

Wildlife Arthropods of Karnataka with Special Reference to KFD Endemic Area of Shivamogga District: Those Parasitic on Small and Large Mammals

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Abstract

Wild animals in forest area and those in captivity in Karnataka State are found infested with many harmful arthropods such as ticks, insects and mites. Following the discovery of the tick vectors for Kyasanur Forest disease in Shivamogga district, systematic studies have been carried out on the specific identification of ticks of various mammals and birds. Altogether 37 species of ticks have been recognized which include one species each of the genera *Boophilus*, *Dermacentor* and *Nosomma*, two species each of *Argas*, *Ornithodoros* and *Hyalomma* and three species each of *Amblyomma*, *Aponomma*, *Ixodes* and *Rhipicephalus* and 16 species of *Haemaphysalis*. Among the captive mammals, ticks, *Rhipicephalus haemaphysaloides* from Indian elephant and *Ornithonyssus bursa* from lion, and the lice, *Haematomyzus elephantis* from Indian elephant and *Haematopinus* from tiger, the flea, *Ctenocephalides felis* from panther, hippoboscids from spotted deer and *Demodex* mites from tiger are the different ectoparasites recorded for the first time from Karnataka. Out of 20 species of tabanid flies belonging to six genera of Rajiv Gandhi National Park, three species are reported for the first time from south India while seven are new records from Karnataka. Except for a single *Aedes albopictus*, no other mosquitoes were traced from the KFD area. A myiasis producing calliphorid fly, *Phaenicia cuprina* confined to hilly areas was recognized.

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Received: 21/12/2016

Accepted: 25/12/2016

Keywords: Large Wild Mammals, Karnataka, Parasitic Arthropods, Ticks, Insects and Mites, Seasonal Abundance.

1. Introduction

The ectoparasites of wild and captive animals consist of various acarines and insects of the phylum Arthropoda. Among acarines, the tick parasites of wild animals had gained significant importance after the discovery of their role as vectors of Kyasanur Forest Disease (KFD) in Shivamogga district of Karnataka during 1957. Before this important discovery, only 50 species of ticks were known from India. But the present record is 106 species accommodating 12 genera of two families, i.e. Ixodidae and Argasidae which forms about one-eighth of a total of 820 tick species known from all over the world (Geevarghese *et al.*, 1997). Apart from ticks, prevalence of insect parasites of importance to wild animals under captivity is also known. This review highlights some of the important findings on the existence of various ectoparasites of small and large wild mammals of Karnataka State.

2. Historical Background

The earliest information on ticks from Karnataka State was of Warburton (1913) who established the occurrence of *Haemaphysalis* species in tiger in Kadra, Belagavi district. His study based on a single female specimen taken from a tiger in November 1910 by N. B. Kinnear after whom the species was named as *H. kinneari*. Nuttall and Warburton (1915) described this species with illustrations along with male and female specimen of *H. spinigera* collected from tiger in Kadra. Sharif (1929) dealt the revision of Indian Ixodidae including those occurring in Karnataka region. Thereafter not much contribution was made on ticks of Karnataka till the later part of fifties when tick study obtained great momentum following the repeated isolation of the flavivirus of KFD from the larvae and nymphs of *H. spinigera* (Work, 1957; 1958; Trapido *et*

al. 1959). Then more attention was concentrated on all the species of *Haemaphysalis* to know their role in disease transmission.

3. Methodology

Various methods were employed for tick collection from wild animals such as trapping, caging, baiting and other means including hand picking of ticks from the dead and sick ones (Rajagopalan *et al.*, 1968a; 1968b). Apart from the ticks found on the body of animals, dormant and developing stages of ticks found on the forest floor hidden under the cover of fallen leaves during the dry months were collected by flag dragging taking all possible precautions to avoid tick bites.

4. Species of Ticks

Till 1964, the original description of most of the species of ticks was based on a few adults, but the larvae, nymphs and many of adult males and females were not described in detail. But Trapido *et al.* (1964b) prepared a full-fledged key with illustrations for the identification of all these stages of *Haemaphysalis* ticks based on their collection from the KFD endemic area, providing due recognition of other species recorded elsewhere in South India. Ticks collected from the body of various species of wild mammals, reptiles and birds as well as their developmental stages from the forest floor were utilized for the identification of different species along the recognition of new species (Trapido and Hoogstraal, 1964; Trapido *et al.*, 1964a; 1964b; Rajagopalan *et al.*, 1968a; 1968b; Bhat, 1989; Geevarghese and Mishra, 2011 and others). They are belonged to 11 genera accommodating nearly 37 species – one species each of the genera *Boophilus*, *Dermacentor* and *Nosomma*, two species each of *Argas*, *Ornithodoros* and *Hyalomma* and three species each of *Amblyomma*, *Aponomma*, *Ixodes* and *Rhipicephalus* and 16 species of *Haemaphysalis*. The ticks belonging to various genera and species are listed in Table 1. The salient features of the key developed by Trapido *et al.* (1964a) for the identification of *Haemaphysalis* ticks of South India are provided below discussion.

