COMMENSAL RODENTS and THEIR PARASITES in ISRAEL

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Abstract New findings on the geographical distribution and ecto- and endoparasites of *Rattus norvegicus*, *Rattus rattus*, and *Mus musculus* were recorded in 1999-2000. Seven specimens of *R. rattus* were trapped in the coastal plain of Israel, six of these in the Haifa area and one in Tel Aviv. Up to this record, the coastal plain was known to harbor only *R. norvegicus*. An adult *R. norvegicus* was trapped in Jerusalem, a new record of this species inland. The rat flea, *Xenopsylla cheopis*, is a parasite of *R. norvegicus* in Israel, and its known geographical distribution was, till now, the coastal plain. *X. cheopis* is the vector of murine typhus, a few cases of which are recorded each year only in the coastal plain. One specimen of *R. norvegicus* trapped in Tel Aviv was infested with a single *X. cheopis*. This level of infestation of 0-1 fleas per rat is in accordance with the infestation index recorded in Israel since the beginning of the 1980s. One specimen of *X. cheopis* was recorded on the *R. norvegicus* trapped in Jerusalem, possibly indicating a changing distribution pattern of the rat flea, together with the invasion of *R. norvegicus* to the inland areas. The most worrying finding was 31 rat fleas recorded on a single *R. norvegicus* in the Lod area. Such a high infestation level has not been observed in Israel since the 1960s, posing a threat to public health. Only a few mite specimens were found on both rat species. A large population of rat lice, *Polyplax spinulosa*, was found on *R. rattus* from the village of Yesodot. Such lice are not a direct danger to man, but it has been shown that they have great epidemiological importance in transferring murine typhus among rats, thus perpetuating the disease cycle. Ten different species of helminths were identified from *R. rattus* and six were recorded from *M. musculus*. The incidence of infection in *R. rattus* was found to be relatively small (38.5%). Bacteriological examination of 37 specimens of commensal rodents revealed *Campylobacter jejuni* in only four specimens of *R. rattus*. No *Salmonella* was found. This is the first record of bacteriological testing of *R. rattus* in Israel. The changing patterns of geographical distribution and parasite infestation of commensal rodents since the 1950s is discussed.

Key Words Rats, fleas, mites, lice, helminths

INTRODUCTION

In Israel there are three species of commensal rodents that are closely associated with man: the Norway rat, *Rattus norvegicus* (Berkenhout), the roof rat, *Rattus rattus* (L.), and the house mouse, *Mus musculus* (L.). The role of these rodents as reservoirs of zoonoses, such as plague, murine typhus, leptospirosis and salmonellosis, has long been known. In addition, other pathogens dangerous to man have been isolated over the last years, such as hantavirus and *Borrelia burgendorfi*. Among the ectoparasites infesting rats, the best known and most dangerous to man is the rat flea, *Xenopsylla cheopis* (Rothschild). This flea is the vector of *Yersinia pestis*, the causative agent of plague, and *Rickettsia typi*, the causative agent of murine typhus. The last cases of plague were recorded in Israel in 1947 (Gratz, 1957a); however, the Indian plague outbreak in 1994, and several other foci in the world, proves that the danger of this disease still exists.

In the 1950s, hundreds of cases of murine typhus were recorded annually in Israel. Since then, there has been a steady decrease in the number of cases and only 2-4 cases annually were recorded in the last decade (Wilamowski, 1999). Between 1954 and 1957, two surveys were carried out in the area of Haifa port on the ectoparasites of rats (Gratz, 1957a, b). A survey carried out by the Entomological Laboratory between 1954 and 1980 (Wilamowski, 1999), and several other surveys carried out during the 1960s on the distribution of commensal rodents (Gratz, 1973), indicated that the Norway rat took over habitats previously occupied by the roof rat in the

