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Original paper

Diversity and prevalence of ticks in the goats in lowland Nepal

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ABSTRACT. Ticks are very harmful blood sucking protozoan- and rickettsial disease-causing arthropods in livestock and cause an adverse economy of the world, including tropical regions like Nepal. Thus, the current study was conducted to determine the distribution, prevalence, and the effects of ticks in the goat of the Rapti Municipality, Chitwan, Nepal. Ticks were picked from different body parts of goats (n=473) and identified to species level by using morphological identification keys under a microscope. The study revealed that 161 (34%) of goats were infested and females had highest prevalence of ticks compared to males (41% vs 28%). A total of 14 species of ticks of genera *Haemaphysalis*, *Amblyomma*, *Rhipicephalus*, *Ixodes* and *Dermacentor* were identified. All tick-positive goats were suffered from inflamed wounds with various skin manifestations. In conclusion, this study suggested that appropriate control measures for ticks need to be employed in the study area for economic goat production.

Keywords: ticks, goats, Nepal, cross-transmission, *Haemaphysalis*

Introduction

Goat is a domesticated ruminant mammal that is the primary choice of poor and marginalized farmers of Asian and African countries [1]. In Nepal, mutton of goat is the second largest consumed meat (20.3%) after the buffalo meat and contributes about 49.2 billion rupees in the national economy [2]. Goat domestication has been affected by various factors like traditional farming methodology, low strain/species of goat, increasing antibiotic resistivity, high concentrations of disease agents and diseases, and others [1]. In addition, the presence of ectoparasites is also in goat production, for example, they can transmit several pathogens, cause zoonotic diseases, and play a critical role in the economy of goat rearing resulting in the deteriorating animal health, growth rate, and production performance [3–5]. Among the different ectoparasites, the role of ticks is critical because they cause substantial losses in livestock production in worldwide [6,7]. It is notable that the losses are because of their potentialities in transmitting tick-borne pathogens (TBPs) like protozoa (*Theileria* spp., *Babesia* spp.), rickettsia (*Anaplasma* spp.), and fatal viral species of livestock, causing blood loss, damage to hides and udder, and paralysis [8,9] in the tropical and subtropical regions in the world. The prevalence of TBPs is usually higher in sheep and goats which effect on health, production and welfare of small ruminants [10]. The tick-borne diseases (TBDs) affect 80% of the world cattle population and are broadly distributed throughout the world, particularly in tropical and subtropical countries [5]. In these countries, it has been estimated that the costs of TBDs in cattle between US$ 13.9 and US$ 18.7 billion annually [11] indicating ticks a critical worry for the farmers as well as the country.

In Nepal, economic loss due to ectoparasite like ticks and tick-borne diseases in livestock was reported by 18.71% of total of the cost [12]. However, there are very few research related to tick infestation in goats of Nepal. As Himalayan country, it is rich in different species of ticks comprising those species present in the Hindu-Kush Himalayas. For example, the presence of *Dermacentor auratus*,

Haemaphysalis anomala, *H. aponommoides*, *H. birmaniae*, *H. montgomeryi*, *H. nepalensis*, *Ixodes acutitarsus*, *I. ovatus*, *Nosomma monstrosum*, *Rhipicephalus haemaphysaloides*, and *R. sanguineus* s. l. in humans and 19 taxa have been reviewed in domestic mammals in Nepal [13]. Nevertheless, how these species occur and affect the goat population in Nepal is not fully understood. The lack of suitable research related to abundance, prevalence, and distribution of ticks is the main limitation for the application of preventive methods in Nepal. Thus, the main objective of the current study was to determine the distribution of ticks in various parts of the body of goats and their intensity and prevalence on these hosts in central Nepal.

