

Study on Prevalence of Hard Ticks and Their Associated Risk Factors in Small Ruminants of Boloso Sore Districts of Wolaita Zone, Southern Ethiopia

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Background: Ticks and tick-borne infections are the most serious health threats to small ruminants in Ethiopia, resulting in huge economic losses.

Methods: A cross-sectional study using a simple random sampling technique was conducted to determine the prevalence and potential risk factors of hard ticks in small ruminants of the Boloso Sore district of Wolaita Zone. Ticks were identified to species level under a stereomicroscope using morphological identification keys.

Results: From a total of 400 examined animals, 68.75% (275/400) of them were infested with hard ticks with the respective prevalence of 69.09% (152/220) in goats and 68.33% (123/180) in sheep. A total of 1192 (552 males and 640 females) adult ixodid ticks that belong to a total of four species, which were grouped under three genera: *Amblyomma*, *Hyalomma*, and *Rhipicephalus*, and one subgenus; *Boophilus* were collected from the head, ear, under tail and legs of goats and sheep. In this study, *Amblyomma variegatum* 44.97% (536/1192) was found to be the most abundant tick species followed by *Boophilus decoloratus* 30.79% (367/1192), *Rhipicephalus pulchellus* 20.47% (244/1192), and *Hyalomma truncatum* 3.77% (45/1192). The sex, age, and body condition score of animals with a high prevalence of hard ticks showed statistically significant differences ($p < 0.05$). Male ticks dominated females in all cases except for *Boophilus decoloratus*. There was no statistically significant relationship ($p > 0.05$) between tick infestation and animal origin or species.

Conclusion: Ticks were the most significant production and health constraints for small ruminants in the study region. Therefore, the increasing threat of ticks of small ruminants warrants urgent strategic application of acaricides and the creation of awareness among livestock owners to prevent and control tick infestation.

Keywords: ixodid ticks, prevalence, small ruminants, Boloso Sore, Southern Ethiopia

Introduction

Ethiopia has Africa's largest livestock population, with 57.83 million cattle, 28 million sheep, 28.6 million goats, 1.23 million camels, 60.5 million poultry, 2.1 million horses, 0.4 million mules, and 7.88 million donkeys.¹ There are 2.4 million sheep and 2.2 million goats in southern Ethiopia, which are key sources of income for the agricultural community.² Livestock generates 12–15% of total export revenues, through the export of live animals, meat, hides, and skins.^{3,4}

Small ruminants contribute significantly to food production in the country, accounting for 35% of meat consumption and 14% of milk consumption. Small

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ruminants contribute 40% of cash revenue and 19% of household meat consumption in the central highlands, where a mixed crop-livestock production system is practiced. Sheep and goats are considered investments and insurance because of their high productiveness, short gestation intervals, and ability to adapt to harsh environments. They also provide income to purchase food during crop failure seasons and to meet seasonal purchases such as improved seed, fertilizer, and medicine for rural households.⁵

Cattle hide is being used at a rate of 48%, goat skin at 75%, and sheep skin at 97% with the expected off-take rate of 33%, 35%, and 7% for sheep, goat, and cattle, respectively. Ethiopia exports a diverse range of processed and semi-processed sheep and goat skins, accounting for 12–16% of total value exports.^{5,6} Unfortunately, in recent years, this rank has been demoted to the fifth level, due to the rejection and downgrading of hides, as well as skin problems caused by parasite infestation.⁷

Ticks are blood-sucking external parasites that feed on the blood of vertebrates, especially mammals and birds.⁸ They are directly or indirectly responsible for significant financial losses in Ethiopia's livestock sector, which accounts for 75% of all animal exports. The rejection and degradation of hides and skins in Ethiopia resulted in a conservative estimate of 1 million birr loss each year.^{9,10} Ticks spend most of their lives away from their hosts, hiding in the ground and plants or their hosts' nests.^{11,12} Ticks are classified into three families: Ixodidae (hard ticks), which has 702 species, Argasidae (soft ticks), which has 193 species, and Nuttalliellidae, which has a single species. There are four stages in the life cycle of the ixodid tick: eggs, six-legged larva, eight-legged nymph, and adult. In accordance with the number of hosts necessary to complete their lifecycle, they are divided into one-host, two-host, and three-host life cycles.^{13,14}

