

Ticks collected from domestic animals in Sinai and adjoining areas in Israel and their medical and veterinary importance

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Summary

The following nine species and subspecies of ticks were found during a faunistic survey in the Sinai peninsula, and adjoining areas of Israel : *Hyalomma dromedarii* (camel and ground), *H. anatolicum excavatum* (camel, oryx and ground), *H. impeltatum* (camel and ground), *H. marginatum marginatum* (camel), *H. schulzei* (camel), *H. sinaii* (camel), *Rhipicephalus sanguineus* (dog, sheep and goat), *Argas persicus* (chicken) and *Ornithodoros savignyi* (ground). In the sampling scheme camel was the most commonly infested host, followed by the sheep and goat. The medical and veterinary importance of the prevailing tick species is discussed.

Key words : Ticks — Medical importance — Sinai.

Résumé

TIQUES TROUVÉES SUR LES ANIMAUX DOMESTIQUES DANS LE SINAI ET LES RÉGIONS LIMITROPHES D'ISRAËL ET LEUR IMPORTANCE MÉDICALE ET VÉTÉRINAIRE. Les neufs espèces et sous-espèces suivantes ont été trouvées pendant une étude faunistique dans la péninsule du Sinai et les régions limitrophes d'Israël : *Hyalomma dromedarii* (chameau et par terre), *H. anatolicum excavatum* (chameau, oryx et par terre), *H. impeltatum* (chameau et par terre), *H. marginatum marginatum* (chameau), *H. schulzei* (chameau), *H. sinaii* (chameau), *Rhipicephalus sanguineus* (chien, mouton et chèvre), *Argas persicus* (volailles), *Ornithodoros savignyi* (par terre).

Dans le programme d'échantillonnage le chameau a été l'hôte le plus infesté suivi par le mouton et la chèvre. L'importance médicale et vétérinaire des tiques trouvées est discutée.

Mots-clés : Tiques — Importance médicale — Sinai.

Introduction

The tick fauna of the Sinai peninsula is not well known. The only extensive study dedicated to the ticks of Sinai was done by Feldman-Musham (1960) following the earlier reports by Theiler and Hoogstraal, (1955) Hoogstraal *et al.* (1954) and Hoogstraal and Kaiser (1958a). Feldman-Muhsam,

(1960) study was based on ticks collected from the southern part of Sinai, many of them from wild animals, essentially rodents, while Theiler and Hoogstraal (1955) reported only the collection of *Ornithodoros savignyi* Audouin from El-Arish in northern Sinai. Hoogstraal *et al.* (1954), reported the collection of *Ornithodoros erraticus* Lucas from rodent burrows at El-Arish in northern Sinai and

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in Wadi Feiran at Sinai mountains. Hoogstraal and Kaiser (1958a) reported the collection of *Hyalomma* sp. no. 1 near *excavatum* (= *H. franchinii* Tonelli-Rondelli according to Hoogstraal and Kaiser, 1958d) from spiny mice (*Acomys russatus*) at St. Catherine's Monastery in Sinai mountains. The present study is based on larger numbers of ticks collected from domestic animals in Sinai, mainly from its northern part, but also from several geographical zones in Israel and from Gaza strip. The number of domestic animals in Gaza strip and Sinai has almost doubled during the past twelve years of the Israeli administration (Pers. Comm., Ministry of Agriculture, Gaza District). In 1978 and 1979 the tick fauna of Sinai and adjoining areas of Israel was studied in conjunction with a survey of suspected vectors of Rift Valley Fever virus. The results of that survey and the medical-veterinary importance of ticks in that area are presented here.

Materials and methods

Collections were made at 52 localities (fig. 1) throughout eight geographical areas in Sinai, Gaza strip and southern Israel. During the survey, 29 two days journeys and one of ten days were carried out from October 1978 to December 1979. Northern Sinai (zone 20) was regularly and most frequently sampled throughout the year, whereas other geographical zones were sampled sporadically. Several localities situated on the route of a visit were sampled each time. With the exception of El-Arish, all the localities were nomad (Beduin) dwellings i.e. tents in which people and domestic animals live in immediate proximity. Although ticks were collected mainly from camels, some were sampled from sheep, goats and dogs, excluding wild animals. Collection from domestic fowl was done only in zones no. 22, 23. Although not all the infesting ticks were removed, considerable numbers were collected from all the sampled animals as well as from the ground in the areas which they frequented. Nymphs of Ixodidae were reared to adults in the laboratory to facilitate species determinations whereas those of Argasidae were identified at the time of collection. As the purpose of the study was a faunistic survey, identification was made mainly to species and not to disputed subspecies. Mostly the keys of Hoogstraal (1956) were used. The systematic status of *Hyalomma anatolicum excavatum* Koch was determined according to Hoogstraal and Kaiser (1959)

and that of *Rhipicephalus sanguineus* Latreille according to Morel and Vassiliades (1962).