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area of the coastal plain. Since the mid 1980s, the Norway rat dominated all this area and was the only species found in Eilat (Lidror et al., 1986). In inland areas, only the roof rat has been caught (Lidror et al, 1986; Wolf, 1982). The roof rat was also the only rat caught in Jerusalem (Wilamowski, 1999). Despite the fact that *X. cheopis* is known as a parasite of both rat species, it has not been recorded in the interior parts of Israel and it is very rare on wild rodents (Theodor and Costa, 1967). Since the 1980s, *X. cheopis* has been found to be common only on the Norway rat in the coastal plain area. According to information from the Epidemiological Department, all cases of murine typhus were reported from this area. Thus the distribution of murine typhus clearly overlaps that of the Norway rat and *X. cheopis*. In the beginning of the 1980s, the infestation rate of *R. norwegicus* with *X. cheopis* was very low, 0-1 flea per rat. In parallel, the number of cases of murine typhus also decreased to a very low level. In the Haifa surveys of Gratz (1957a, b), three additional species of fleas were recorded, *Leptopsylla segnis* (Schoenherr), *Echidnophaga murina* (Tiraboschi) and *Ctenocephalides felis* (Bouché) as well as two species of lice, *Polyplax spinulosa* (Burm.), and *Hoplopleura oenomydis* Ferris, and three species of mites, *Laelaps echidninus* (Berlese), *Laelaps nuttalli*, Hirst, and *Ornithonyssus bacoti* (Hirst). This work deals with the changes that have occurred in the distribution of rats and their parasites since the 1980s and up to the last survey carried out in 1999-2000.

Rats and mice are known to be infested with many species of helminths, among which are some that may also infect people, such as the cestodes *Hymenolepis nana* Blanchard and *H. diminuta* Blanchard, as well as the nematode *Trichinella spiralis* (Owen), which may cause severe sickness in man that is sometimes fatal (Witenberg, 1951). The helminth fauna of *R. norvegicus* has been studied mainly by Wertheim (1963), Lengy and Wertheim (1963) and Wertheim and Lengy (1964). The helminths of *R. rattus* and *M. musculus* were studied in surveys carried out in Jerusalem in 1981-85 and in various parts of Israel in 1999-2000.

The only bacteriological studies on enteric bacteria from commensal rodents were carried out by Gerichter and Sechter (1970), who isolated 114 strains of *Salmonella* from rats, most of them from *R. norvegicus*.

MATERIALS and METHODS

The information reported in this paper is based on data collected in the Central Laboratories of the Ministry of Health. Between 1954 and 1980, an annual survey was carried out trapping rodents monthly in order to check the ectoparasites in the areas of Tel Aviv and Eilat. Other surveys were undertaken in Jerusalem in 1981-1985 and 1997-1998 and in several regions of Israel in 1999-2000. In addition to these surveys, rats and mice sporadically trapped by pest control operators over the last two decades were also checked for ectoparasites.

In the Jerusalem survey of 1981-1985, the commensal rodents were also checked for helminths, and in 1999-2000, they were additionally checked bacteriologically for the human pathogenic enteric bacteria, *Salmonella* and *Campylobacter*. In all the surveys, the rats and mice were trapped in cage-type live traps, which were set before dusk and collected after dawn. The traps were placed in pathways where rats were known to be active according to various signs such as fecal droppings, gnawing marks and other rodent damage, as well as human sightings. The rats were brought alive to the laboratory and anaesthetized with ether. In the last survey, we used 10% Haloten as an anaesthetic, which is more effective and less dangerous to the handlers.

The rodent fur was combed with a louse comb to remove all the ectoparasites. The comb products were transferred to 70% ethanol and examined under a stereomicroscope. When relevants, the *X. cheopis* index (X.c.i.) was determined. This is the average number of fleas per rat in a sample of rats caught at the same place and time. In order to identify the lice and mites, the specimens were mounted in Hoyer solution for microscopic examination. The commensal rodents were also checked visually and by stereoscope for ticks, between the digits and behind the ears.

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Because of the possibility that rats may be carriers of leishmania (Blum, 1978), the rats were checked visually for lesions suspected to be cutaneous leishmaniasis. Immediately after the rodents were combed and checked, they were dissected and various organs were examined under a stereo microscope for helminths. The helminths were fixed in AFA solution for further examinations. For bacteriological examinations, caecal samples were cultured on specific media including enrichment media for *Salmonella* and *Campylobacter*.

RESULTS

Geographical Distribution of Rats

Since the mid-1980s until the present survey, the general rat distribution pattern known in Israel was that *R. norvegicus* dominated the coastal plain and *R. rattus* was found in inland areas (Lidror et al., 1986; Wilamowski, 1999); see Figure 1. During the recent survey of 1999-2000, eight rats were trapped in locations different from these: 6 specimens of *R. rattus* were trapped in the Haifa area; 1 specimen of *R. rattus* in the Tel Aviv area; 1 specimen of *R. norvegicus* in Jerusalem.

