J Vet Sci. 2023 Jan;24(1):e8
https://doi.org/10.4142/jvs.21211
pISSN 1229-845X·eISSN 1976-555X

Journal of Veterinary Science

Original Article
Epidemiology

Check for updates

Prevalence of intestinal parasites in animal hosts and potential implications to animal and human health in Edo, Nigeria

Collins Usunobun Inegbenosun [1], **Clement Isaac** [1,*], **Felicitas Ugienosomi Anika** [2], **Ogbeide Philip Aihebholoria** [1]

[1]Department of Zoology, Faculty of Life Sciences, Ambrose Alli University, Ekpoma, Nigeria
[2]Department of Biological Science and Technology, Auchi Polytechnic, Auchi, Nigeria

OPEN ACCESS

Received: Jul 27, 2021
Revised: Aug 30, 2021
Accepted: Sep 25, 2021
Published online: Nov 19, 2021

***Corresponding author:**
Clement Isaac
Department of Zoology, Faculty of Life Sciences, Ambrose Alli University, Ekpoma 310001, Nigeria.
E-mail: cle21200@gmail.com
https://orcid.org/0000-0002-6320-0312

ABSTRACT

Background: Intestinal parasites in livestock cause huge economic setbacks. Moreover, these parasites can threaten human health when also present in companion animals.
Objectives: The study examined the prevalence and burden of intestinal parasites among roaming/migrating animals (goats, sheep, cattle, and dogs) to provide insights into the risk of potential human parasitic infections.
Methods: A total of 1,741 fecal samples from goats (n = 920), sheep (n = 335), cattle (n = 230) and dogs (n = 256) were obtained randomly across 18 local government areas in Edo State, Nigeria. The parasite samples were recovered and identified under a microscope. Molecular tools were used to identify *Toxocara* spp.
Results: Eighteen different parasites were isolated. Among the different groups of parasites observed, nematodes occurred the most, followed by protozoans. Among nematodes, *Haemonchus* was most prevalent in goats (28.04%) and sheep (29.85%), while *Strongyloides* (10.86%) and *Bunostomum* (8.69%) were relatively high in cattle. *Strongyloides* (3.9%), hookworm (3.9%), and *Toxocara* (3.12%) were the predominant parasites in dogs. For protozoan parasites, *Eimeria* was most common in all 4 animal hosts. Several goats (2.39%) and sheep (2.38%) tested positive for *Fasciola* spp. Molecular analysis confirmed *Toxocara canis* in dogs for the first time in Nigeria.
Conclusions: The major parasites recovered from these roaming/migrating animals have zoonotic potentials that can threaten human health.

Keywords: Livestock; dogs; Nematodes; Protozoans; Zoonotic potential; *Toxocara canis*

INTRODUCTION

The livestock industry is a major source of income and livelihood for most Nigerians, who are rural settlers, and contributes approximately 5.2% to the National Gross Domestic Product [1]. In Nigeria, the practice of moving cattle and small ruminants under a semi-extensive system is still common. In rural areas of southern Nigeria, a subsistence management system is mostly practiced as many farmers allow their animals to move freely within the community, searching for food and water [2]. Similarly, many 'local' dogs move around the villages and towns untamed,

ORCID iDs
Collins Usunobun Inegbenosun
https://orcid.org/0000-0001-6800-6570
Clement Isaac
https://orcid.org/0000-0002-6320-0312
Felicitas Ugienosomi Anika
https://orcid.org/0000-0002-6477-8765
Ogbeide Philip Aihebholoria
https://orcid.org/0000-0002-6532-7480

Author Contributions
Conceptualization: Isaac C; Data curation: Inegbenosun CU, Isaac C; Formal analysis: Isaac C; Funding acquisition: Inegbenosun CU; Investigation: Inegbenosun CU, Isaac C, Anika FU, Aihebholoria OP; Methodology: Inegbenosun CU, Isaac C, Anika FU, Aihebholoria OP; Project administration: Isaac C; Resources: Isaac C; Software: Isaac C; Supervision: Isaac C; Validation: Isaac C, Inegbenosun CU; Visualization: Inegbenosun CU, Isaac C, Anika FU, Aihebholoria OP; Writing - original draft: Inegbenosun CU, Isaac C; Writing - review & editing: Inegbenosun CU, Isaac C, Anika FU, Aihebholoria OP.

Conflict of Interest
The authors declare no conflicts of interest.

Funding
Funding was made available by Tertiary Education Trust Fund (TETFUND), Nigeria.

This paper was published with special support from the Korean Society of Veterinary Science.

which exposes these roaming/moving animals to a high risk of acquiring a range of parasites through various sources [3]. Several factors (environmental, nutritional, immunological, and grazing system) could influence parasitic disease conditions in animals [4,5].

The parasites acquired by these animals can adversely affect their economic value and pose serious public health challenges [6-8]. The effects of parasitic infections could be exacerbated in places where there is little or no veterinary care with inadequate policies on disease control [9], which is largely the case in rural Edo. In Nigeria, most studies reporting the prevalence of intestinal parasites in a locality indicate that the samples were from abattoirs [10]. The implication is that some of the prevalence results, including the parasite distribution, may misrepresent the local situation because many of the animals in abattoirs within southern Nigeria are not sourced from local breeders.

