compuscript

ORIGINAL ARTICLE

Zoonotic Enteric Parasites among Pastoralists, Cattle, and Soil in the Upper Benue Trough of Northeastern Nigeria

Sani Njobdi[1],*, Oladele Benjamin Akogun[2] and Mohammed Inuwa Ja'afaru[3]

Abstract

Objective: The occupation, lifestyle, and lack of formal education among pastoralists place them at higher risk of zoonoses. Moreover, zoonoses among pastoralists and their livestock in the Upper Benue Trough in northeastern Nigeria has not been studied holistically. Therefore, we investigated zoonotic enteric parasite (ZEP) infections by *Entamoba* spp*., Cryptosporidium* spp*., Giardia intestinalis, Fasciola* spp*., Taenia* spp*. and Trichostrongylus* spp. among this group.

Methods: Demographic information and faecal samples were collected from humans and cattle in 12 pastoral communities along the trough using a cross-sectional, observational study design. Soil samples were also collected from homes. Specimens were examined microscopically for ZEPs and the data were analysed.

Results: The prevalence of ZEPs was 40.3% among humans, 48.2% among cattle, and 74.6% in home soil. The prevalence of ZEP infections among humans did not differ significantly with respect to gender and husbandry practices, but did differ significantly with respect to age and clan. There was a strong correlation (R=0.750) between ZEP prevalence in humans, cattle, and soil across study communities.

Conclusion: The correlation between the distribution of ZEPs in different sample categories across communities strongly suggests that zoonotic transmission of ZEP is ongoing in the study area. Adopting an integrated approach to intervention will potentially be more effective in disease control. Further investigation, continuous monitoring, and surveillance are recommended to forestall enteric infection outbreaks.

Keywords: cattle, One Health, pastoralists, zoonosis, zoonotic enteric parasites

*Corresponding author:
E-mail: saninjbodi@yahoo.com;
saninjobdi@mau.edu.ng (SN)

[1]Infectious Disease of Poverty Research Laboratory, Department of Biotechnology, Modibbo Adama University, Yola, PMB 2076, Yola, Adamawa State, Nigeria
[2]Public Health Research, Common Heritage Foundation, Abuja, Nigeria
[3]Department of Microbiology, Modibbo Adama University, Yola, PMB 2076, Yola, Adamawa State, Nigeria

INTRODUCTION

Zoonotic diseases directly affect animals and humans, and can also be transmitted between animals and humans. The etiologic agents of zoonoses include bacteria, viruses, fungi, and parasites [1]. The mode of transmission also varies. While some of the pathogens are vector-borne, others are transmitted via aerosol, direct contact through body fluids, contact with inanimate objects (fomites), or food-borne (including water borne). Zoonotic diseases are usually associated with pets

(dogs and cats), livestock (cattle), domestic birds, and other vertebrate pests of human dwellings (rats) [2-4].

The unusual changes in the interactions between humans, animals, and the environment that are caused by climate change, increase in global migration, and international trade drive an increased risk of emerging health threats across the globe [5,6]. Greater than one-half of existing infectious diseases are zoonotic and up to 75% of emerging infections can be traced to animal origins [7]. This finding implies that as the overall prevalence of infectious diseases declines among the human population, more animal pathogens adapt to human systems.

Although zoonoses can be transmitted by both wild and domestic animals (livestock and pets), geographic regions with a high density of livestock keepers have a high potential for zoonoses transmission and are so regarded as zoonotic "hotspots" [8]. Nigeria ranks second in the global ranking of countries harbouring poor livestock keepers. Moreover, Nigeria also ranks first among countries with the highest prevalence of endemic zoonoses [8].

Parasites (helminthes and protozoans) account for more zoonotic diseases among mammals than bacteria or viruses [1]. Despite mass drug administration (MDA) and parasite eradication campaigns, many parasitic zoonoses of public health and veterinary importance continue to cause significant morbidity and mortality worldwide [9,10]. Among parasites, enteric parasites, which are mostly transmitted through ingestion, account for a greater zoonotic burden [11]; however, enteric parasites receive disproportionately less attention from public health officials [5].

Ungulates are the most important non-human host of zoonotic pathogens. In fact, ungulates harbour more zoonotic pathogens and are responsible for more of the emerging and re-emerging zoonotic species [12]. Cattle are one of the most common domesticated ungulates. Cattle provide essential sources of meat, milk, other dairy products, manure for crops, clothing, and animal traction. These products and services continue to be vital in the lives of the most economically-challenged humans because cattle are often an important source of food security and revenue.

People who engage in extensive mobile livestock production involving grazing and the use of water across a rangeland as their livelihood are known as pastoralists [13]. Pastoralists share the environment with their livestock, often in large numbers, that requires an occupational interaction [14]. The close interaction between cattle pastoralists, cattle, and cattle products, such as milk and cheese, provides the best opportunity for zoonotic disease transmission [15,16].

The Upper Benue Trough in the Adamawa State of northeastern Nigeria is one of the major pastoralist activity centres in Nigeria. Although a few studies have separately evaluated zoonotic diseases among livestock [17] and humans [18] around the Upper Benue Trough, none has reported on concurrent zoonotic diseases or pathogens among humans, animals and/or the environment in the Upper Benue Trough.

Documentation of the zoonotic enteric parasite (ZEP) distribution, which included *Entamoba* spp*., Cryptosporidium* spp*., Giardia intestinalis, Fasciola* spp*., Taenia* spp., and *Trichostrongylus* spp. among humans, livestock, and the environment in the current study, is important for an objective appraisal of the ZEP burden and will form the basis for developing more effective integrated intervention programmes towards addressing human and veterinary health within the concept of One Health. We report herein the distribution of and correlation between ZEPs among pastoralists, cattle, and soil with respect to geography and other socio-demographic variables within Adamawa State segment of the Upper Benue Trough.