In Ethiopia, ticks have been the subject of a lot of research as compared to other key skin disorders that affect animals. The main genera of ticks found in Ethiopia are *Amblyomma*, *Rhipicephalus*, *Hyalomma* and *Haemaphysalis*, and a subgenus *Rhipicephalus* (*Boophilus*). Previous studies documented the presence of more than 60 species of ticks in the country including genus *Amblyomma* (8 spp.), subgenus *Boophilus* (2 spp.), *Haemaphysalis* (4 spp.), *Hyalomma* (9 spp.), *Rhipicephalus* (15 spp.), *Ixodes* (1 spp.), *Argas* (1 spp.) and *Ornithodoros* (2 spp.) which are reported to have great

veterinary and medical importance in Ethiopia. Among these, *A. variegatum* and *Rh. (Boophilus) decoloratus* are the most important and widely distributed.^{15,16} *A. coherence*, *A. gemma*, *A. lepidium*, *H. marginatum rufipes*, *H. truncatum*, and *R. evertsi* are also commonly found in Ethiopia.¹⁷

Even though different studies were done in several parts of the country including southern Ethiopia, no study was conducted on the prevalence and associated risk factors of hard ticks of small ruminants in the selected districts of the Wolaita zone due to little emphasis given to ectoparasites of small ruminants. As a result, the goal of this study was to evaluate the risk factors and determine the prevalence of Ixodid ticks in small ruminants in selected districts of Boloso Sore, southern Ethiopia.

Materials and Methods

Study Area

Boloso Sore is located 380 kilometers southwest of Ethiopia's capital city, Addis Ababa, in the Wolaita Zone of the southern Nations, Nationalities, and Peoples' Region. It is bordered on the west by Boloso Bombe, on the north by Kembata Tembaro, on the south by Sodo Zuria and Damot Sore, and on the east by Damota Gale. Based on the climate, 80% of the population was live in Woina Dega (mid-altitude), the rest was live in Kola (Lowland), and a negligible percentage was live in Dega (Highland). The site is situated at 7°05' N 37°40' E/7.083° N 37.667° E and has an elevation of 1350–2380m above sea level. A short-wet season runs from March to May, and a long rainy season runs from June to September, with an average annual rainfall of 1300mm and an average daily temperature of 20.4°C. The livestock population of Boloso Sore district was estimated to be 84,391 cattle, 57,331 ovines, 8396 caprines, 7321 equines, and 91,375 poultry, according to the Wolaita Zone Livestock and Fishery Resources office's 2016 report.¹⁸

Study Animals

The study animals were local goats and sheep that were brought to Areka wereda (Boloso Sore) veterinary clinics and animal health posts of Areka Ketema, Doubo, Dolla, Gurumo Koyesha, and Gara Godo. It is comprised of both sexes, of all ages, and from intensive, semi-intensive, and extensive farming systems. The animals' ages were estimated by information collected from their owners and by examining the dentition patterns of the animals. According

to the classification approach of Gatenby,¹⁹ the small ruminants were classified as young (0 to 1 year), adult (2 to 4 years), and old (above 4 years old animal). The body condition score was determined according to²⁰ and classified into three groups as poor, medium, and good.

Study Design

A cross-sectional study was employed to assess the associated risk factors and determine the prevalence of Ixodidae ticks of small animals from September 2020 to June 2021 in Boloso sore districts. During data collection, the origin of the animal, species, sex, age, body condition score of the research animals, and tick predilection sites were recorded to determine the risk variables associated with the occurrence of tick infestation.