Detailed characteristics of the surveyed areas including topographic, soil and climatic features have been previously described by Braverman *et al.* (1981). Two areas not included in that report are characterized as follows :

1. Southern Negev (fig. 1, zone no. 16) Hamada soil and coarse desert alluvium; in the mountainous area — desert stony land and Hamada soils of mountains (Ravikovitch, 1970). Seasonal temperatures ranging from 12-14°C in January to 30°C in August. Annual rainfall up to 50 mm (Roseman, 1970); desert climate (Köppen and Geiger, 1953).
2. Central Sinai foothills (fig. 1, zone no. 21). In the plain — recent alluvium sands, gravel, in the hills and mountainous area — limestone, dolomite chalk, Nubian sandstone. Average temperature of January : 8°C, of August : 28°C (Orni and Efrat, 1973). Annual rainfall about 32 mm (Israel Meteorological Service). Desert climate (Köppen and Geiger, 1953).

The numbers and distribution of domestic animals in Sinai and the Gaza strip were probably similar to that vaccinated in 1979 against Rift Valley Fever virus disease which are as follows : Gaza strip : sheep and goats 81,886 ; cattle 3,241 ; camels 3,105. Northern Sinai : sheep and goats 90,140 ; cattle 61 ; camels 8,874. Southern Sinai : sheep and goats 24,500 ; camels 200. Domestic fowl were kept by the Beduin throughout Sinai (Israel Ministry of Agriculture, Veterinary Services, 1980 annual report). The wild mammals of Sinai consist of mainly 12 species of rodents. Larger mammals are gazelles (*Gazella dorcas*), ibexes (*Esraa ibex*) and hyaxes (*Procapra capensis*). The carnivores are two species of foxes (*Vulpes vulpes*, *Vulpes rueppeli*), fennec (*Fennecus zerda*), wolf (*Canis lupus araba*), hyaena (*Hyaena hyaena*), African wild cat (*Felis lybica*) and caracal lynx (*Felis caracal*). The bird fauna consist of about 30 residing species and the reptile fauna about 20 species (Lakhis and Nezer, 1978 ; Paz, 1979).

Results

A total of 2,142 ticks : 1,784 adults and 358 nymphs were collected (table I), representing seven Ixodid and two Argasid species. The faunistic and geographical details are noted in table I.