Materials and Methods

Study area

The study was conducted in goats from Rapti Municipality (27.6089°N, 84.6460°E), 130 kilometers away from Kathmandu, which lies in the eastern part of the Chitwan district in central Nepal. The climatic condition from March to early June is very hot, with temperatures rising progressively to a peak in May. This municipality possesses a total of 35,090 goat heads, reported by the Ministry of Livestock Development [2]. The study area was divided into Community Forest Area (CFA) (27°36'.02''N, 84°40'.25''E), Adjacent to National Park Area (ANPA) (27°34'.20''N, 84°41'.08''E), Mahendra Highway Area (MHA) (27°36'.22''N, 84°36'.53''E). CFA lies in the area of Parewasori community forest. In ANPA, goats are domesticated by the semicaptive system, in which groups of goats are sent to the national park for grazing and brought to the shed at evening. The MHA area lies in the city and people rear very few goats mainly for meat purposes.

Field survey, sampling, and sample collection

A purposive sampling technique was used for the study of goats of three study sites. Therefore, 150 houses were selected (each 50 house) from CFA, ANPA, and MHA. A total 473 goats were selected for the study of three areas. Thus, tick infestations in different body parts of goats from CFA (n=169), ANPA (n=159), and MHA (n=145) were studied. Structured questionnaires (n=150) were prepared and an interview was taken with each farmer/goat owner on the goat health and environmental status of the its domestication.

Ticks were picked from ears, neck, shoulders, forelegs, ventral abdomen, an inguinal region, hind legs, and tail (Fig. 1). They were collected using the forceps and gloves and counted manually. Collected ticks were stored in a sterile container containing 70% alcohol with 5% glycerin until laboratory identification [14,15]. Ectoparasitic infestation was studied in relation with age, sex, rearing situation, different body parts of goats, effects of ticks and treatment history.

Laboratory techniques

To prepare the permanent slide, specimen was left to the 15% potassium hydroxide (KOH) solution at room temperature overnight. Then specimen was boiled in 15% of KOH for 5 minutes. Then, specimen was passed to the alcohol series (30%, 50%, 70%, 90% alcohol) to dehydrate it. Then, it was soaked into xylene/safranin for 2 minutes and then washed with 100% ethanol. Finally, the specimen was mounted on the DPX on a slide and allowed to dry. All the specimens were observed under the microscope at ×40, ×100, and ×400 total magnifications and photographs were taken using the camera. Taxonomic studies of ticks were dealt using the keys [16,17].

Statistical analysis

The intensity of ticks per goat was calculated by dividing the total numbers of ticks in all goats by the total numbers of tick positive goats. The prevalence of ticks was calculated by dividing the total numbers of tick-positive goats by the total numbers of studied goats. The organ-specific intensity of ticks was calculated by dividing the total numbers of ticks present in a particular organ in all goats by the total numbers of tick-positive goats. The organ-specific prevalence of ticks was calculated by dividing the total numbers of tick-positive specific organ by the total numbers of studied goats. Incidence was calculated by using single plus (+) and double (++) parameters. The + meant presence of adult and nymphal stages of ticks with one to 10 in numbers in a particular organ or host. The ++ meant presence of adult and nymphal stages of ticks with more than 11 in a particular organ or host. Data were analyzed with the help of Microsoft Excel 2007 and Graph Pad Prism (Prism 5 for windows, version 5.00, March 7, 2007). Chi-square (χ^2) tests and Fisher's exact tests were used to analyze the significance difference between two or more than two variables and *P*-value less than 0.05 (confidence level: 95%)

Table 1. Prevalence and intensity of ticks in goats of different study areas in central Nepal

Intensity				
Sex of goats	CFA	MHA	ANPA	Total
Male	24	65	35	41
Female	35	68.1	46.5	46.7
Total	31	66.4	41.8	44.3
Prevalence				
Male	23	22	38	28
Female	34	33	56	41
Total	29	26	47	34
Intensity				
Age groups (Years)				
0–6	29.5	50	22.9	34.9
7–12	26.5	60	39.4	39.8
13–18	35	125	105	83
19–24	55	0	80.8	74.4
25–30	70	105	58.3	70
>30	31.7	106.3	27.5	46.4
Total	31	66.4	41.8	44.3
Prevalence				
0–6	26	38	30	30
7–12	49	20	58	42
13–18	22	25	21	23
19–24	14	0	86	32
25–30	11	25	38	24
>30	32	24	57	36
Total	29	26	47	34
Intensity				
Group	30.2	65.4	40.7	43.3
Single	70	105	120	91.7
Prevalence				
Group	29	26	47	34
Single	50	33	50	43

was considered statistical significance.

