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RESEARCH PAPER

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Tick-borne blood parasites in small ruminants: An epidemiological study of *Anaplasma* sp. and *Babesia* sp. in Cagayan, Philippines

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ABSTRACT

This study examined the incidence of tick-borne blood parasites, particularly *Anaplasma* sp. and *Babesia* sp., among small ruminants in the three (3) districts of Cagayan, Philippines. A total of 384 (191 sheep and 193 goats) small ruminants were examined for the presence of tick-borne blood parasites. The findings revealed that *Anaplasma* sp. had an overall incidence of 14.58% (56/384), while *Babesia* sp. revealed a slightly higher incidence of 16.67% (64/384). *Anaplasma* sp. incidence rate differed by district; highest in District II, III and I, chronologically. While *Babesia* sp. incidence rate is highest in District III, followed by I and II. Sheep had greater rates of tick-borne blood infection, and are vulnerable to *Babesia* sp. A number of host-related and management determinants were substantially correlated with tick-borne blood parasite infection. Infections were higher in females (70.57%), who were more likely than males (29.43%). Additionally, compared to younger animals, adult animals (>8 months) had significantly higher incidence rate of 28.9% (p= 0.0013). The incidence rate of tick-borne blood parasites was lowest in native breed (3.13%), followed by pure breed (18.54%), while cross breed (20.42%) is highest. The study found significant correlations between incidence rates and species, sex, age, and breed, indicating that tick-borne blood parasitic infections in the 3 districts are influenced by a variety of factors. These findings demonstrate that tick-borne blood parasite diseases continue to be prevalent in the small ruminant population of Cagayan, posing a threat to the animals' health and productivity. Also, adopting the One Health Approach to lessen the negative effects of these infections will include farmer education initiatives, integrated tick control and prevention programs for livestock and use of environment friendly acaricides are crucial.

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INTRODUCTION

Cagayan is a province in the Philippines situated in the Cagayan Valley region, occupying the northeastern section of Luzon (Philippine Statistics Authority, 2021). It has abundant natural resources and is rich in agriculture, which includes livestock production specifically on small ruminants like sheep and goat that add stability to farm incomes and food security in the province (Department of Agriculture – Regional Field Office 02, 2020).

The livestock industry was one of the strongest growth areas in the Philippine agriculture from 1986 to 2000. At the farm level, livestock raising is a major activity in rural areas. For a large proportion of smallholder households engaged in livestock raising, the activity is the primary source of income. Sheep and goats are among the major economically important livestock, playing a part in the livelihood of resource-poor farmers. For being small-sized animals, sheep and goats require a small initial investment (Food and Agriculture Organization of the United Nations, 2018; Devendra and McLeroy, 1982; Cruz *et al.*, 2024). Because of the increasing scale of livestock raising in the rural areas, emerging problems are inevitable that become a threat not only to the animals but also to the raisers. One of the emerging concerns in the livestock industry, especially in ruminants, is the incidence of tick-borne blood parasite infections (Cheah *et al.*, 1999; Taylor *et al.*, 2016; Salih *et al.*, 2015, Cruz *et al.*, 2021).

Parasitism is a type of host–parasite relationship between two organisms in which one benefits at the expense of the other (Roberts and Janovy, 2013). Parasitic diseases like blood parasitism are economically important globally (Yitayew and Derso, 2015). Blood parasites and their vectors, like ticks, also known as tick-borne blood parasites, are the most destructive diseases of our animal health and the biggest hindrance to successful animal production. Tick-borne blood parasites like *Anaplasma* sp., *Babesia* sp., and *Theileria* sp. are the most important affecting small ruminants (Taylor *et al.*, 2007, 2016; Cruz *et al.*, 2018). Tick-borne blood parasites can be addressed by providing and understanding the benefits of applying the appropriate animal health policies and programs in order to safeguard public health and ensure food safety (World Organization for Animal Health, 2021: Cruz *et al.*, 2018; Cruz *et al.*, 2021).

This study aimed to conduct an epidemiological investigation of tick-borne blood parasite infections, specifically *Anaplasma* sp. and *Babesia* sp., in small ruminants across the three districts of Cagayan Province, Philippines, by detecting and identifying these infections in goats and sheep and assessing their distribution, incidence rate, and associated determinants in relation to species, age, sex, and breed, as well as examining the correlation between infection rates and their spatial distribution and epidemiological risk factors.

MATERIALS AND METHODS

Identification of study area

Cagayan province is composed of 3 districts with 29 municipalities and a component city.

Records on the population of registered small ruminant farms from the 3 districts were gathered from the Department of Agriculture Regional Field Office 02 – Livestock Division and were considered as study area. Survey- questionnaires were also given to the farm owners/managers or caretakers to be able to gather data on the farm population and profile.

Collection of blood samples from small ruminants

Blood samples of goats and sheep were collected randomly from the different small ruminant farms. Each measuring three milliliters of whole blood in an EDTA (lavender top) tube was taken from the jugular vein of both sheep and goats. First, the site for venipuncture was cleansed with70% alcohol, then digital pressure was applied on the jugular vein, with the use of a 21 – 22-gauge needle attached to a 3mL syringe, and the blood was drawn from the jugular vein.

Collected blood samples were sent to Cagayan State University- College of Veterinary Medicine Parasitology Laboratory for Blood Parasite Examination (BPE).

Procedure for the blood parasite examination (BPE)

Preparation of the blood smears

A clean slide was placed on a flat surface; one drop of blood was placed on one end of the slide, and using another slide (as a spreader), placed horizontally, forming an acute angle (30°-49°).

The spreader was pushed back until it had touched the blood, and then pulled smoothly and gently forward. Then the prepared blood smear was allowed to air dry.

Staining of prepared blood smear

The prepared blood smear was fixed with ethyl alcohol and allowed to dry for three to five minutes. After which, the fixed dried blood smear was stained using Giemsa staining solution and was allowed to stand for approximately one minute.