Sampling Technique and Sample Size Determination

Small ruminants were chosen from five kebeles in the Boloso sore areas using a simple random sampling technique. Because no previous research had been conducted on the prevalence and risk factors of Ixodidae ticks in small ruminants in the study area, the current study used a 50% expected prevalence, a 95% confidence level, and a 5% absolute precision. The overall number of animals to be included in the study was calculated using a formula of Thrusfield²¹:

$$N = \frac{[Z\alpha^2 p_{\text{exp}}(1 - p)]}{d^2}$$

where P_{exp} = expected prevalence (0.5), $Z\alpha$ = significance level (1.96), p = prevalence (50%), N = required sample size and d = desired absolute precision (0.05).

Therefore,

$$N = \frac{(1.96)^2 0.5(1 - 0.5)}{(0.05)^2}$$

Accordingly, the sample size of 384 animals was determined. But 400 small animals were sampled to increase precision from five kebeles; 100 from Doubo (54 goats and 46 sheep), 60 from Dolla (34 goats and 26 sheep), 69 from Gurumo Koysha (38 goats and 31 sheep), 90 from Areka Ketema (49 goats and 41 sheep) and 81 from Gara Godo (45 goats and 36 sheep).

Study Method

Collection and Identification of Ticks

All visible adult ticks were removed with forceps and gloved handpicking while rotating horizontally to avoid damage to the tick mouthparts and harm to the host, and the tick was then preserved in a 70% ethanol. The bottle was tagged with the date, location, gender, age, and body site before being sent to the Wolaita Sodo University Veterinary Laboratory for parasitological examination. Ticks from each container were placed on Petri dishes and inspected under a stereomicroscope with tick identification keys to determine the species as described by Taylor et al and Walker,^{22,23} and which was identified by the color, size, and shape of their mouthparts, as well as the scutum, anal groove, festoon, punctuation, and legs.²⁴

Data Management and Analysis

The data was coded and placed into a Microsoft Excel spreadsheet, which was then analyzed using STATA version 20. The number of tick-infested animals divided by the total number of tick-infested animals in each study area was used to assess the tick prevalence in small ruminants in each study area. The Pearson chi-square (χ^2) test was used to determine the degree of connection with the major risk factors. Also, multivariate logistic regression analyses were used to examine the relationship between tick prevalence (0 = negative, 1 = positive) and categorical independent factors. A significant association was defined at a p-value less than 0.05.

Results

Prevalence of Hard Ticks in Small Ruminants

In the present study, a total of 275 (68.75%) out of 400 small ruminants (220 goats and 180 sheep) were found to be infested with at least one and/or different species of ticks. Infestation rates were found to be higher in goats at 69.09% (152/220) than in sheep at 68.33% (123/180). A statistically significant difference ($p < 0.05$) was observed between the sex, age groups, and body conditions, and tick infestation except for species of study animals with the occurrence of ixodid tick (Table 1).

The odds of old small ruminants infested by hard ticks were 4.27 (CI, 2.014–9.053) times higher than young small ruminants, while adults were held constant. The odds of female small ruminants infested by hard ticks were 2.54 (CI, 1.639–3.926) times higher than male. Moreover,

Table 1 Association of Tick Infestation with Various Risk Factors

Factors	Category	No of Examined Animals	No of Tick-Infested Animals	Prevalence (%)	Chi-Square (X ²)	p-value
Origin	Areka Ketema	90	65	72.2	3.402	1.000
	Doubo	100	70	70.0		
	Dolla	60	42	70.0		
	Gara Godo	81	56	69.14		
	Gurumo Koysha	69	43	62.32		
Species	Caprine	220	152	69.09	0.026	0.871
	Ovine	180	123	68.33		
Sex	Male	190	111	58.42	17.97	0.0001
	Female	210	164	78.10		
Age	Old	78	68	87.18	15.318	0.0001
	Adult	235	151	64.26		
	Young	87	56	64.37		
BCS	Good	236	150	63.56	12.509	0.002
	Medium	98	68	69.39		
	Poor	66	57	86.36		

the odds of small ruminants with poor body conditions infested by hard ticks were 8.41 (CI, 0.616–1.904) times higher than that of medium body conditioned animals, while good body conditioned small ruminants were held constant (Table 2).