MATERIALS AND METHODS

Study area

The Upper Benue Trough in Adamawa State is one of the most notable livestock zones in Nigeria. Nomadic, semi-nomadic, and sedentary pastoralists occupy several rural communities and temporary camps scattered in almost all localities within and near the Benue and Gongola River valleys. Cattle are the principal livestock of the pastoralists, although pastoralists also engage in raising small ruminants and birds. The sedentary or semi-sedentary pastoralists also engage in some small-scale crop cultivation around their dwellings.

This study focused on the cattle pastoralist communities in Demsa, Girei, and Yola South local government areas (LGAs), all of which are located within Adamawa State segment of the Upper Benue Trough. The study area is located between latitudes 9.187465°N and 9.593930°N, and between longitudes 12.023074°E and 12.555911°E (Fig 1). Although the estimated combined population of the 3 LGAs is 724,100 [19], there is no data on the population of pastoralists in the study area. It has been estimated, however, that Adamawa State, which has an estimated population of 4.2 million, harbours approximately 450,000 cattle pastoralists [20]. The cattle population in the State has also been estimated at 3.3 million [21].

Study site, population, and environmental samples

Twelve accessible pastoralist communities were purposively selected based on the consideration that they would yield an adequate number of participants to meet the required sample size. The selection was also done in such a way to generate a relatively proportionate representation of the Fulani clans (Kiri, Uda, Bodi'en, Jahun, and Wiiti), husbandry practices (nomadic, semi-nomadic, and sedentary), and spread across the three LGAs around the trough. The study covered two sets of population groups (human [cattle pastoralists] and livestock populations [cattle in possession of the pastoralist]). The environmental samples reported here are soil samples collected from the pastoralist homes.
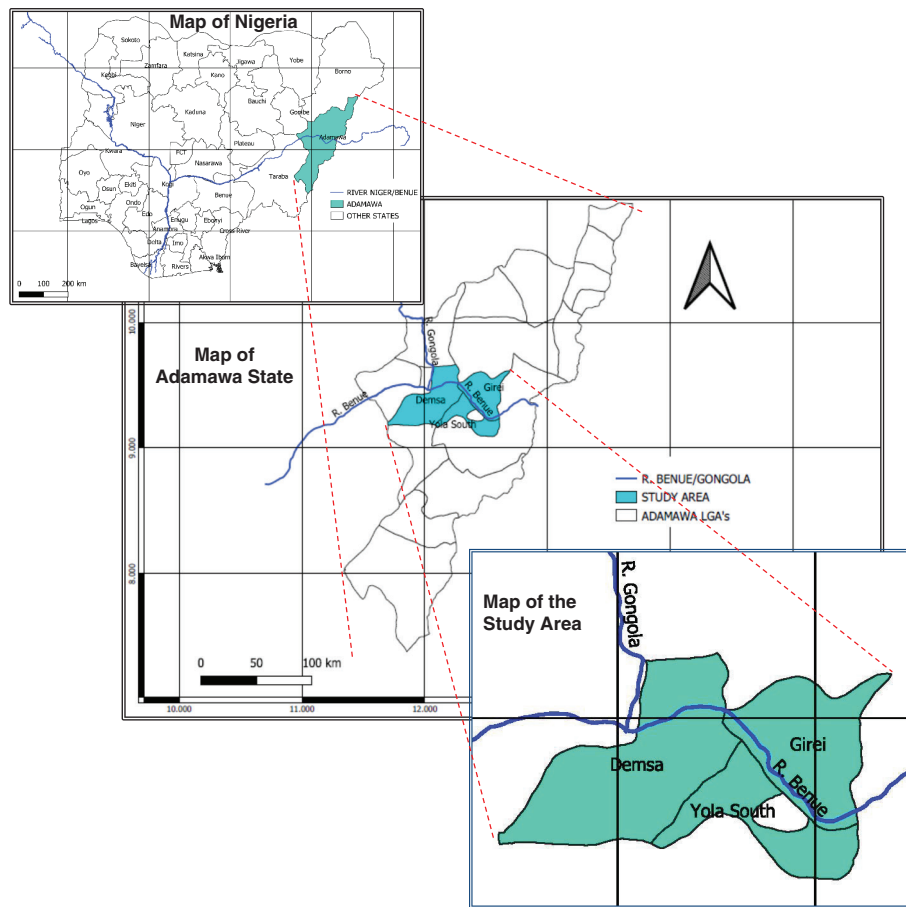
FIGURE 1 | Map of Adamawa State showing three local government areas where the study was conducted.

Sample and sampling technique

Surveys system (www.systemsurveys.com), a web-based sample size calculator by Creative Research Systems [22], was used to calculate the sample size with an assumed population of 100,000 pastoralists in the 3 LGA included in the study. At a 95% confidence level and confidence interval of 5, the required sample size was 383. This sample size estimate was further increased to target 500 to compensate for anticipated data inconsistencies and allow for some degree of stratification during the analysis. The same sample size was targeted for the cattle population.

Owing to the small populations of the selected settlements and frequent absenteeism of some household members at the time of data collection, a complete coverage of selected communities was adopted. All members of eligible households who consented or assented (in the case of minors) were included in the survey.

Based on availability, cattle faecal samples were collected from five cattle from the herd of each household included in the survey. Home soil was also collected from each participating household.