Examination for the presence of tick-borne blood parasites

The stained blood smear was examined using a light microscope focused under Oil Immersion Objective (OIO) and magnified 100x. The Meander System Technique was used in counting and identifying the tick-borne blood parasites present.

Data analysis

A descriptive cross-sectional study was conducted to determine the epidemiology of *Anaplasma* sp. and *Babesia* sp. infections in small ruminants in the 3 Districts of Cagayan, Philippines. The Chi-Square Test was used to determine the association between incidence of tick-borne blood parasites in relation to age, sex, and breed. Results with $p<0.05$ were considered significant.

RESULTS AND DISCUSSION

In this present study results showed the distribution of the tick-borne blood parasites as shown in Fig. 1 namely *Anaplasma* sp. and *Babesia* sp. infecting sheep and goats in the 3 Districts of Cagayan; Tables 2, 3 and 4 showed the determinants affecting the small ruminants, revealing the incidence rate of *Anaplasma* sp. and *Babesia* sp. infections and correlated the distribution and determinants in small ruminants in Cagayan, Philippines.

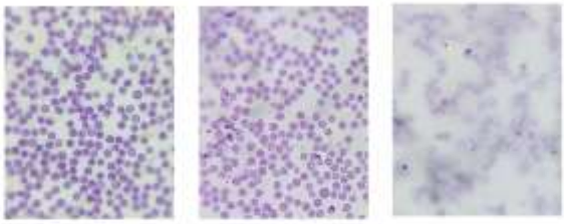

Fig. 1. Tick-borne blood parasites, *Anaplasma* sp. and *Babesia* sp. showing co-infection in sheep and goats from the 3 districts of Cagayan

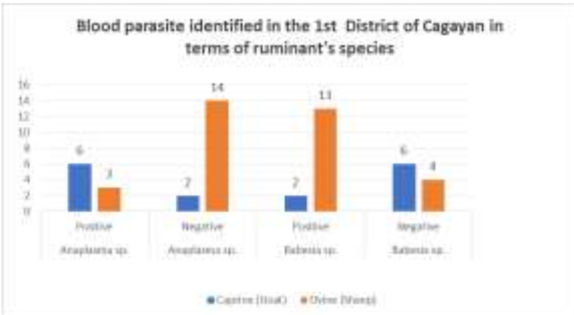

Fig. 2a. Tick- borne blood parasite identified in the 1st district of Cagayan in terms of ruminant's species

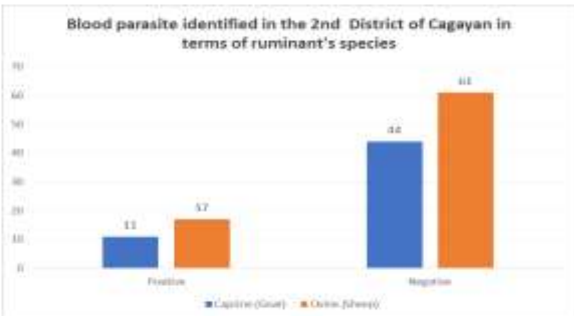

Fig. 2b. Tick-borne blood parasite identified in the 2nd district of Cagayan in terms of ruminant's species

The findings in Table 1 demonstrate a significant disparity in the distribution of *Anaplasma* sp. and *Babesia* sp. infections throughout the areas. In District I (Fig. 2a), the incidence of *Anaplasma* sp. infection was 36% (9/25), whereas *Babesia* sp.

exhibited a incidence of 60% (15/25), with sheep demonstrating a notably elevated incidence of *Babesia*-positive cases. District II (Fig. 2b) exhibited a moderate *Anaplasma* infection incidence of 21% (28/133) and notably reported no instances of *Babesia* sp., indicating the absence or minimal presence of *Babesia* vectors in the region. In contrast, District III (Fig. 2c) demonstrated a reduced incidence of *Anaplasma* sp. Infection rate of 8.4% (19/226) with a greater incidence of *Babesia* sp. The infection rate is 21.7% (49/226), suggesting varying environmental or ecological circumstances that may promote the transmission of one parasite over another. These findings achieve the primary purpose of delineating the distribution of these tick-borne blood parasites among districts and host species. To ascertain determinants influencing infections, although the table omits environmental or species-specific variables such as age, sex, or management systems, the disparity in infection rates across districts and between goats and sheep suggests possible underlying factors. The total lack of *Babesia* in District II may indicate that vector ticks capable of transmitting *Babesia* sp. are not present. are either absent or are properly regulated in that district. Furthermore, sheep exhibited elevated rates of *Babesia* infections relative to goats, particularly in Districts I and III, potentially signifying species-specific vulnerability or variations in grazing behavior that increase their exposure to ticks, aligning with prior research, including Ybañez *et al.* (2013), which highlighted the significance of vector ecology in pathogen dissemination. Ascertaining the overall infection rate-calculations derived from the data indicate that *Anaplasma* sp. had an overall infection incidence of approximately 14.6% (56/384), whereas *Babesia* sp. Had a somewhat elevated infection rate of 16.7% (64/384). These rates align with endemic levels observed in tropical and subtropical areas, where tick-borne diseases thrive due to conducive climatic conditions for tick proliferation. This offers quantifiable evidence supporting the study's objective of evaluating the impact of these illnesses on the small ruminant population in Cagayan.