Species Wise Prevalence of Hard Tick in Small Ruminants

The current investigation revealed that four tick species (three tick genera and one sub-genera) were identified based on different identification keys of ticks. Taking into account the relative abundance of each tick, *Amblyomma variegatum* (44.97%) was the most abundant tick species followed by *Boophilus decoloratus* (30.79%), *Rhipicephalus pulchellus* (20.47%), and *Hyalomma truncatum* (3.77%) in both goats and sheep. Both sheep and goats were infested with these identified tick genus and species during the study period. Factors such as sex, age, and body conditions score have showed a statistically significant differences ($p < 0.05$) with the prevalence of hard ticks (Table 3).

Sex Ratio of Tick Species

A total of 1192 ticks were gathered from 152 of 220 goats and 123 of 180 sheep in this investigation. The tick count in males of the genus *Amblyomma*, *Rhipicephalus*, and *Hyalomma* species was higher in female. However,

females of the subgenus *Rh. (Bo.) decoloratus* were collected in greater numbers than males. *A. variegatum*, *Rh. (Bo.) decoloratus*, *Rh. pulchellus* and *H. truncatum* had male to female ratios of 1.47:1, 0.3:1, 1.05:1, and 1.04:1, respectively (Table 4).

Tick Species Attachment Sites

The present study disclosed that the preferred attachment sites of ixodid ticks infesting small ruminants vary among different genera of ticks. This study revealed that *A. variegatum* has got greater preference for head, tail, ear, and leg part of small ruminants in descending order of tick attachment, whereas *H. truncatum* showed a greater preference for ear, tail, and leg. Likewise, *Rh. pulchellus* has got greater preferences of attachment on the head, ears, and tail regions. *Rh. (Bo.) decoloratus* appears to have a stronger predilection for attachment sites on small ruminants' heads, ears, and tails (Table 5).

Discussion

In this study period, a total of 400 sheep and goats were examined and a total of 1192 visible adult ticks were collected from different parts of the body, ie, 152 of 220 goats and 123 of 180 sheep. Four types of tick genera, including *Amblyomma* (44.97%), *Boophilus* (30.79%), *Rhipicephalus* (20.47%), and *Hyalomma* (3.77%) were

Table 2 Multivariate Logistic Regression Analysis of Risk Factors with Tick Prevalence in the Study Area

Risk Factors	Category	Odds Ratio	95% CI	p-value
Origin	Doubo	1.04	0.526–2.052	0.913
	Dolla	1.01	0.462–2.196	0.983
	Gara godo	0.86	0.421–1.74	0.674
	Gurumo Koysa	0.65	0.31–1.34	0.311
	Areka Ketema	Ref	Ref	Ref
Species	Ovine	1.64	0.983–2.749	0.06
	Caprine	Ref	Ref	Ref
Sex	Male	Ref	Ref	Ref
	Female	2.54	1.639–3.926	0.0001
Age	Old	4.27	2.014–9.053	0.0001
	Young	0.65	0.346–1.224	0.183
	Adult	Ref	Ref	Ref
BCS	Medium	1.08	0.616–1.904	0.781
	Poor	8.41	3.584–19.721	0.0001
	Good	Ref	Ref	Ref

Abbreviation: Ref, reference value.

identified from small ruminants of the study area. Consequently, this study indicated that tick infestation is still common in the study site, and ticks are the most prevalent external parasites of small ruminants.