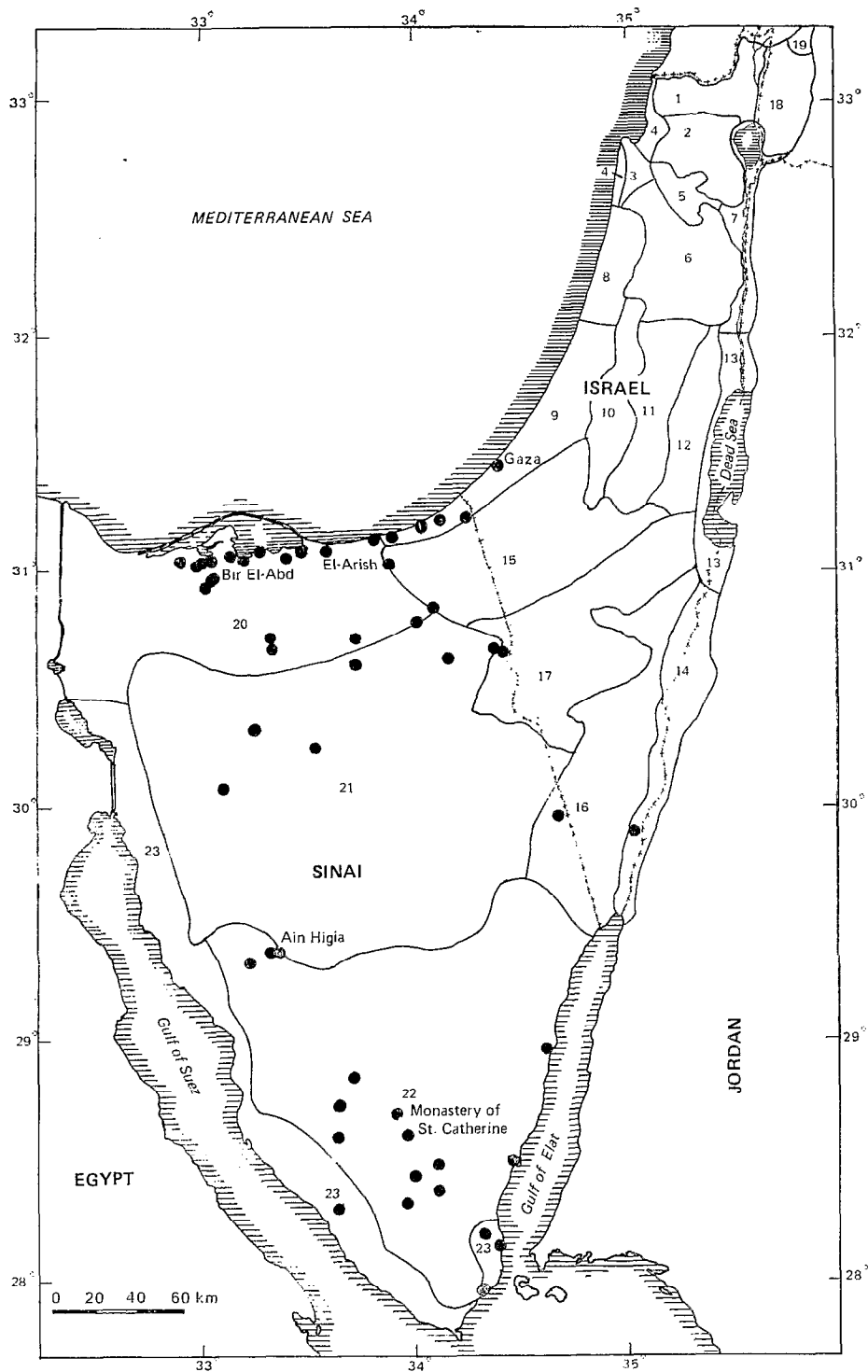


FIG. 1. — Collecting sites, in Israel, Gaza strip and Sinai peninsula. Key. 1. Upper Galilee. 2. Lower Galilee. 3. Carmel Ridge. 4. Northern Coastal Plain. 5. Valley of Yizre'el. 6. Samaria. 7. Jordan Valley and Southern Golan. 8. Central Coastal Plain. 9. Southern Coastal Plain. 10. Foothills of Judea. 11. Judean Hills. 12. Judean Desert. 13. Dead Sea Area. 14. Arava Valley. 15. Northern Negev. 16. Southern Negev. 17. Central Negev. 18. Golan Heights. 19. Mount Hermon. 20. Northern Sinai. 21. Central Sinai Foothills. 22. Sinai Mountains. 23. Southwestern Sinai.

TABLE I
Number of ticks collected in Sinai and adjoining areas of Israel from 1978 to 1979

Tick Species	Geographical Areas (No. corresponds to fig. 1)								Total
	20 Northern Sinai	21 Central Sinai Foothills	22 Sinai Mountains	23 South- western Sinai	9 Southern Coastal Plain	17 Central Negev	16 Southern Negev	14 Arava Valley	
<i>Hyalomma dromedarii</i>	874	29	177	35	21	12	12	0	1 160
<i>Hyalomma anatolicum excavatum</i>	353	16	18	0	35	16	1	3	442
<i>Hyalomma impeltatum</i>	74	3	2	0	43	0	0	0	122
<i>Hyalomma marginatum marginatum</i>	3	0	22	0	4	17	0	0	46
<i>Hyalomma schulzei</i>	4	0	1	0	0	0	0	0	5
<i>Hyalomma sinaiti</i>	0	0	1	0	0	0	0	0	1
<i>Rhipicephalus sanguineus</i>	0	0	31	0	92	0	0	0	123
<i>Argas persicus</i>	0	0	64	3	0	0	0	0	67
<i>Ornithodoros savignyi</i>	176	0	0	0	0	0	0	0	176
TOTAL	1 484	48	316	38	195	45	13	3	2 142

Camels were most frequently sampled (table II) and larger numbers of ticks were collected from them than from the other hosts. As a result the camel tick *H. dromedarii* was collected in the highest number. *H. sinaiti* was the rarest. All the *O. savignyi* were collected from the ground and all the *A. persicus* were collected from fowls. The largest numbers of *R. sanguineus* were collected from dog, then sheep and goat. The monthly fluctuation (table II) in the number of ticks is due to varying number of collections and varying number of hosts from which ticks were removed.

Discussion

The extent of the geographical area covered, the number of localities (fig. 1), and ticks sampled in this survey is rather large. Northern Sinai (zone no. 20) was quite regularly sampled during one year and therefore the results of the collection at least from camel (table II) are well based. That most *Hyalomma* ticks were collected from camels reflects besides host specificity the relative ease of

handling these animals by the Beduins. Camels are more easily approached than goats, sheep and donkeys.

Hyalomma dromedarii Koch was the dominant species in the samples. It was found throughout the year in almost all the localities (table I). Most of them were collected from camels and their association with that host had already been noted by Hoogstraal (1956). In Sinai Feldman-Muhsam (1960) found larvae extensively on the jerboa and gerbil and adults on camels. The following arboviruses have been isolated from specimens of this species removed from camels: Dera Ghazi Khan (Bunyaviridae) (Converse *et al.*, 1975); Quarantil (Quarantil group) (Converse and Moussa, 1982) and Dhori (Bunyaviridae) (Darwish and Hoogstraal, 1981).

Hyalomma anatolicum excavatum Koch. This species was found throughout most of the surveyed area, and was taken from camels almost throughout the year (table II). In Israel, 95% of *Hyalomma* spp. particularly on cattle was this species (Feldman-Muhsam and Saturen, 1961). In Sinai and adjoining areas, where cattle are practically absent,

TABLE II
Monthly collection of *Hyalomma* ticks from animals and on the ground from 1978 to 1979.