Ethical statement

The samples of ticks were collected from the study sites without harming goats. Written consent was obtained from each household head (the farmer) for studying the goats and collecting the sample of ticks. Permission of research was taken from the local government (Rapti Municipality, Certificate Ref. No: 3490/075) and the central government (the Ministry of the Forest and Environment, Certificate Ref. No: 19/075).

Figure 1. Examination of pinna of goat and collecting ticks

Results

Prevalence and intensity of ticks

The results revealed that out of 473 goats, only 161 goats (34%) were infested with ticks. The prevalence of goats in ANPA, CFA, and MHA was 47%, 29%, and 26% respectively with statistical significant difference (P<0.05). The total prevalence of ticks was higher in females compared to that in the males in the study areas. The prevalence was higher in both male and female goats of ANPA compared to those of CFA or MHA. Similarly, the average intensity of ticks (AIT) per female was higher than male in all study areas. The AIT per male or female was higher in the goats of MHA compared to those of CFA or ANPA (Tab. 1). Similarly, the age-wise prevalence rate was highest in the goats of age 7 to 12 months (42%) (P<0.05)

Table 2. Detected ticks, their primary and alternative hosts, and keys used for taxonomic status [16,17]

	Primary hosts	Alternative hosts	Morphologic characters	
			Male	Female
Haemaphysalis sulcata Canestrini and Fanzago 1878	Mammals, reptiles, and birds	Humans	1. Palp segments 2 lateral extension is small 2. Cornua length is long	1. Palp articles 2 lateral extension is small 2. Palp articles 2 dorsal spur is absent 3. Coxae 1 to 3 spurs are short 4. Festoons number is nine
H. chordeilis (Packard, 1869)	Birds	Mammals including humans	1. Ventral cornua is absent 2. Lateral margin of dorsal basis capituli is pointed	
H. leporispalustris (Packard, 1869)	Rabbits	Ground-feeding birds	1. Ventral cornua is present 2. Prominent dorsal cornua	
H. punctata Canestrini and Fanzago, 1878	Mammals	Humans	1. Palp articles 2 lateral extension is small 2. Cornua length is short 3. Festoons number is eleven	1. Palp articles 2 lateral extension is small 2. Coxae 1 to 3 spurs length is medium 3. Festoons number is eleven
H. longicornis Neumann, 1901	Livestock	Mammals including man and birds	1. Lateral margin of dorsal basis capituli is straight 2. Dorsal spur is present	
H. leachi Audouin, 1826	Carnivores	Domestic animals	1. Palp articles 2 lateral extension is large 2. Coxae 4 spurs length is medium 3. Festoons number is eleven 4. Cornua length is long	1. Palp articles 2 lateral extension is large 2. Festoons number is eleven 3. Coxae 1 to 3 spurs length is medium 4. Punctation distribution is dense
R. muhsamae Morel and Vassiliades, 1965	Cattle, dogs, and wild carnivores	Rodents	1. Conscutum colour is dark 2. Accessory adanal plates are small 3. Adanal plates shape is broad and curved 4. Lateral grooves type is a distinct groove	1. Basis capituli lateral angles are blunt 2. Palp pedicels are long 3. Scutum posterior margin is slightly sinuous 4. Scutum colour is dark
R. bursa Canestrini and Fanzago, 1878	Sheep, goats, cattle, and horses	Rodents and rabbits	1. Conscutum colour is black 2. Accessory adanal plates are small 3. Adanal plates shape is broad and curved 4. Posterior grooves are distinct 5. Lateral grooves is distinct	
R. lunulatus Neumann, 1907	Cattle, sheep, pigs, dogs	Horses and camels	1. Cervical fiels depression is not apparent 2. Conscutum colour is dark 3. Posterior grooves are absent	–
R. (Boophilus) decoloratus Koch, 1844	Cattle	Horses, donkeys, sheep, and goats	1. Cornua are distinct 2. Coxae 1 spurs length is short 3. Festoon are absent	1. Coxae 1 spurs are distinct 2. Coxae 2 and 3 spur are present 3. Festoon are absent
R. (Boophilus) geigyi Aeschliman and Morel, 1965	Cattle	Sheep and wild ungulates	1. Cornua are indistinct 2. Ventral plates are distinct 3. Caudal appendage is narrow in males 4. Coxae 1 length is short	–

