young et al., 1982 and Mutinga et al., 1983). Sergentomyia adami (Abonnenc, 1960) was recorded in Machakos district and also recently by Rogo

(1985). Southgate and Minter (cited by Lewis, 1971) reported that S. clydei is widespread in Africa and India. Sergentomyia clydei has been shown to be the vector of the Lizard parastie L. adleri in Kenya. It is possible that this may cause transient infections in man and thus affect the result of immunity surveys (Mutinga and Ngoka, 1981).

From the time Kala-azar was recognised as an endemic disease in Kenya, its spread has been rapid. To date, a number of vectors of Kala-azar have been reported from the affected areas. These vectors include P. martini which is encountered in all endemic areas (Mutinga and Ngoka, 1978), P. duboscqi and 10 Sergentomyia species have been reported from Baringo district, S. schwetzi being the most abundant. Many Sergentomyia species bite man and Phlebotomus species have been the major incriminated vectors of leishmaniases. Two sergentomyia species; S. garnhami and S. ingrami have been shown to be possible vectors of zoonotic L. major and S. garnhami is a possible vector of VL (Kaddu et al., 1986).

Sergentomyia garnhami, S. bedfordi and S. antennatus have been reported from Machakos including P. martini (Ramasamy et al., 1981; Jamnadas et al., 1983).

Cutaneous leishmaniasis due to Leishmania aethiopica was first discovered in Kenya in 1969 (Mutinga and Ngoka, 1970). It was shown to be primarily a zoonotic disease with sporadic occurrence in people living on the forested eastern slopes of Mt. Elgon in Bungoma district (Mutinga and Ngoka, 1970; Kung'u et al., 1972 and Sang et al., 1983). Leishmania aethiopica parasites were isolated from a cave dwelling sandfly P. pedifer (Mutinga, 1975, 1981). Mutinga and Odhiambo (1986) demonstrated that P. pedifer was able to transmit L. aethiopica parasites from infected humans to clean hamsters by bite, incriminating this species as a competent vector of the disease in Kenya. Phlebotomus pedifer is therefore a vector and P. elgonensis is a suspected vector (Sang et al., 1983; Ngoka et al., 1975).

The other type of cutaneous leishmaniasis found in Kenya is that caused by L. major (Mutinga & Ngoka, 1983). Githure (1984) later also isolated L. major from several species of rodents in Baringo district. Phlebotomus duboscqi a vector of cutaneous leishmaniasis (L. major) which occurs in a wide area of North Africa (Lariviere *et al*., 1961 and Lewis, 1974) was first reported from the Rift Valley Province of Kenya in 1976 (Mutinga and Ngoka, 1983). Mutinga *et al*, (1983) demonstrated the cycle of *L. major* in rodents and 3 phlebotomine sandflies namely *P. duboscqi*, *P. martini* and *S. ingrami*. *Phlebotomus duboscqi* is therefore, subsequently incriminated as the vector of *L. major* and *P. martini* and *S. ingrami* as secondary vectors.

Justification of the study

Since areas adjoining Nairobi for example Machakos and Kitui have cases of leishmaniasis transmission taking place, it is possible that this disease may spread to Nairobi area if the vectors are present. This study was therefore, aimed at finding out whether the sandflies existing in Nairobi area are the incriminated or suspected vectors of leishmaniasis.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Introduction

Sandflies were collected from their natural habitats which included animal burrows, termite mounds, dugouts, caves and rock crevices in Langata, Kibera and Roysambu within Nairobi.

During this study, four trapping methods viz. light traps, aspiration, castor oil traps and human baits were employed. All these methods were necessary because first and fore-most sandflies are very small and therefore difficult to find. Secondly, some methods are not suitable for trapping some species of sandflies. For example, it has been shown that the castor oil trap is repellant to Phlebotomus orientalis (Kirk and Lewis, 1955; Quate, 1964).

3.2 Trapping Methods

3.2.1. The sticky trap method

Transparent polythene sheets measuring 1x1m and 0.25mm thick devised by Mutinga (1981), were coated with castor oil on both surfaces and fixed near resting sites of sandflies as described by Mutinga (1981). These sheets were held by strings in and outside houses, in the forest near tree trunks (Plate 1a), in caves and in the open near termite mounds. The sandflies were expected to be trapped as they flew in and out of their habitats or as they came into houses to feed. Similar sheets measuring (20x30)cm were also used. These sheets were fixed on forked sticks and inserted into animal burrows on cracks in the ground. The sheets were also rolled and placed in the ventilation shafts of termite mounds and sandflies were trapped as they hopped in and out of the shafts (Plate 1b).

The caster oil traps were placed in the habitats in the evenings at 1830 hrs and removed in the mornings at 0700 hrs. A total of 30 traps were set for 3 righrts a week. The trapped sandflies were then picked from the transparent sheets since they were easily distinguished from other dipterans. A

Plate 1a. A photograph showing the Im x Im sticky trap set at Langata.

Plate 1b. A photograph showing the (20 x 30)cm rolled sticky traps placed in the ventillation shafts of a termite mound at Roysambu.

fine camel hair brush (No.2) was used to remove the sandflies from the sheets. The sandflies were then placed in specimen tubes which were well labelled and contained detergent saline.

3.2.2. The light trap method

The light traps, a modification of Smith and Downes' (1970) CDC light traps consisted of a plexiglass body, a horizontal screen mesh, a torch bulb (3 volts), a plastic fan and a removable collecting sandfly net. The net was attached to the plexiglass body with a rubber band. Four "eveready" torch batteries (1.5 volts each) were held on the two opposite sides of the plexiglass body by metal brackets which contained the electrical contact points. The trap was protected from rain by a metal roof (Plate 2). When in use plugs were connected into the sockets, automatically illuminating the bulb and rotating the fan. This created suction pressure inside the trap body, so that insects attracted to the light, or simply flying above the trap were sucked into the collecting net. These were retained in the net until the plugs were disconnected in the morning after killing the insects with an insecticide ("Doom") after which they were sorted out as many other dipterans were also caught. Three light

Plate 2. A photograph showing the CDC light trap at Roysambu.

traps were operated at a height of 1-1.5m above the ground for 3 trap nights a week for 2 months.

The light traps had shortcomings in that they were used at night only and could not be used in the open as they could easily attract passersby and therefore, stood

high chances of being stolen. They also attracted a large number of other diptera which made it difficult to sort out the sandflies.

3.2.3. Human-bait method

This method was developed by Kerr (1933). It is an important method of sampling anthropophilic sandflies and this was the main reason why the method was employed in this study. An assistant sat on a stool around the termite hills late in the evening at 1830 and 0700 hrs in the morning when the sandflies were very active. The assistant exposed his legs and arms (Plate 3). This exercise was carried out 3 times a week for 2 months. It was hoped that unfed anthropophilic species would be attracted to the human bait for a blood meal.

Plate 3. A photograph showing the human bait on a termite mound at Roysambu.

3.2.4. Aspiration

The aspirators (sunction tubes) used were made in the department of zoology, University of Nairobi. They were made of a glass chamber with a glass tubing traversing a rubber stopper closing one end of the chamber. Suction was applied by mouth of the operator through a rubber tube connected by a glass tubing to the perforated stopper closing the other end of the chamber. A piece of fine mesh gauze inserted between

the rubber stopper and the chamber prevented the sandflies from entering the operators mouth. When suction was applied before and during the approach of the catcher to a sandfly, the resulting draught caused the insect to cling lightly to the surface on which it was resting so that it was easily caught. Torches were used to locate the resting sandflies in their habitats. Slight prodding of sandflies lurking in holes and crevices caused sandflies resting deep in these apertures to appear on the surface. The operator had to keep sucking or close the end of tube with a finger, otherwise captured sandflies easily escaped (Plate 4). Two aspirators were used and the exercise was carried

Plate 4. A photograph illustrating the mouth aspiration technique inside a cave at Langata.

out 3 times a week for 6 months. The flies caught were then blown into a sandfly cage.

3.3 Processing the sandflies for mounting

The sandflies were processed in the conventional way. The sandflies were thoroughly washed in 10% detergent saline to remove castor oil and excess hairs from the sandflies. A fine camel hair brush (No.2) was used to wash the sandflies. The sandflies were then rinsed in physiological saline and preserved in 70% alcohol in well labelled specimen tubes.

3.4 Mounting

For the purpose of identification, the sandflies were mounted on transparent slides and covered with coverslips under a dissecting microscope on gum chloral. Gum chloral consisted of:

distilled water	(10cc)
gum acacia	(8gm)
chloral hydrate	(70gm)
glycerine	(5cc)
acetic acid	(3cc)

This mixture was dissolved on a water bath at 80^{o}C, then filtered through glass wool.

The head was separated from the body using two 1cc syringes. One syringe was used to hold the thorax and the other to cut off the head. The head was then placed with the ventral surface upward, next to the body so as to reveal important taxonomic structures. The wings, antennae, palps and in the case of males the terminalia were straightened out.

Mounted specimen were left in the open for 48 hours after which they were ready for identification. It was important to leave them for this period of time to clear so that taxonomically important internal structures could be seen without difficulties. Those specimens that required storage were ringed with clear nail vanish.

3.5 Identification

Identification of the sandflies was done using the already developed entomological keys of Kirk and Lewis (1951) and a pictorial key developed by Mutinga (unpublished) for Kenyan sandflies.