Data collection

The survey data collection entailed administration of a structured questionnaire (reported elsewhere), faecal sample collection from human participants and cattle subjects, and collection of soil samples. All tools and procedures for data collection were pilot-tested in a pastoralist community (not included in the main study) prior to the actual data collection exercise.

Stool sample collection

A labelled, sterile, stool sample container was given to each member of the eligible household, who consented to providing the stool sample and the procedure for collection of the stool was described to the participant or caregiver. The stool samples were collected by the team the next day so that the samples did not remain in possession of the participants. The demographic details of each participant were documented under the same identifier as the sample container label given.

Targeting the same sample size as for humans and assuming an average household size of five in Nigeria, stool samples were collected from five cattle from the herd of each household. Cattle inclusion in sampling was based on the availability of faeces around the anal/rectal area or freshly voided faeces during the time of field visits by team members. An approximate 10-gram faecal sample was collected into a labelled container directly from the rectum or at the time a cow or bull was defecating, the freshly voided droppings were carefully collected

immediately in such a way that averted contamination. The animal's sex, age, and other cattle identifiers were also documented to correspond with the label on the respective sample containers.

All faecal samples were preserved in 10% formalin immediately after retrieval and conveyed to the Infectious Diseases of Poverty Laboratory at Modibbo Adama University in Yola for storage. Faecal samples were stored in the refrigerator at 4° Celsius in the laboratory until processed for microscopy. Environmental samples were kept at room temperature.

Soil sample collection

Home soil samples were collected in each household at a place adjudged to have most contact with humans (i.e., the children's playground). Approximately 50 grams of topsoil (3 cm deep) was collected at 1 spot per household using a clean hand trowel and the sample was placed in a clean polythene bag for further laboratory processing.

Preparation of samples

Preserved faecal samples from humans and cattle were similarly processed using a formalin–ether sedimentation technique (mainly for detection the of helminthe eggs, but not ignoring protozoan ova and cysts), then a zinc sulphate floatation technique for the detection of protozoan ova and cysts, as described by the World Health Organisation [23] with modifications adopted from Arora & Arora [24]. Two smears were made from each floatation preparation. One of the smears was directly examined and the other smear was negatively-stained with malachite green. To enhance detection of *Cryptosporidium* spp., malachite green stain was prepared by dissolving 5 grams of malachite green in 100 ml of distilled water and stirring for 30 min. The solution was filtered to remove any undissolved crystals. The filtrate was then used for staining smears by placing a drop on the slide and mixing with the sample prior to examination. Although *Taenia* spp. eggs are not normally found in cattle faecal samples, no specific technique was used for detection of cysticercosis in cattle.

Approximately 50 grams of soil sample was immersed in distilled water and filtered through a strainer with 500-μm pores to remove large particles. The filtrate was allowed to passively sediment overnight in a straight-sided container. A portion of the supernatant was decanted until approximately 10 ml of the content at the base of the container. The content was swirled and transferred into a 15-ml centrifuge tube. The content was centrifuged at 2000 rpm for 2 min. After centrifugation, the supernatant was decanted and the sediment was kept in a rack to settle. The sediment was subsequently agitated by shaking and apportioned as follows: one portion was examined after formalin–ether sedimentation; and the other portion was used for the zinc sulphate floatation procedure. The portion for flotation was further aliquoted; one aliquot was examined directly and the other aliquot was stained with malachite green, as described for stool samples.

Faecal and environmental sample microscopy

Each smear (the formol–ether sedimentation preparation, and the stained and unstained smears of the zinc sulphate floatation preparations) was examined under a light microscope at 10X, 40X, and 100X by 2 investigators. In cases in which the results of the same specimen from the two investigators disagreed, a third more experienced investigator examined the slide and adjudicated on inconsistencies. The results were documented on data forms.

TABLE 1 | Distribution of study participants and samples by community.

Community	Number of human participants (%)	Number of cattle sampled (%)	Number of home soil samples (%)
Bilingo	62 (12.3)	55 (9.2)	11 (9.6)
Yolde	60 (11.9)	54 (9.0)	10 (8.8)
Lugga	11 (2.2)	18 (3.0)	3 (2.6)
Gindin Dutse	27 (5.4)	50 (8.3)	8 (7.0)
Veterinary	18 (3.6)	39 (6.5)	6 (5.3)
Wuro Ardo Yerima	48 (9.5)	65 (10.9)	13 (11.4)
Wuro Ardo Saleh	64 (12.7)	78 (13.0)	16 (14.0)
Wuro Nduroi	40 (7.9)	34 (5.7)	7 (6.1)
Yolde Ginnaji	67 (13.3)	89 (14.9)	16 (14.0)
Yolde Na'i	53 (10.5)	39 (6.5)	8 (7.0)
Changala 1	36 (7.1)	45 (7.5)	9 (7.9)
Changala 2	18 (3.6)	33 (5.5)	7 (6.1)
Total	504 (100.0)	599 (100.0)	114 (100.0)

Data analysis

Data collected was entered into EpiData (www.epidata. dk) and analysed using IBM-SPSS 20 (IBM). Simple percentages were used to present the infection prevalence and the distribution across socio-demographic variables (community, gender, age group, clan and husbandry practice). A chi-square test was used to determine the association between ZEP infections and socio-demographic variables. The Pearson correlation was used to measure the direction and degree of correlation between the distribution of ZEP infectiosn among human cattle and soil across communities.

TABLE 2 | Distribution of human participants by gender, age group, clan, and husbandry practice, and cattle by sex and age group.