Fleas

Xenopsylla cheopis. The rat flea infestation index of *R. norvegicus* in the center of Tel Aviv between the years 1954-1980 is shown in Figure 2 (Wilamowski, 1999).

The infestation of *R. norvegicus* in Eilat is shown in Table 1. Since 1959, all specimens trapped in Eilat were *R. norvegicus*; since 1983, no *X. cheopis* were recorded from there.

In 1983 in Netivot (southern coastal plain), 45 specimens of *X. cheopis* were recorded from 21 *R. norvegicus* trapped (X.c.i. = 2.14). From 1983 till 1999, no *X. cheopis* were recorded from rats that were trapped all over Israel and brought to our laboratory. In the last survey of 1999-2000, one specimen of *X. cheopis* was recorded from one *R. norvegicus* trapped in Tel Aviv; 31 specimens were recorded from one *R. norvegicus* caught in Lod; and one specimen was found on one *R. norvegicus* trapped in Jerusalem. The infestation of *R. rattus* with *X. cheopis* is given in Table 2.

Other flea species recorded from rats. The infestation of *R. norvegicus* with the fleas *L. segnis, E. murina,* and *C. felis* is given in Table 3. Since 1980 no other species of fleas have been

Table 1. Infestation of *X. cheopis* on *R. norvegicus* from Eilat

Year	No. rats	No. fleas	X.c.i.
1965	21	41	1.4
1978	22	10	0.45
1982	8	17	2.12

Table 2. Infestation of *X. cheopis* on *R. rattus*

Year	Location	No. rats	No. fleas	X.c.i.
1968	Kfar Shmariyahu*	37	14	0.37
1980	Kfar Shmariyahu	43	3	0.07
1981–1985	Jerusalem	86	0	–
1997–2000	Jerusalem	86	0	–

* Kfar Shmariyahu is located on the coastal plain, north of Tel Aviv.

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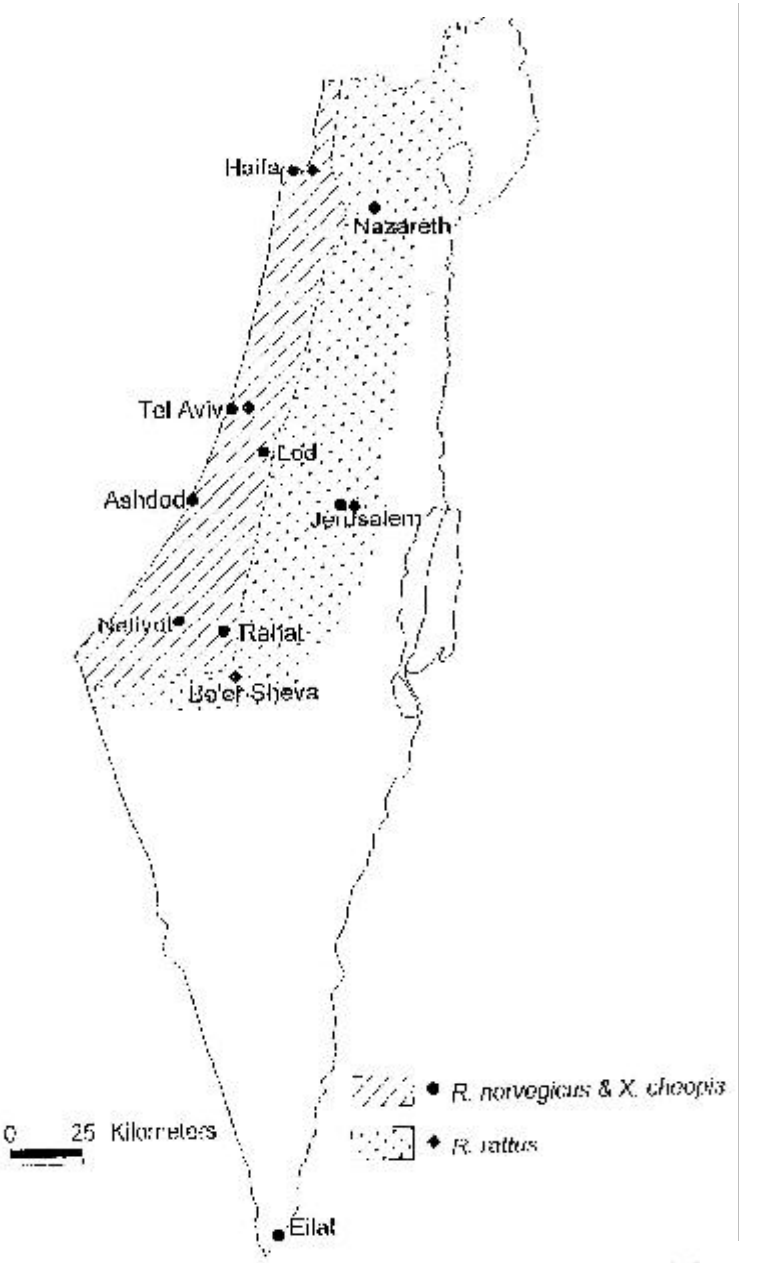