5. Identification of *Haemaphysalis*

Larvae are identified mainly by observing the parts of the dorsal or ventral side of the capitulum as well as the coxae and trochanters of the first pair of legs. Further they are divided first into two major groups based on the presence or absence of the dorsal cornua. Those with cornua show various graded series from strong cornua which is as much as half the length of the dorsal basis capituli, to others with weak cornua.

In all the species, the ventral surface of palpal segment 3 is provided with a projection or spur and its length and shape provides important recognizing features. Similarly the coxa I in all the species show a posteriorly directed spur or ridge-like projection, the extent of its development is taken into criterion.

The salience of nymphs is broad, flared or less well-developed. Very useful character in separation of nymphs into two major groups is the outline of the palps, viewed either dorsally or ventrally. It is broader in eight species (*H. spinigera*, *H. leachi*, *H. megalaimae*, *H. centropi*, *H. papuana kinneari*, *H. cornigera shimoga*, *H. kysanurensis* and *H. minuta*) but it is narrower in six species (*H. aculeata*, *H. cuspidata*, *H. turturis*, *H. bispinosa*, *H. intermedia* and *H. wellingtoni*) giving the capitulum a compact appearance. The spur of the ventrobasal of palpal segment 2 varies in sharpness or overlapping of the margin is noticed. The length of the ventral spur of palpal segment 3 in relation to 2 is an important character. The internal margin of palpal segment 2 is provided with one seta dorsally, but their number differs ventrally.

In adult males, the ventrobasal external margin of palpal segment 2 is rounded or developed into prominent spur or projection. The coxa IV, if provided, has elongated sharp spur/s exceeding length of other coxal spurs. In females the salience is broad and the palpal segment 2 is broader than long or otherwise. In the palpal segment 3 is having ventral retrovert spur which is prominent or reduced (Trapido *et al.*, 1964b).

6. Ticks of Small and Large Mammals

The immature or the adult forms of ixodid ticks such as *Haemaphysalis*, *Boophilus*, *Dermacentor*, *Amblyomma*, *Ixodes* and *Rhipicephalus* were recorded from various wild mammals. About 90% of ticks collected were constituted by three species of *Haemaphysalis* namely, *H. spinigera*, *H. turturis* and *H. papuana kinneari* and the rest 10% by others (Bhat, 1989). The specific identification of a few ticks is yet to be done. The available data indicate that several species of ticks other than *H. spinigera* can amplify and transmit the virus of KFD (Mourya and Yadav, 2016). Information on the species of ticks of small and large wild mammals of Karnataka is presented in Table 2.

6.1 Non-Human Primates

The two simian monkeys, the langur (*Presbytis entellus*) and the bonnet macaque (*Macaca radiata*) are present in KFD endemic area of Shivamogga, the former being more abundant than the latter. Ticks were usually found on the ears, face, soft skin at the base of the fingers and toes, in the axillae and groin and about

Table 1: Species of ticks recorded from KFD endemic area, Shivamogga

No.	Species of ticks	No.	Species of ticks
1	<i>Argas robertsi</i>	22	<i>H. kysanurensis</i>
2	<i>A. vespertilionis</i>	23	<i>H. leachi</i>
3	<i>Amblyomma</i> sp.	24	<i>H. megalaimae</i>
4	<i>A. integrum</i>	25	<i>H. minuta</i>
5	<i>A. javanense</i>	26	<i>H. spinigera</i>
6	<i>A. testudinarium</i>	27	<i>H. turturis</i>
7	<i>Aponomma gervaisi</i>	28	<i>H. wellingtoni</i>
8	<i>A. leave</i>	29	<i>Hyalomma anatolicum anatolicum</i>
9	<i>A. lucasi</i>	30	<i>H. marginatum issaci</i>
10	<i>Boophilus microplus</i>	31	<i>Ixodes ceylonensis</i>
11	<i>Dermacentor auratus</i>	32	<i>I. vespertilionis</i>
12	<i>Haemaphysalis</i> sp.	33	<i>I. petauristae</i>
13	<i>H. aculeata</i>	34	<i>I. radfordi</i> (to be confirmed)
14	<i>H. bispinosa</i>	35	<i>Nosomma monstrosus</i>
15	<i>H. canestrinii</i>	36	<i>Ornithodoros chiropterophilia</i>
16	<i>H. cornigera shimoga</i>	37	<i>O. piriformis</i>
17	<i>H. cuspidata</i>	38	<i>Rhipicephalus</i> sp.
18	<i>H. donitzi</i>	39	<i>R. haemaphysaloides</i>
19	<i>H. indica</i>	40	<i>R. ramachandrai</i>
20	<i>H. intermedia</i>	41	<i>R. sanguineus</i>
21	<i>H. papuana kinneari</i>		