Month, Year (No. of trips)	Host or Site of Collection	Species of <i>Hyalomma</i>						Total <i>Hyalomma</i> ticks
		<i>H. drome- darii</i>	<i>H. anat. excavatum</i>	<i>H. impel- tatum</i>	<i>H. margi- natum marginatum</i>	<i>H. schul- zei</i>	<i>H. sinaii</i>	
October 1978 (2)	Camel	19	2	—	—	—	—	21
November 1978 (5)	Camel	302	80	22	2	—	—	406
December 1978 (1)	Camel	62	52	9	—	—	—	123
January 1979 (3)	Camel	344	33	12	—	4	—	393
February 1979 (2)	Camel	80	119	5	5	—	—	209
March 1979 (5)	Camel	118	56	11	10	1	—	196
	On the ground	12	1	—	—	—	—	13
	Total	130	57	11	10	1	—	209
April 1979 (4)	Camel	60	32	14	—	—	—	106
	Oryx	—	3	—	—	—	—	3
	Total	60	35	14	—	—	—	109
May 1979 (3)	Camel	15	30	6	3	—	—	54
June 1979 (11)	Camel	124	48	—	22	—	1	165
	On the ground	1	—	—	—	—	—	1
	Total	125	48	—	22	—	1	166
July 1979 (1)	Camel	19	16	42	4	—	—	81
September 1979 (1)	Camel	2	—	—	—	—	—	2
October 1979 (1)	On the ground	2	—	1	—	—	—	3
	Camel	1 145	438	121	46	5	1	1 756
TOTAL	Oryx	—	3	—	—	—	—	3
	On the ground	15	1	1	—	—	—	17
	Total	1 160	442	122	46	5	1	1 776

the camel is its primary host. Feldman-Muhsam (1960) previously found this tick in Sinai Mountains (fig. 1, zone no. 22). Adults were removed from camels and goats whereas the immature stages were taken on hares and small rodents. Ticks of this species are suspected of transmitting *Leptospira*

grippotyphosa in the jird *Meriones tristrami* (Hadani *et al.*, 1966).

Hyalomma impeltatum Schulze and Schlottko was collected most of the year from camels (table II) in Northern Sinai, Central Sinai Foothills, Sinai Mountains and the southern Coastal Plain (fig. 1,

zones no. 9, 20, 21, 22). In Israel it is a rare species and was collected mainly in the southern part of the country (Feldman-Muhsam, 1960). Since that record, it appears that this species has not been recorded in the southern part of Israel. Feldman-Muhsam (1960) found the immature stages of *H. impeltatum* on small rodents and hares at St. Catherine's Monastery (fig. 1, zone no. 22). In Egypt large numbers of nymphs were found on small rodents and lizards, and few on birds (Hoogstraal and Kaiser, 1958b and c). Hoogstraal (1956) noted that this species is common in many African and Asian countries, parasitizing a wide range of domestic animals. Crimean-Congo hemorrhagic fever virus has been isolated from this tick (Causey *et al.*, 1970). Dugbe virus (Bunyaviridae) and the unclassified Wanowrie virus have both been isolated from *H. impeltatum* taken from camels (Darwish and Hoogstraal, 1981).

Hyalomma marginatum marginatum Koch. This species was collected only in small numbers from camels (table II) in the southern Coastal Plain, Central Negev, Northern Sinai, and the Sinai Mountains (fig. 1, zones no. 9, 17, 20, 22). Feldman-Muhsam (1960) reported finding two males on camels, and three nymphs on hares in the Sinai Mountains. This species is widespread in Israel, where adults parasitize cattle and horses (Theodor and Costa, 1967). Immature stages are found on small rodents and birds (Hoogstraal and Kaiser, 1958b; Theodor and Costa, 1967). Ticks of this species have been found naturally infected with Bahig (Converse *et al.*, 1974) and Matruh viruses (Moussa *et al.*, 1974), both members of the Bunyaviridae. Crimean-Congo hemorrhagic fever virus (Bunyaviridae, *Nairovirus*) and *Babesia* species are also vectored by *Hyalomma marginatum marginatum* (Hoogstraal, 1979).

Hyalomma schulzei Olenov. Only five males (table II) were taken from camels, four in Northern Sinai and one in the Sinai mountains (fig. 1, zones no. 20, 22). In the same region, Feldman-Muhsam (1960) found adult ticks on camels and on the ground, and nymphs on small rodents. This species, the largest of all *Hyalomma* ticks, is specific to the camel (Feldman-Muhsam and Saturen, 1961). In Israel *H. schulzei* is found sporadically on cattle or on the soil (Theodor and Costa, 1967). According to Feldman-Muhsam (1960), *H. schulzei* is likely of Asiatic origin, and may have been carried by camel caravans through southern Israel into Sinai and Egypt.

Hyalomma sinaii Feldman-Muhsam. This spe-

cies was originally described in 1960 from one male and three females, taken from a goat at St. Catherine's Monastery (fig. 1, zone no. 22). In the present study (table II), a single male was taken from a camel at Ain-Sura, a locality in the Sinai mountains, which is situated 110 km northwest of the type locality.