Figure 1. Distribution of rat species and X.cheopis *in Israel. After Lidror et al. (1986) and 1999-2000 findings.*

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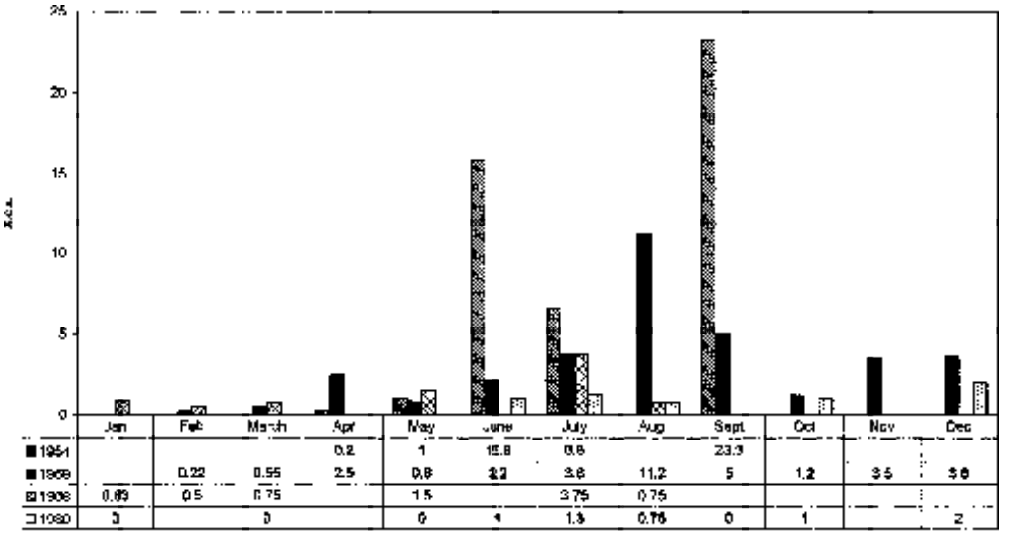

Figure 2. Xenopsylla cheopis *index (X.c.i) in central Tel Aviv.*

recorded on *R. norvegicus* in Israel. *L. segnis* was recorded on *R. rattus* from Kfar Shmariyahu in 1968 (2 specimens) and in 1980 (one specimen). *Nosopsyllus fasciatus* (Bosc) was also found on *R. rattus* from Kfar Shmariyahu in 1980. In the Jerusalem survey of 1981-85, one specimen of the endemic flea *Leptosylla algira costai* Smit was recorded from *R. rattus* and five specimens were found on *M. musculus.*

Lice and Mites

The infestation of *R. norvegicus* from central Tel Aviv with lice and mites is shown in Table 4. In 1999, one specimen of *Lalaps echidninus* was found on *R. norvegicus* caught in Tel Aviv. Since 1980, this in the only mite recorded from *R. norvegicus.*

The infestation of *R. rattus* from several localities with lice and mites is shown in Table 5.

Helminths

The helminths recovered from 65 specimens of R. rattus and 39 specimens of M. musculus are summarized in Table 6. In addition, helminth infestation data from 135 R. norvegicus published by Wertheim (1963) are included.