Table 2: Ticks and their small and large mammalian hosts in the forest area of Shivamogga, Karnataka

No.	Tick species	Host animals
1	<i>Haemaphysalis. aculeata</i>	Bonnet monkey, langur monkey, spotted deer, mouse deer, cattle, buffalo
2	<i>H. bispinosa</i>	Bonnet monkey, langur monkey, tiger, jackal, leopard, dog, jungle cat, spotted deer, cattle, buffalo
3	<i>H. cornigera shimoga</i>	Indian bison, sambar deer
4	<i>H. cuspidata</i>	Bonnet monkey, leopard, panther, spotted deer, mouse deer
5	<i>H. intermedia</i>	Bonnet monkey, leopard, jackal, jungle cat, mouse deer, wild boar
6	<i>H. kysanurensis</i>	Bonnet monkey, langur, jackal, wild boar, wild dog, mouse deer
7	<i>H. leachi</i>	Jackal
8	<i>H. indica</i>	Leopard, jackal, fox, jungle cat, large civet cat
9	<i>H. papuana kinneari</i>	Bonnet monkey, langur monkey, tiger, leopard, panther, Indian bison, wild boar, wild dog
10	<i>H. spinigera</i>	Bonnet monkey, langur monkey, panther, jungle cat, wild dog, Indian bison, mouse deer
11	<i>H. turturis</i>	Bonnet monkey, langur, leopard, panther, jungle cat, deer, wild dog, wild boar
12	<i>H. wellingtoni</i>	Bonnet macaque, langur, mouse deer, cattle, buffalo,
13	<i>Boophilus microplus</i>	Deer, camel, Indian bison
14	<i>Rhipicephalus</i> sp.	Bonnet monkey, langur, tiger, lion, panther, wild boar
15	<i>R. haemaphysaloides</i>	Bonnet monkey, langur, tiger, panther, wild dog, Indian bison, wild boar, deer, spotted deer
16	<i>R. sanguineus</i>	Panther
17	<i>Dermacentor auratus</i>	Bonnet monkey, langur, leopard, panther, wild dog, spotted deer, wild boar
18	<i>Ixodes petauristae</i>	Bonnet monkey, langur, panther, wild dog, spotted deer, mouse deer
19	<i>I. ceylonensis</i>	Langur, leopard, jungle cat
20	<i>A. integrum</i>	Sambar deer, wild boar
21	<i>A. testudinarium</i>	Sambar deer, Indian bison, wild boar
22	<i>Nosomma monstrosus</i>	Wild boar, buffalo

the buttock. Of the 232 langurs examined during the period 1957-61, 85 (36.64%) were found positive for ticks and of the 125 bonnet monkeys, 42 (33.60%) were positive. Of the total 891 ticks collected from both the species of monkeys, 78% belonged to the

genus *Haemaphysalis*, 20% belonged to *Dermacentor* and 2% were made up by the genera *Amblyomma*, *Ixodes* and *Rhipicephalus*. Of all the *Haemaphysalis*, 90% were *H. spinigera*. The predominant stages noticed were larvae and nymphs suggesting that

monkeys are not the preferred hosts of adult ticks. *Ixodes* ticks are the rarest species seen on monkeys and only 15 specimens were obtained in a single collection (Trapido *et al.* (1964a). The results of another two years survey conducted from November 1965 to November 1967 by Rajagopalan and Anderson (1971) indicated that *H. spinigera* and *H. turturis* constituted 85% of all the ticks taken from the two species of monkeys. In langur, 168 (70.2%) of the 239 and in bonnet macaque 117 (74.5%) of the 157 monkeys were infested mostly by larvae followed by nymphs and few adults. The finding of comparatively more numbers of adult *H. turturis* than *H. spinigera* in this survey was considered significant. Surprisingly only one adult *H. intermedia* was recovered. The maximum average tick load of ten monkeys was 577 and two animals carried over 1100 ticks each. The ticks borne by non-human primates of the KFD endemic area by various authors since 1958 are presented in Table 3.