CHAPTER 4

4.0 Results

4.1 Sandfly species recorded

In total, 9 species of sandflies were recorded during this study. The sandflies were collected from various microhabitats in three sites within Nairobi as shown in Table 1. The sandfly species varied from one microhabitat to another. For instance, Phlebotomus guggisbergi occurred only in the cave and rock crevices and the unidentified species was dominant in the ventilation shafts of termite mounds.

The sandflies also varied in numbers and species composition from one month to another. There was a clear seasonal variation of sandfly species as reported in this study. The sandfly species that were caught sometimes varied from one locality to another (Figs I, II & III). Fig. IV, shows the general trend of the phlebotomine sandflies of Nairobi area over a period of 6 months.

4.1.1 Sandfly variation in terms of species composition and total numbers within Roysambu site over a period of six months.

Table 1. Summary of species of sandflies and their total numbers collected from different microhabitats in Roysambu, Kibera and Langata areas over a period of 6 months

Species	Microhabitat	♂	♀	Total
Phlebotomus guggisbergi	RC,C	34	14	48
Phlebotomus rodhaini	AB, TM	9	6	15
Sergentomyia clydei	AB, TM	16	0	16
Sergentomyia harveyi	TM DO	0	21	21
Sergentomyia teesdalei	TM, AB, DO	0	72	72
Sergentomyia squamipleuris	DO, AB, TM	49	14	63
Sergentomyia adleri	TM, C	2	0	2
Sergentomyia bedfordi	AB, DO	0	4	4
Sergentomyia spp.	TM, AB, DO	98	0	98
Grand Total		208	131	339

KEY:

AB - Animal burrows

TM - Termite mounds

RC - Rock crevices

C - Cave

DO - Dugouts

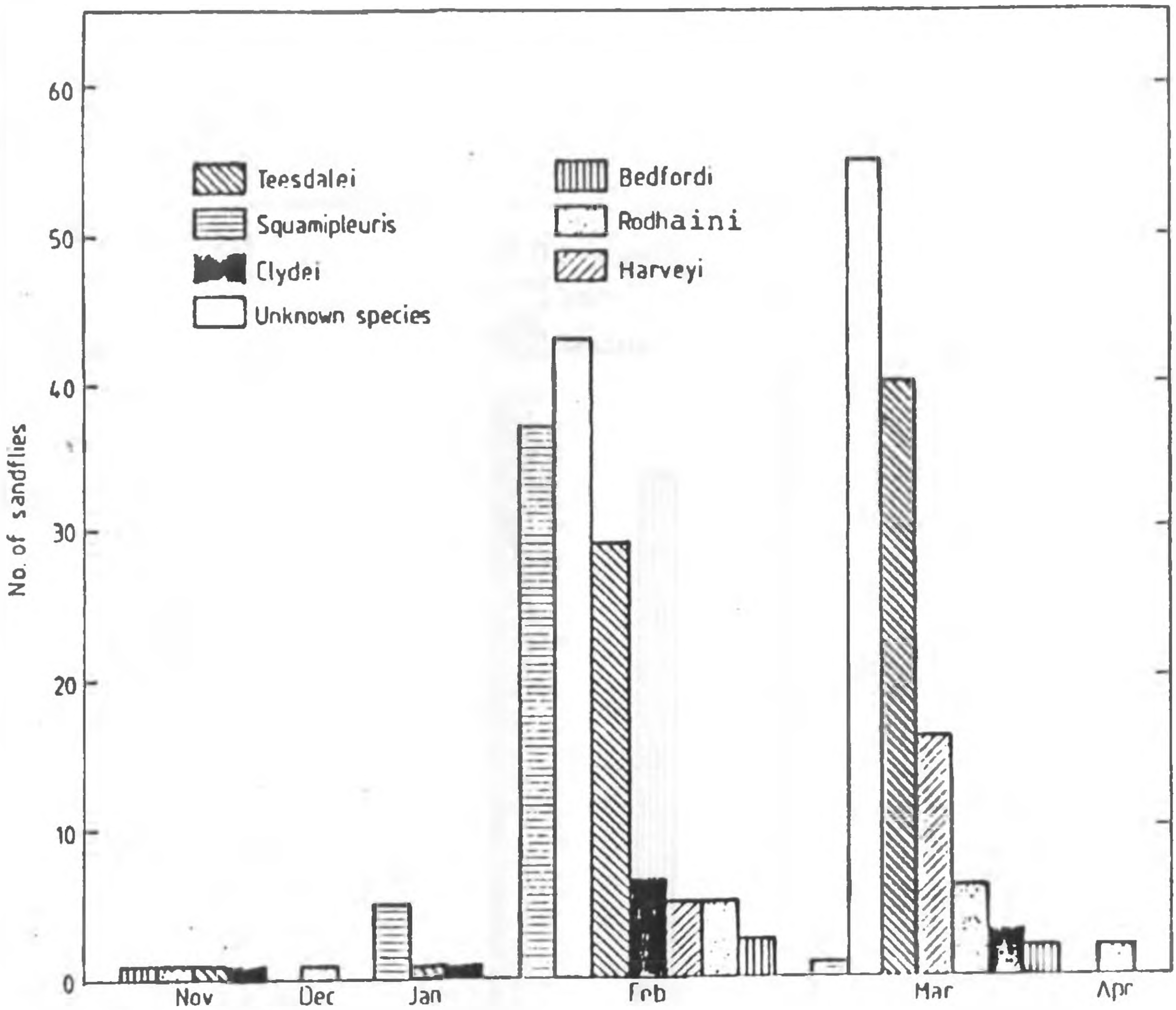


Fig. I - Sandfly variation in terms of species composition and total numbers within Roysambu site over a period of 6 months.

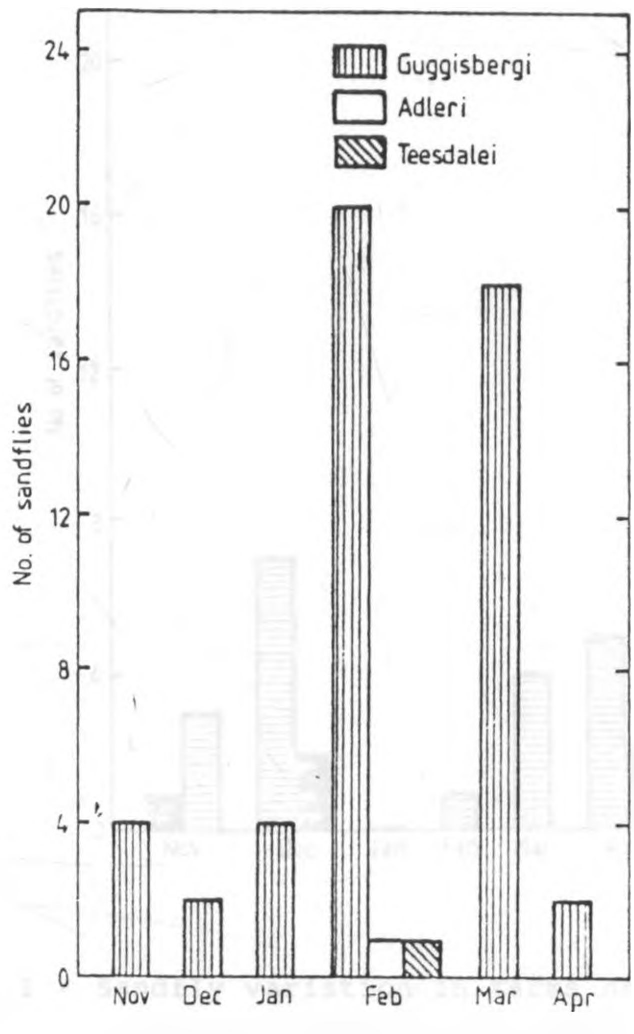


Fig. II - Sandfly variation in terms of species composition and total numbers within Langata site over a period of 6 months.