Table 3. Flea infestation index (I.i.) of *Rattus norvegicus* in central Tel Aviv with various fleas, 1954 – 1980

Year	No. of rats examined	*L. segnis* I.i. (n*)	*E. murina* I.i. (n)	*C. felis* I.i. (n)
1954	62	0.09 (5)	0	0.38 (24)
1959	146	0.10 (15)	0.02 (3)	0.5 (73)
1968	40	0.02 (7)	0	0.175 (7)
1980	30	0	0	0

* n = no. of fleas

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Table 4. Lice and mites infestation index (I.i.) of *R. norvegicus* in central Tel – Aviv, 1954 – 1980

Year	1954	1959	1968	1980
No. of rats examined	62	146	40	30
	I.i. (n)	I.i. (n)	I.i. (n)	I.i. (n)
Lice				
Polyplax spinulosa	2.87 (178)	6.39 (934)	0.5 (20)	0.033 (1)
Hoplopleura oenomydis		0.14 (9)	0	0.025 (1)
0.97 (29)				
Mites				
Laelaps echidninus	2.9 (179)	1.2 (175)	0.07 (3)	0.46 (14)
Laelaps nuttalli	0	0.76 (112)	0.35 (14)	0.13 (4)
Ornithonyssus bacoti	0.05 (3)	0.53 (78)	0.77 (31)	0

Table 5. Lice and mites infestation index (I.i.) of *R. rattus*

Year	Location	No. rats examined	*P. spinulosa* I.i. (n)	*L. echidninus* I.i. (n)	*O. bacoti* I.i. (n)
1968	Kfar Shmariyahu	37	1.6(59)	0.24 (9)	3.9(145)
1980	Kfar Shmariyahu	43	0.3(13)	0.16 (7)	0
1981–1985	Jerusalem	50	1.86 (93)	0	6.25(313)
1997–2000	Jerusalem	36	0.13 (5)	0	0.16 (6)
1999–2000	Yesodot*	11	5.63 (62)	0	0

* Yesodot is located on the coastal plain, south of Tel Aviv.

Bacteriology

The examination of 37 specimens of commensal rodents revealed *Campylobacter jejuni* in only four specimens *R. rattus*. No *Salmonella* was found. This is the first record of bacteriological testing of *R. rattus* and *M. musculus* in Israel.

Ticks and Suspected Leishmania Lesions

No ticks were found on any of the rats or mice examined. Two *R. rattus* with suspected lesions on were checked for cutaneous leishmaniasis. Both proved to be negative.

DISCUSSION

In the survey of 1999-2000, eight rats were trapped in areas outside their previously known distribution patterns of the last two decades. The most interesting finding was that of *R. norvegicus* caught in Jerusalem, the first record of this species caught inland. This rat was trapped in an industrial area. It probably came with one of the many cargoes delivered in this area from a port city in the coastal plain where *R. norvegicus* is the dominant species. This finding confirms reports of pest control operators over a long time period of the existence of *R. norvegicus* in this industrial area. Of the six *R. rattus* caught in the Haifa area, four were trapped in the port area, and two others in a wooded region of the city periphery. The single specimen of *R. rattus* from Tel Aviv was caught in the city center. Since the mid-1960s this area was known to harbor *R. norvegicus* (Gratz, 1973; Wilamowski, 1999). These changes in the relative distribution of the rat species have important implications, both regarding the different control techniques of the two species, as well as their significance as vectors and reservoirs of disease. Thus it is imperative to continue the monitoring and control operations.

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Table 6. Helminths recovered from commensal rodents in Israel

	M. musculus n=39		*R. norvegicus* n=135*		*R. rattus* n=65	
Helminth species	No.	%	No.	%	No.	%
Cestoda						
Hymenolepis diminuta Blanchard	–	–	51	37.8	4	6.2
Hymenolepis nana Blanchard	19	48.7	25	18.5	6	9.2
Taenia taeniaeformis (Bloch)	3	7.7	3	2.2	–	–
Nematoda						
Capillaria hepatica Travassos	1	2.6	–	–	2	3.1
Gongylonema neoplasticum (Fib. and Ditl.)	–	–	8	5.9	1	1.5
Heterakis spumosa (Schneider)	–	–	5	3.7	–	–
Mastophorus muris (Gmelin)	–	–	22	16.3	2	3.1
Nippostrongylus brasiliensis (Travassos)	–	–	8	5.9	6	9.2
Strongyloides ratti (Sandg.) + *S. venezuelensis* (Brumpt)	–	–	16	11.9	–	–
Thenorastrongylus josephi (Wertheim)	7	17.9	–	–	–	–
Trichosomoides crassicauda (Bellingham)	–	–	36	26.7	2	3.1
Trichuris muris (Schrank)	–	–	–	–	1	1.5
Aspiculuris sp.	17	43.6	–	–	–	–
Syphacia sp.	9	23.1	–	–	–	–
Oxyuridae sp.	–	–	–	–	3	4.6
Acanthocephala						
Moniliformis moniliformis (Bremser)	–	–	5	3.7	1	1.5
Total infestation	28	71.8	95	70.4	25	38.5