In Ethiopia, the range and number of tick species infesting small ruminants varies by region. The finding of the current prevalence of tick was 68.75% in the study area and this was comparable with the previous

Table 3 Association of Tick Infestation with Potential Risk Factors in Small Ruminants

Factors	Category	Tick Species				X ²	p-value
		<i>Amblyomma variegatum</i>	<i>Boophilus decoloratus</i>	<i>Hyalomma truncatum</i>	<i>Rhipicephalus pulchellus</i>		
		N(%)	N(%)	N(%)	N(%)		
Origin	Areka Ketema	30(24.39)	18(21.43)	3 (21.43)	14 (25.93)	3.402	1.000
	Doubo	32(26.02)	21(25.0)	3 (21.43)	14 (25.93)		
	Dolla	19(15.45)	12(14.29)	3 (21.43)	8(14.81)		
	Gara Godo	24(19.51)	18(21.43)	3 (21.43)	10(18.52)		
	Gurumo Koyesha	18(14.63)	15(17.86)	2(14.29)	8(14.81)		
Species	Caprine	68(30.90)	50(22.73)	8(3.64)	26(11.82)	0.026	0.871
	Ovine	55(30.55)	34(18.89)	6(3.33)	28(15.56)		
Sex	Female	72(34.3)	54(25.71)	4(1.9)	34(16.2)	17.97	0.000
	Male	51(26.84)	30(15.8)	10(5.26)	20(10.53)		
Age	Adult	82(34.89)	39(16.6)	3(1.28)	27(11.49)	115.85	0.000
	Old	20(25.56)	24(30.77)	4(5.13)	20(25.64)		
	Young	21(24.12)	21(24.14)	7(8.04)	7(8.05)		
BCS	Good	82(34.75)	41(17.37)	0(0)	27(11.44)	90.85	0.000
	Medium	27(27.55)	28(28.57)	0(0)	13(13.27)		
	Poor	14(21.21)	15(22.73)	14(21.21)	14(21.21)		

Table 4 Total Adult Tick Species, the Sex Ratio in Small Ruminants of the Study Area

Identified Tick Species	Sex Ratio			Overall M/F Ratio
	Male	Female	Total Count	
<i>Amblyomma variegatum</i>	319	217	536	1.47:1
<i>Rh. (Bo.) decoloratus</i>	85	282	367	0.30:1
<i>Rhipicephalus pulchellus</i>	125	119	244	1.05:1
<i>Hyalomma truncatum</i>	23	22	45	1.04:1
Total	552	640	1192	0.86: 1.16

investigation conducted by Ahmed et al²⁵ who reported a prevalence of 72.39% from Dire Dawa, Eastern Ethiopia, and by Abunna et al²⁶ who recorded a prevalence of 66.12% in goats and 80.30% in sheep from Bedelle district. However, the present study revealed a prevalence of 69.09% in goats and 68.33% in sheep as compared to the earlier report described by Desalegn et al²⁷ from Haramaya district, eastern Hararghe who reported a prevalence of 87.5% in goats and 89.9% in sheep, by Kifle et al²⁸ who reported prevalence of 85.26% in goats from Benatsemay district, south omo zone, south-western Ethiopia, by Eyob and Matios²⁹ who reported a prevalence of 97.58% in goats and 69.86% in sheep from Dhas district of Borana pastoral area, southern Ethiopia.

This research also found a greater prevalence of tick infestation than earlier studies done by Yacob et al⁶ from in and around Wolaita Sodo who recorded a prevalence of 18.6% in goats and 31.8% in sheep, by Sertse and Wossene³⁰ from the Eastern part of Amhara, North East Ethiopia who recorded a prevalence of 3.4% in goats and 22.2% in sheep and by Abebe et al³¹ from selected districts of Tigray region who recorded a prevalence of 58.8% in goats and 40% in sheep. Geographical differences, seasons of investigation, and regular exposure to the

same community grazing lands may have contributed to the variation in prevalence.