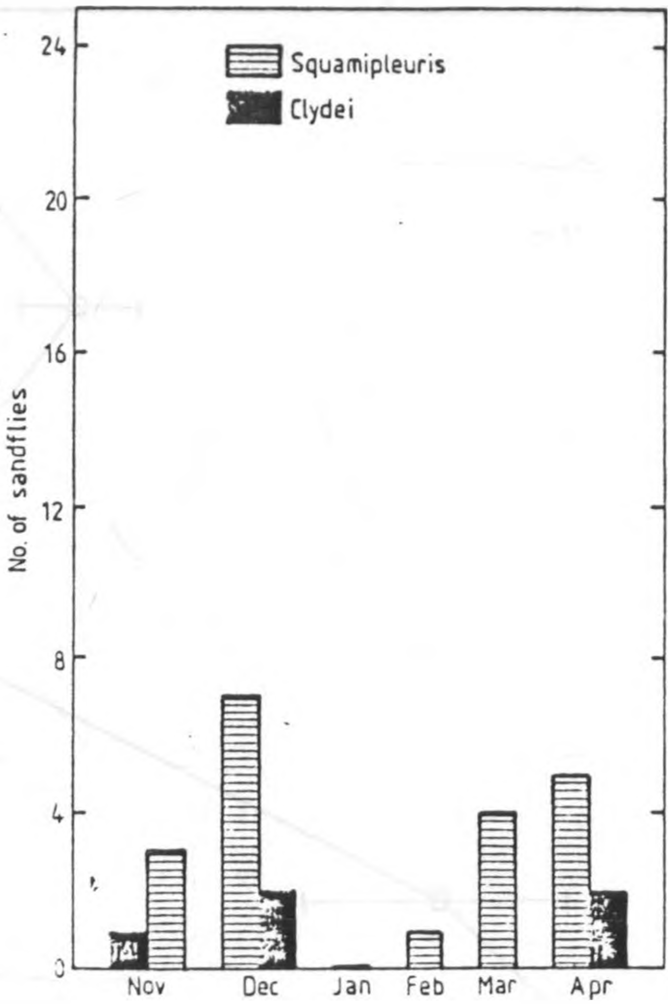
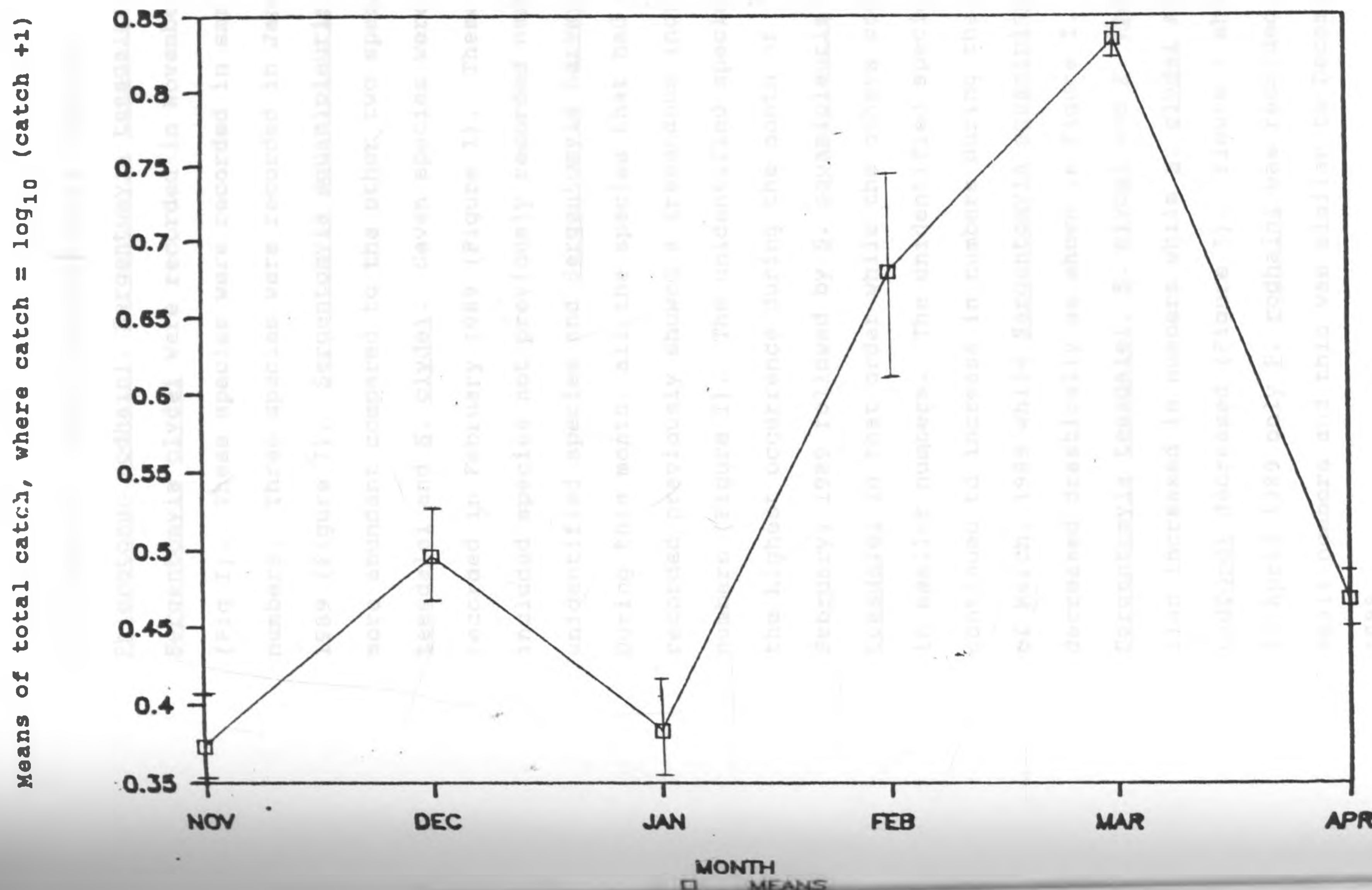


Fig. III - Sandfly variation in terms of species composition and total numbers within Kibera site over a period of 6 months.

Fig. IV. Graph showing the trends of phlebotomine sandflies in Nairobi area.



Four species namely, Sergentomyia bedfordi, Phlebotomus rodhaini, Sergentomyia teesdalaei and Sergentomyia clydei were recorded in November 1988 (Fig I). These species were recorded in small numbers. Three species were recorded in January 1989 (Figure I). Sergentomyia squamipleuris was more abundant compared to the other two species S. teesdalei and S. clydei. Seven species were recorded in February 1989 (Figure I). These included species not previously recorded namely: an unidentified species and Sergentomyia harveyi. During this month, all the species that had been recorded previously showed a tremendous increase in numbers (Figure I). The unidentified species had the highest occurrence during the month of February, 1989 followed by S. squamipleuris and S. teesdalei in that order while the others occurred in smaller numbers. The unidentified species continued to increase in numbers during the month of March, 1989 while Sergentomyia squamipleuris decreased drastically as shown in Figure I. Sergentomyia teesdalei, S. clydei and P. rodhaini also increased in numbers while S. clydei and S. bedfordi decreased (Figure I). Figure I shows that in April 1989 only P. rodhaini was recorded in small numbers and this was similar to December 1988.

Figure V shows the mean rainfall figures superimposed on the bar graph of sandflies. The pattern indicates that there was less rainfall in November 1988 which increased gradually reaching a peak in January 1989. The rainfall then decreased to a minimum in February 1989 and again increased through March reaching a peak in April. Figure VI shows the trend of sandflies in relation to temperature. The highest temperature was recorded in March 1989 when the highest number of some species such as the unidentified species, Sergentomyia teesdalei and Sergentomyia harveyi were recorded. Seven species, the highest number of species recorded throughout the study period, occurred in the months of February and March, 1989. However, the total numbers of any particular sandfly species caught varied in these two months.

Figure VII shows the relative humidity of Roysambu site for a period of 6 months. During the months of November and December, 1988 and January 1989 the relative humidity was high, but it decreased in February 1989 increasing through March and reaching the peak in April 1989.

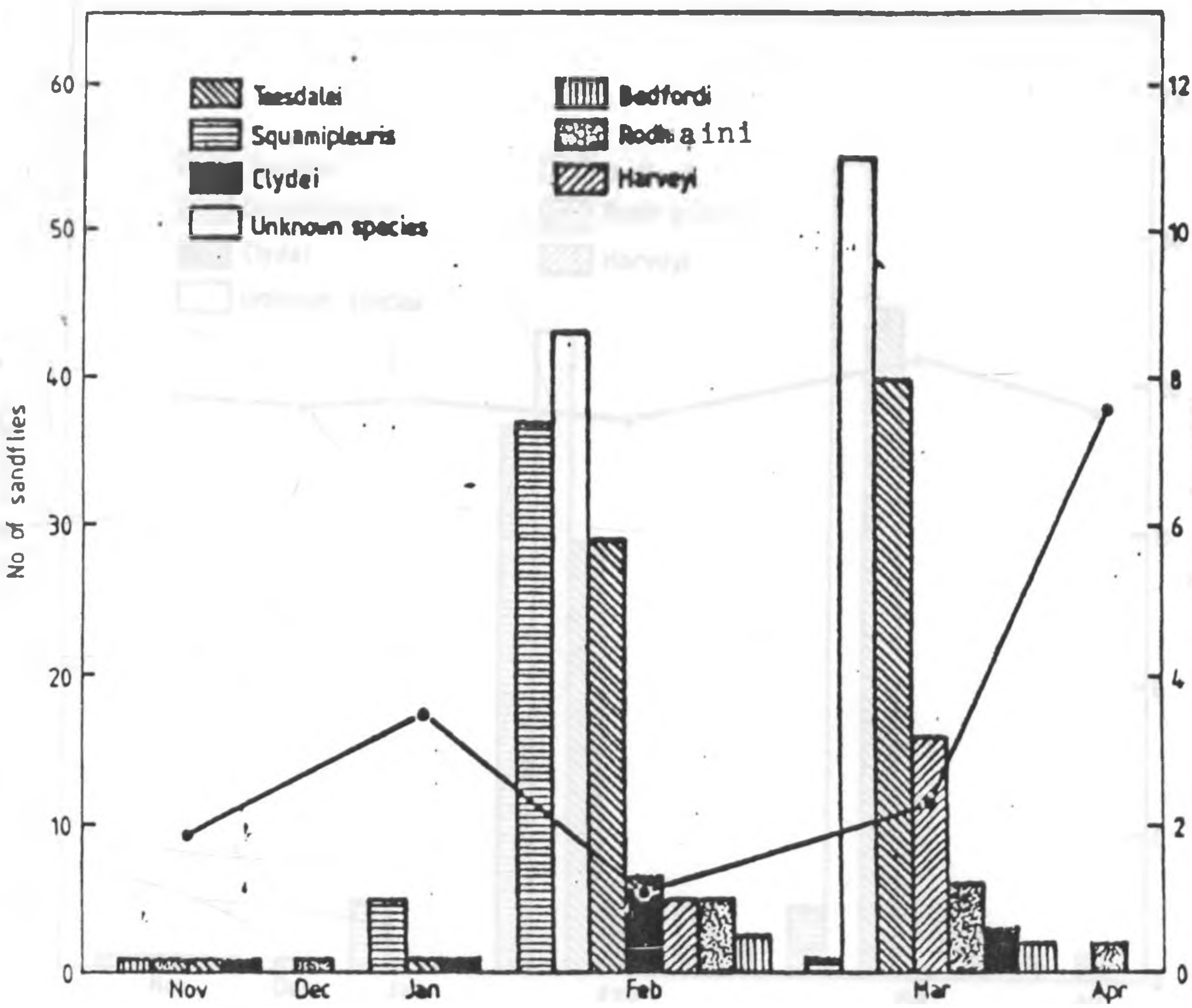


Fig. V. The number of sandflies in relation to rainfall witin Roysambu site.