* According to Wertheim (1963).

The most prominent phenomenon in the infestation of rats with ectoparasites is the decrease in the level of infestation of all species from 1954 to 1980. Some species have not been recorded on rats since the 1970s and some were found with very low infestation levels. Since the 1980s, the level of infestation of *X. cheopis* was 0-1, except for two outbreaks in Eilat in 1982 and Netivot in 1983, following a sharp increase in population levels of *R. norvegicus*. Since 1983 and up to the last survey of 1999-2000, no *X. cheopis* was recorded from any of the rats examined. There is a strong correlation between the abundance of *X. cheopis* and the incidence of murine typhus in humans (Traub et al., 1978). In the last decade, only a few cases annually (2-4) of murine typhus have been recorded, all of them from the known distribution areas of *R. norvegicus* and *X. cheopis*. This number is in accordance with the known, very low, infestation level of *R. norvegicus* with *X. cheopis*.

The examination of rats in 1999-2000 showed several new and important findings. The *R. norvegicus* trapped in Jerusalem was infested with one specimen of *X. cheopis*, which is the first record of this flea inland, indicating a possible change in the distribution pattern of the flea together with the invasion of this rat inland. The most worrying finding was 31 specimens of *X. cheopis* found on one *R. norvegicus* from the Lod area. Such a high infestation level has not been observed since the 1960s. *R. rattus* was found to be infested with *X. cheopis* only in the coastal plain. The level of infestation was significantly lower than that of *R. norvegicus*. Similar findings were made by Gratz (1957a, b).

Three other species of flea, *L. segnis*, *E. murina*, and *C. felis* were also recorded from rats in Tel Aviv. The level of infestation of these fleas is lower than that of *X. cheopis*, and the level was lower on *R. rattus* than on *R. norvegicus*. Similar findings were made in Haifa by Gratz

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(1957a ,b) and Soliman et al. (2001) in Egypt. The phenomenon that infestation of *R. rattus* is lower than of *R. norvegicus* can be explained by the fact that the nesting sites of *R. norvegicus* are underground, while those of *R. rattus* are found on trees, buildings, etc., thus there is less contact between the rats and the nesting sites of the fleas in the ground. According to Gratz (1957a) and Ryckman (1971), the extreme temperature changes occurring in the higher nests of *R. rattus* are unsuitable for fleas. Since the 1980s, *L. segnis, E. murina,* and *C. felis* have not been recorded from commensal rodents in Israel. It is surprising that *C. felis*, the most common flea in Israel, parasitizing pets, farm animals, and a large range of other hosts, has not been recorded on rats since the 1980s. Mumcuoglu et al. (2001) found an unusually high infestation index of *X. cheopis* (5.45) and of *E. murina* (3.77) on *R. norvegicus* in the Beduin town of Rahat. Over 76% of the rats were seropositive to *Rickettsia typhi* and ten cases of murine typhus were recorded in humans. This local point infestation is due to the conditions and lifestyle of the Beduins of Rahat, enabling the development of a large population of rats and a high infestation of *X. cheopis* and *E. murina.* By comparison, in a Jewish suburban community about 1km from Rahat, no rats were trapped at all (Mumcuoglu et al., 2001).

House mice have not been found to be infested with fleas, apart from two specimens trapped in Jerusalem in 1983 that were found to be carrying the endemic flea *Leptosylla algira costai* Smit. This flea was previously found on feral *Mus musculus* (Theodor and Costa, 1967).