The age-wise tick prevalence of the current study showed that a higher (87.18%) tick burden in older animals followed by young (64.37%) and adults (64.26%) and showed a statistically significant association ($p < 0.05$) with the occurrence of tick infestation. According to Ahmed et al²⁵ in Dire Dawa, eastern Ethiopia, there was a significant difference in age groups, which is in line with the present study. Tick infestation in older animals was shown to be considerably greater than in other age groups. This might be due to young animals were kept in the house and grazed around the house until they grew stronger, reducing their chances of acquiring ticks compared to older animals kept in an outdoor system. This, in turn, contributes to a lower risk of tick exposure since the number of ticks in the household is lower, and is likely linked to older animals that have low immunity and resistance.

Tick infestation has a significant ($p < 0.005$) effect on the animal body conditions of the small ruminants. Animals with poor body condition scores, medium and good revealed an infestation rate of 86.36%, 69.39%, and 63.56%, respectively. This was incomparable with the

Table 5 Tick Species' Attachment Preferences on Small Ruminants of the Study Area

Predilection Site	Tick Species							
	<i>A. variegatum</i>		<i>Rh. (Bo.) decoloratus</i>		<i>H. truncatum</i>		<i>Rh. pulchellus</i>	
	N	%	N	%	N	%	N	%
Head	177	33	215	58.6	0	0	109	44.7
Ear	120	22.4	110	29.9	23	51.1	71	29.1
Under tail	128	23.9	42	11.4	11	24.4	64	26.2
Leg	111	20.7	0	0	11	24.4	0	0
Total	536		367		45		244	

Abbreviations: N, frequency; %, percentage.

study conducted by Ahmed et al²⁵ in Dire Dawa, eastern Ethiopia, and by Seid³² in Mizzen Teferi Bench Maji Zone, SNNPRS. This might be due to the fact that animals in poor physical condition have low tick resistance and lack the body ability to develop resistance, whereas animals in good physical condition are able to combat the infestation effectively.³³ Furthermore, because ticks consume a huge quantity of blood and fluid, a major tick infestation may result in poor body health and condition.

The sex-wise comparison revealed that females had a higher rate of tick infestation (78.1%) than males (58.42%). Although the actual explanation of female animals having a greater frequency of tick infestation is unknown, females may feed on fields where they are in touch with other animals and they are also allowed to live a long time for birth-giving purposes that increase the probability of being infested with tick than males that are mainly kept at home for fattening (meat purpose) for a short period. Furthermore, production stress, such as pregnancy and lactation, may have made female animals more vulnerable to infestation. In the current study, the analysis of logistic regression reporting odds ratio revealed that the odds of older, male and small ruminants with poor body conditions were more infested by hard ticks than young, female, and medium body conditioned ones while adult and good body conditioned small ruminants were held constant. This could probably be due to those animals with old age and poor condition became immunocompromised, but its higher occurrence in a male could be related to male small ruminants that were mostly kept under extensive management while those female counterparts were kept indoors for the sake of gestation.

This study found no significant association ($p > 0.05$) between tick prevalence and factors, such as origin and species. These include *Amblyomma variegatum*, *Boophilus decoloratus*, *Rhipicephalus pulchellus*, and *Hyalomma truncatum* as the most common tick species infesting small ruminants in the research region at the time of the study. The most common and numerous tick species was *Amblyomma variegatum* (44.97%), which was in accordance with earlier investigations in Ethiopia by Pegram et al³⁴ and Kumsa et al.³⁵ The observation of *Rh. (Bo.) decoloratus* (30.79%) as the second most abundant tick species in the present study agrees with the previous findings of Kassa and Yalew³⁶, Wasihun and Doda³⁷; Meaza et al³⁸ and Bedaso et al³⁹ who reported that *Rh. (Bo.)*

decoloratus was the most abundant tick species in their study.