Thus far, studies on the prevalence of helminths infections among small ruminants and cattle in Nigeria have shown a significant level of heterogeneity [10]. However, there is a paucity of data on the prevalence and distribution of intestinal parasites in roaming/stray and migrating animals (goats, sheep, cattle, and dogs) in Edo state. In this case, sample collection was not concentrated in a location but obtained across all local government areas (LGAs) within the state to represent the general prevalence and spread of various parasites. These data are expected to assist in intervention programs for parasitic disease control [11] and provide insights into the parasites likely to affect public health. In addition, this study used molecular tools to identify *Toxocara canis* as the major potential parasite of dogs in the state.

MATERIALS AND METHODS

Study area

Edo State (6.6342°N, 5.9304°E) is in South-South Nigeria with an area of 17,802 km^2 that comprises 18 LGAs (**Fig. 1**). Edo is largely rural with a rainforest vegetation type. Two seasons are seen: dry (November to March) and wet (April to October). Many homes in Edo, especially those in rural communities, rear goats and sheep at the subsistence level that are allowed to stray, while cattle rearing is done by more economically endowed persons. Cattle are moved regularly from one point to another in search of food and water. Dogs are seen roaming house premises, streets, and in unfenced schools.

Sample collection and analysis

Sample collections were carried out in the 18 LGAs from September 2018 to March 2021. No collection was done in 2020 due to the coronavirus disease 2019 lockdown. The samples were obtained in at least 2 communities from each LGA with a near-equal sample size for each animal host within the surveyed locations (LGAs) (**Fig. 1**). For the inclusion criteria, samples were collected largely from livestock and dogs not caged or restricted but often led to pastures in the case of cattle and those allowed to fend for themselves and return to their base at dusk in the case of small ruminants and dogs. After obtaining permission from the owners, fresh fecal samples were collected into sterile containers with the owner's assistance. The qualitative fecal analysis was performed using a saturated sucrose solution (781.25 g per 500 mL) floatation technique [12], in which crushed fecal pellets (2 g) were suspended and sieved through a tea strainer. The filtrate was then poured into 10 mL floatation bottles. Coverslips were then applied and left to stand for 10 min. The coverslips were mounted on glass slides and examined under 100× magnification for morphological identification of the oocyst, cyst, trophozoite, egg,