Variable/values	Number enrolled	Percentage
Humans		
Gender		
Male	254	50.4
Female	250	49.6
Age group		
<5 years	206	40.9
5-15 years	147	29.2
16-39 years	109	21.6
40-59 years	42	8.3
Clan		
Kiri	154	30.6
Bodien	71	14.1
Jahun	166	32.9
Uda	102	20.2
Wiiti	11	2.2
Husbandry practice		
Nomadic	25	5.0
Semi-nomadic	414	82.1
Sedentary	65	12.9
^Total	504	100.0
Cattle		
Sex		
Male	240	40.1
Female	359	59.9
Age group		
<=2 years	175	29.2
>2 but <5 years	209	34.9
5 years & above	215	35.9
^Total	599	100

Ethical approval

Ethical approval (approval no. ADHREC 15/07/2019/036) was obtained from the Health Research Ethics Committee of Adamawa State Ministry before data collection commenced.

RESULTS

Stool samples and demographic information from 504 human participants across 12 pastoral communities were analysed (Table 1). The participants included 50.4% males and 49.6% females of different ages (range, 6 months-59 years), and 5 Fulani clans (Kiri, Jahun, Bodi'en, Uda, and Wiiti) who engage in nomadic, sedentary, or semi-sedentary husbandry practices (Table 2). Faecal samples were also collected from 599 cattle (40.1% males and 59.9% females) between 4 months and 9 years of age across the same 12 communities in 3 LGAs. Soil samples were collected from 114 homes in the 12 communities that were included in the study (Table 1).

Distribution of ZEP infections
The distribution of ZEP infection among humans, cattle, and soil across the study communities

The ZEP infections in the study included *Cryptosporidium* spp. (prevalence of 14.1% in humans, 17.9% in cattle, and 37.7% in soil), *Entamoeba* spp. (prevalence of 12.3% in humans, 14.9% in cattle, and 24.6% in soil), *Giardia intestinalis*, (prevalence of 12.1% in humans, 14.9% in cattle, and 31.6% in soil), *Fasciola* spp. (prevalence of 1.8% in humans, 6.3% in cattle, and 3.5% in soil), *Taenia* spp. (prevalence of 3.0% in humans, 0.5% in cattle, and 7.0% in soil), and *Trichostrongylus* spp. (prevalence of 3.2% in humans, 6.7% in cattle, and 8.8% in soil).

The overall prevalence of ZEP infections among humans in the study area was 40.3%. The prevalence in Yolde Na'i (54.7%) was the highest, followed by Changala I, (52.8%); Gindin Dutse was shown to have the lowest ZEP infections at 29.6%. The overall prevalence of ZEP infections were not significantly different across communities (P=0.05; Table 3). Among cattle, the overall prevalence of ZEP infections was 48.2% and the highest prevalence of ZEP infections was recorded in Lugga (66.7%), while the lowest prevalence of ZEP infections was in Gidin Dutse (34%). Overall, the prevalence of ZEP infections was significantly different across communities (P=0.05; Table 3). The overall prevalence of ZEP infections in home soil samples was 74.6%, with the highest community prevalence of ZEP infections at 100% in Lugga and the lowest prevalence of ZEP infections at 54.3% in Bilingo. The prevalence of ZEP infections in home soil was not significantly different across communities (P=0.05; Table 3).

Distribution of ZEP infections by gender, age group, clan, and husbandry practice

Of the 504 participants examined, 42.1% were males and 38.4% were females; however, the difference in

TABLE 3 | Prevalence of ZEPs among humans, cattle, and home soil by community.

Community	Prevalence of ZEPs					
	Among humans		Among cattle		In home soil	
	Number examined	% positive	Number examined	% positive	Number examined	% positive
Bilingo	62	33.9	55	49.1	11	54.5
Yolde	60	30.0	54	35.2	10	60.0
Lugga	11	45.5	18	66.7	3	100.0
Gindin Dutse	27	29.6	50	34.0	8	75.0
Veterinary	18	44.4	39	59.0	6	83.3
Wuro Ardo Yerima	48	37.5	65	50.8	13	92.3
Wuro Ardo Saleh	64	45.3	78	55.1	16	87.5
Wuro Nduroi	40	47.5	34	41.2	7	71.4
Yolde Ginnaji	67	31.3	89	38.2	16	56.3
Yolde Na'i	53	54.7	39	59.0	8	75.0
Changala 1	36	52.8	45	57.8	9	77.8
Changala 2	18	44.4	33	54.5	7	85.7
Total /(% of)	504	40.3	599	48.2	114	74.6
P value (X^2 test)		0.134		0.025*		0.390

*= significant at a P=0.05.

prevalence between male and female participants was not statistically significant (P=0.05). Participants < 5 years of age had the highest prevalence of ZEP infections (50%), while the group 40-59 years of age had the lowest prevalence of ZEP infections (21.4%). A chi-square test showed that the prevalence of ZEP infections was significantly associated with age group (P=0.005). With respect to the 5 clans included in the study, the prevalence of ZEP infections differed significantly across clans, as follows: Bodi'en, 52.1%; Wiiti, 45.5%; Jahun, 44.6%; Uda, 39.2%; and Kiri, 30.5%. The pastoralists with a semi-nomadic husbandry practice had the highest proportion of ZEP infections (41.1%), followed by the nomadic and sedentary practices (40% and 35.4%), respectively (P =0.005; Table 4). With respect to cattle subjects, The difference in prevalence of ZEP infections between males (52.1%) and females (45.7%) was not statistically significant; however, the prevalence of ZEP infections in younger cattle (≤ 2 years of age) was significantly higher (62.9%) than the older category (>2 and < 5 years of age) which had a ZEP infection prevalence of 49.8%. Cattle that were ≥ 5 years of age had the lowest prevalence of ZEP infections (34.9%; Table 4).