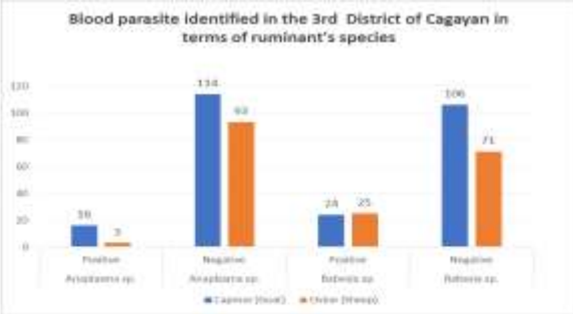

Fig. 2c. Tick-borne blood parasite identified in the 3rd district of Cagayan in terms of ruminant's species

The fourth objective—to associate infection rates with distribution and determinants—is partially achieved by observable data patterns. The regional distribution of infection underscores potential environmental or ecological factors. The elevated incidence of *Babesia* in Districts I and III, contrasted with its total absence in District II, may be attributable to climatic or geographical variances, including humidity, vegetation cover, or livestock management techniques that influence tick population density and activity. These associations emphasize the necessity for additional research into risk variables, such as farm biosecurity, animal movement, and tick control measures, as shown in comparable epidemiological studies (Aktas *et al.*, 2011; Zahid *et al.*, 2005).

Table 1 presents a fundamental epidemiological overview of *Anaplasma* and *Babesia* infections in small ruminants across the three districts of Cagayan. The study effectively achieves its aims by illustrating substantial variation in infection rates and indicating the impact of environmental and species-specific factors. To comprehensively achieve the study's objectives, subsequent research must integrate supplementary data regarding animal demography, tick vector incidence, and management techniques to enhance the understanding and control of these economically significant parasites. The table provides the distribution of *Anaplasma* sp. infection across two species, caprine (goats) and ovine (sheep), in the 1st district of Cagayan. The data shows the number of ruminants testing positive and negative for the infection in both species. Out of a total of 25 animals, 9 tested positive and 16 tested negative. Specifically, among the caprine species, 6 tested positive and 2 tested negative, while among the ovine species, 3 tested positive and 14 tested negative. The Chi-square test produced a Pearson Chi-Square statistic of 7.766544 with a *p*-value of 0.00532. Since the p-value is less than 0.05, we reject the null hypothesis and conclude that there is a statistically significant association between species and infection status.

Table 1. Tick-borne blood parasite identified in the three (3) districts of Cagayan in terms of ruminant's species

Districts	Tick-borne blood parasite	Caprine (Goat)	Ovine (Sheep)	Total	Grand total
	Anaplasma sp.				
	Positive	6	3	9	
	Negative	2	14	16	
	Total	8	17	25	
	Babesia sp.				
	Positive	2	13	15	
	Negative	6	4	10	
	Total	8	17	25	
I					25
	Anaplasma sp.				
	Positive	11	17	28	
	Negative	44	61	105	
	Total	55	78	133	
	Babesia sp.				
	Positive	0	0	0	
	Negative	55	78	133	
	Total	55	78	133	
II					133
	Anaplasma sp.				
	Positive	16	3	19	
	Negative	114	93	207	
	Total	130	96	226	
	Babesia sp.				
	Positive	24	25	49	
	Negative	106	71	177	
	Total	130	96	226	
III					226
Grand total		193	191		384

This shows that goat tend to have higher infection of Anaplasma compared to sheep. In district 1, The table provides the distribution of *Babesia* sp. infection across two species—caprine (goats) and ovine (sheep)—in the 1st district of Cagayan. Out of a total of 25 ruminants, 15 tested positive for the infection, and 10 tested negative. Specifically, among the caprine species, 2 tested positive and 6 tested negative. In contrast, among the ovine species, 13 tested positive and 4 tested negative. The Chi-square test yielded a Pearson Chi-Square statistic of 6.004902 with a p-value of 0.01427. Since the *p*-value is less than 0.05, we reject the null hypothesis and conclude that there is a statistically significant association between species and infection status.

This shows that sheep tend to have higher infection of *Babesia* sp. compared to goat. In district 2, The table presents the distribution of *Anaplasma* sp**.** infection status (negative and positive) across seven different locations in the 2nd District of Cagayan: Ballesteros, Abulug, Piat, Csu-Piat, IBJ Lasam, Sanchez Mira, and Rizal. The data shows the number of animals that tested negative and positive for *Anaplasma* sp**.** in each location. In total, there were 105 negative cases and 28 positive cases, with the remaining distributed across the different locations. For example, Ballesteros had 21 negative cases and 0 positive cases, while Abulug showed a higher incidence of infection, with 14 negative cases and 5 positive cases. Locations such as Csu-Piat, IBJ Lasam, and Sanchez Mira exhibited more positive cases, with Csu-Piat having 7 positive cases out of 20, and IBJ Lasam showing 8 positives out of 12 animals. The Chi-square test result, with a Pearson Chi-Square statistic of 31.61936 and a *p*-value of 0.00002, indicates a significant association between *Anaplasma* sp. infection and location. Locations such as Ballesteros show no infection, while others like Abulug, IBJ Lasam, and Csu-Piat have higher rates of *Anaplasma* sp. infection.

Table 2. Tick-borne blood parasite identified in the three (3) districts of Cagayan in terms of ruminant's sex

Districts	Tick-borne blood parasite	Sex		Total	Grand total
		Female	Male		
	Anaplasma sp.				
	Positive	6	3	9	
	Negative	12	4	16	
	Total	18	7	25	
	Babesia sp.				
	Positive	12	3	15	
	Negative	6	4	10	
	Total	18	7	25	
I					25
	Anaplasma sp.				
	Positive	24	4	28	
	Negative	69	36	105	
	Total	93	40	133	
	Babesia sp.				
	Positive	0	0	0	
	Negative	93	40	133	
	Total	93	40	133	
II					133
	Anaplasma sp.				
	Positive	17	2	19	
	Negative	143	64	207	
	Total	160	66	226	
	Babesia sp.				
	Positive	33	16	49	
	Negative	127	50	177	
	Total	160	66	226	
III					226
Grand total		271	113		384