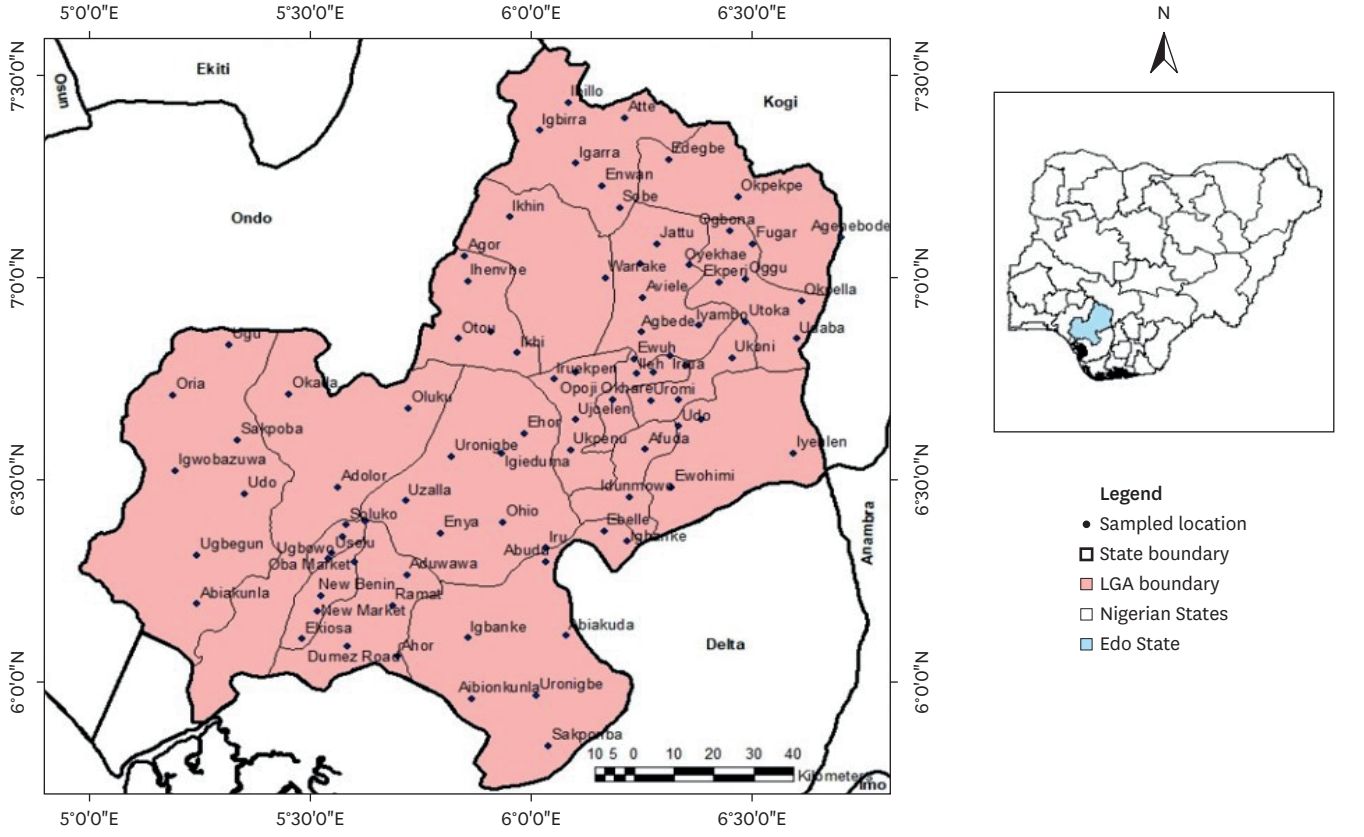

Fig. 1. Map of Edo showing sampling locations.
LGA, local government area.

and larval stages [13]. Positive samples were subjected to quantitative analysis using a simple McMaster technique with a sensitivity of 50 eggs/oocyst per gram (epg/opg) of feces. Egg/oocyst counts were categorized as mild/low (50–799 epg/opg), moderate (800–1,200 epg/opg), or severe/heavy (> 1,200 epg/opg) [12].

Primer design and amplification for *Toxocara*

DNA was extracted from 8 microscopically positive samples for *Toxocara* (dog samples, n = 8). Using a primer pair (TcNad-1 F = 5′ ACCCCTTGAATTCTTCTGAGGTATCT 3′ and TcNad-1 R = 5′ GATCATAACGAAAACGCGGGTAAGC 3′) designed based on the complete mitochondrial genome of *T. canis* (GenBank: AM411108), the partial *nad*1 gene was amplified by polymerase chain reaction (PCR) in a 25 μL final volume using 2 mM $MgCl_2$, 0.2 mM dNTPs, 5 μL of 5× Taq buffer, 10 pmol of each primer, 0.5 μL of Ex Taq DNA polymerase (5 U/μL; TaKaRa, Japan), 0.5 μL of genomic DNA extract and RNAse free water to make up the final volume. The PCR conditions were as follows: 95°C for 5 min initial denaturation, followed by 30 cycles of denaturation at 95°C for 30 sec, annealing at 55°C for 30 sec, extension at 72°C for 40 sec, and a final extension at 72°C for 10 min. The PCR products were detected in a 1.5% (w/v) agarose gel stained with GelRedTM. Five microliters of the amplicon were used for visualization, while the rest were sequenced in an ABI3730xl DNA Analyser.

Phylogenetic analysis

The phylogenetic tree was inferred using the Maximum Likelihood method based on the Hasegawa-Kishino-Yano model with Gamma distributed rates (HKY+G), as determined by

Journal of Veterinary Science

the lowest BIC score in MEGA X [14]. The number of bootstraps replications was set to 1,000. The analysis involved 12 nucleotide sequences. All positions containing gaps and missing data were eliminated. A total of 529 bp was available for tree construction. The analysis was conducted in MEGA X [15]. *Ascaridia galli* was used as an outgroup.

Statistical analysis

A student *t*-test was applied to compare the prevalence data as the mean values indicated SE and 95% confidence interval (CI) using SPSS version 25, 2015 (IBM, USA). Differences between the mean results were significant at $p < 0.05$.

RESULTS

Compared to the other groups of parasites, the prevalence of nematodes in goats was higher in 14 LGAs, while protozoan parasites occurred the most in 4 LGAs (**Table 1**). The number of

Table 1. Prevalence of various groups of parasites in goats according to the LGA

LGA	Nematodes	Protozoans	Cestodes	Trematodes
Esan West (n = 47)	5	4	-	-
	20 (42.55)	11 (23.4)	-	-
Esan North East (n = 48)	5	4	-	-
	13 (27.08)	13 (27.08)	-	-
Esan South East (n = 47)	2	3	-	-
	14 (29.78)	8 (17.02)	-	-
Esan Central (n = 60)	1	2	-	-
	5 (8.33)	7 (11.66)	-	-
Etsako Central (n = 69)	2	3	-	1
	51 (73.91)	27 (39.13)	-	1 (1.44)
Etsako West (n = 17)	3	3	-	-
	5 (29.41)	4 (23.52)	-	-
Owan East (n = 44)	2	1	-	-
	23 (52.27)	1 (2.27)	-	-
Oredo East (n = 51)	3	3	-	1
	7 (13.72)	13 (25.49)	-	4 (7.84)
Owan West (n = 62)	2	2	-	1
	14 (22.58)	3 (4.83)	-	1 (1.61)
Egor (n = 49)	3	1	-	1
	20 (40.81)	1 (2.04)	-	1 (2.04)
Ikpoba-Okha (n = 41)	5	1	-	1
	1 (2.43)	4 (9.75)	-	2 (4.87)
Uhunmwonde (n = 49)	2	2	-	1
	24 (48.97)	22 (44.89)	-	1 (2.04)
Ovia North East (n = 50)	4	3	1	1
	20 (40)	11 (22)	1 (2)	6 (12)
Ovia South East (n = 50)	3	2	-	-
	20 (40)	11 (22)	-	-
Akoko Edo (n = 45)	3	2	-	-
	39 (86.66)	17 (37.77)	-	-
Etsako East (n = 49)	2	2	-	1
	31 (63.26)	39 (79.59)	-	9 (18.36)
Orhionmwon (n = 49)	3	2	-	1
	13 (26.53)	6 (12.24)	-	11 (22.44)
Igueben (n = 44)	3	2	-	1
	27 (61.36)	23 (52.27)	-	5 (11.36)
Total No. of positive	347 (37.71)	221 (24.02)	1 (0.21)	41 (4.66)