Rhipicephalus sanguineus (Latreille). 123 ticks of this species were collected: from dogs (91 specimens), sheep (25 specimens) and goats (7 specimens) in the Southern Coastal Plain and Sinai Mountains (table I; fig. 1, zones no. 9, 22). In the Feldman-Muhsam's (1960) survey in Sinai, ticks were removed from domestic and wild animals, and nymphs from small mammals. This tick is very common everywhere in the Near East and attacks a wide range of domestic and wild animals (Hoogstraal, 1956). In Israel its main hosts are dogs (Feldman-Muhsam, 1956). The following arboviruses were isolated from this species: Crimean-Congo hemorrhagic fever virus (Bunyaviridae) (Hoogstraal, 1979); Wad Medani (Reoviridae) from ticks taken from sheep (Taylor *et al.*, 1966; Berge, 1975). Viruses causing canine hepatitis and human lymphocytic choriomeningitis were also isolated from this tick (Hoogstraal, 1973). Several rickettsial agents have been isolated from and/or transmitted by *Rhipicephalus sanguineus*: Rocky Mountain Spotted Fever (*Rickettsia rickettsi*) (Burgdorfer *et al.*, 1975; Hoogstraal, 1979); *Rickettsia conori* which causes Boutonneuse Fever, a disease which has been reported from Israel and other Mediterranean countries (Balashov, 1972; Goldwasser *et al.*, 1974) and *Rickettsia siberica* which causes Siberian tick typhus (Hoogstraal, 1981). Bovine anaplasmosis (*Anaplasma marginale*) can be mechanically transmitted by *R. sanguineus* (Stiles, 1939). *Ehrlichia canis* (Rickettsia) is transmitted by *R. sanguineus* (Philip and Burgdorfer, 1961; Burgdorfer and Varma, 1967), and as well as the usually nonpathogenic *Haemobartonella canis* (Rickettsia) that parasitized the erythrocytes of dogs in many parts of the world (Seneviratna *et al.*, 1973). Two spotted-fever-group rickettsiae of low pathogenicity have been isolated from *R. sanguineus* in Mississippi, U.S.A. (Burgdorfer *et al.*, 1975).

Tularemia, a bacterial disease caused by *Francisella tularensis* has been experimentally transmitted by *R. sanguineus* (Hoogstraal, 1956). The disease is also known from Israel (Gelman, 1961). In Israel, *R. sanguineus* is one of the species suspected of maintaining and occasionally transmitting

Leptospira to cattle and goats (Van der Hoeden, 1967).

Canine babesiosis (*Babesia canis*) known as malignant jaundice of dogs, is vectored by *R. sanguineus* in many parts of the world, including Asia (Shortt, 1973). Tick paralysis caused by *R. sanguineus* is known to occur in humans and also in dogs in Venezuela (Hoogstraal, 1956; Harwood and James, 1979).

Argas persicus Oken. Adults and nymphs of this species were found in poultry enclosures in the Sinai Mountains and Southwestern Sinai (fig. 1, zones no. 22, 23). This fowl parasite has become increasingly less common in Israel due to modern methods of poultry husbandry (Theodor and Costa, 1967). This species was not recorded in the study of Feldman-Muhsam (1960), most probably because fowl were not sampled.

Crimean-Congo hemorrhagic fever virus was isolated from this species in Uzbek SSR (Chumakov *et al.*, 1974; Hoogstraal *et al.*, 1979). *Argas persicus* was found to be associated in the transmission of fowlpox virus (Shirinov *et al.*, 1969) and the virus of Newcastle's disease (Petrov, 1972). Rehacek *et al.* (1977) reported Rocky Mountain Spotted Fever rickettsiae heavily infecting *A. persicus* in Armenia. *A. persicus* can be naturally infected with *Aegyptianella pullorum* and transmit the agent with the next bloodmeal (Gothe and Englert, 1978). The apathogenic *Rickettsia slovaca* has been isolated from *A. persicus* (Hoogstraal, 1981). *A. persicus* is a proven vector of a spirochetosis caused by *Borrelia anserina* (Marchoux and Selimbeni, 1903). According to Glukhov (1970) *Salmonella pullorum-gallorum* can be transtadially maintained as well as transmitted by the bite of *A. persicus*.

Ornithodoros savignyi (Audouin) was found at Bir-El-Abd in Northern Sinai (fig. 1, zone no. 20). 174 nymphs and two adults were collected from the ground. This species was collected in Israel only once, 54 years ago when two females were

removed from a camel in the Negev, in May 1929 (Theodor, 1932). In Sinai it was found by Theiler and Hoogstraal (1955) at El-Arish 78 km east from Bir-El-Abd, but it was not mentioned in the study of Feldman-Muhsam (1960). This tick attacks a wide range of domestic animals in Africa and Asia (Theiler, 1962). According to Hoogstraal (1956) this tick, called eyed tampan, is well known wherever it occurs and sometimes thousands of hungry eyed tampans can be seen under the trees questing for host. Hurlbut and Thomas (1960) reported that Quarantil virus can be propagated by serial passage in this tick. In South Africa it was shown that Wesselsbron virus can be passaged transtadially (Jupp and McIntosh, 1981). According to Howell *et al.* (1975), this tick possesses protein-like toxins in the saliva and mice may be killed from it. Eyed tampans can cause great suffering and even kill camels and cattle by exsanguination (Hoogstraal, 1956).