Correlation between ZEP infections among humans, cattle, and soil

Pearson correlation analysis was performed to determine the correlation between the prevalence of ZEP infections in humans and cattle within the study area. There was a strong positive correlation (R = 0.750) between the overall prevalence of ZEP infections among humans and cattle with respect to the study communities (P=0.005; Fig 2).

Bivariate Pearson correlations between the prevalence of specific ZEP types among humans and cattle were also analysed (Fig 3). Figure 3(A) shows a strong positive correlation (R=0.770) between *Cryptosporidium* spp. among humans and cattle in the studied communities (P=0.005). Figure 3(B) also shows a very strong positive correlation (R = 0.840) between *Entamoeba* spp. among humans and cattle in the studied communities at the 99.5% confidence level. Similarly, Fig 3(C) shows a very strong positive correlation (R =0.902) between *G. intestinalis* among humans and cattle across the study communities at the 99.5% confidence level. Figure 3(D) also shows a strong positive correlation (R =0.706) between *Fasciola* spp. among humans and cattle across the communities at the 95% confidence level. Figure 3(E) shows a very strong positive correlation (R = 830) between the prevalence of *Taenia* spp. among humans and among cattle across the study communities (P = 0.001). Also, Fig 3(F) shows a weak positive correlation (R = 0.260) between the prevalence of *Trichostrongylus* spp. among humans and cattle in the study communities; the correlation was not statistically significant (P=0.05; Fig 3).

The bivariate Pearson correlation between the prevalence of ZEP infections among humans and home soil was moderately positive (R = 0.484), but not statistically significant (P = 0.05). There was a strong positive correlation (R = 0.677) between the prevalence of ZEP infections among cattle and home soil samples (P = 0.05; Fig 4). A multivariate representation of the correlation between

TABLE 4 | Distribution of ZEPs by gender, age group, clan, and husbandry practice.

Variable/values	Number enrolled	% positive	P value (X^2 test)
Humans			
Gender			0.394
Male	254	42.1	
Female	250	38.4	
Age group			0.001**
<5 years	206	50.0	
5-15 years	147	38.1	
16-39 years	109	32.1	
40-59 years	42	21.4	
Clan			0.020*
Kiri	154	30.5	
Bodien	71	52.1	
Jahun	166	44.6	
Uda	102	39.2	
Wiiti	11	45.5	
Husbandry practice			0.686
Nomadic	25	40.0	
Semi-nomadic	414	41.1	
Sedentary	65	35.4	
^Total	504	40.3	
Cattle			
Sex			0.124
Male	240	52.1	
Female	359	45.7	
Age group			<0.001**
<=2 years	175	62.9	
>2 but <5 years	209	49.8	
5 years & above	215	34.9	
^Total	599	48.2	

*= significant at a P=0.05; **= significant at a P=0.005.

FIGURE 2 | Correlation between ZEP infections among humans and cattle by community. R= 0.750 (P=0.005**). *= significant at a P=0.05; **= significant at a P=0.005.

the prevalence of ZEP infections in 3 sample categories (humans, cattle, and home soil) also showed a significant (P = 0.005), strong positive correlation (R = 0.750; Fig 5).

DISCUSSION

Six ZEPs were identified across human participants, cattle, and soil samples in the study area. The overall prevalence of the parasites was within the ranges of findings from similar studies conducted in Nigeria. Specifically, a review of the intestinal parasite prevalence among human populations in Nigeria reported the overall prevalence of intestinal helminthes was approximately 40% [25].
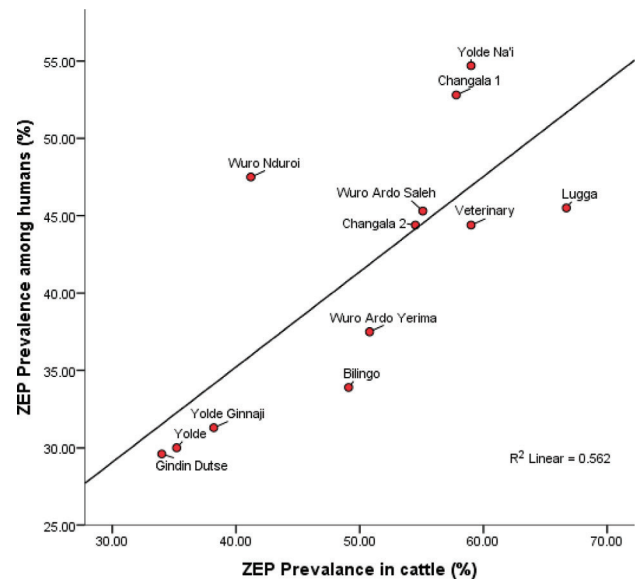
A study of intestinal parasites among school children in Rivers State of Nigeria found an overall prevalence of 27.4% [26], while a similar study in Oshodi of Lagos State reported an overall prevalence of 58.3% [27]. A study in the Plateau State of central Nigeria determined that the prevalence of gastrointestinal parasites among cattle was 46% [28]; however, several other studies have reported a prevalence of 70%–100% in different parts of Nigeria [29-31]. In another study conducted among pastoral Fulani in the Zamfara State of Nigeria, the prevalence of gastrointestinal parasites was 67% [32].