Three species of mites were recorded from the two rat species trapped in the coastal plain area. Only *O. bacoti* was recorded on *R. rattus* in Jerusalem and other inland areas. This species has not been found on other wild mammals (Theodor and Costa, 1967). In Egypt, the infestation of *R. rattus* with *O. bacoti* was significantly higher than the infestation on *R. norvegicus* (Soliman et al., 2001). During the Haifa survey of 1954-1957, a sharp decrease in the level of infestation by mites was found (Gratz, 1957, a, b). *L. nuttalli* has not been recorded since the 1980s, and only a single specimen of *L. echnidninus* was recorded in the last survey. Several cases were recorded in Israel in which laboratory workers dealing with laboratory rats and mice were bitten by *O. bacoti* (Mumcuoglu, 1986); thus this species is suspected as a potential vector of pathogens from rats to humans (Traub et al., 1978). The sharp decrease to very low population levels of both fleas and mites, or even to their disappearance, is the result of massive control operations, begun in the 1950s, when hundreds of cases of murine typhus were recorded, and which continued for many years afterwards, as well as drastic urban changes that have occurred over the last 50 years, reducing the available nesting sites for fleas and mites.

It is known that the increased prevalence and general infestation index of ectoparasites are positively correlated to the increased densities of their hosts (Anderson, 1982). In spite of the fact that an increase occurred in the population levels of the rats in different urban areas in Israel and at various periods of time, a parallel increase in the level of ectoparasites did not take place, a result that can probably be explained as the result of a lack of appropriate conditions and suitable sites for the development of ectoparasites in urban areas.

The dominant louse that infected both rat species in the coastal plain was *Polyplax spinulosa*. Only this species was recorded, sometimes in quite large numbers, on *R. rattus* in inland areas. Theodor and Costa (1967) found this species on wild *R. rattus.* The louse *Hoplopleura oenomydis* was first found in Israel during the Haifa survey predominantly on *R. norvegicus*; only a few specimens of *R. rattus* were infested. The level of infestation of *H. oenomydis* was significantly lower than that of *P. spinulosa* for both rat species. *H. oenomydis* is cosmopolitan and was found only in the port area, and probably invaded with *R. norvegicus* (Gratz, 1957a, b). In the Tel Aviv survey, a similar infestation of *H. oenomydis* was found. In 1980, the infestation index of *H. oenomydis* was slightly higher than earlier years, but since 1980, it has not been recorded at all.

P. spinulosa does not bite humans and therefore does not directly threaten their health. However, Rosen (1961) showed in his work on rats in Tel Aviv that this louse is very important

epidemiologically, being the main means of transferring *Rickettsia typhi* from rat to rat; thus the disease cycle is perpetuated. In contrast, the flea *X. cheopis* appears to play an insignificant role in the transmission of murine typhus between rats although it is a vector of this disease to humans (Rosen, 1961).

The findings of the last survey (1999-2000) show the possibility of change in the distribution patterns of rats and their ectoparasites, in particular the rat flea. Movement of produce and people as well as urban changes and style of life are the main factors influencing the distribution of the commensal rodents and their ectoparasites. Since these changes may be very rapid and since rodents are known as vectors of several diseases, health authorities must carry out constant monitoring and control operations in order to prevent any possible danger.

At least 17 species of helminths were recovered from commensal rodents. The infestation of *R. rattus* (38.5%) was very low compared with that of *R. norvegicus* (70.4%). The highest infestation was found in *M. musculus* (71.8%). Only six species were found in *M. musculus*, among them three species not found in rats, viz, *Thenorastrongylus josephi, Aspicularis* sp., and *Syphacia* sp. The cestode *H. nana* was recovered from all three commensal rodents. The mice in particular were heavily infested with this worm (48.7%). It is possible that this is a factor in the epidemiology of human *Hymenolepis* infection. The nematodes *Strongyloides ratti* and *S. venezuelensis* were presumably imported with their host *R. norvegicus* and were first recorded in Israel by Wertheim (1963), but have not yet been recorded from *R. rattus*. The peculiar nematode *Trichosomoides crassicaudata*, which inhabits the bladder and its tiny males hyperparasitize the uterus of the female, was found in several wild rodents in Israel (Greenberg, 1969). The infection rate of *T. crassicaudata* in *R. norvegicus* from the coastal plain was 26.7%. It is interesting that only 3.1% of *R. rattus* (many captured in Jerusalem) were found to be infected, while in the spiny mouse, *Acomys cahirinus* Desmarest, from the hills around Jerusalem, the rate is over 67% (Greenberg, 1969).

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