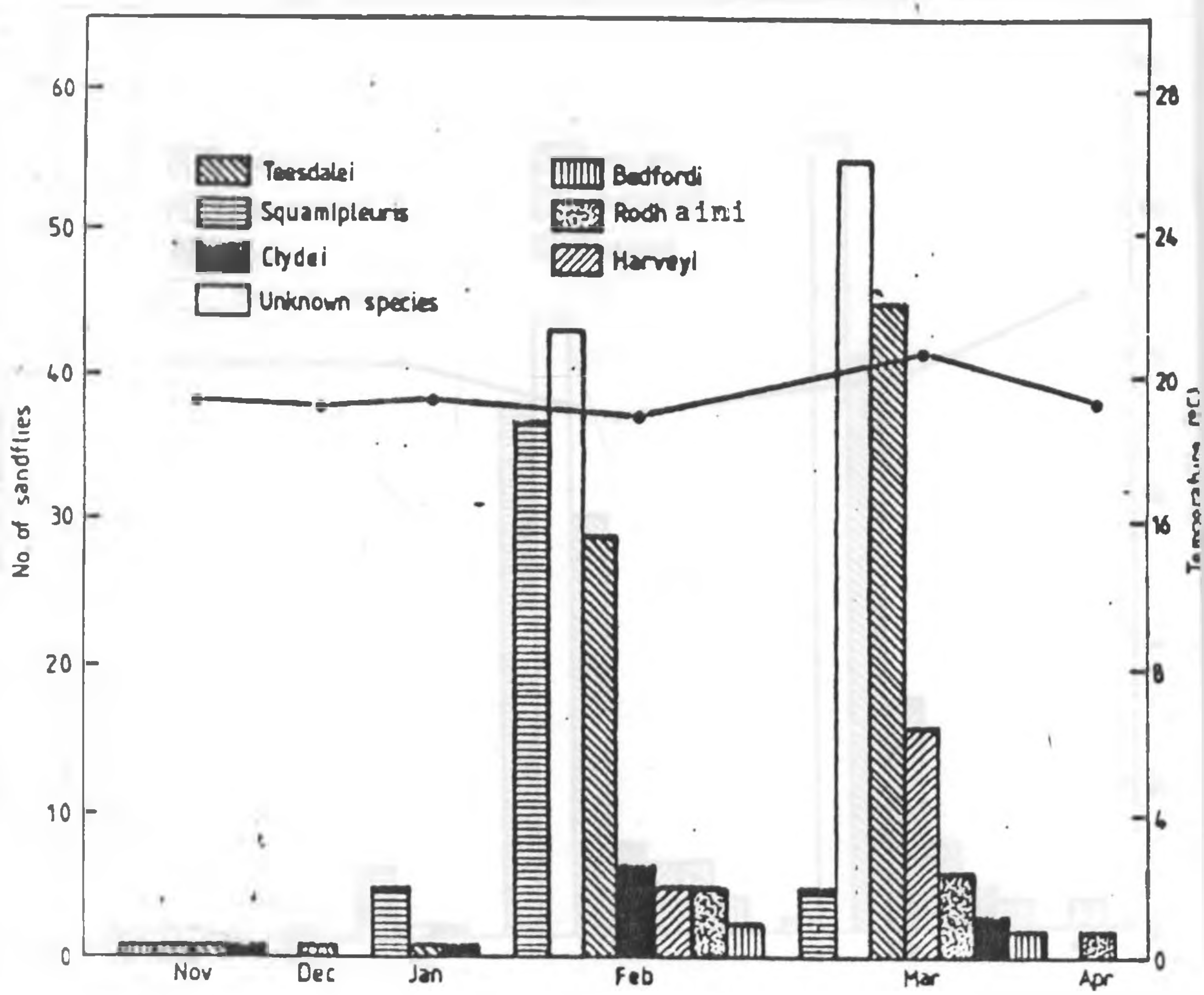


Fig. VI. The number of sandflies in relation to temperature within Roysambu site.

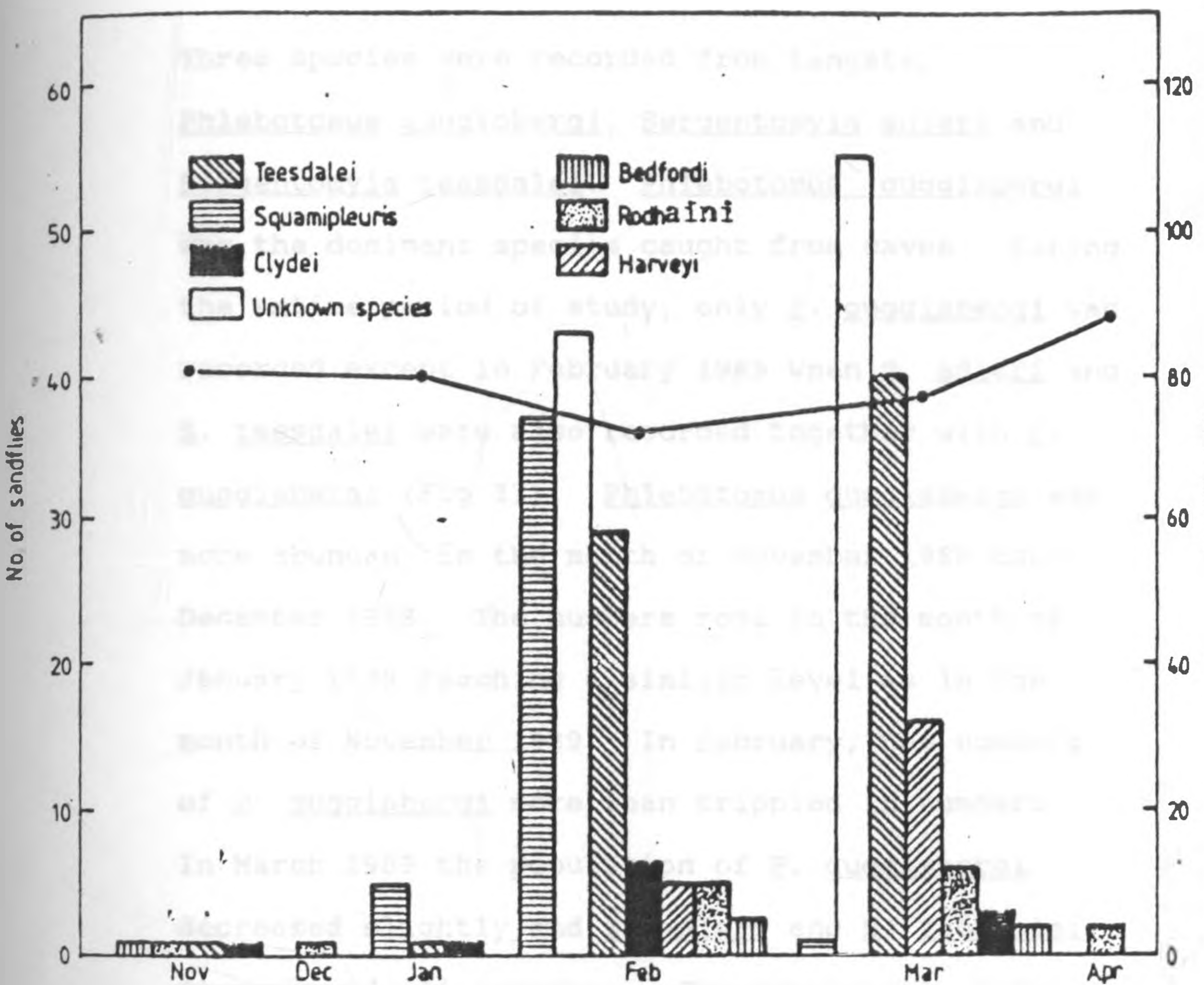


Fig. VII. The number of sandflies in relation to humidity within Roysambu site.