D. marginatus Sulzer, 1776	Domestic animals	Elephant, rhino and humans	–	1. Mouth part is small 2. Palp articles 2 posterior spur is absent from the dorsal surface
Amblyomma gemma Donitz, 1909	Cattle and camel	Giraffes and buffaloes	1. Festoon number is eleven 2. Posteromedian stripe is broad 3. Leg coloration is with pale rings	–
Ixodes rubicundus Neumann, 1904	Caracal, sheep, goats, and mountain reedbuck	Elephant, shrews and red rock hares	–	1. Pulps alignment curves outward 2. Scutum posterior margin is distinctly sinuous 3. Setae on scutum are absent

although the AIT per goat was highest in the age of 19 to 24 months. In the same way, goats domesticated in groups had a lower prevalence rate of ticks compared to those in single (34% vs. 43%) (P>0.05). Similar results were obtained when analyzing total as well as area-wise AIT per goat (Tab. 1).

In another part, the prevalence of ticks with their low incidence (1 to 10) was higher in legs, tail/anus in CFA, legs, tail/anus, cheek/nose, and jaw in ANPA, and legs, tail/anus, jaw, and eyes in MHA (P<0.05). In comparison, goats with high incidence (>10 ticks) were found in cheek/nose in CFA, flank/back in ANPA, and in flank/back in MHA (P<0.05) (Fig. 2).

The organ-specific intensity of ticks was highest in flank/back of all the study areas; however, in total, the decreasing order of intensity followed as the flank/back, chest, ears, crown, and others. Each study area had a significant difference in the numbers/intensity of the ticks in different body parts (P<0.05) (Fig. 3).

We detected six species of *Haemaphysalis* (*H. sulcata*, *H. chordeilis*, *H. leporispalustris*, *H. longicornis*, *H. punctata*, and *H. leachi*), five species of *Rhiphicephalus* (*R. muhsamae*, *R. lunulatus*, *R. decoloratus*, *R. geigyi*, and *R. bursa*), one species of *Dermacentor* (*D. marginatus*), one species of *Amblyomma* (*A. gemma*), and one species of *Ixodes* (*I. rubicundus*) (Tab. 2).

Discussion

The current study firstly determined the intensity, prevalence, and distribution of ticks in the goats in central Nepal. The prevalence rates (34%) of ticks in this study was lower than reported in Pakistan (41.53%–60%) [18,19], India (97.66%) [20], Ethiopia (66.12%–87.5%) [21,22], and Iran (35.83%) [23] and higher than in Southern Ethiopia (18.63%) [24]. Different prevalence rates are different because of different seasons, geography, and host characteristics.

Interestingly, goats domesticated in groups had a lower prevalence rate of ticks compared to those in single and this is due to very high numbers of studied goat populations living in groups compared to very low numbers of studied goat living single. Similarly, goats domesticated in single had a double fold of intensity of ticks compared to those reared in groups suggesting the dilution of these ectoparasites among all members living in the groups.