The most prevalent ZEP among humans was *Cryptosporidium* spp., followed by *Entamoeba* spp. and *Giardia intestinalis* (14.1%, 12.3%, and 12.1% respectively). This order of prevalence is similar, but with a relatively narrower disparity to a study among children in Lagos, in which the prevalence of the parasites were 17.1%, 9.5%, and 4.8%, respectively [33]. It is noteworthy that similar trends in the prevalence of ZEPs were found among cattle and other environmental samples. The similarity in prevalence of different ZEPs across different study samples can be regarded as a subtle indicator of zoonotic transmission. The least prevalent ZEP in the study was *Fasciola* spp., with a prevalence much higher in cattle (4.7%) than humans (1.8%). The difference in the prevalence can be explained by the fact that the transmission of *Fasciola* spp. requires an aquatic intermediary host (the snail). Moreover, the infective stage (cercariae) is usually found on aquatic vegetation where the infective stage is much more likely to be ingested by cattle than by humans. For cattle, because only faecal samples were examined, the proper diagnostic method for *Taenia* spp. was not carried out and hence only 3 (0.5%) of the faecal samples were shown to be positive for *Taenia* spp. Because
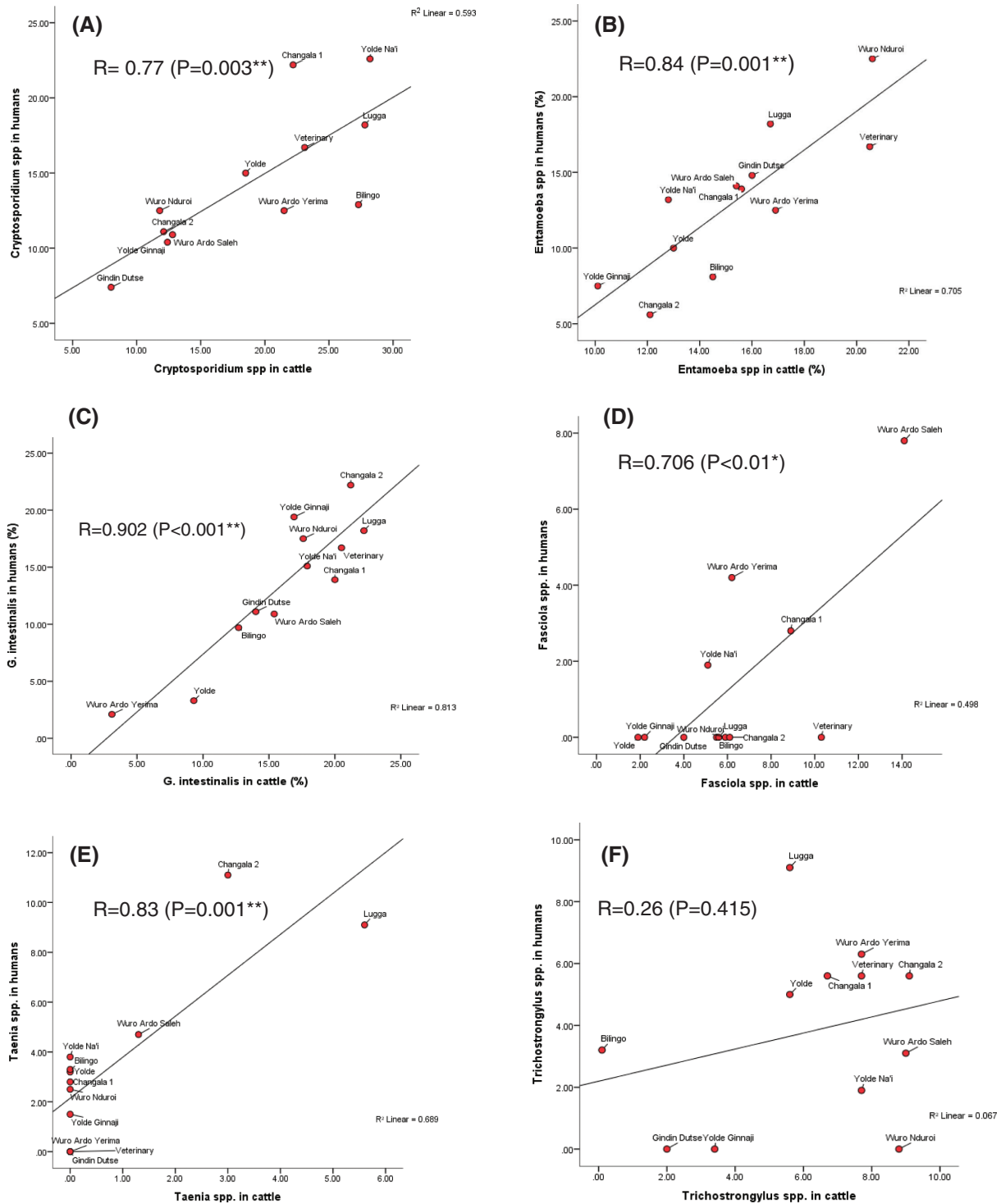
FIGURE 3 | Correlations between the different zoonotic ZEP infections among humans and cattle by community. *= significant at a P=0.05; **= significant at a P=0.005.

Taenia spp. is not known to lay eggs in its intermediate host (cattle) the few Taenia eggs detected in cattle faecal samples might be attributable to contamination during collection, processing, or some non-viable ingested egg passing through the faeces.

There was a strong positive correlation (R=0.750; P<0.005) between the overall prevalence of ZEP infections among humans and cattle across the study communities. Similar trends of correlations in prevalence were also observed with respect to all but one (*Trichostrongylus* spp.) of the parasite types. This finding is a strong indicator of an ongoing zoonotic transmission of the parasites.