4.1.2 Sandfly variation in terms of species composition and total numbers within Langata site over a period of 6 months.

Three species were recorded from Langata, Phlebotomus guggisbergi, Sergentomyia adleri and Sergentomyia teesdalei. Phlebotomus guggisbergi was the dominant species caught from caves. During the entire period of study, only P. guggisbergi was recorded except in February 1989 when S. adleri and S. teesdalei were also recorded together with P. guggisbergi (Fig II). Phlebotomus guggisbergi was more abundant in the month of November 1988 than December 1988. The numbers rose in the month of January 1989 reaching a similar level as in the month of November 1989. In February, the numbers of P. guggisbergi more than trippled in numbers. In March 1989 the population of P. guggisbergi decreased slightly and S. adleri and S. teesdalei disappeared all together. The population of P. guggisbergi decreased even further in the month of April 1989.

Fig VIII, shows the number of sandflies caught as well as the mean rainfall figures superimposed on it. The trend is very similar to that of Roysambu (Fig V). Fig IX , shows the graph of the number

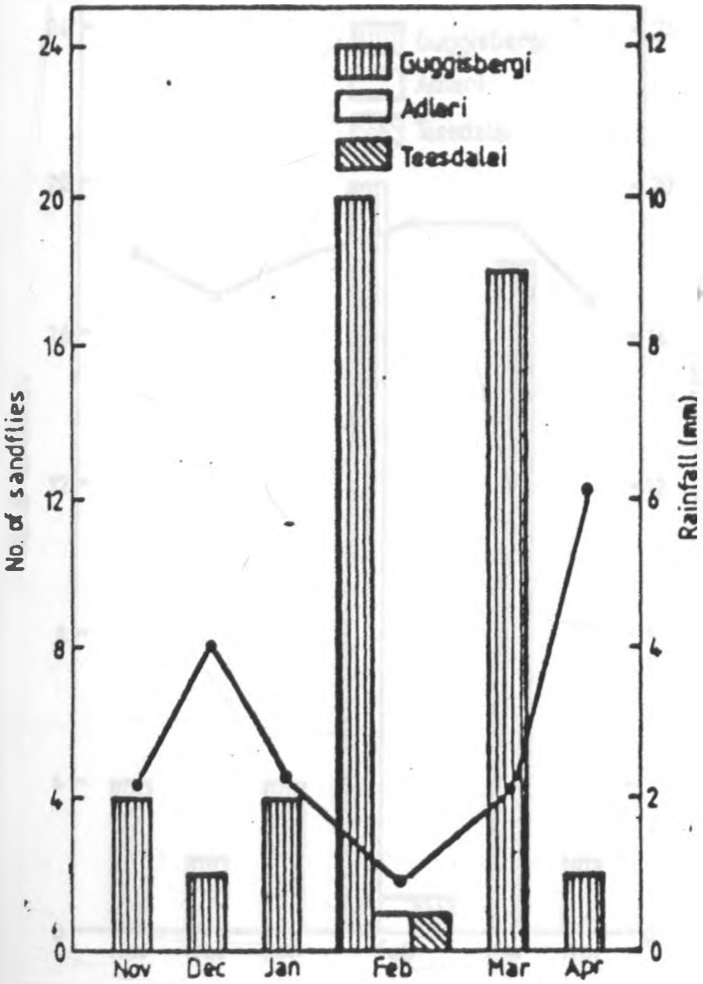


Fig. VIII. The number of sandflies in relation to rainfall within Langata site.

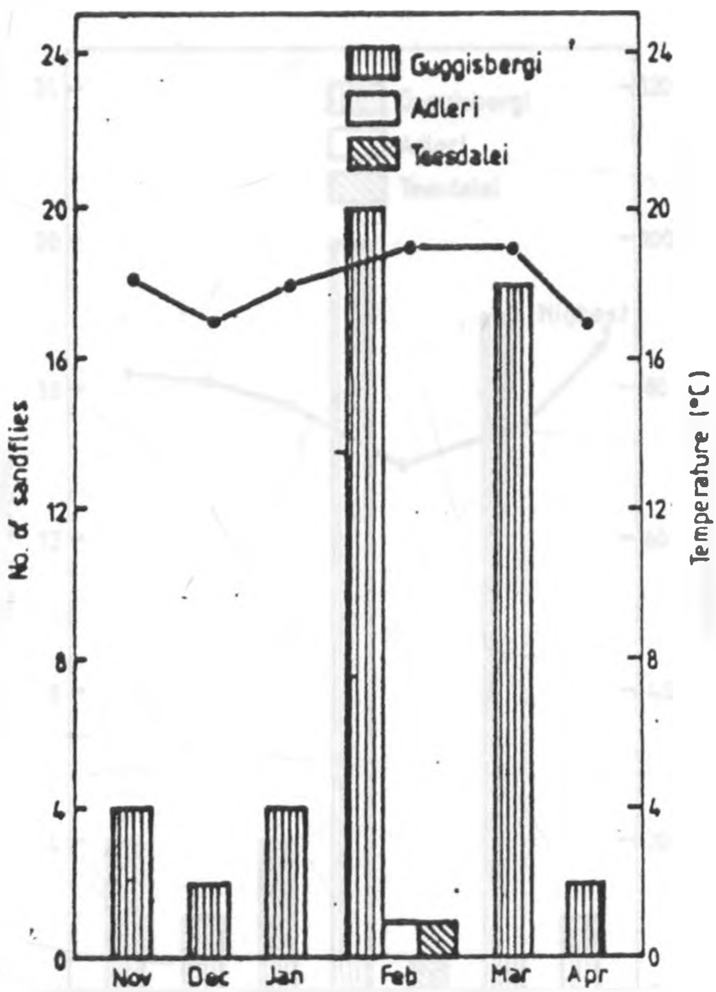


Fig. IX . The number of sandflies in relation to Temperature within Langata site.

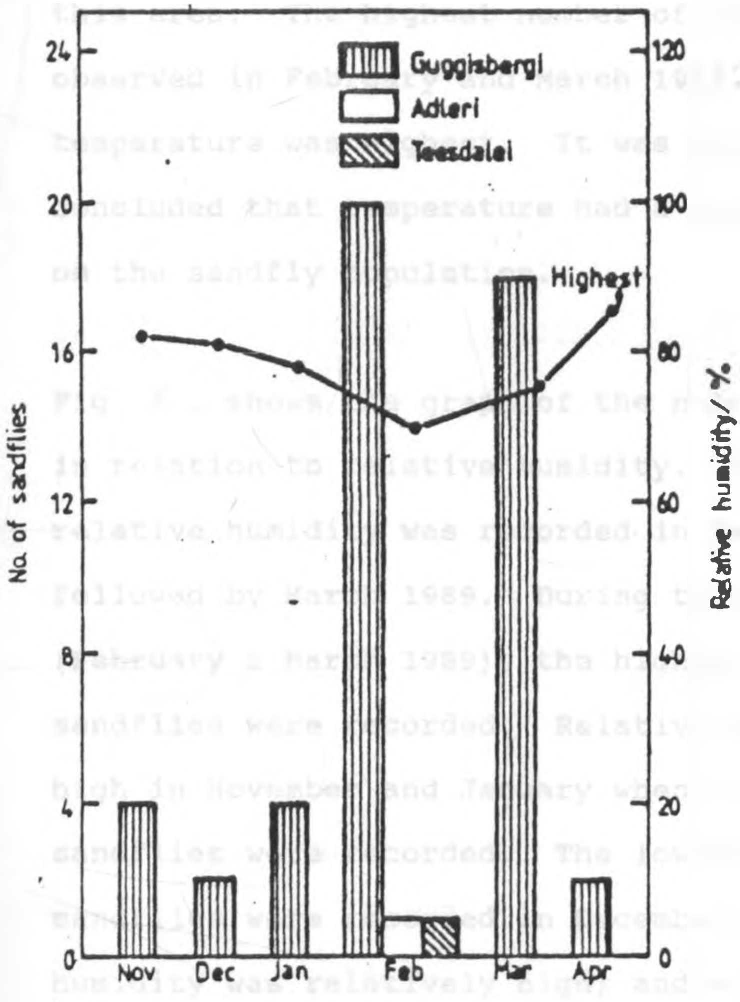


Fig. X . The number of sandflies in relation to humidity within Langata site.

of sandflies in relation to temperature. The lowest temperature was recorded in December 1988 and April 1989. These were also the months when the lowest number of sandflies were recorded in this area. The highest number of sandflies were observed in February and March 1989, when temperature was highest. It was therefore concluded that temperature had a positive influence on the sandfly population.

Fig X , shows the graph of the number of sandflies in relation to relative humidity. The lowest relative humidity was recorded in February 1989 followed by March 1989. During these two months (February & March 1989), the highest number of sandflies were recorded. Relative humidity was high in November and January when a lower number of sandflies were recorded. The lowest number of sandflies were recorded in December (relative humidity was relatively high) and April when the relative humidity was highest. Relative humidity had therefore, an influence over the sandfly population.

4.1.3 Sandfly variation in terms of species composition and total numbers within Kibera site over a period of 6 months.

Only two species were recorded in Kibera; Sergentomyia squamipleuris and Sergentomyia clydei (Figure III). However, S. squamipleuris was the most abundant species. Sergentomyia squamipleuris and S. clydei were recorded in small numbers in the month of November 1988. The number of S. squamipleuris more than doubled in December, 1988 while that of S. clydei did not change. No sandfly was recorded in January 1989 and only a few of Sergentomyia squamipleuris appeared in February 1989 gradually increasing through the months of March and April, 1989. Sergentomyia clydei which had disappeared in January 1989, again reappeared in April 1989 in numbers similar to that in December 1988.