The results displayed in Table 2 offers a comprehensive analysis of infection patterns differentiated by sex among the ruminants sampled from three districts in Cagayan. This study further examines the research objectives-specifically the identification of factors and the association of infection rates with these determinants. The table indicates that in all three districts, female ruminants demonstrated consistently elevated positivity rates for both *Anaplasma* sp. and *Babesia* sp. in comparison to their male counterparts. In District I (Fig. 3a), 6 out of 18 females (33.3%) tested positive for *Anaplasma* sp., whereas 3 out of 7 males (42.9%) were positive, suggesting a marginally elevated infection rate among males. Nonetheless, for *Babesia* sp. Within the same district, the female infection rate was markedly elevated at 66.7% (12/18), in contrast to the male rate of 42.9% (3/7). In District II (Fig. 3b), devoid of *Babesia* cases, female animals exhibited a significantly greater incidence of positive *Anaplasma* cases (24 females compared to 4 males), accounting for 85.7% of all infections in that region. District III (Fig. 3c) had a pronounced female bias in infection rates for both parasites, with 17 of the 19 *Anaplasma* cases (89.5%) and 33 of the 49 *Babesia* cases (67.3%) originating from female ruminants. These data indicate that sex may be a possible variable affecting susceptibility or exposure to these hemoparasites. The increased incidence in females may be ascribed to physiological and hormonal reasons, including pregnancy and lactation, which might result in temporary immunosuppression, rendering them more vulnerable to infections (Ristic, 1988; Radostits *et al.*, 2007). Furthermore, females are sometimes kept on farms for extended periods for breeding and milk production, thereby augmenting their cumulative exposure to tick vectors and, consequently, to tick-borne infections such as *Anaplasma* and *Babesia* (Farooq *et al.*, 2017).

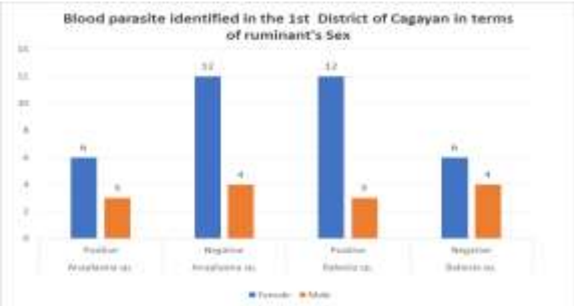

Fig. 3a. Tick -borne blood parasite identified in the 1st district of Cagayan in terms of ruminant's sex

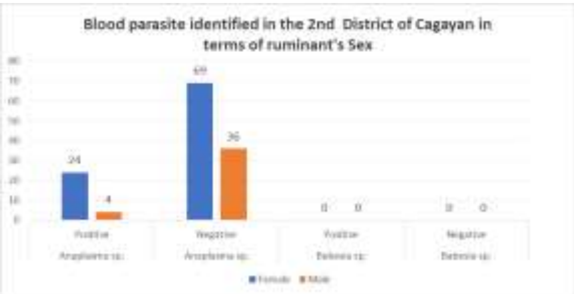

Fig. 3b. Tick-borne blood parasite identified in the 2nd district of Cagayan in terms of ruminant's sex

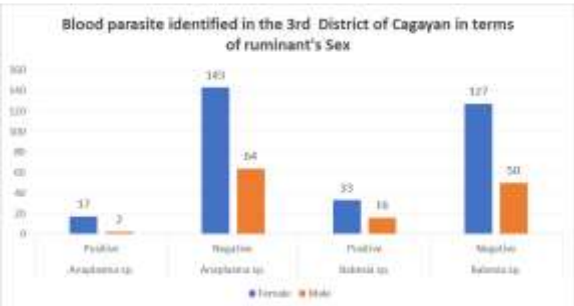

Fig. 3c. Tick-borne blood parasite identified in the 3rd district of Cagayan in terms of ruminant's sex

Females represented 47 of 56 (83.9%) positive *Anaplasma* cases and 78.1% (45 of 64) of *Babesia* cases across all districts, indicating a significant disparity in the incidence of hemoparasitic diseases. This substantially reinforces the second particular purpose of the study, which was to discover factors influencing infection. It also supplies significant data to achieve the fourth objective: connecting infection rates with distribution and determinants. The discovered sex-based discrepancy could guide targeted control approaches, such as improved tick control methods for breeding females or selective deworming regimens during critical physiological phases. Furthermore, these findings correspond with earlier epidemiological research, including that of Karimuribo *et al.* (2011), which documented analogous trends in East African livestock populations, and Ybañez *et al.* (2013), who highlighted the influence of host characteristics on the epidemiology of tick-borne diseases in the Philippines. The lack of *Babesia* sp. In District II, across both genders, consistent with the findings in Table 1, underscores the impact of geographic and environmental factors on parasite dispersion and suggests that district-specific vector ecology warrants additional examination. In conclusion, Table 2 augments the epidemiological profile of *Anaplasma* sp. and *Babesia* sp. Infections are underscored by emphasizing sex-based disparities in incidence, hence necessitating the consideration of animal-level risk variables in disease surveillance and management. The evident sexual bias in infection indicates that control programs ought to incorporate management measures attuned to the biological and productive functions of female animals, which may alleviate disease load and enhance productivity in impacted herds. The table provides information on how the infection is distributed between female and male ruminants in the 2nd district of Cagayan. Among the 133 ruminants in total, 105 tested negative for the infection, while 28 tested positive. Of the female ruminants, 69 were negative, and 24 were positive. For the male ruminants, 36 were negative, and only 4 were positive. The Chi-square test results, with a Pearson Chi-Square statistic of 4.204516 and a *p*-value of 0.04032, show a statistically significant association between sex and the infection. Since the *p*-value is below 0.05, we can confidently say that the sex of the ruminants plays a role in whether they test positive or negative for the infection. Females have a higher number of positive cases compared to males, suggesting that female ruminants may be more susceptible to the infection than their male counterparts.