6.2 Carnivores and Herbivores

Among the carnivores of the KFD area, panther served as good host for the adults of *H. turturis* and larval stages of *H. spinigera*, *H. papuana kinneari*, *D. auratus* and *Amblyomma* sp. Of the three *Rhipicephalus* species, only two, *R. sanguineus* and *R. haemaphysaloides* were observed on small and large mammals. *R. haemaphysaloides* was recorded from panther and wild dog (Rajagopalan *et al.*, 1968b). Renukaprasad *et al.* (2011) reported the recovery of this tick from tigers stationed at Bannerghatta Biological Park (BBP), Bengaluru. *Ornithonyssus bursa* was recorded from lion cubs of Mysore Zoo (Anon 2012-13). The rare occurrence of *R. sanguineus* was also reported from leopard from the forest of Chikkamagaluru by Ananda *et al.* (2016). In herbivorous animals, *R. haemaphysaloides* was recorded from Indian bison, spotted deer, wild boar (Rajagopalan *et al.*, 1968b). This species was also reported from a captive Indian elephant for the first time by Jagannath *et al.* (1979) from Kodagu. Among *Hyalomma* species, *H. marginatum isaaci* and *H. anatolicum anatolicum* were observed on wildlife of KFD area (Bhat, 1989).

It was found that certain ticks are host specific and others have multi-hosts. According to Rajagopalan *et al.* (1968b) *H. cornigera shimoga* adults are host specific to Indian bison (*Bos gaurus*). Later Bhat and Srinivasan (1981) collected 18 nymphs and 44 adults of *H. intermedia* from a jungle cat, 37 adults of *H. cornigera shimoga* from sambar deer and 310 adults of *H. turturis*, 22 adults of *H. kinneari* and six adults of *D. auratus* from wild boar showing host predilection. Cattle grazing in forest area are acted as efficient host of *H. spinigera* adults, and sheep and goats carry *H.*

intermedia and *H. bispinosa*. The ectoparasites recorded from various carnivorous and herbivorous wild mammals are presented in Table 4 and 5 respectively.

7. Seasonal Activities of Ticks of Large Mammals

The activity of most of the adult ticks synchronizes with monsoons depending on humidity and temperature. Most of the *Haemaphysalis* species have a definite stage-wise seasonal activity (Fig 1). Ticks in general deposit eggs in clusters on the forest floor throughout the rainy season. The larval population builds up in the monsoon months and remains dormant under litter. They become suddenly active when the litter dries up during post-monsoon months of October and November and reach the peak in November and December and gradually declines thereafter. Depending on gradual reduction of humidity and the nymphs emerge and develop in pre-monsoon period from about January to May. The adults of *Haemaphysalis* including *H. spinigera* become active after a few monsoon rains and showed an increase in the number from May. They reach their peak during July and August and gradually start declining in September. However, the duration for each developmental stage of tick may vary depending on the climatic factors conducive to tick species. Adult population builds up simultaneously even during the period of nymphal activity, but remains dormant until the commencement of monsoon showers. The span between each stage is restricted to one season and mostly the life-cycle is completed by one year. Thus overlapping of two adult population was also observed (Bhat, 1989; Geevarghese and Mishra, 2011).

7.1 Periodicity of Dropping

Ticks exhibited periodicity in their engorgement by feeding on their hosts which have great influence in their dropping, though this period showed variation from species to species. This phenomenon was observed in *H. cuspidata*, *H. kysanurensis*, *H. shimoga*, *H. wellingtoni*, *D. auratus* and *R. haemaphysaloides* (Bhat, 1989). All stages of ticks engorged by sucking bulk of blood of their hosts and they exhibited two phases of engorgement. The first phase was of longer duration and ticks showed only slight dorso-lateral bulging while during the second phase of duration of 4-8 hours, they attained their maximum size. A biphasic feeding habit was observed in *H. spinigera* and *Ixodes* sp. of ticks in KFD area and the mechanism involved for this diurnal rhythm is not fully understood.