In this study, the prevalence rate was higher in females compared to those in males. The results are similar to other studies in Bangladesh [25–27], Iran [28], and Pakistan [18]. Although it is not easy to explain the underlying mechanisms of a higher prevalence and incidence of ticks in females, it is already a hypothesized fact that some hormonal influences as well as stress factors during pregnancy and lactation may cause immune-suppression, reduced resistance to tick infestation, and ultimately, the infestation with high frequency of ectoparasites [29]. In addition, male goats are usually kept in the house with the good management system and with freedom because people due to their immediate economic and high quality meat values preferentially love them. Interestingly, before sale or before the festival, the owners usually practice the handpicking to remove the ticks from the male goats especially to beautify and increase their price.

The current study found higher prevalence rates in the younger goats of six to 12 months compared to other age groups. Normally, goats more than six months are freely allowed for grazing in the pasture

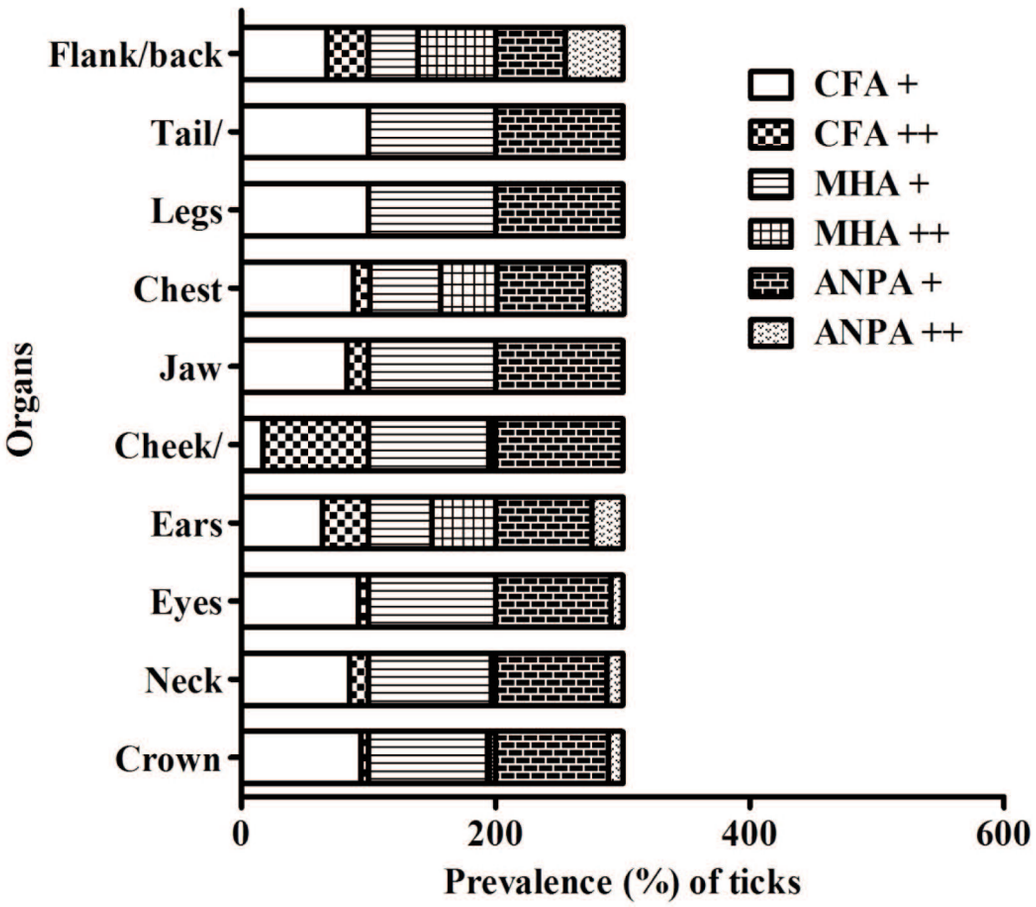

Figure 2. Organ-wise prevalence of ticks in study areas. +: 1–10 ticks/body, ++: more than 10 ticks per body. Statistical values were determined comparing the numbers of ticks between + and ++ in each study site ($P<0.05$) and total ($P<0.05$)