Table 3. Tick-borne blood parasite identified in the three (3) districts of Cagayan in terms of ruminant's age

Districts	Tick-borne blood parasite	Age range		Total	Grand total
		>8 mos	<8mos		
	Anaplasma sp.				
	Positive	6	3	9	
	Negative	10	6	16	
	Total	16	9	25	
	Babesia sp.				
	Positive	7	3	10	
	Negative	9	6	15	
	Total	16	9	25	
I					25
	Anaplasma sp.				
	Positive	64	41	105	
	Negative	26	2	28	
	Total	90	43	133	
	Babesia sp.				
	Positive	0	0	0	
	Negative	90	43	133	
	Total	90	43	133	
II					133
	Anaplasma sp.				
	Positive	18	1	19	
	Negative	172	35	207	
	Total	190	36	226	
	Babesia sp.				
	Positive	38	11	49	
	Negative	152	25	177	
	Total	190	36	226	
III					226
Grand total		296	88		384

Table 3 illustrates the distribution of *Anaplasma* sp. and *Babesia* sp. Infections in ruminants are classified by age across the three districts of Cagayan. The classification employs age ranges of higher than 8 months (>8 mos) and less than 8 months (<8 mos). This analysis aims to fulfill the second and fourth specific objectives of the study, which involve identifying factors of tick-borne blood parasite infections and correlating infection rates with these determinants.

The data indicate that older ruminants (>8 months) had a significantly greater incidence of both *Anaplasma* and *Babesia* infections in all three districts. In District I (Fig. 4a), 6 out of 9 *Anaplasma*-positive cases (66.7%) and 7 out of 10 *Babesia*-positive cases (70%) were identified in animals beyond 8 months of age.

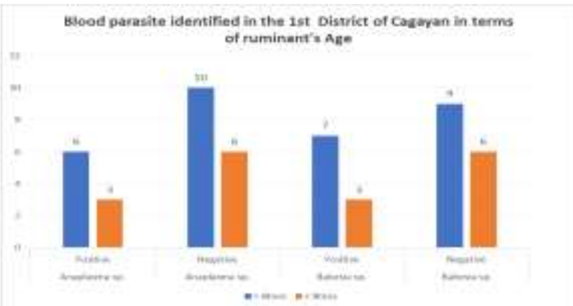

Fig. 4a. Tick-borne blood parasite identified in the 1st district of Cagayan in terms of ruminant's age

This pattern persists in District II, where *Anaplasma* was the sole tick-born blood parasite identified. Of the

105 confirmed positive cases in District II (Fig. 4b), 64 were from animals beyond 8 months of age, while 41 were from those below 8 months.

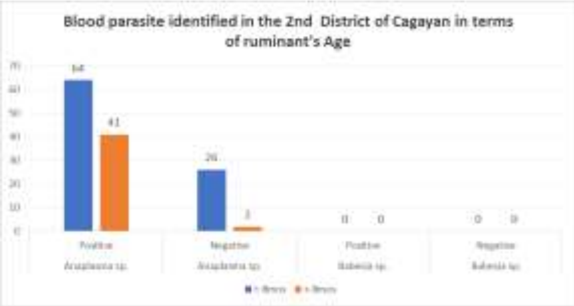

Fig. 4b. Tick-borne blood parasite identified in the 2nd district of Cagayan in terms of ruminant's age

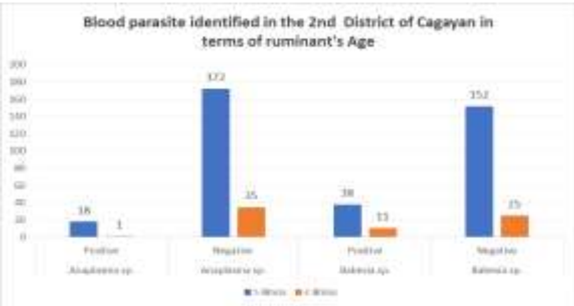

Fig. 4c. Tick-borne blood parasite identified in the 3rd district of Cagayan in terms of ruminant's age

Similarly, District III (Fig 4c) accounted for 18 of the 19 *Anaplasma*-positive cases (94.7%) and 38 of the 49 *Babesia*-positive cases (77.6%) among the older age demographic. The total figures further emphasize this trend: for *Anaplasma* sp., 88 of 133 positive cases (66.2%) were observed in animals exceeding 8 months of age. Likewise, for *Babesia* sp., 45 of 64 total infections (70.3%) were identified in the older age demographic. The results indicate that age is a crucial factor in the vulnerability and/or exposure to tick-borne blood parasites. Numerous biological and management-related rationales can substantiate these findings. Older animals are typically more susceptible over time to vector populations, especially ticks, which are the primary vectors for both *Anaplasma* sp. and *Babesia* sp. (Bock *et al.,* 2004). Extended environmental exposure, particularly in free-range or grazing systems common in several regions of the Philippines, heightens their susceptibility to diseases (Radostits *et al.*, 2007). Furthermore, maternal antibodies in juvenile animals can provide transient protection against hemoparasites during early developmental stages, thus elucidating the reduced infection rates observed in ruminants under 8 months (Uilenberg, 2006). Considering the immunological maturity of older ruminants is also crucial. Although it may be anticipated that younger animals are more vulnerable owing to an undeveloped immune system, research indicates that older animals are more prone to testing positive due to chronic or persistent infections that become detectable over time (Zintl *et al.*, 2003). In areas where ticks are endemic, enduring low-level infections frequently occur in adult animals, influencing the observed incidence rates. The lack of *Babesia* sp. In District II, the consistency across all age groups, as evidenced by the preceding tables, indicates that either the vector presence or ecological conditions in that region may not facilitate the life cycle of *Babesia*, or that management approaches substantially diverge from those in Districts I and III.

The statistics presented in Table 3 underscore the necessity for age-specific control measures. For instance, strategic tick management initiatives should be addressed for older ruminants, especially those above 8 months of age. Moreover, vaccine techniques or preventative interventions for hemoparasites could be synchronized with age milestones to enhance efficacy.