Figure XI , shows the number of sandflies in relation to rainfall in Kibera which is similar to the rainfall pattern of Roysambu (Figure V). The lowest amount of rainfall was recorded in February corresponding to the lowest number of sandflies recorded during the study period in Kibera site. The highest amount of rainfall was recorded in April followed by that recorded in the month of December and this corresponded to the highest number of sandflies recorded in Kibera.

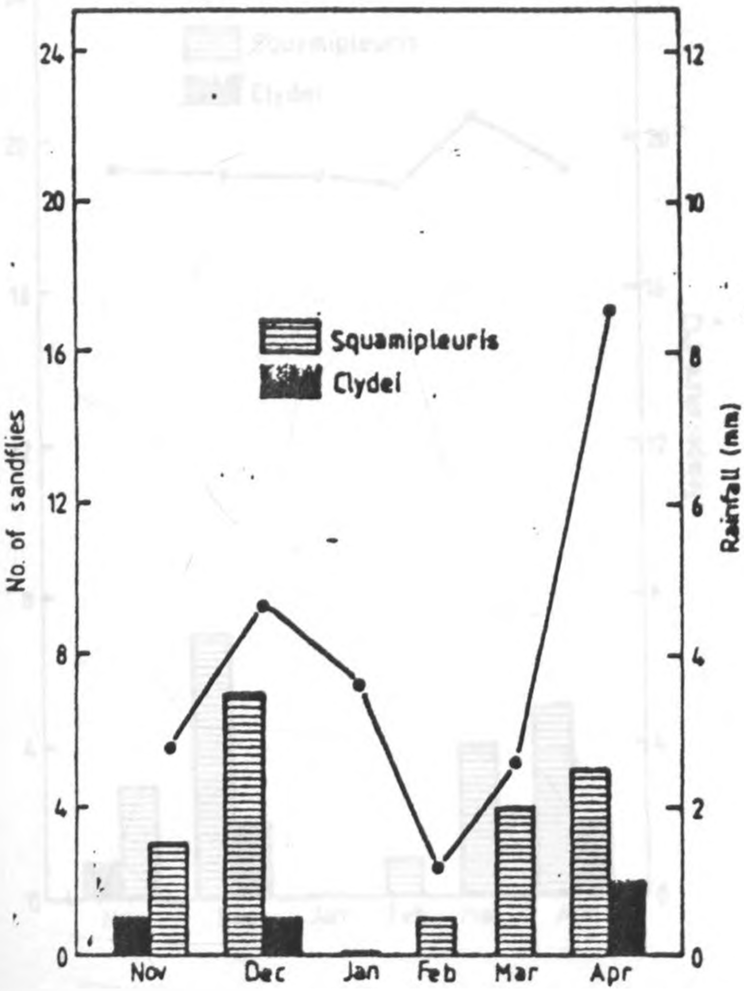


Fig. XI . The number of sandflies in relation to rainfall within Kibera site.

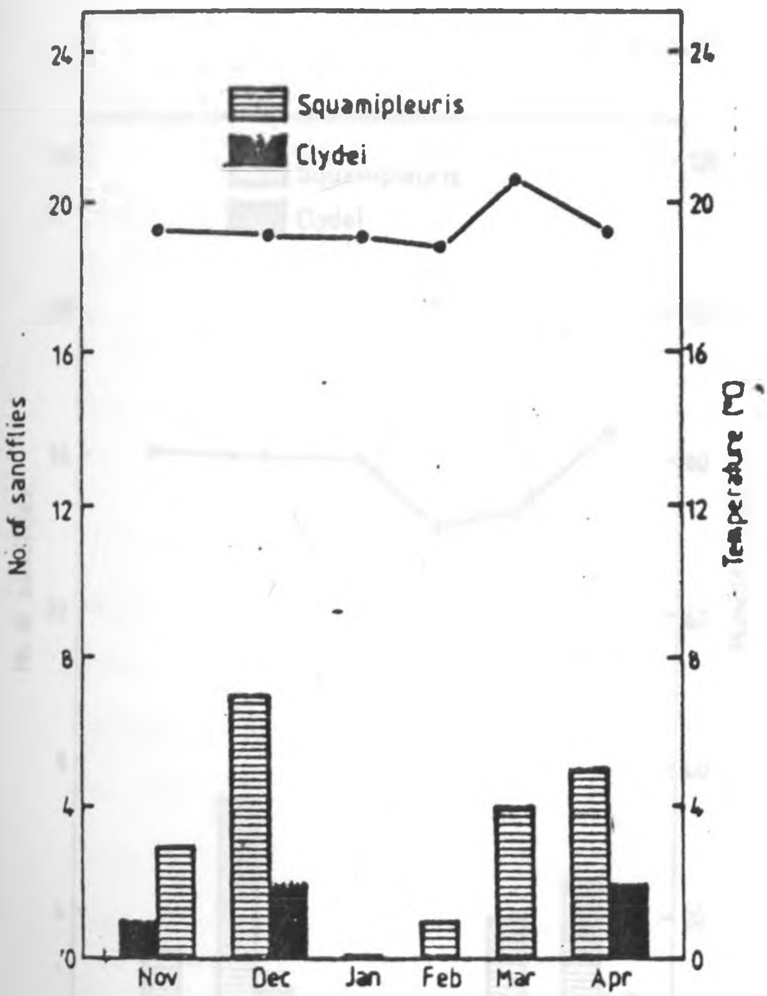


Fig. XII. The number of sandflies in relation to temperature within Kibera site.

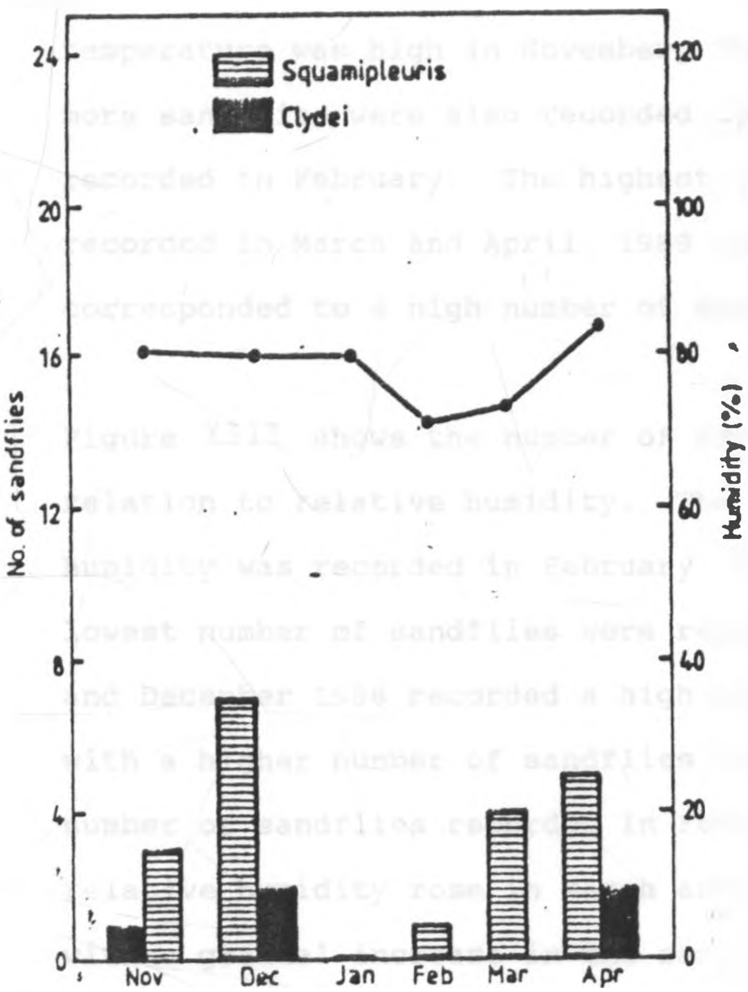


Fig. XIII. The number of sandflies in relation to humidity within Kibera site.

Figure XII, shows the number of sandflies in relation to temperature in Kibera site. The lowest temperature was recorded in February when the lowest number of sandflies was recorded. The temperature was high in November, December 1988 and more sandflies were also recorded compared to those recorded in February. The highest temperature was recorded in March and April, 1989 and this also corresponded to a high number of sandflies.

Figure XIII, shows the number of sandflies in relation to relative humidity. The lowest relative humidity was recorded in February 1989, when the lowest number of sandflies were recorded. November and December 1988 recorded a high relative humidity with a higher number of sandflies compared to the number of sandflies recorded in February 1989. The relative humidity rose in March and April 1989, with a gradual increase in the sandfly population.