Values are presented as number of genera seen or number of positive (prevalence%).
LGA, local government area.

https://doi.org/10.4142/jvs.21211

goats in which trematodes were isolated was relatively low (4.66 ± 1.63, 95% CI, 1.21–8.12). On the other hand, the infection pattern with trematode by LGA showed that most LGAs in the central region recorded non-positive results. In most LGAs in southern and northern Edo, some goats tested positive for trematodes (4.66 ± 1.63, 95% CI, 1.21–8.12). *Moneiza* spp. were isolated in a goat from Ovia North East. The parasite prevalence in goats was higher with nematodes (37.71 ± 5.27, 95% CI, 28.66–50.83) than protozoans (24.02 ± 4.64; 95% CI, 15.59 ± 35.18), but the difference was not statistically significant.

More protozoan parasites were isolated in sheep than other groups of parasites in 10 LGAs (**Table 2**). In the other 8 LGAs, nematode parasites were more prevalent than other groups of parasites. Trematodes were isolated in 7 LGAs (4.55 ± 1.91, 95% CI, 0.51–8.58). Cestodes (*Moneiza* spp.) were recovered in samples from 2 LGAs. The prevalence was higher with nematodes (45.07 ± 5.95, 95% CI, 23.04–48.18) than protozoans (32.53 ± 4.64, 95% CI, 18.76–38.34) but not statistically significant.

Table 2. Prevalence of various groups of parasites in sheep according to LGA

LGA	Nematodes	Protozoans	Cestodes	Trematodes
Esan West (n = 24)	1	3	-	-
	1 (4.16)	4 (16.66)	-	-
Esan North East (n = 18)	2	4	-	-
	4 (22.22)	16 (88.88)	-	-
Esan South East (n = 21)	2	1	-	-
	8 (38.09)	2 (9.52)	-	-
Esan Central (n = 17)	1	2	-	-
	1 (5.88)	3 (17.64)	-	-
Etsako Central (n = 42)	2	3	-	2
	30 (71.42)	11 (26.19)	-	7 (16.66)
Etsako West (n = 40)	4	3	-	-
	23 (57.5)	9 (22.5)	-	-
Owan East (n = 16)	1	1	-	-
	5 (31.25)	1 (6.25)	-	-
Oredo (n = 18)	3	2	-	-
	6 (33.33)	7 (38.88)	-	-
Owan West (n = 23)	1	1	-	-
	3 (13.04)	1 (4.34)	-	-
Egor (n = 19)	3	1	-	1
	3 (15.78)	3 (15.78)	-	1 (5.26)
Ikpoba-Okha (n = 19)	3	3	1	1
	9 (47.36)	10 (52.63)	1 (5.26)	1 (5.26)
Uhunmwonde (n = 20)	2	3	-	1
	3 (15)	8 (40)	-	1 (5)
Ovia North East (n = 16)	3	1	1	-
	5 (31.25)	6 (37.5)	1 (6.25)	-
Ovia South East (n = 25)	1	2	-	-
	2 (8)	9 (36)	-	-
Akoko Edo (n = 22)	4	2	-	1
	22 (100)	6 (27.27)	-	1 (4.54)
Etsako East (n = 17)	2	2	-	1
	9 (52.94)	4 (23.5)	-	5 (29.41)
Orhionmwon (n = 17)	3	1	-	-
	7 (41.17)	5 (29.41)	-	-
Igueben (n = 19)	2	2	-	1
	10 (52.63)	4 (21.05)	-	3 (15.78)
Total No. of positive	151 (45.07)	109 (32.53)	2 (0.59)	19 (5.67)

Values are presented as number of genera seen or number of positive (prevalence%).
LGA, local government area.

https://doi.org/10.4142/jvs.21211

Journal of Veterinary Science

Table 3. Prevalence of various groups of parasites in cattle according to the LGA

LGA	Nematodes	Protozoans	Trematodes
Esan West (n = 15)	2	-	-
	9 (60)	-	-
Esan North East (n = 17)	3	-	1
	3 (17.64)	-	3 (17.64)
Esan South East (n = 13)	1	1	-
	2 (15.38)	1 (7.69)	-
Esan Central (n = 15)	1	1	-
	2 (13.33)	1 (6.66)	-
Etsako Central (n = 23)	1	1	-
	1 (4.34)	1 (4.34)	-
Etsako West (n = 18)	-	-	-
	-	-	-
Oredo (n = 18)	1	2	-
	1 (5.55)	6 (33.33)	-
Owan West (n = 40)	-	-	-
	-	-	-
Egor (n = 16)	2	2	-
	5 (31.25)	4 (25)	-
Ikpoba-Okha (n = 11)	3	1	-
	5 (45.45)	2 (18.18)	-
Uhunmwonde (n = 14)	2	2	-
	2 (14.28)	4 (28.57)	-
Ovia North East (n = 16)	5	2	-
	6 (37.5)	6 (37.5)	-
Ovia South East (n = 14)	3	1	-
	6 (42.85)	1 (7.14)	-
Akoko Edo (n = 20)	-	-	-
	-	-	-
Etsako East (n = 20)	2	1	-
	2 (10)	2 (10)	-
Orhionmwon (n = 14)	2	1	-
	2 (14.28)	2 (14.28)	-
Igueben (n = 5)	1	2	-
	5 (100)	2 (40)	-
Total No. of positive	51 (22.17)	32 (13.91)	3 (1.3)

Values are presented as number of genera seen or number of positive (prevalence%).
LGA, local government area.