Preventive strategies must acknowledge that older animals act as reservoirs of infection, presenting a transmission risk to younger and more susceptible herd members (Kocan *et al.*, 2004). Table 3 demonstrates a distinct age-related pattern in the incidence of *Anaplasma* and *Babesia* infections, indicating that older animals exhibit a persistently elevated risk. This underscores the significance of age as a critical epidemiological variable in disease management and corroborates previous research on hemoparasitic illnesses in ruminants within tropical and subtropical areas. This study examines the relationship between *Anaplasma* sp. infection and age, categorized as greater than 8 months and less than 8 months, based on a dataset of 25 observations. The findings indicate that the infection rates are similar between the two age groups, with 37.5% of individuals over 8 months being positive and 33.3% of those under 8 months. A statistical analysis using the Pearson Chi-Square test reveals no significant association between age and infection status, as evidenced by a high p-value of 0.835. Hence, the data do not support a significant relationship between age and *Anaplasma* infection on small ruminants. This analysis focuses on *Babesia* sp. infection patterns in small ruminants, using a dataset of 25 observations categorized by age (>8 months vs. <8 months). The results show that 56.25% (9/16) of individuals over 8 months tested positive for *Babesia*, while 66.67% (6/9) of those under 8 months were positive. However, a statistical analysis using the Pearson Chi-Square test revealed no significant association between age and infection status ($\chi^2 = 0.260$, $p = 0.610$). In District 2 of Cagayan, a study on *Anaplasma* infection in small ruminants (goats and sheep) reveals a significant association between age and infection rates. Among 133 animals, 28.9% of those over 8 months were positive, compared to only 4.7% of those under 8 months. A Pearson Chi-Square test confirmed this trend as statistically significant ($\chi^2 = 10.28$, df = 1, $p = 0.0013$), indicating a moderate association between older age and higher infection rates. This finding aligns with global patterns where older animals tend to have higher *Anaplasma* incidence due to prolonged exposure to ticks, which are the primary vectors of the disease. This indicate that older ruminants are more prone to *Anaplasma* sp infection compared to those below 8-month-old ruminant. The table presents the distribution of infection across different age groups in ruminants from the 2nd district of Cagayan. The data shows the number of ruminants testing negative and positive for the infection in five distinct age categories: above 3 years, 7-12 months, 2-6 months, 13 months to 2 years, and 3 years. In total, there were 105 negative cases and 28 positive cases across all age groups. Among the age categories, the group of ruminants above 3 years showed the highest number of positive cases, with 9 positives out of 29 ruminants, followed by the age 3 years group, which had 7 positive cases out of 28 ruminants. The 7-12 months group had 5 positive cases out of 30 ruminants, while the 13 months to 2 years group had 7 positive cases out of 16 ruminants. The 2-6 months group, however, had no positive cases, showing only negative results.

The Chi-square test yielded a Pearson Chi-Square statistic of 15.30760 and a p-value of 0.00410, indicating a statistically significant association between age and infection status. Since the p-value is less than 0.05, we reject the null hypothesis and conclude that there is a significant association between age and the incidence of infection across different age groups. Older ruminants, particularly those above 3 years, appear more susceptible to the infection, while younger ruminants, especially those in the 2-6 months age group, show no signs of infection. This suggests that age may be an important factor in the susceptibility to the infection, with older ruminants potentially being more prone to it.

Table 4 delineates the incidence of *Anaplasma* sp. and *Babesia* sp. infections among different ruminant breeds across the three districts of Cagayan, elucidating breed-specific sensitivity to hemoparasitic infections. This data corroborates the third particular purpose of the study: to ascertain if breed influences the incidence of tick-borne blood parasites in ruminants.

In District I (Fig. 5a), infections of *Anaplasma* and *Babesia* were predominantly identified in indigenous breeds and hybrids. Among the 9 animals testing positive for *Anaplasma*, 6 were indigenous breeds and 3 were hybrids, specifically of Anglo x Boer and St. Croix x Katahdin lineage. Similarly, 15 animals were found to be positive for *Babesia*, with 2 native specimens and the others being crossbreeds, predominantly from the Anglo x Boer and St. Croix x Katahdin hybrids. This pattern may indicate the incidence of native and crossbred ruminants in District I, which are generally raised in traditional, extensive systems that expose them to a greater tick burden, thereby heightening their susceptibility to tick-borne infections (Bock *et al.*, 2004; Radostits *et al.*, 2007). Indigenous breeds typically receive less management regarding parasite control than more extensively bred purebreds.

Table 4. Tick-borne blood parasite identified in the three (3) districts of Cagayan in terms of ruminant's breed

Districts	Tick-borne blood parasite	Breed						Grand total
		Native	Total	Purebreed	Total	Crossbreed	Total	
	Anaplasma sp.							
	Positive	6		1		2		
	Negative	2		9		5		
	Total	8		10		7		
	Babesia sp.							
	Positive	2		9		4		
	Negative	6		1		3		
	Total	8		10		7		
I			8		10		7	25
	Anaplasma sp.							
	Positive	1		18		9		
	Negative	7		50		48		
	Total	8		68		57		
	Babesia sp.							
	Positive	0		0		0		
	Negative	8		68		57		
	Total	8		68		57		
II			8		68		57	133
	Anaplasma sp.							
	Positive	9		3		7		
	Negative	39		97		71		
	Total	48		100		78		
	Babesia sp.							
	Positive	0		24		25		
	Negative	48		76		53		
	Total	48		100		78		
III			48		100		78	226
Grand total			64		178		142	384