4.2 Microhabitats from where sandflies were collected

Four microhabitats were identified from which the sandflies were caught. These were narrow animal burrows (Plate 5), termite mounds which were mainly found to be of the eroded type with many

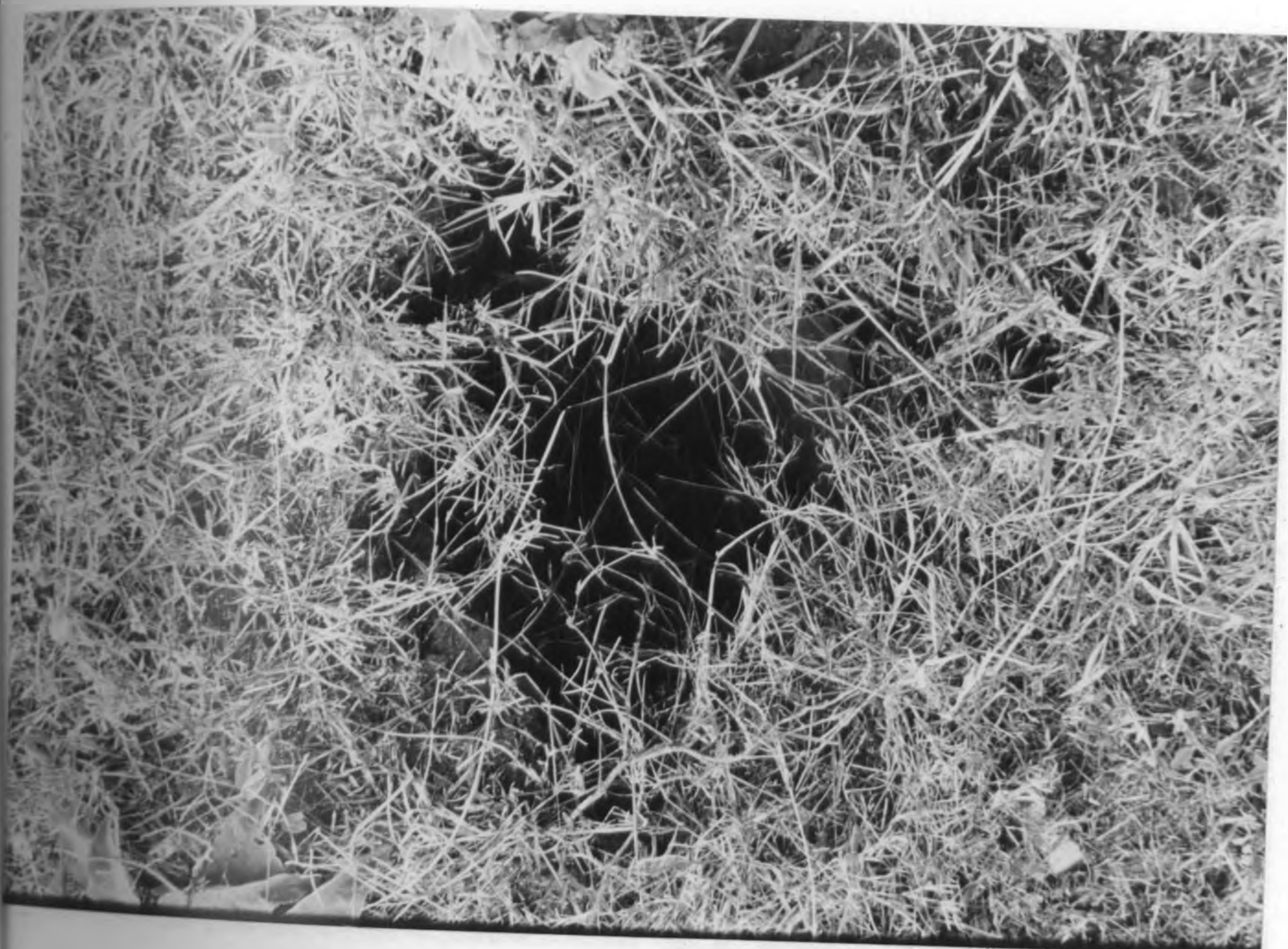


Plate 5. A photograph showing an animal burrow from where sandflies were collected at Roysambu.

Plate 6. A photograph showing a dugout from where sandflies were collected at Roysambu.

Plate 7. A photograph showing a cave from where sandflies were collected at Langata.

Plate 8. A photograph showing a rock crevice from where sandflies were collected at Langata.

ventilation shafts, where the traps were set (Plate 1a). There were also dugouts which seemed to have been made during a road construction project in one of the sites (Plate 6). The dugouts were located just by the road side. Plate 7, shows a cave at Langata which was one of the microhabitats where a number of sandflies were caught. Last but not least were rock crevices (Plate 8) which were ideal microhabitats for some species.

4.3 Statistical Analysis

When analysis of variance was done, only the months and species were found to be significant at the 5% level (Table 2).

It was therefore concluded that the prevailing weather conditions during a particular month vis. temperature, rainfall and relative humidity had an influence on the sandfly species that occurred and therefore affected the number of sandflies that were caught. The sandflies varied in abundance from one month to another (Table 3). The sandflies also varied in species over the 6 months period of this study (Table 4).

Though in the ANOVA, temperature was found not to be significant, stepwise regression showed that the catches were dependent on temperature. The regression was found to be significant at the 5% level (Table 5).

The regression formular Y = A+BX could be used to predict any future catches at any given time if temperature is known.

where Y is the catch

A is the intercept

B is the slope

X is the temperature

In this predictive formular,

catch = -41.4613 + 2.4985 x Temperature (Table 5).

This formula was found to be useful in predicting the number of sandflies of a particular species that one expects to catch at a given time.

Table 2. Showing ANOVA for the various factors that influenced sandfly catches over a period of 6 months.

	DF	SS	MS	FValue	PR>F
Locality	2	0.2507	0.1254	1.39	0.2627
Month	5	1.5488	0.3098	3.44	0.0130
Species	8	2.2040	0.2838	3.15	0.0092
Habitat	2	0.1709	0.0855	0.95	0.3973
Sex	1	0.1737	0.1737	1.93	0.1742
Temperature	9	0.5436	0.0604	0.67	0.7290
Error	33	2.9713	0.0900		

Table 3. Summary of sandfly population changes (November 1988 to April 1989).

Month	Mean
November	0.373[b]
December	0.496[ab]
January	0.383[b]
February	0.679[ab]
March	0.834[a]
April	0.467[b]

Means followed with same letter(s) are not significantly different at the 5% level.
Means followed with different letter(s) are significantly different at the 5% level.

Table 4. Summary of the occurrence of sandfly species over a period of 6 months (November 1988 to April 1989)

Species	Mean
Sergentomyia spp	1.157[a]
Phlebotomus guggisbergi	0.788[ab]
Sergentomyia harveyi	0.770[ab]
Sergentomyia teesdalei	0.740[ab]
Sergentomyia squamipleuris	0.521[b]
Sergentomyia clydei	0.518[b]
Phlebotomus rodhaini	0.404[b]
Sergentomyia bedfordi	0.360[b]
Sergentomyia adleri	0.301[b]

Means followed with the same letter(s) are not significantly different at 5% level.
Means followed with different letter(s) are significantly different at the 5% level.

Table 5. Regression of temperature on months and its effects on sandfly catches.

	DF	SS	MS	F	PR>F
Regression	1	470.4586	470.4586	5.31	0.00248
Error	59	5230.6889	88.6557		
Total	60	5701.1475			

Variable	Parameter Estimate	Standard Error	SS	F	PR>F
Intercept	-41.4613	20.4394	364.8009	4.11	0.0470
Slope	2.4985	1.0846	470.4586	5.31	0.0248

4.4 Overall evaluation of the results

During this study, the unidentified species was the most abundant species while S. adleri was the least abundant species (Table 1). Only the males of the unidentified species, S. clydei and S. adleri were caught. In the case of S. bedfordi, S. harveyi and S. teesdalei, only the females were caught. Both males and females were caught in 3 species viz. P. guggisbergi, P. rodhaini and S. squamipleuris. However, in all these 3 species, there were more males than females (Table 1).

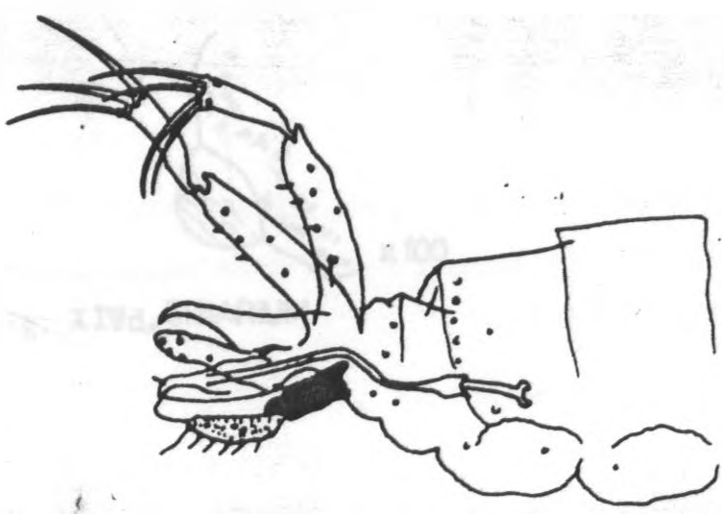
4.5 Description of the Unidentified species

Figs XIVa, XIVb, XIVc and XIVd show the male wing, terminalia, pharynx and cibarial armature of the unidentified species. Although this species was found to belong to the sub-genus Neophlebotomus of the genus Sergentomyia, quite a number of them had five spines on the style instead of the usual four that occur in this genus. The male terminalia of this species differed from any of the known male terminalia of this genus in the arrangement of the spines on the style, shape of the penis sheath, paramere and aedeagus shape.