Nematodes recovered from cattle were most prevalent in 5 LGAs, while protozoan parasites were most common in 4 LGAs (**Table 3**). Trematodes were isolated in Esan North East only. The prevalence of nematodes in cattle was significantly higher (22.17 ± 6.41, 95% CI, 10.62–37.82) than protozoan parasites (13.91 ± 3.26, 95% CI, 7.49–21.35) ($t = 1.36$; $p = 0.04$).

Nematodes were isolated in dogs located in 12 LGAs, while protozoan parasites were recovered in dogs from 9 LGAs (**Table 4**). Trematodes in dogs were observed in 2 LGAs. The prevalence of nematode parasites in dogs was higher (10.54 ± 2.75, 95% CI, 5.15–16.91) than protozoans (4.29 ± 2.41, 95% CI, 1.54–11.81), but the difference was not significant.

Eighteen parasites were observed (**Table 5**). For small ruminants, among the nematode parasites recovered, *Haemonchus* was most prevalent, followed by *Strongyloides*, while *Eimeria* had the highest prevalence among protozoans. Trematodes were relatively rare, but *Fasciola* was more prevalent. For cattle, *Strongyloides* were most prevalent among nematodes, followed by *Bunostomum* spp., while *Eimeria* was most prevalent among protozoans. Frequently occurring parasites in dogs among nematodes were *Strongyloides*, hookworm, and *Toxocara*, while *Eimeria* was observed the most among the protozoan group. Trematodes (*Fasciola* and *Schistosoma*) were relatively rare in few dogs.

https://doi.org/10.4142/jvs.21211

Table 4. Prevalence of various groups of parasites in dogs according to the LGA

LGA	Nematodes	Protozoans	Trematodes
Esan West (n = 14)	1	-	-
	1 (7.14)	-	-
Esan North East (n = 4)	-	-	-
	-	-	-
Esan South East (n = 11)	2	-	-
	3 (27.27)	-	-
Esan Central (n = 11)	-	1	-
	-	1 (9.09)	-
Etsako West (n = 23)	2	-	-
	6 (26.08)	-	-
Oredo (n = 12)	-	-	-
	-	-	-
Owan West (n = 30)	1	1	-
	3 (10)	1 (3.33)	-
Egor (n = 15)	1	1	-
	1 (6.66)	1 (6.66)	-
Ikpoba-Okha (n = 8)	1	1	-
	1 (12.5)	1 (12.5)	-
Uhunmwonde (n = 15)	1	1	-
	3 (20)	1 (6.66)	-
Ovia North East (n = 15)	1	1	-
	1 (6.66)	1 (6.66)	-
Ovia South East (n = 12)	1	-	-
	1 (8.33)	-	-
Akoko Edo (n = 23)	-	-	-
	-	-	-
Etsako East (n = 13)	3	1	1
	5 (38.46)	2 (15.38)	2 (15.38)
Orhionmwon (n = 15)	1	-	-
	1 (6.66)	-	-
Igueben (n = 8)	1	3	1
	2 (25)	3 (37.5)	1 (12.5)
Total No. of positive	27 (10.54)	11 (4.29)	3 (1.17)

Values are presented as number of genera seen or number of positive (prevalence%).
LGA, local government area.

Two dog samples were sequenced and showed 99.66% similarity, with differences in only 2 nucleotide sites: positions 54 and 410. The final and usable sequences were 583 bp long. The *T. canis nad*1 sequence obtained was deposited in the GenBank database under accession numbers MN635719 and MN0635720. Phylogenetic analysis revealed more than 99% similarity with the samples from Europe (EU730761) and China (AM411108) (**Fig. 2**).

DISCUSSION

The West African Dwarf (WAD) is the major goat breed in the state. Nematodes (*Haemonchus* and *Strongyloides*) followed by protozoan infections (*Eimeria*) were the most common in these goats with *Fasciola* spp. being highest among trematodes. *Haemonchus* has been reported to have little impact on the health status because of the resistance of WAD to such infections [16]. On the other hand, one study reported the pathologic impact of *Haemonchus* on WAD because it significantly reduced the packed cell volume, body weight, and body condition score [17]. Similarly, infections with *Strongyloides* could lead to a gamut of symptoms (maceration of pedal skin, diarrhea, dehydration, anorexia, and anemia) [18], including death in some heavy infections [19]. Most reported coccidian infections among goats are due to

Table 5. Prevalence of gastrointestinal parasites in goat, sheep, cattle, and dogs in the state