Although the positive correlation between the prevalence of ZEP infections among humans and in home
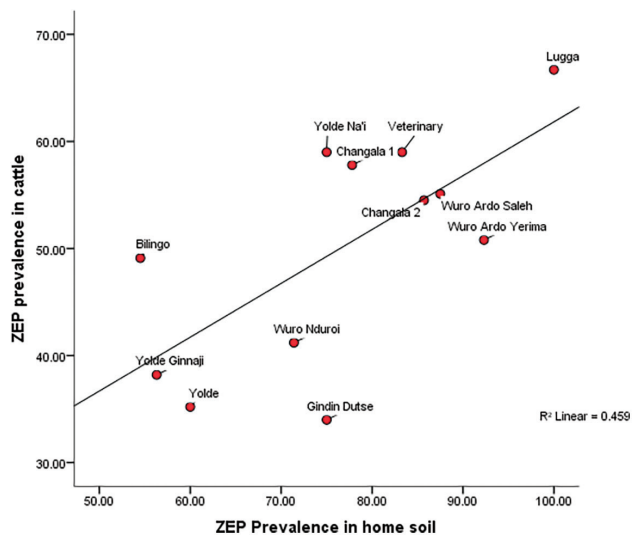
FIGURE 4 | Correlation between ZEP infections among cattle and home soil by community. R= 0.750 (P=0.005**). *= significant at a P=0.05.

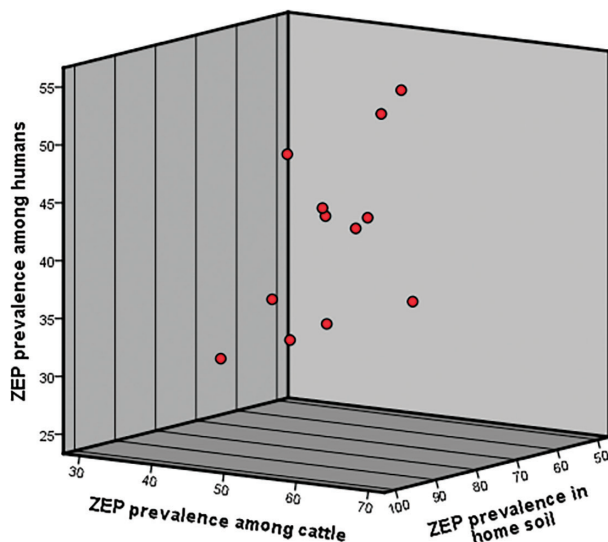**FIGURE 5** | Multivariate correlation between ZEP infections among humans, cattle, and home soil by community. R= 0.750 (P=0.005**). *= significant at a P=0.05; **= significant at a P=0.005.

soil across communities was only moderate ($R = 0.484$) and not statistically significant ($P = 0.05$). The positive correlation between the prevalence of ZEP among cattle and home soil was strong ($R = 0.677$) and statistically significant. Also, the multivariate correlation involving the prevalence of ZEP infections with respect to the three sample categories (humans, cattle, and home soil) was also strongly positive ($R = 0.750$) and statistically significant ($P = 0.005$). These positive correlations of prevalence, which were stronger between humans and cattle than between humans and soil or cattle and soil, further strengthens the indication that there is an ongoing zoonotic transmission of ZEPs in the study area.

CONCLUSION

The current study showed that the prevalence of ZEPs in all the three categories of samples collected from the study area were moderately high in relation to reported prevalence in similar settings. The prevalence of ZEP infections was 40.3% among humans, 48.2% among cattle, and 74.6% in home soil. Although the prevalence of ZEP infections across communities was not markedly the same for each of the sample categories, the differences across communities were not statistically significant, except among cattle in which some slightly significant difference was observed ($P = 0.05$).

There was a strong positive correlation between prevalence of ZEP infections among humans and cattle (R=750), and between cattle and soil (R=677) across the study communities. This finding strongly suggests ongoing zoonotic disease transmission in the study area.

RECOMMENDATIONS

Efforts to control infectious diseases, and more specifically zoonoses among pastoralists should consider integrated approaches that attend to livestock health as well because many of the pathogens are shared between humans and livestock.

Further research should explore the strengthening of evidence for ongoing zoonotic disease transmission by determining the genetic associations between zoonotic infectious agents in humans and cattle. Further research with a different or broader scope to include zoonotic infections other than enteric parasites will also be useful in highlighting the extent of the problem.

CONFLICTS OF INTEREST

No conflicts of interest are declared.

REFERENCES

1. Han BA, Kramer AM, Drake JM. Global patterns of zoonotic disease in mammals. Trends Parasitol. 2016;32:565-577.
2. Pelzer KD, Currin N. Zoonotic diseases of cattle. In *VCE Publications*, Volume 400. Virginia: Virginia Cooperative Extension; 2009:1-5.
3. Lo Iacono G, Cunningham AA, Fichet-Calvet E, Garry RF, Grant DS, Leach M, et al. A unified framework for the infection dynamics of zoonotic spillover and spread. PLoS Negl Trop Dis. 2016;10:e0004957.
4. Menghistu HT, Hailu KT, Shumye NA, Redda YT. Mapping the epidemiological distribution and incidence of major zoonotic

diseases in South Tigray, North Wollo and Ab'ala (Afar), Ethiopia. PLoS One. 2018;13:e0209974.

5. Pisarski K. The global burden of disease of zoonotic parasitic diseases: top 5 contenders for priority consideration. Trop Med Infect Dis. 2019;4:44.

6. Vesterinen HM, Dutcher TV, Errecaborde KM, Mahero MW, Macy KW, Prasarnphanich OO, et al. Strengthening multi-sectoral collaboration on critical health issues: one health systems mapping and analysis resource toolkit (OH-SMART) for operationalizing one health. PLoS One. 2019;14:e0219197.

7. Grace D. Infectious diseases and agriculture. In *Encyclopedia of Food Security and Sustainability.* 1st edition. Edited by Ferranti P, Berry EM, Anderson JR. Oxford: Elselvier; 2019:439-447.