Hyalomma marginatum rufipes Koch was recorded by Feldman-Muhsam (1960), but not in the present survey. Viruses isolated from this species include Crimean-Congo hemorrhagic fever (Hoogstraal, 1979); Tete, Matruh (Hoogstraal, 1977) and Dugbe (Causey *et al.*, 1971) all belonging to the family Bunyaviridae. This tick is also a vector of *Rickettsia conori* (Hoogstraal, 1967) and of other pathogens infecting herbivores (Hoogstraal, 1979).

Rhipicephalus rossicus Yakimoff and Kohl-Yakimova was recorded by Feldman-Muhsam (1960), but not in the present survey. Strains of Crimean-Congo hemorrhagic fever were isolated from this species (Hoogstraal, 1979).

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REFERENCES

- BALASHOV (Y. S.), 1972. — Blood sucking ticks (Ixodoidea) vectors of diseases of man and animals. Nauka, Leningrad. Translated from Russian. *Miscell. Publ. Ent. Soc. Amer.*, 8, 5 : 1-319.
- BERGE (T. O.), (Ed.), 1975. — International catalogue of arboviruses including certain other viruses of vertebrates. 2nd ed., U.S. Department of Health, Education and Welfare, Atlanta, DHEW Publ. No. (CDC) 75-8301, 789 p.
- BRAVERMAN (Y.), DELECOLLE (J. C.), FRISH (K.), RUBINA (M.), and KREMER (M.), 1981. — New records of *Culicoides* species (Diptera : Ceratopogonidae) from Golan Heights, Israel and Sinai peninsula. *Isr. J. Entomol.*, 15 : 13-20.