Table 3: Ixodid ticks of non-human primates recorded from the KFD areas by different workers

Host	Species of ticks	Reference
Bonnet macaque (<i>Macaca radiata</i>)	<i>Haemaphysalis spinigera</i>	Work (1958)
Bonnet macaque	<i>H. spinigera</i> , <i>Ixodes</i> sp.	Trapido <i>et al.</i> (1959)
Bonnet macaque	<i>H. spinigera</i> , <i>H. turturis</i> , <i>H. kinneari</i> , <i>H. wellingtoni</i> , <i>H. minuta</i> , <i>H. bispinosa</i> , <i>H. aculeata</i> , <i>H. cuspidata</i> , <i>H. kysanurensis</i> , <i>Amblyomma</i> sp., <i>Dermacentor auratus</i> , <i>Rhipicephalus</i> sp., <i>R. haemaphysaloides</i> , <i>Ixodes</i> sp.	Trapido <i>et al.</i> (1964a)
Bonnet macaque	<i>H. spinigera</i> , <i>H. turturis</i> , <i>H. kinneari</i> , <i>H. kysanurensis</i> , <i>H. bispinosa</i> , <i>H. cuspidata</i> , <i>H. intermedia</i> , <i>I. petauristae</i> , <i>I. ceylonensis</i> , <i>D. auratus</i> , <i>Amblyomma</i> sp., <i>Rhipicephalus</i> sp.	Rajagopalan and Anderson (1971)
Bonnet macaque	<i>H. spinigera</i> , <i>H. turturis</i> , <i>H. kinneari</i> , <i>H. kysanurensis</i> , <i>H. wellingtoni</i> , <i>H. bispinosa</i> , <i>H. cuspidata</i> , <i>H. aculeata</i> , <i>I. petauristae</i> , <i>D. auratus</i> , <i>Amblyomma</i> sp., <i>Rhipicephalus</i> sp.	Srinivasan <i>et al.</i> (1989)
Bonnet macaque	<i>H. aculeata</i>	Geevarghese <i>et al.</i> (2009)
Langur (<i>Presbytis entellus</i>)	<i>H. spinigera</i> , <i>H. turturis</i> , <i>H. kinneari</i> , <i>H. wellingtoni</i> , <i>H. minuta</i> , <i>H. bispinosa</i> , <i>H. aculeata</i> , <i>H. cuspidata</i> , <i>H. kysanurensis</i> , <i>Amblyomma</i> sp., <i>D. auratus</i> , <i>Rhipicephalus</i> sp., <i>R. haemaphysaloides</i> , <i>Ixodes</i> sp.	Trapido <i>et al.</i> (1964a)
Langur	<i>H. spinigera</i> , <i>H. turturis</i> , <i>H. kinneari</i> , <i>H. kysanurensis</i> , <i>H. bispinosa</i> , <i>H. wellingtoni</i> , <i>I. petauristae</i> , <i>D. auratus</i> , <i>Amblyomma</i> sp., <i>Rhipicephalus</i> sp.	Rajagopalan and Anderson (1971)
Langur	<i>H. spinigera</i> , <i>H. turturis</i> , <i>H. kinneari</i> , <i>H. kysanurensis</i> , <i>H. wellingtoni</i> , <i>H. bispinosa</i> , <i>H. cuspidata</i> , <i>H. aculeata</i> , <i>I. petauristae</i> , <i>D. auratus</i> , <i>Amblyomma</i> sp., <i>Rhipicephalus</i> sp.	Srinivasan <i>et al.</i> (1989)
Langur	<i>H. aculeata</i>	Geevarghese <i>et al.</i> (2009)
Monkeys	<i>H. spinigera</i> , <i>H. turturis</i> , <i>H. wellingtoni</i> , <i>H. kinneari</i> , <i>H. cuspidata</i> , <i>H. aculeata</i>	Geevarghese <i>et al.</i> (1997)

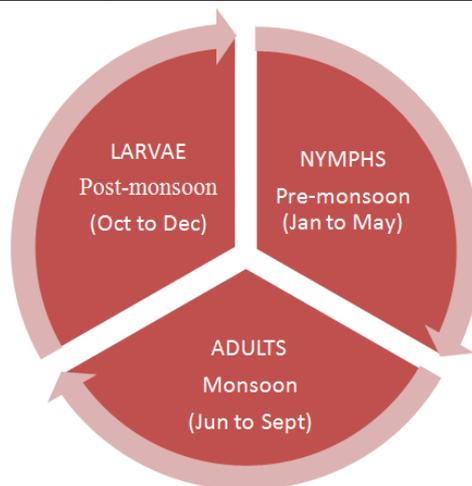


Fig 1: Development of larvae, nymphs and adults of *Haemaphysalis* ticks in the endemic area of KFD

Table 4: Ectoparasites of wild carnivores recorded in Karnataka by different workers