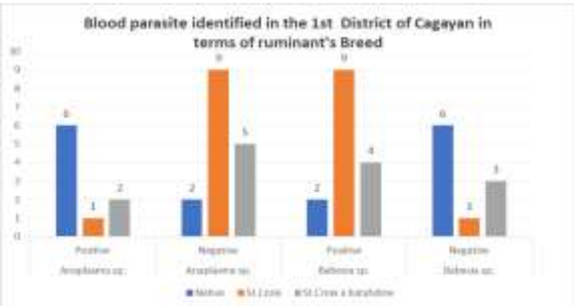

Fig. 5a. Tick-borne blood parasite identified in the 1st district of Cagayan in terms of ruminant's breed

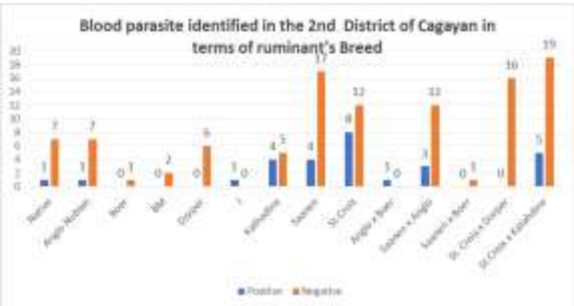

Fig. 5b. Tick-borne blood parasite identified in the 2nd district of Cagayan in terms of ruminant's breed

District II (Fig.5b) exhibited a broader variety of purebreds and crossbreeds, encompassing Anglo Nubian, Boer, BM, Dorper, Kathadine, Saanen, and other cross combinations. All 28 positive instances of *Anaplasma* were distributed among native (1 case), purebreds (Anglo Nubian, Dorper, Kathadine, Saanen), and crossbreeds (Anglo x Boer, Boer x Native, Saanen x Anglo, Saanen x Boer, Suffolk x Kathadine). The statistics indicate that no one breed was resistant to *Anaplasma* infection in this district, while certain breeds were more prevalent. The elevated infection rates in crossbreeds (e.g., 8 cases in Anglo x Boer) may indicate heightened exposure resulting from grazing methods or inadequate integrated parasite treatment. The general diversity of infected breeds underscores the pervasive presence of *Anaplasma* in the district, rather than indicating a specific breed predilection. No *Babesia* infections were documented in District II, in accordance with prior tables. This absence indicates environmental or vector-related constraints in this district that inhibit

Babesia transmission, rather than breed resistance. In District III, *Anaplasma* and *Babesia* infections were significantly correlated with both purebreds and crossbreeds, particularly Saanen and Saanen hybrids. Among the 19 *Anaplasma*-positive cases, 9 originated from native breeds, while 10 came from Saanen and its hybrids. All 49 *Babesia*-positive cases originated from Saanen (24), Suffolk x Kathadine (1), and Crossbreed goats (24). The concentration of diseases in particular breeds may indicate greater susceptibility or heightened exposure within these populations. Saanen goats are recognized for their dairy yield; nonetheless, they are generally less suited to tropical conditions and parasite challenges than indigenous breeds (Zintl *et al.*, 2003). These animals may necessitate more stringent tick and parasite care, which, if inadequate, could lead to elevated infection rates. Notably, native breeds in District III (Fig. 5c) exhibited a significant population (69 total animals), although their infection rates were comparatively low (only 9 positives for *Anaplasma*, none for *Babesia*). This may indicate the inherent tolerance or resilience of indigenous fauna to local vectors and infections, a pattern noted in multiple studies throughout Southeast Asia (Gharbi *et al.*, 2006).

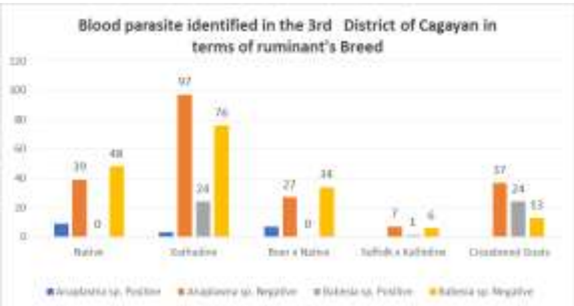

Fig. 5c. Tick-borne blood parasite identified in the 3rd district of Cagayan in terms of ruminant's breed

The results across all three districts indicate that breed influences the distribution of hemoparasitic infections; however, this relationship is intricate and affected by management strategies, environmental conditions, and vector availability. Crossbreeds and exotic purebreds, such as Saanen and Anglo Nubian, seem more vulnerable or frequently exposed to tick vectors, potentially due to higher metabolic demands and diminished resilience in tropical environments, increased housing density or communal pastures that may promote tick infestations, and inadequate adaptation to local parasite burdens relative to indigenous breeds. The lack of *Babesia* in District II, despite the presence of analogous breeds to those in District III, highlights the significance of environmental and ecological factors in disease transmission, indicating that breed susceptibility must not be assessed in isolation (Kocan *et al.*, 2004). The findings underscore the necessity for focused tick control initiatives and breed-specific management approaches, particularly for high-value or exotic breeds that may exhibit susceptibility to local vectors. Routine screening and vector surveillance must be fundamental components of herd health programs, especially in regions where tick-borne illnesses are prevalent. Moreover, crossbreeding initiatives must prioritize the equilibrium between productivity traits and resistance attributes to improve resilience against tick-borne blood parasites, particularly in resource-constrained environments. The table provides the distribution of *Anaplasma* sp. infection across three different breeds-Native, St. Croix x Katahdin, and St. Croix—in the 1st district of Cagayan. Out of a total of 25 ruminants, 9 tested positive and 16 tested negative for the infection. Specifically, among the Native breed, 6 tested positive and 2 tested negative. In the St. Croix x Katahdin breed, 2 tested positive and 5 tested negative, while the St. Croix breed had 1 positive and 9 negative cases. The Chi-square test produced a Pearson Chi-Square statistic of 8.382936 with a p-value of 0.01512. Since the p-value is less than 0.05, we reject the null hypothesis and conclude that there is a statistically significant association between breed and infection status. This suggests that the breed of the ruminants is associated with the likelihood of testing positive for *Anaplasma* sp. Specifically, the Native breed has a higher incidence of infection compared to the other breeds, indicating that certain breeds may be more susceptible to the infection. The native breed tends to be more prone to *Anaplasma* sp. infection compared to St. Croix x Katahdin and St. Croix. In