- BURGDORFER (W.), SEXTON (D. J.), GERLOFF (R. K.), ANACKER (R. L.), PHILIP (R. N.) and THOMAS (L. A.), 1975. — *Rhipicephalus sanguineus*: vector of new spotted fever group rickettsia in the United States. *Infect. Immun.*, 12 : 205-210.
- BURGDORFER (W.) and VARMA (M. G. R.), 1967. — Transstadial and transovarial development of disease agent in arthropods. *Ann. Rev. Ent.*, 12 : 347-376.
- CAUSEY (O. R.), KEMP (G. E.), CASALS (J.), WILLIAMS (R. W.) and MADBOULY (M. H.), 1971. — Dugbe virus, a new arbovirus from Nigeria. *Niger. J. Sci.*, 5 : 41-43.
- CAUSEY (O. R.), KEMP (G. E.), MADBOULY (M. H.) and DAVID-WEST (T. S.), 1970. — Congo virus from domestic livestock, african hedgehog and arthropods in Nigeria. *Am. J. Trop. Med. Hyg.*, 19 : 846-850.
- CHUMAKOV (M. P.), ZAVODOVA (T. I.) and MART'YANOVA (L. I.) et al., 1974. — Detection of Crimean hemorrhagic fever virus in a few bloodsucking tick species collected in 1973 in Kirgiz SSR and Uzbek SSR : 35-39, in *Medical virology* (M. P. Chumakov, ed.), Trudy Inst. Polio. Virus. Entsef. Akad. Med. Nauk SSSR, 22, 2 (English translation : NAMRU-3, T 1112).
- CONVERSE (J. D.), HOOGSTRAAL (H.), MOUSSA (M. I.), CASALS (J.) and KAISER (M. N.), 1975. — Pretoria virus : A new African agent in the tickborne Dera Ghazi Khan (DGK) group and antigenic relationship within the DGK group. *J. Med. Entomol.*, 12 : 202-205.
- CONVERSE (J. D.), HOOGSTRAAL (H.), MOUSSA (M. I.), STEK (M.), Jr. and KAISER (M. N.), 1974. — Bahig virus (Tete group) in naturally and transovarially-infected *Hyalomma marginatum* ticks from Egypt and Italy. *Arch. Ges. Virusforsch.*, 46 : 29-35.
- CONVERSE (J. D.) and MOUSSA (M. I.), 1982. — Quarantil virus from *Hyalomma dromedarii* (Acari : Ixodoidea) collected in Kuwait, Iraq and Yemen. *J. Med. Entomol.*, 19 : 209-210.
- DARWISH (M.) and HOOGSTRAAL (H.), 1981. — Arboviruses infecting humans and lower animals in Egypt : a review of thirty years of research. *J. Egypt. Publ. Hlth. Ass.*, 56 : 112 p.
- FELDMAN-MUHSAM (B.), 1956. — Host specificity of *Rhipicephalus sanguineus* (Latreille) and *R. secundus* Feldman-Muhsam in Israel. *Bull. ent. Res.*, 47 : 43-45.
- FELDMAN-MUHSAM (B.), 1960. — The ticks of Sinai. *Bull. Res.ounc. of Israel*, 9B : 57-64.
- FELDMAN-MUHSAM (B.) and SATUREN (M.), 1961. — Notes on the ecology of Ixodid ticks of domestic stock in Israel. *Bull. Res. Counc. of Israel*, 10B : 53-61.
- GELMAN (A. C.), 1961. — The ecology of tularemia. In *Studies in Disease Ecology* (J. M. May, ed.), Hafner, New York, 89 p.
- GLUKHOV (V. F.), 1970. — Transmission of *Salmonella gallinarum-pullorum* by the tick *Argas persicus*. *Veterinariya*, 47 : 60-61.
- GOLDWASSER (R. A.), STEIMAN (Y.), KLINGBERG (W.), SWARTZ (T. A.) and KLINGBERG (M. A.), 1974. — The isolation of strains of rickettsiae of the spotted fever group in Israel and their differentiation from other members of the group by immunofluorescence methods. *Scand. J. Infect. Dis.*, 6 : 53-62.
- GOTHE (R.) and ENGLERT (R.), 1978. — Quantitative untersuchungen zur toxinwirkung von larven neoarktischer *Persicargas*. *Zbl. Vet. Med.*, B 25 : 122-133.
- HADANI (A.), DOLJANSKY (N.), VISHINSKY (Y.) and KAPELNER (S.), 1966. — Studies on the transmission of *Lep-tospira grippotyphosa* by hard ticks (Ixodoidea, Ixodidae). 1. Transmission by *Hyalomma excavatum*. *Refuah Vet.*, 23 : 128-132.
- HARWOOD (R. F.) and JAMES (M. T.), 1979. — Entomology in human and animal health. Macmillan Publ. Co. Inc., New York, 548 p.
- HOOGSTRAAL (H.), 1956. — African Ixodoidea. 1. Ticks of the Sudan. Res. Rep. NAMRU-3 : 1101 p.
- HOOGSTRAAL (H.), 1967. — Ticks in relation to human diseases caused by *Rickettsia* species. *Ann. Rev. Ent.*, 12 : 377-420.
- HOOGSTRAAL (H.), 1973. — Viruses and ticks. Chapter 18. In *Viruses and Invertebrates* (A. J. Gibbs, ed.), North Holland Press : 349-390.
- HOOGSTRAAL (H.), 1977. — Viruses and ticks from migrating birds : 27-50, in 2. Int. Arbkkolloq. Naturh. Infektionskr. Zent. Europ. Graz, February, 1976.
- HOOGSTRAAL (H.), 1979. — The epidemiology of tick-borne Crimean-Congo haemorrhagic fever in Asia, Europe and Africa. *J. Med. Entomol.*, 15 : 307-417.
- HOOGSTRAAL (H.), 1981. — Changing patterns of tickborne disease in modern society. *Ann. Rev. Ent.*, 26 : 75-99.
- HOOGSTRAAL (H.), CLIFFORD (C. M.), KEIRANS (J. E.) and WASSEF (H. Y.), 1979. — Recent developments in biomedical knowledge of *Argas* ticks (Ixodoidea : Argasidae). *Recent Adv. in Acarol.*, 2 : 269-278.
- HOOGSTRAAL (H.) and KAISER (M. N.), 1958a. — Observations on Egyptian *Hyalomma* ticks (Ixodoidea, Ixodidae). 1. Parasitism of lizards by nymphs. *Ann. Entomol. Soc. Amer.*, 51 : 7-12.
- HOOGSTRAAL (H.) and KAISER (M. N.), 1958b. — Observations on Egyptian *Hyalomma* ticks (Ixodoidea, Ixodidae). 2. Parasitism of migrating birds by immature *H. rufipes* Koch. *Ann. Entomol. Soc. Amer.*, 51 : 12-16.
- HOOGSTRAAL (H.) and KAISER (M. N.), 1958c. — Observations on Egyptian *Hyalomma* ticks (Ixodoidea, Ixodidae). 3. Infestation of greater gerbils, especially by immature *H. impeltatum*. S. and S. *Ann. Entomol. Soc. Amer.*, 51 : 17-19.
- HOOGSTRAAL (H.) and KAISER (M. N.), 1958d. — Observations on Egyptian *Hyalomma* ticks (Ixodoidea, Ixodidae). 4. Identity, distribution, and hosts of *H. franchinii* Tonelli-Rondelli (new combination). Systematic status of *H. tunesiacum* Sc. and Sc. and its subspecies. *Ann. Entomol. Soc. Amer.*, 51 : 397-400.
- HOOGSTRAAL (H.) and KAISER (M. N.), 1959. — Observations on Egyptian *Hyalomma* ticks (Ixodoidea, Ixodidae). 5. Biological notes and differences in identity of *H. anatolicum* and its subspecies *anatolicum* Koch and *excavatum* Koch among Russian and other workers. Identity of *H. lusitanicum* Koch. *Ann. Entomol. Soc. Amer.*, 52 : 243-261.
- HOOGSTRAAL (H.), SALAH (A. A.) and KAISER (M. N.), 1954. — Summary of the known distribution and biology of *Ornithodoros erraticus* (Lucas, 1849) (Ixodoidea, Argasidae) in Egypt. *J. Egypt. Publ. Hlth. Ass.*, 29 : 127-138.
- HOWELL (C. J.), NEITZ (A. W. H.) and POTGIETER (D. J. J.), 1975. — Some toxic, physical and chemical properties of the oral secretion of the sand tampan, *Ornithodoros savignyi* Audouin (1827). *Onderstepoort J. Vet. Res.*, 42 : 99-102.
- HURLBUT (H. S.) and THOMAS (J. I.), 1960. — The experimental host range of the arthropod-borne animal viruses in arthropods. *Virology*, 12 : 391-407.
- JUPP (P. G.) and McINTOSH (B. M.), 1981. — Ticks and arthropod-borne viruses in South Africa : 177-180, in