The findings of *Rh. pulchellus* (20.47%) as the third predominant tick species were in agreement with previous studies from Borena province by Regassa⁴⁰ and from West Hararghe Zone, East Ethiopia, by Ababa et al.⁴¹ Conversely, this is in contrast to previous reports of the least abundance of this tick species from Western Amhara by Alemu et al⁴² and Haramaya, Eastern Ethiopia by Kassa and Yalew.³⁶ In Ethiopia, this tick prefers semi-arid and lowland environments as described by Pegram et al.³⁴ Contrary to the previous research by Ahmed et al,²⁵ *Hyalomma truncatum* was the least common tick encountered in small ruminants of the study area. This could be due to the difference in the season as reported by De Castro⁴³ and Tiki and Addis.⁴⁴

The male-to-female ratio of ticks was 0.86:1.16 and this was comparable to previous reports of Ahmed et al²⁵ who reported that in all but *B. decoloratus*, male ticks dominated females because males typically stay on the host longer than females. Female ticks that are fully engorged will drop to the ground to lay eggs, but male ticks will stay on the host for several months to continue eating and mating with other females before falling off.⁴⁵ In this study, females of *B. decoloratus* outnumbered males, most likely due to the male's small size, which may not be visible during collecting.⁴⁶

The current study suggested that all *Amblyomma* tick species have a similar preference for head, tail, ear, and leg which is in line with the previous observation of Wasihun and Doda³⁷ in southern Ethiopia. Members of the genus *Hyalomma* showed similar preferences for the ear, tail, and leg which is consistent with the earlier report by Ayalew et al⁴⁷ in central Oromia, Ethiopia. Members of the *Rhipicephalus* species were encountered mainly in the head, ears, and under the tail, which has been reported earlier by Kassa and Yalew³⁶. The *Rh. (Bo.) decoloratus* showed a preference for attachment sites head, ears, and tail which is again in agreement with the finding of Kariuki et al⁴⁸ from Kenya.

Conclusion

The current investigation revealed a significant prevalence of tick infestation in small ruminants of Boloso sore district and this causes a major health constraint that results in huge economic losses through blood-sucking, damage to hide, and transmitting a variety of vector-borne diseases. This study showed that *A. variegatum* and *B. decoloratus* are the predominant and common tick species followed by *Rh.*

pulchellus and *Hyalomma truncatum* in the study district. The prevalence of tick infestation was shown to be statistically significant ($p < 0.05$) across the sexes, ages, and body conditions of sheep and goats. Due to the high prevalence of small ruminant ticks in the study area, districts require immediate attention at all levels to reduce the impact on the health and production of small ruminants and thereby enhance the living conditions of farmers in the study area. The strategic application of acaricides and minimizing frequent contact between different herds might minimize the infestation of ticks. Awareness creation to the livestock owners on the potential effect of ticks is also needed.

Abbreviations

CI, confidence interval; CSA, Central Statistical Agency; ESGPIP, Ethiopian Sheep and Goat Productivity Improvement Program; STATA, Software for Statistics and Data Science; WZLFR, Wolaita Zone Livestock and Fishery Resources office.

Data Sharing Statement

The corresponding author will provide the datasets that were used and analyzed during this work on reasonable request.

Ethics Approval and Consent to Participate

Ethical permission was granted for this study by the Wolaita Sodo University of Research Ethics Committee. Before gathering samples from small ruminant owners' goats and sheep, a verbal agreement was obtained, and appropriate sanitary precautions were followed when taking tick samples from the body's surface. The best veterinary practice guidelines were followed, and the study's aim was explained to sheep and goat owners, and the Wolaita Sodo University of Research Ethics and Review Committee accepted the oral informed consent method described in the paper.

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Author Contributions

All authors contributed significantly to the conception and design, data acquisition, and data analysis and interpretation; participated in the drafting of the article or critically

revised it for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work.

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