Wing and male terminalia

x40

Fig. XIVa. WING



x100

Fig. XIVb. MALE TERMINALIA

Cibarial armature and pharynx

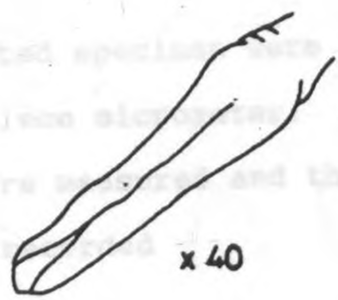


Fig.XIVc. PHARYNX

Fig. XIVd. CIBARIUM

The cibarial armature and shape of teeth were found to be distinctly different from any of the known species. Various body measurements of this species were made. Table 6 shows the average of the measurements which were important in describing this species.

Mounted specimen were measured with a calibrated eyepiece micrometer. An average of 20 adult specimens 12were measured and the average of each measurement was recorded

The following measurements were made from the flies.

1. Wing length (WL), wingbreath (WB): measured from the proximal end of the hairy basal costal node.

2. Labrium length (LL): measured from the tip of its junction with the clypeus.

3. Body length (BL): measured from the first abdominal segment.
   Body width (BW) was measured at the widest segment.

4. Length of 3rd antennal segment and segment 3+4 were measured.

5. Head length (HL) and head breath (HB)

6. Pharynx length (PL) and pharynx breath (PB): measured at the widest part.

Table 6. Average measurements of the unknown species.

Measurement	Unit
Body Length (BL)	10.13
Body width (BW)	3.67
Wing Length (WL)	15.15
Wing Breath (WB)	3.17
Head Length (HL)	4.95
Head breath (HB)	2.84
Pharynx Length (PL)	1.24
Pharynx Breath (PB)	0.40
Labrum Length (LL)	2.64
3rd Antennal Segment	2.81
4 + 5 Antennal Segment	4.09

CHAPTER 5

5.0 GENERAL DISCUSSION AND CONCLUSIONS

Prior to this study, nothing was known about the prevalence and incidence of phlebotomine sandflies in Nairobi area. However, the results of this study have shown that several sandfly species exist in Nairobi area as indicated in Table 1.

The sandflies varied in numbers with the undescribed species being the most abundant species while Sergentomyia adleri was the least in abundance. A sandfly similar to the undescribed species has been encountered in Machakos district (Mutinga M.J. personal communication) and is under study.

Two genera of sandflies namely, Phlebotomus and Sergentomyia were recorded during this study. The genus Sergentomyia had a greater number of sandflies compared to the genus Phlebotomus. This is in agreement with the findings of Perfil'ev (1966) who reported from the Ethiopian region that most sandfly species belonged to the genus Sergentomyia and only about 20 out of 600 species belonged to the genus Phlebotomus. Similar findings have been reported by Mutinga et. al (1984) in West Pokot and they have shown that Sergentomyia species represent a high proportion of the total population of the phlebotomine sandflies. Basmike (1988) has also reported similar findings in Marigat where he showed that 97% of the sandflies caught belonged to the genus Sergentomyia while only 3% belonged to the genus Phlebotomus.

The sandflies were collected from 5 major microhabitats namely; animal burrows, termite mounds, rock crevices, caves and dugouts. These findings are in agreement with Petrishcheva and Izyumskaya (1914) and Perfil'ev (1966) who found that animal burrows were preferred habitats of sandflies in nature in the USSR. Heisch et al (1956) found animal burrows, termite hills, soil crevices and piles of stones to be preferred habitats for sandflies and is in line with the findings of this study.

The results of this study also showed that some sandflies had preference for certain microhabitats. Phlebotomus guggisbergi was a regular inhabitant of the cave, only 2 flies were caught from a rock crevice although the unidentified species was occasionally caught from animal burrows and dugouts, the majority of these sandflies were caught from the ventilation shafts of termite mounds. Sergentomyia clydei was mostly caught from animal burrows which confirms the findings of Heisch (1954) who found gerbil burrows to be their main habitat.

The results of this study indicate that termite mounds constitute an important breeding site for sandflies followed by animal burrows. Similar findings on breeding sites of sandflies have been reported by Heisch et al (1956) and Minter, (1964c). However, the analysis of variance (Table 2) showed that there were no significant differences between the microhabitats at the 5% level.

During this study, two seasons were observed viz. a rainy season which occurred in December (1988) and January (1989) and then again in April (1989) and a drier season which occurred in November (1988) and between February and March (1989). The highest amount of rainfall was recorded in April followed by December and January in that order. The months experiencing the least amount of rain during this study were November (1988) and February and March (1989) (Figures Ia, IIa and IIIa). The sandflies were divided into two groups in relation to their prevalence. One group occurred mostly during the drier months and the other group occurred throughout the entire study period. The group which occurred during the drier months was composed of the unidentified species and Sergentomyia harveyi. These two species of sandflies occurred only in February and March when the least amount of rainfall was recorded. All the other species collected viz. Phlebotomus guggisbergi, P. rodhaini, Sergentomyia clydei, S. teesdalei, S. squamipleuris, S. adleri and S. bedfordi occurred throughout the study period. This is in line with the findings of Quate (1964) who reported S. squamipleuris to be a 'non-seasonal' species in the Sudan. Similarly Basimike (1988) reported P. rodhaini, S. bedfordi, S. adleri and S. clydei to be 'non-seasonal' species. Wijers and Minter (1962) also had earlier reported S. clydei to be a 'non-seasonal' sandfly.

The general trend of Phlebotomine sandflies in Nairobi area was found to show two peaks when the mean number of sandflies was plotted against the months (Figure IV). With the rains that occurred in December the number of sandflies quickly rose reaching a peak (Figures V and IV). However, as the rains continued through the month of January, the number of sandflies quickly decreased (Figures V and IV). As the rains decreased in the month of February, the number of sandflies again rose steadily reaching a peak in the month of March (Figures V and IV). This was followed by a sharp decrease in the numbers of sandflies with the onset of heavy rains in the month of April (Figures V and IV). This trend has been observed by a number of other workers. Wijers and Minter (1962) reported that most of the sandflies decreased in numbers in the middle of the rains. Similarly Disney (1966) reported that heavy rainfall resulted in a brief but sharp fall in population density while during the dry season, a shower of rain led to a brief but sharp increase in the sandfly population. The findings of this study agree with Chaniotis et al (1971b) who reported a steady decline of sandfly population which resulted from heavy rainfall. They reported that sandfly population was usually much lower in the dry season and reached a peak just before the wettest month of the year. This study confirms this finding whereby a sandfly population peak was reached in March just before the heavy rains in April.

Thatcher and Hertig (1966) found that the sandfly population density declined gradually during the dry season. The results of this study show similar findings (Figures V and IV) whereby only a small number of sandflies were realized during the dry month of November (1988).

Minter (1964c) showed that the pattern of rainfall distribution had more influence on the seasonal incidence and relative abundance of most sandfly species than the total amount of precipitation. This is in line with the findings of this study which showed that evenly distributed rains led to a higher sandfly population for most species. This was the case in February and March (1989) whereby 7 out of 9 species found were recorded, most of them in large numbers compared to the other months (Figure V).

The results of this study showed that too much rain or very dry conditions were detrimental to the existence of sandflies. The reasons for this are probably due to water logging and drying of breeding sites respectively which alter the microclimate thus affecting the breeding and resting sites and hence interfering with the development of the immature stages. Sandfly larvae and pupae have been known to be extremely susceptible to dryness as well as to excessive dampness (Chaniotis _et al_., 1971a). The dryness or dampness alter the microclimate in the microhabitat killing or washing away the eggs, larvae or pupae and entangling the adults in the water after which they easily drown (Theodor, 1936).

When the data was analyzed, a negative correlation coefficient (r = -Q.53) was obtained with rainfall indicating a decrease in the number of sandflies as the rainfall increased. However, this was not significant at the 5% level. Basimike (1988) reported similar findings.

The highest relative humidity (87.5%) was recorded in April which was the wettest month while the lowest relative humidity (71.4%) was recorded in February which was the driest month. When the total monthly sandfly population was correlated with relative humidity, a negative correlation coefficient was observed for the maximum relative humidity (r = -0.78). This indicates that relative humidity had a negative influence on the population density but it was not significant at the 5% level. Similar results were obtained by Basimike (1988) in Marigat.

Table 5 shows that temperature was significant at the 5% level. Temperature was also shown to have a positive correlation coefficient (r = 0.42) with the sandfly's abundance. This is in agreement with the findings of Basimike (1988) who found a positive correlation for temperature in animal burrows in Marigat.

Climatic factors, particularly rainfall have been reported to have important effects on the gross distribution and local abundance of sandflies (Minter, 1964c). Similarly, Theodor (1936), reported that temperature and humidity are critical factors in sandfly ecology. This study has also shown that rainfall, temperature and relative humidity have an effect on the sandfly abundance but temperature was the main factor controlling the abundance of sandflies in Nairobi area.

The analysis of variance (Table 2) showed that the months and species were significant at the 5% level and therefore, influenced the sandfly catches during the 6 months of this study. Months influenced the catches because each month had different weather conditions prevailing. The prevailing weather conditions were the ones that influenced the abundance of sandflies and species that occurred in any given month. The species that occurred also influenced the abundance of sandflies.

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