and posses the higher risk of tick infestation. In contrast, goats of younger ages are usually not allowed in pastureland and are kept separately from mothers in nighttime. Separation results in the lower risk of tick transmission in animal populations [30,31]. Compared to older animals, young groups can protect themselves from ticks by an innate and cell-mediated immunity [32] despite the fact that we did not assess the immune status of the goats here. Contrary to the results, a higher prevalence of ticks were found in the adult goats than in the young in other studies [18,25,33–35]. Similarly, kids less than 6 months had high prevalence rate than adult goats [27,36]. Kids and young were more susceptible than adults and older animals [26] indicating different results were due to different environment factors, study design, sampling, and sampling populations.

Interestingly, we have found that the highest numbers of ticks as well as their prevalence were recorded from flank/back compared to other organs of the goats. The results are different in different regions of the world, the highest tick infestation was present in ear [19,37,38] and then on the underside of the tail and the hind legs [19]. Ticks were highly present in ear, and the tail was the least, although they were present in neck, tail, mammary glands, groin, and perianal parts [36]. Groin was the most infested part and face and neck were the least infested part in a study [39]. The tail, ear, udder and testis, chest, shoulder of neck, and other parts had the decreasing infestation rates of ticks [23]. It is known that the attachment of tick depends on the temperature and the thickness of the skin of the animal [40]. Ticks usually prefer warm, moist and hidden sites with good vascular supply and thin skin [41]. Using soft tissues for the establishment has few advantages [42]. First, ticks can easily attach with the soft tissues and make contact with the blood capillaries of the host. Second, proper attachment will secure their protection from predators like birds. If they are externally observed and not firmly attach on the skin, their predators can easily identify and consume them. These reasons are