8. Grace D, Mutua F, Ochungo P, Kruska R, Jones K, Brierley L, et al. Mapping of poverty and likely zoonoses hotspots. In *Zoonoses Project.* Kenya: International Livestock Research Institute; 2012b:119.

9. Wharam B, Lazarou L. Ethical considerations in an era of mass drug administration. Parasit Vectors. 2013;6:234.

10. Torgerson PR, Devleesschauwer B, Praet N, Speybroeck N, Willingham AL, Kasuga F, et al. World Health Organization estimates of the global and regional disease burden of 11 foodborne parasitic diseases, 2010: a data synthesis. PLoS Med. 2015;12:e1001920.

11. Kirk MD, Pires SM, Black RE, Caipo M, Crump JA, Devleesschauwer B, et al. World Health Organization Estimates of the global and regional disease burden of 22 foodborne bacterial, protozoal, and viral diseases, 2010: a data synthesis. PLoS Med. 2015;12:e1001921.

12. Woolhouse ME, Gowtage-Sequeria S. Host range and emerging and reemerging pathogens. Emerg Infect Dis. 2005;11:1842-1847.

13. Truebswasser U, Flintan F. Extensive (pastoralist) cattle contributions to food and nutrition security. In *Encyclopedia of Food Security and Sustainability.* Edited by Ferranti P, Berry EM, Anderson JR. Oxford: Elsevier; 2019:310-316.

14. Tamou C. Understanding relations between pastoralism and its changing natural environment. PhD. Wageningen University, Institute of Animal Sciences; 2017.

15. Morand S, McIntyre KM, Baylis M. Domesticated animals and human infectious diseases of zoonotic origins: domestication time matters. Infect Genet Evol. 2014;24:76-81.

16. McDaniel CJ, Cardwell DM, Moeller RB, Jr., Gray GC. Humans and cattle: a review of bovine zoonoses. Vector Borne Zoonotic Dis. 2014;14:1-19.

17. Mai HM, Irons PC, Kabir J, Thompson PN. A large seroprevalence survey of brucellosis in cattle herds under diverse production systems in northern Nigeria. BMC Vet Res. 2012;8:144.

18. Na'acha E, Vandi P, Chessed G. Species and prevalence determination of Human Intestinal Parasites among Patients attending two Medical Centers in Yola, Adamawa State, Nigeria. J Appl Sci Environ Manage. 2017;21:431-437.

19. City Population: Nigeria, Administrative Divisions, Adamawa State. [https://citypopulation.de/php/nigeria-admin.php?adm1id=NGA002]. Accessed 11 June 2019.

20. John S, Tyndall JA, Okoye V, Osewe OEO. Leprosy among the Fulani nomadic pastoralist population of Adamawa State, Nigeria. Lepr Rev. 2017;88:364-372.

21. Adamawa State Ministry of Livestock and Aquaculture Development: Population of livestock in Adamawa State. Unpublished official record of the Adamawa State Ministry of Livestock and Aquaculture Development, Yola, Nigeria; 2019:1. Accessed 6 February 2019.

22. Survey Systems Sample Size Calculator. [https://www.surveysystem.com/sscalc.htm]. Accesssed 12 June 2019.

23. World Health Organisation. Techniques of collection, preparation and examination: Faecal specimens. In *Basic Laboratory Methods in Medical Paraitology.* England: Macmillan/Clays; 1991:9-24.

24. Arora DR, Arora BB. Medical parasitology. New Delhi: CBS Publishers and Distributors; 2014.

25. Funso-Aina O, Chineke H, Adogu P. A Review of Prevalence and Pattern of Intestinal Parasites in Nigeria (2006-2015). Eur J Med Health Sci. 2020;2:1-6.

26. Abah AE, Arene FOI. Status of intestinal parasitic infections among primary school children in rivers state, Nigeria. J Parasit Res. 2015;2015:937096.

27. Ajayi MB, Sani AH, Ezeugwu SMC, Afocha EE, Adesesan AA. Intestinal parasitic infection and body mass index among school children in oshodi lagos nigeria. Adv Cytol Pathol. 2017;2:44-49.

28. Daminabo V, Damen J. Prevalence of intestinal parasites from abattoir effluents in jos metropolis, Nigeria. International. J Photochem Photobiol. 2020;4:1-10.

29. Okike-Osisiogu FU, Arinze AG, Ekaiko MU. Prevalence of intestinal parasites in cattle slaughtered in Aba. J Agric Res. 2016;2:20-27.

30. Qadeer MA, Gumel MA, Chessed G, Nganjiwa JI, Bernard K, Vandi P, et al. A cross sectionnal study on the gastrointestinal and haemoparasites of trade cattle in Girei And Yola North Local Government areas of Adamawa State, Nigeria. IOSR J Agric Vet Sci. 2015;8:3-5.

31. Dogo GIA, Karaye PG, Patrobas MG, Galadima M, Gosomji IJ. Prevalence of Gastrointestinal Parasites and their impact in Domestic animals in Vom, Nigeria. Saudi J Med Pharm Sci. 2017;3:3-5.

32. Jombo GT, Damen JG, Safiyanu H, Odey F, Mbaawuaga EM. Human intestinal parasitism, potable water availability and methods of sewage disposal among nomadic Fulanis in Kuraje rural settlement of Zamfara state. Asian Pac J Trop Med. 2010;3:491-493.

33. Wellington O, Chika O, Teslim O, Oladipo O, Adetayo F, Godswill I. Cryptosporidium and other intestinal protozoans in children with diarrhoea in Lagos, Nigeria. Internet J Trop Med. 2018;5:1-5.