Parasite group	Parasite	Goat (n = 920)	Sheep (n = 335)	Cattle (n = 230)	Dog (n = 256)
Nematodes	*Haemonchus*	258 (28.04) *Eggs*	100 (29.85) *Eggs*	5 (2.17) *Eggs*	-
	Strongyloides	83 (9.02) *Embryonated eggs (49)* *Larvae (34)*	39 (11.64) *Embryonated eggs (25)* *Larvae (14)*	25 (10.86) *Embryonated eggs (15)* *Larvae (10)*	10 (3.9) *Embryonated eggs (15)* *Larvae (10)*
	Hookworm*	-	-	-	10 (3.9) *Unembryonated eggs*
	Bunostomum	-	-	20 (8.69) *Eggs*	-
	Trichostrongylus	4 (0.43) *Unembryonated eggs*	2 (0.59) *Unembryonated eggs*	2 (0.86) *Unembryonated eggs*	1 (0.39) *Unembryonated egg*
	Ascaris	7 (0.76) *Eggs*	-	1 (0.43) *Egg*	-
	Trichuris	13 (1.41) *Unembryonated eggs*	12 (3.58) *Unembryonated eggs*	2 (0.86) *Unembryonated eggs*	-
	Capillaria	1 (0.1) *Unembryonated eggs*	-	-	-
	Toxocara	-	-	-	8 (3.12)
Protozoans	*Eimeria*	55 (5.97) *Unsporulated oocysts*	64 (19.10) *Unsporulated oocysts*	17 (7.39) *Unsporulated oocysts*	12 (4.68) *Unsporulated oocysts*
	Isospora	-	4 (1.19) *Unsporulated oocysts*	-	-
	Entamoeba	4 (0.43) *Trophozoites (1)* *Cysts (4)*	1 (0.29) *Cyst*	-	-
	Giardia	8 (0.86) *Trophozoites (6)* *Cysts (2)*	6 (1.79) *Cysts*	-	-
	Buxtonella	1 (0.1) *Cyst*	-	1 (0.43) *Cyst*	-
Cestodes	*Moneiza*	1 (0.1) *Unembryonated egg*	1 (0.29) *Unembryonated egg*	- *Unembryonated eggs*	-
Trematodes	*Fasciola*	22 (2.39) *Unembryonated eggs*	8 (2.38) *Unembryonated eggs (4)* *Embryonated eggs (3)* *Adult fluke (1)*	-	2 (0.78) *Unembryonated eggs*
	Schistosoma	5 (0.54) *Eggs*	6 (1.79) *Eggs*	-	1 (0.39) *Egg*
	Dicrocoelium	-	3 (0.89) *Embryonated eggs*	-	-

Values are presented as number of positive (prevalence%). More than 2 different parasites were isolated in 30 goats as a heavy infection was recorded with *Haemonchus* (n = 45) and *Eimeria* (n = 42). For sheep, heavy infection was seen with *Haemonchus* (n = 14), *Trichostrongylus* (n = 1), and *Eimeria* (n = 16). Meanwhile, in 5 sheep, more than 2 different parasites were recovered. Two cattle had more than 2 different parasites. For the other recovered parasites in the 4 animal hosts, one or 2 parasites were noted with a mild or moderate load.
*Not a genus (common name).

Eimeria spp. Although goats can be parasitized by 16 different *Eimeria* spp., most do not cause visible clinical coccidiosis [20]. *E. ninakohlyakimovae* and *E. arloingi* are considered the most pathogenic species [21]. The incidence of infections with *Fasciola* spp. was higher than other species of trematodes, of which its presence could cause huge economic losses [22]. The host animals are at high risk of infection with *Fasciola* when they ingest contaminated vegetation close to or within the water bodies [23].

The breed of sheep observed in Edo is predominantly WAD, having similar infection patterns to goats. Although results showed a higher infection rate in sheep than goats for both nematode and protozoan infections (**Tables 1** and **2**), the signs and symptoms of infections are closely related in most cases. *Eimeria* occurs more in sheep than other animal hosts and

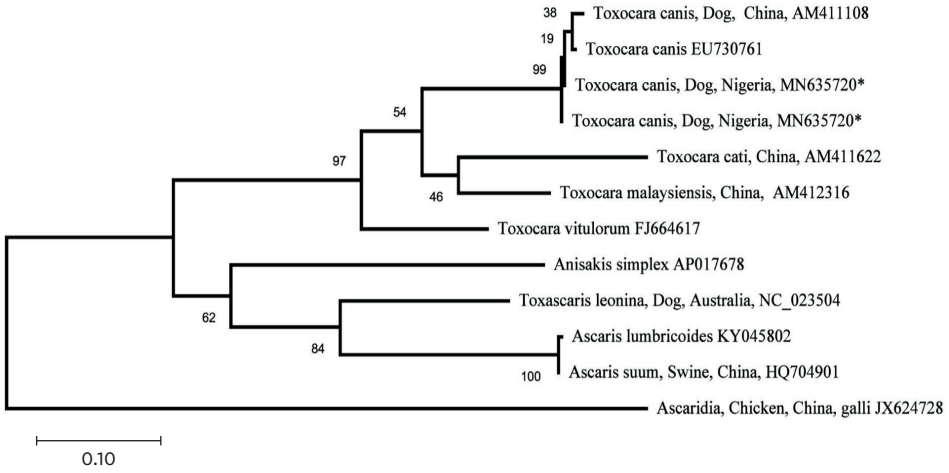

Fig. 2. Maximum-likelihood phylogenetic tree of *Toxocara canis* from dogs in Edo, Nigeria inferred using partial *nad*1 mitochondrial gene. sequences (529 bp). Sequences from this study are asterisked (*). Where available, 'host' and 'country' of isolation are added to each of the GenBank sequences. Figures on the branches are bootstrap probabilities (in %) based on 1,000 bootstrapped trees.