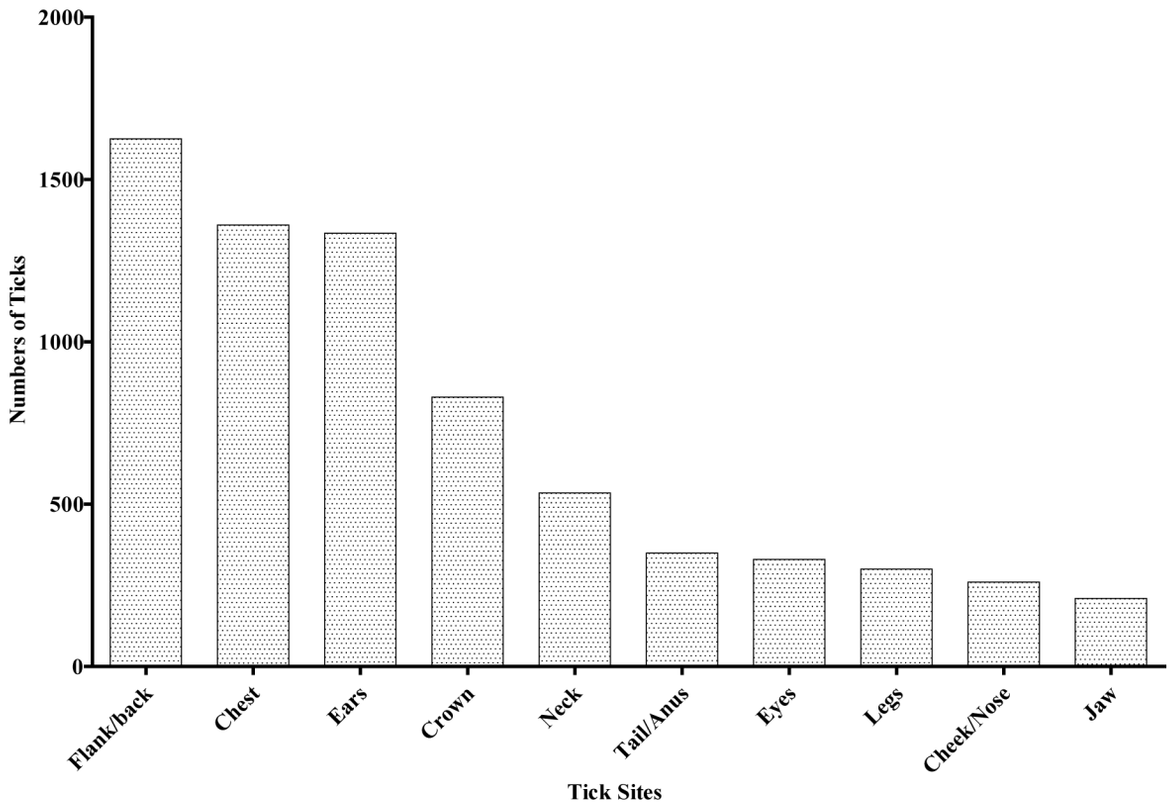

Figure 3. Numbers of ticks in each body site

concurrent to the notion that it is hard to penetrate the skin of legs and tail region due to unavailability of muscles, hair and peripheral blood circulation. However, though the skin near the anal region is very thin and vascular, ticks cannot be settled due to odor and chemical from the anus. This explains the absence of high intensity of ticks near the anal region in the current goat populations. Ticks have been unusually reported within the mouth, under the tongue, the ear canal (the tympanic membrane), the nostril, the anus, the vulva and within the prepuce. Similar results have been described in the study of dogs [43]. While these explanations may exist, tick distribution has been shown to be determined by selection pressure, intraspecificity [44], interspecific competition [45], and expired respiratory gases [46] which should be determined further.

The current study firstly reported total 14 species of the genera of *Haemaphysalis*, *Rhiphicephalus*, *Dermacentor*, *Amblyomma* and *Ixodes* in the goats and importantly, many of their primary hosts include livestock and canids whereas humans and wild animals act as accidental hosts [16,17]. Our observation of 100% tick-positive goats with various skin symptoms and pathology indicates that many of these arachnid species are the causal factors of irritation, allergy, toxicosis, inflamed wounds leading secondary infections by bacteria and fungi and ultimately to deaths [47–52]. Interestingly, few of these genera like *Boophilus*, *Haemaphysalis*, *Hyalomma*, *Ixodes* and *Rhipicephalus* have been recorded on livestock, including cattle, goats, sheep, and dogs at different altitudinal areas with different climates of Nepal [53–55] as well as India, Pakistan, and Bangladesh [5,10,23, 36,56–58]. These countries share almost similar environmental conditions and other internal factors such as the crowd of herds, grazing of livestock in groups and similar kinds of alternative hosts like canids, birds, and other animals. The presence of ticks in the goats indicates the possible accidental cross-transmission from domestic and wild mammals and birds. It can be evinced by the highest prevalence rate in ANPA that might be due to the close contact with herbivores like deer, rabbit, and others. These areas probably provide plenty of hosts for ticks, thereby expanding their transmitting and survival rates. Most of the goats in the ANPA areas used to be taken to the nearby national park areas for grazing. Grassland and shrubs may act as shelter for rodents and smaller mammals. In this situation, goats and wild herbivores share ground and vegetation habitat in which there might be the possible larval, nymphal, and adult stages of ticks.

In addition, the local farmers bring the grasses and feeds from the national park areas. This can increase the chance of survival and transmission of ticks. This finding is similar to results of others [59,60] illustrating that host activity plays an important role in which ticks are distributed in the environment. It is because of the low temperature in winter and the relatively high temperature in summer indicating distribution of ticks is determined by climatic and geographic factors.

In conclusions, the current study is the basis of tick abundance, prevalence, and distribution in the goats in a small area in Nepal. It firstly described and explained 14 species of the ticks in the domesticated goats in the city as well as rural areas of the lowland in Nepal. Ticks normally prefer flank and back parts with the thin skin in which they are the underlying effects of itching, swelling, and severe damage to the outlook of skins. Ticks are usually neglected arachnids in Nepal; therefore, the local and central government authorities should prioritize urgent attention to the tick medication in the goats and an awareness program especially in the agricultural area.

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