Location	Host	Arthropod	Reference
Kadra, Belagavi	Tiger (<i>Panthera tigris</i>)	<i>Haemaphysalis kinneari</i>	Warburton (1913)
Kadra, Belagavi	Tiger	<i>H. spinigera</i>	Nuttall and Warburton (1915)
Kyasanur Forest (KF), Shivamogga	Tiger	<i>H. kinneari</i>	Geevarghese <i>et al.</i> (1997)
Bannerghatta Biological Park (BBP), Bengaluru	Tiger	<i>Rhipicephalus haemaphysaloides</i>	Renukprasad <i>et al.</i> (2011)
BBP, Bengaluru	Tiger	<i>Haematopinus</i> sp. (lice)	Renukprasad <i>et al.</i> (2011)
BBP, Bengaluru	Tiger	<i>Demodex</i> sp. (mite)	Renukprasad <i>et al.</i> (2011)
Mysore Zoo	Lion cub (<i>Panthera leo</i>)	<i>Ornithonyssus bursa</i>	Anon (2012-13)
KF, Shivamogga	Panther (<i>Panthera pardus</i>)	<u>In order of intensity</u> <i>H. turturis</i> , <i>H. spinigera</i> , <i>H. kinneari</i> , <i>Dermacentor auratus</i> , <i>Amblyomma</i> sp., <i>R. haemaphysaloides</i> , <i>Rhipicephalus</i> sp., <i>H. bispinosa</i> , <i>H. cuspidata</i> <i>Ixodes petauristae</i>	Rajagopalan <i>et al.</i> (1968a)
KF, Shivamogga	Panther	<u>In order of intensity</u> <i>H. turturis</i> , <i>H. spinigera</i>	Rajagopalan (2008)
KF, Shivamogga	Leopard cat (<i>Felis bengalensis</i>)	<u>In order of intensity:</u> <i>Amblyomma</i> sp., <i>D. auratus</i> , <i>H. kinneari</i> , <i>H. turturis</i> , <i>H. kyananurensis</i> , <i>H. intermedia</i> , <i>I. ceylonensis</i>	Rajagopalan <i>et al.</i> (1968b)
KF, Shivamogga	Leopard	<i>H. cuspidata</i>	Geevarghese <i>et al.</i> (1997)
KF, Shivamogga	Leopard	<i>H. aculeata</i>	Geevarghese <i>et al.</i> (2009)
Forest, Chikkamagaluru	Leopard	<i>R. sanguineus</i>	Ananda <i>et al.</i> (2016)
KF, Shivamogga	Jungle cat (<i>Felis chaus</i>)	<u>In order of intensity:</u> <i>H. turturis</i> , <i>H. spinigera</i> , <i>I. ceylonensis</i> , <i>H. intermedia</i>	Rajagopalan <i>et al.</i> (1968b)
KF, Shivamogga	Jungle cat	<i>H. intermedia</i>	Bhat and Sreenivasan (1981)
KF, Shivamogga	Wild mammals	<i>H. turturis</i>	Rajagopalan <i>et al.</i> (1968b)
KF, Shivamogga	Jackal (<i>Canis aureus</i>)	<i>H. leachi</i>	Trapido <i>et al.</i> (1964b)
KF, Shivamogga	Jackal	<i>H. kyananurensis</i>	Rajagopalan (1972)
KF, Shivamogga	Wild dog (<i>Coun alpines</i>)	<u>In order of intensity:</u> <i>H. turturis</i> , <i>H. kinneari</i> , <i>Amblyomma</i> sp., <i>D. auratus</i> , <i>H. spinigera</i> , <i>H. kyananurensis</i> , <i>R. haemaphysaloides</i> <i>I. petauristae</i>	Rajagopalan <i>et al.</i> (1968b)
KF, Shivamogga	Wild dog	<i>H. kyananurensis</i>	Geevarghese <i>et al.</i> (1997)
KF, Shivamogga	Wild dog	<u>In order of intensity</u> <i>H. turturis</i> , <i>H. spinigera</i> <i>H. kyananurensis</i>	Rajagopalan (2008)
KF, Shivamogga	Hyena	<i>A. testudinarium</i>	Geevarghese <i>et al.</i> (1997)
KF, Shivamogga	Carnivores	<i>H. turturis</i>	Geevarghese <i>et al.</i> (1997)

Table 5: Ectoparasites of herbivorous wild mammals recorded in Karnataka by different workers