is clinically characterized by diarrhea, while growth impairment has been reported in the subclinical form [24,25]. The pathogenic species of *Eimeria* in sheep *are E. ovinoidalis*, *E. ovina*, *E. crandallis*, and *E. ashata* [26].

The 2 most frequently occurring parasites in these migrating cattle were *Strongyloides* and *Bunostomum* spp. As these cattle move within the community in search of pasture, they litter the environment with feces, thereby exposing the inhabitants to a risk of infections. Filariform larvae of *Bunostomum* spp. can penetrate the skin and potentially cause cutaneous larva migrans, while some others could move into deeper body tissues resulting in visceral larva migrans.

The major nematode parasites isolated from these roaming/stray dogs were *Strongyloides* spp., hookworms, and *Toxocara* spp. The clinical signs of dogs with *Strongyloides* spp. include asymptomatic to severe conditions [27]. The zoonotic potential of *Strongyloides stercoralis* has been reported in dogs [28], which may be the case in Edo. Canine hookworm infections can pose a risk to humans because hookworm species recovered from dogs were also seen among residents in close contact [29]. Two dog samples were identified as *T. canis*, and being a zoonosis, humans could acquire infection via the ingestion of embryonated/larvated eggs in the soil or contaminated food [30]. Although infections in humans can be asymptomatic, extra-intestinal pathologies may be seen [31].

In the communities surveyed, goats and sheep may harbor zoonotic parasites. They are allowed to move and defecate within home premises and wander farther from their residence to areas, such as schools that are not fenced [8]. Consequently, children play with soil within and around home premises and even in open fields in schools, exposing them to potential zoonotic infections. These animals should be treated regularly, and the practice of intensive breeding systems should be encouraged. Open grazing, which demands many cattle movements within the communities, poses a serious threat to human health. Therefore, open grazing in Nigeria should be discouraged and replaced with absolute ranching systems. In managing hookworm and other major parasites of dogs, as it relates to public health, dog-roaming should be discouraged through local policies in which mandatory provision of

shelter and restricted movement of pets are strongly advocated. With these approaches, the possible risk of human infection would be reduced significantly [32].

The traditional method (microscopy) used for diagnosis in this study is limited to ova/oocyst and larva identification. Consequently, the species presence and profile may have been marginally under-reported. On the other hand, as this is the first comprehensive survey for the state, we believe that these results have enriched epidemiological data with the potential of stimulating further studies. As culturing some parasites for identification purposes is laborious and requires special skills, future studies should incorporate complementary microscopy. Furthermore, although *T. canis* was confirmed by sequencing, all other major parasites (*Haemonchus*, *Strongyloides*, Hookworm, *Bunostomum*, *Eimeria*, and *Fasciola*) recovered should be profiled at the species level. If this can be achieved, a clearer picture of the level of zoonotic infections occurring in these animal hosts can be obtained. In addition, by deploying molecular techniques in epidemiological studies, disease mapping becomes more reliable, and targeted approaches with anthelmintics can be adopted easily. This targeted anthelmintic application can reduce the rate of parasite resistance to anthelmintic drugs caused by overuse, in addition to providing greater protection for consumers of animal products.

ACKNOWLEDGEMENTS

The authors' wish to thank Dr. Ohiolei of the Veterinary Research Institute, CAAS, Lanzhou, China for his technical assistance with the molecular work.

REFERENCES

1. Adedipe NO, Bakshi JS, Odegbaro OA, Aliyu A. *Evolving the Nigeria Agricultural Research Strategy Plan: Agro-Ecological Inputs*. Ibadan: National Agricultural Research Project (NARP); 1996.
2. Anyanwu NJ, Oguala JO, Odoemelam VU, Kalio GA, Ekpe II. Sheep and goat farming in Imo state southeast Nigeria: a traditional vocation at the verge of extinction. Niger J Anim Prod. 2020;47(4):237-246. CROSSREF
3. Greenland K, Dixon R, Ali Khan S, Gunawardena K, Kihara JH, Jennifer L, et al. The epidemiology of soil-transmitted helminths in Bihar State, India. PLoS Negl Trop Dis. 2015;9(5):e0003790. PUBMED | CROSSREF
4. McNeilly TN, Nisbet AJ. Immune modulation by helminth parasites of ruminants: implications for vaccine development and host immune competence. Parasite. 2014;21:51. PUBMED | CROSSREF
5. Radostits OM, Blood DC, Gay CC. Diseases caused by helminth parasites. In: *Veterinary Medicine: a Textbook of Diseases of Cattle, Sheep, Pigs, Goats and Horses*. 8th ed. London: Bailliere Tindall; 1994.
6. Karshima NS, Bata SI, Bobbo AA. Prevalence risk factors and economic losses associated with fascioliasis in slaughtered cattle in Bauchi, North-Eastern Nigeria. Alex J Vet Sci. 2016;50(1):87-93. CROSSREF
7. Balicka-Ramisz A, Ramisz A, Vovk S, Snitynskyj V. Prevalence of coccidia infection in goats in Western Pomerania (Poland) and West Ukraine region. Ann Parasitol. 2012;58(3):167-171. PUBMED
8. Isaac C, Turay PN, Inegbenosun CU, Ezekiel AS, Adamu OH, Ohiolei AJ. Prevalence of soil-transmitted helminths in primary school playgrounds in Edo State, Southern Nigeria. Helminthologia. 2019;56(4):282-295. PUBMED | CROSSREF
9. Ugbomoiko US, Ariza L, Heukelbach J. Parasites of importance for human health in Nigerian dogs: high prevalence and limited knowledge of pet owners. BMC Vet Res. 2008;4(1):49. PUBMED | CROSSREF