District 1, The table shows the distribution of *Babesia* sp**.** infection across three ruminant breeds; Native, St. Croix x Katahdin, and St. Croix, in the 1st district of Cagayan. Out of a total of 25 ruminants, 15 tested positive for the infection, and 10 tested negative. Specifically, among the Native breed, 2 tested positive and 6 tested negative. In the St. Croix x Katahdin breed, 4 tested positive and 3 tested negative, while in the St. Croix breed, 9 tested positive and 1 tested negative. The Chi-square test yielded a Pearson Chi-Square statistic of 7.857143 with a *p*-value of 0.01967. Since the p-value is less than 0.05, we reject the null hypothesis and conclude that there is a significant association between breed and infection status. This indicates that the breed of the ruminants affects their likelihood of testing positive for *Babesia* sp. The St. Croix breed, in particular, has a much higher infection rate compared to the Native and St. Croix x Katahdin breeds. In district 2, The table presents the distribution of infection across different ruminant breeds in the 2nd district of Cagayan. It shows the number of ruminants testing negative and positive for the infection in 16 distinct breeds: St. Croix, Katahdin X St. Croix, Saanen, Saanen X Anglo, Anglo, St. Croix X Dorper, Bm, Dorper, Anglo Nubian, Saanen X Boer, Anglo X Boer, Boer, J, St. Croix X Katahdin, Native, and Katahdin. In total, there were 105 negative cases and 28 positive cases across all breeds. Several breeds exhibited no positive cases, including Katahdin X St. Croix, St. Croix X Dorper, Bm, Dorper, Anglo Nubian, Saanen X Boer, and Boer. On the other hand, breeds such as St. Croix had 12 negative and 8 positive cases, Saanen had 17 negative and 4 positive cases, and Saanen X Anglo showed 12 negative and 3 positive cases. Katahdin exhibited 5 negative and 4 positive cases, while breeds like Anglo X Boer, J, St. Croix X Katahdin, and Native showed a mix of positive and negative cases. The Chi-square test yielded a Pearson Chi-Square statistic of 35.12411 with a p-value of 0.00236, indicating a statistically significant association between breed and *Anaplasma* sp. infection status. Since the *p*-value is less than 0.05, we reject the null hypothesis and conclude that there is a significant association between breed and the likelihood of testing positive for the infection. Some breeds, such as Katahdin X St. Croix, St. Croix X Dorper, Bm, Dorper, Anglo Nubian, Saanen X Boer, and Boer, exhibited no positive cases, while other breeds like St. Croix, Saanen, and Katahdin had higher *Anaplasma* sp. infection rates. These findings suggest that breed-specific factors may influence the susceptibility to the infection. In district 3, The table presents the distribution of *Anaplasma* sp. infection across five different breeds of goats and sheep in three districts of Cagayan. Among the Goat-Native breed, 39 animals were negative, and 9 were positive for *Anaplasma* sp. In the Sheep-Katahdin breed, 97 animals tested negative, and 3 tested positive. The Sheep-Suffolk x Katahdin breed, with a small sample size of 7 animals, had no positive cases. Similarly, all Crossbreed-Goat animals tested negative. In the Goat-Boer x Native group, 27 animals were negative, and 7 tested positive. The Chi-square test for statistical significance yielded a Pearson Chi-Square statistic of 21.05546 with a *p*-value of 0.00031, indicating a significant association between breed and *Anaplasma* sp. infection status. This means that the likelihood of an animal testing positive for *Anaplasma* sp. varies significantly depending on the breed. Specifically, Goat-Native and Goat-Boer x Native breeds showed higher incidence of infection, while Sheep-Katahdin and Crossbreed-Goat had fewer or no positive cases. The results suggest that certain breeds may be more genetically or environmentally susceptible to *Anaplasma* sp. infection, and farmers may need to implement breed-specific management strategies to control and prevent the spread of the disease. The table presents the distribution of *Babesia* sp. infection across five different breeds of goats and sheep in three districts of Cagayan. The data reveals that Goat-Native and Goat-Boer x Native breeds showed no positive cases of *Babesia* sp., as all animals tested negative for the parasite. In contrast, the Sheep-Katahdin breed exhibited a notable incidence of *Babesia* sp. infection, with 24 out of 100 sheep testing positive. The Crossbreed-Goat group also had a significant number of positive cases, with 24 out of 37 animals testing positive, while the Sheep-Suffolk x

Katahdin group, despite being small in sample size (7 total), had one animal test positive. The Chi-square test for statistical significance, with a Pearson Chi-Square statistic of 63.8761 and a *p*-value of 0.00000, indicates a significant association between animal breed and the presence of *Babesia* sp. infection. This suggests that the breed of the animals significantly influences the likelihood of testing positive for the parasite, with certain breeds like Sheep-Katahdin and Crossbreed-Goat being more susceptible, while others like Goat-Native and Goat-Boer x Native show no evidence of infection. The results imply that breed-specific factors, potentially including genetics and environmental exposure, could play a role in the susceptibility to *Babesia* sp. infection.

CONCLUSION

Based on the result of the study, the *Anaplasma* sp. and *Babesia* sp. were present among small ruminants in the Province of Cagayan, indicating the incidence of tick-borne blood parasite infections. Study shows high incidence of *Babesia* sp., especially in sheep, female, adult (>8 mos old) and pure breed small ruminants. With these results, there is a need to modify and update the province' tick control and prevention program. Further adopting the One Health Approach is a must to lessen the negative effects of these tick-borne blood parasite infections that will include farmer education initiatives, integrated tick control and prevention programs for livestock and use of environment friendly acaricides.

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