Location	Host	Arthropod	Reference
Kyasanur Forest (KF), Shivamogga	Indian bison/ Gaur (<i>Bos gaurus</i>)	<u>In order of intensity</u> <i>Haemaphysalis spinigera</i> , <i>H. cornigera shimoga</i> , <i>Boophilus microplus</i> , <i>Rhipicephalus haemaphysaloides</i> , <i>Amblyomma</i> sp., <i>A. testudinarium</i>	Rajagopalan <i>et al.</i> (1968b)
KF, Shivamogga Kodagu (Coorg)	Indian bison Indian elephant (<i>Elephas maximus</i>)	<i>H. cornigera shimoga</i> <i>R. haemaphysaloides</i>	Geevarghese <i>et al.</i> (1997) Jagannath <i>et al.</i> (1979)
Bannerghatta Biological Park (BBP), Bengaluru KF, Shivamogga	Indian elephant Spotted deer (<i>Axis axis</i>)	<i>Haematomyzys elephantis</i> (lice)	Renukaprasad <i>et al.</i> (2011)
KF, Shivamogga KF, Shivamogga KF, Shivamogga	Spotted deer Spotted deer Sambar deer (<i>Cervus unicolor</i>)	<u>In order of intensity</u> <i>H. bispinosa</i> , <i>D. auratus</i> , <i>H. turturis</i> , <i>R. haemaphysaloides</i> , <i>I. petauristae</i> <i>H. aculeata</i> , <i>H. cuspidata</i> <i>H. aculeata</i>	Rajagopalan (1972) Geevarghese <i>et al.</i> (2009) Rajagopalan <i>et al.</i> (1968b)
KF, Shivamogga KF, Shivamogga	Sambar deer Sambar deer	<i>H. spinigera</i> , <i>H. turturis</i> <i>H. cornigera shimoga</i> <i>A. integrum</i> , <i>A. testudinarium</i> , <i>H. cornigera shimoga</i>	Bhat and Sreenivasan (1981) Geevarghese <i>et al.</i> (1997)
KF, Shivamogga	Deer	<i>H. turturis</i> , <i>R. haemaphysaloides</i> , <i>I. petauristae</i>	Geevarghese <i>et al.</i> (1997)
Mysore Zoo	Swamp deer (<i>Rucervus duvaucelii</i>)	<i>Ctenocephalides</i> sp.(flea)	Anon (2012-2013)
KF, Shivamogga	Mouse deer (<i>Tragullus meminna</i>)	<u>In order of intensity</u> <i>H. aculeata</i> , <i>H. cuspidata</i> , <i>H. spinigera</i> , <i>H. turturis</i> , <i>I. petauristae</i>	Rajagopalan <i>et al.</i> (1968b)
KF, Shivamogga KF, Shivamogga BBP, Bengaluru	Mouse deer Mouse deer Black buck(<i>Antelope cervicapra</i>)	<i>H. aculeata</i> , <i>H. cuspidata</i> <i>H. aculeata</i> <i>C. canis</i>	Rajagopalan (1972) Geevarghese <i>et al.</i> (2009) Renukaprasad <i>et al.</i> (2011)
KF, Shivamogga	Wild boar (<i>Sus scrofa</i>)	<u>In order of intensity</u> <i>H. turturis</i> , <i>H. kinneari</i> , <i>D.auratus</i> , <i>A. integrum</i> , <i>R. haemaphysaloides</i> , <i>Nosomma monstrosum</i> , <i>A. testudinarium</i> , <i>H. kyananurensis</i> , <i>Amblyomma</i> sp., <i>Rhipicephalus</i> sp.	Rajagopalan <i>et al.</i> (1968b)
KF, Shivamogga	Wild boar	<u>In order of intensity</u> <i>H. turturis</i> , <i>H. kinneari</i> , <i>D. auratus</i>	Bhat and Sreenivasan (1981)
KF, Shivamogga KF, Shivamogga KF, Shivamogga	Wild boar Wild boar Wild boar	<i>D. auratus</i> <i>H. kinneari</i> <i>D. auratus</i> , <i>H. kyananurensis</i> , <i>H. kinneari</i> , <i>Nosomma monstrosum</i>	Bhat (1989) Rajagopalan (1972) Geevarghese <i>et al.</i> (1997)
KF, Shivamogga	Wild boar	<i>H. intermedia</i>	Geevarghese and Mishra (2011)
KF, Shivamogga	Large mammals	<i>D. auratus</i> , <i>A. integrum</i> , <i>A. testudinarium</i>	Bhat (1989)
KF, Shivamogga	Wild mammals	<i>H. spinigera</i> , <i>H. cuspidata</i> , <i>H. bispinosa</i> , <i>R. haemaphysaloides</i>	Geevarghese <i>et al.</i> (1997)