- Tick biology and control (G. B. Whitehead and Y. D. Gibson., ed.), Grahamstown, S. Africa.
- KÖPFEN (W.) and GEIGER (R.), 1953. — Die Klimate der Erde (Map). Neubearbeitung 1953 von R. Geiger und W. Pohl, J. Perthes, Gotha.
- LAKHIS (I.), and NEZER (R.) 1978. — Central Sinai : El Tih Desert. Publ : The Kibbutz Movements, Geography Unit, 154 p.
- MARCHOUX (E.) and SELIMBENI (A.), 1903. — La spirillose des poules. *Ann. Inst. Pasteur*, 17 : 569-580.
- MOREL (P. C.) and VASSILIADES (G.), 1962. — Les *Rhipicephalus* du groupe *sanguineus* : espèces africaines (Acariens : Ixodoidea). *Rev. Elev. Méd. vét. Pays trop.*, 15 : 343-386.
- MOUSSA (M. I.), IMAM (I. Z. E.), CONVERSE (J. D.) and KARAMANY (B. E.), 1974. — Isolation of Matruh virus from *Hyalomma marginatum* ticks in Egypt. *J. Egypt. Publ. Hlth. Ass.*, 49 : 341-348.
- ORNI (E.) and EFRAT (E.), 1973. — Geography of Israel. Third Revised Edition. Israel Universities Press, Jerusalem, 551 p.
- PAZ (U.), 1979. — The Fauna of Sinai. Israel Guide. Sinai and the Gaza Plain. Publ. : Ketter, Israel Ministry of Defence : 25-30.
- PETROV (D.), 1972. — Role of *Argas persicus* in the epidemiology of Newcastle disease. *Vet. Med. Nauki*, 9 : 13-17.
- PHILIP (C. B.) and BURGDORFER (W.), 1961. — Arthropod vectors as reservoirs of microbial disease agents. *Ann. Rev. Ent.*, 6 : 391-412.
- RAVIKOVITCH (S.), 1970. — Soil map. In Atlas of Israel. Edit. Ministry of Labour (Survey of Israel).
- REHACEK (J.), URVOLGYI (J.) and KOVAKOVA (E.), 1977. — Massive occurrence of rickettsiae of the spotted fever group in fowl tamarin, *Argas persicus* in the Armenian SSR. *Acta virol.*, 21 : 431-438.
- ROSEMAN (N.), 1970. — Climate. In Atlas of Israel. Edit. Ministry of Labour (Survey of Israel).
- SENEVIRATNA (P.), WEERASINGHE (N.) and ARIYADASA (S.), 1973. — Transmission of *Haemobartonella canis* by the dog tick, *Rhipicephalus sanguineus*. *Res. Vet. Sci.*, 14 : 112-114.
- SHIRINOV (F. B.), FARZALIEV (I. A.), ALEKPEROV (Y. G.) and IBRAGIMOVA (A. A.), 1969. — The transmission of the virus of fowl-pox by *Argas persicus*. *Veterinariya*, 46 : 37-39.
- SHORTT (H. E.), 1973. — *Babesia canis* : the life cycle and laboratory maintenance in its arthropod and mammalian hosts. *Int. J. Parasitol.*, 3 : 119-148.
- STILES (G. W.), 1939. — Anaplasmosis in cattle. U. S. Dept. Agr. Circ. no. 154 (revised), 10 p.
- TAYLOR (R. M.), HOOGSTRAAL (H.) and HURLBUT (H. S.), 1966. — Isolation of a virus (Wad Medani) from *Rhipicephalus sanguineus* collected in Sudan. *Am. J. Trop. Med. Hyg.*, 15 : 75.
- THEILER (G.), 1962. — The sandtaman *Ornithodoros savignyi* : an ecological puzzle and an economic problem. *Ann. Cape Prov. Mus.*, 2 : 212-222.
- THEILER (G.) and HOOGSTRAAL (H.), 1955. — The identity of *Ornithodoros savignyi* (Audouin, 1927) and *O. pavimentosus* Neumann, 1901 (Ixodoidea, Argasidae). *J. Parasit.*, 41 : 245-247.
- THEODOR (O.), 1932. — Über *Ornithodoros coniceps* Canestrini in Palästina. *A. Parasitenk.*, 5 : 69-79.
- THEODOR (O.) and COSTA (M.), 1967. — A survey of the parasites of wild mammals and birds in Israel. Part one. Ectoparasites. The Israel Academy of Science and Humanities, Jerusalem, 117 p.
- VAN DER HOEDEN (J.), 1967. — Twenty years of epidemiological research on leptospirosis in Israel. *Refuah Vet.*, 24 : 158-165.