7.2 Lateral and Vertical Migration of Ticks

The migration of ticks after dropping from their hosts helps for their dissemination and increases the chance of searching their preferred hosts. After completion of lateral movement up to three to six meters in search of plants, they start to climb up on the grass or bushes. Pattern of vertical distribution of ixodid ticks on vegetation in KFD area was studied in detail (Bhat *et al.*, 1983). Different species climb on the vegetation to certain height and settle there for seeking their final hosts to get themselves attached. The adults of *H. spinigera*, *H. shimoga*, *A. integrum* and *A. testudinarium* seemed to reach higher height of about 65-80cm on vegetation corresponding to the height of their preferred hosts such as gaur and sambar deer, while other ticks viz. *H. turtuis*, *H. kinneari* and *D. auratus* prefer hosts of lower height of nearly 40-55cm. This criterion for host-seeking of ticks is not restricted to the adult population, but stage-wise differentiation was also noted.

8.0 Insect Fauna

A two years study conducted by Vasudev *et al.* (2007) on the tabanid fauna of Rajiv Gandhi National Park, Karnataka recorded 20 species of tabanids belonging to five genera of three sub families. The following three species namely *Haematopota cordigera*, *Tabanus dorsilinea* and *T. monotaeniatus* were reported for the first time from south India while seven of the collected species viz. *Atylotus virgo*, *Chrysops dispar*, *H. javana*, *T. diversifrons*, *T. gertrudae*, *T. speciosus* and *T. triceps* are new records for Karnataka. Six of the recorded species, *A. agrestis*, *A. virgo*, *C. dispar*, *T. dorsilinea*, *T. rubidus*, and *T. striatus*, have been reported as vectors of surra caused by *Trypanosoma evansi*, a deadly disease of wild and domestic animals, while *H. montana*, *T. indianus*, and *T. rubidus* are potential vectors of anthrax. Hovering of certain flies over carcasses and wounds of wild animals for laying eggs which after hatching develop to larvae and maggots causing myiasis, was observed. Valandikar (1980) had indicated the presence of calliphorid fly, *Phaenicia cuprina* was confined to animals of hilly areas of Karnataka. Except for a single *Aedes albopictus*, which is a tree-hole breeder (Rajagopalan, 2008), no other reference on mosquitoes found in the KFD area could be traced.

Rajasekariah *et al.* (1971) reported the occurrence of the flea, *Ctenocephalides felis* on panther cubs from Anekal near Bengaluru. Another species, *C.*

canis causing massive itching and alopecia was noticed in black bucks at BBP, Bengaluru during winter months. The infestation of *Ctenocephalides* fleas was also reported in swamp deer of Mysore Zoo (Anon, 2012-13). Renukaprasad *et al.* (2011) recorded *Hamatomyzus elephantis* and *Haematopinus* sp. lice on elephants and tigers respectively at BBP, Bengaluru and hippoboscids affecting spotted deer in large numbers during outbreaks of foot rot at Bandipur.

9. Control

The information on the use of latest insecticides and acaricides on wild animals of KFD areas is scanty. Spraying of lindane 1.12 kg/ha in grazing areas of wildlife was reported to be effective for the control of ticks (Geevarghese and Mishra, 2011). Parasitism of fed nymphs of *H. spinosa* by a hymenopteran chalcid parasite, *Hunterellus sagarensis* was noticed in cattle sheds in and around KFD areas (Geevarghese and Srinivasan, 1973; Geevarghese, 1977) which can be extensively used for biocontrol of these ticks. By taking the advantage of the acaricidal properties of leguminous fodder plant, *Stylosanthes scabra*, aerial broadcasting of their seeds along with aerial spraying with eco-friendly botanical ectocides can be attempted in inaccessible forest terrain. The possibility for exploiting endosymbionts of ticks to disturb their growth and for developing a vaccine against *H. spinigera* infestation for cattle grazing near the outskirts of the forest can be considered in the future control strategy (Ghosh *et al.*, 2007).

10. Conclusion

This review indicated that small and large wild mammals were infested by vast number of arthropod parasites, especially ticks which acts as vectors of zoonotic infections like KFD virus. Diseases like anthrax and trypanosomiasis are also transmitted from wild animals to domestic stocks grazing near the forest through tabanid bites. The exact extent of these wild animals acting as reservoir or transmitter of common haemoprotozoans to domestic animals is not known. Though it is difficult to check tick infestations in wildlife unlike captive animals, effective and practical methods suggested above have to be developed in this direction. The arthropods acting as intermediate hosts of various helminth parasites of wildlife may be explored to control these infections.

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