10. Karshima SN, Maikai BV, Kwaga JK. Helminths of veterinary and zoonotic importance in Nigerian ruminants: a 46-year meta-analysis (1970-2016) of their prevalence and distribution. Infect Dis Poverty. 2018;7(1):52.
PUBMED | CROSSREF
11. Ghisi M, Kaminsky R, Mäser P. Phenotyping and genotyping of *Haemonchus contortus* isolates reveals a new putative candidate mutation for benzimidazole resistance in nematodes. Vet Parasitol. 2007;144(3-4):313-320.
PUBMED | CROSSREF
12. Urquhart GM, Armour J, Duncan JL, Dunn AM, Jennings FW. *Veterinary Parasitology*. 2nd ed. Oxford: Blackwell Science; 1996.
13. Soulsby EJ. *Helminths, Arthropods and Protozoa of Domesticated Animals*. 7th ed. London: Bailliere Tindall; 1982.
14. Hasegawa M, Kishino H, Yano T. Dating of the human-ape splitting by a molecular clock of mitochondrial DNA. J Mol Evol. 1985;22(2):160-174.
PUBMED | CROSSREF
15. Kumar S, Stecher G, Li M, Knyaz C, Tamura K. MEGA X: Molecular Evolutionary Genetics Analysis across computing platforms. Mol Biol Evol. 2018;35(6):1547-1549.
PUBMED | CROSSREF
16. Chiejina SN, Behnke JM, Nnadi PA, Ngongeh LA, Musongong GA. The responses of two ecotypes of Nigerian West African Dwarf goat to experimental infections with *Trypanosoma brucei* and *Haemonchus contortus*. Small Rumin Res. 2009;85(2-3):91-98.
CROSSREF
17. Ngongeh AL, Onyeabor A Comparative response of the West African Dwarf goats to experimental infections with Red Sokoto and West African Dwarf goat isolates of *Haemonchus contortus*. J Pathog. 2015;2015:728210.
PUBMED | CROSSREF
18. Pienaar JG, Basson PA, du Plessis JL, Collins HM, Naude TW, Boyazoglu PA, et al. Experimental studies with *Stronglyloides papillosus* in goats. Onderstepoort J Vet Res. 1999;66(3):191-235.
PUBMED
19. Taira N, Ura S. Sudden death in calves associated with *Strongyloides papillosus* infection. Vet Parasitol. 1991;39(3-4):313-319.
PUBMED | CROSSREF
20. Silva LM, Vila-Viçosa MJ, Nunes T, Taubert A, Hermosilla C, Cortes HC. Eimeria infections in goats in Southern Portugal. Rev Bras Parasitol Vet. 2014;23(2):280-286.
PUBMED | CROSSREF
21. Chartier C, Paraud C. Coccidiosis due to Eimeria in sheep and goats, a review. Small Rumin Res. 2012;103(1):84-92.
CROSSREF
22. Abunna F, Asfaw L, Megersa B, Regassa A. Bovine fasciolosis: coprological, abattoir survey and its economic impact due to liver condemnation at Soddo municipal abattoir, Southern Ethiopia. Trop Anim Health Prod. 2010;42(2):289-292.
PUBMED | CROSSREF
23. Jean-Richard V, Crump L, Abicho AA, Naré NB, Greter H, Hattendorf J, et al. Prevalence of *Fasciola gigantica* infection in slaughtered animals in south-eastern Lake Chad area in relation to husbandry practices and seasonal water levels. BMC Vet Res. 2014;10(1):81.
PUBMED | CROSSREF
24. Foreyt WJ. Coccidiosis and cryptosporidiosis in sheep and goats. Vet Clin North Am Food Anim Pract. 1990;6(3):655-670.
PUBMED | CROSSREF
25. Zhao GH, Lei LH, Shang CC, Gao M, Zhao YQ, Chen CX, et al. High prevalence of Eimeria infection in dairy goats in Shaanxi province, northwestern China. Trop Anim Health Prod. 2012;44(5):943-946.
PUBMED | CROSSREF
26. Catchpole J, Gregory MW. Pathogenicity of the coccidium Eimeria crandallis in laboratory lambs. Parasitology. 1985;91(Pt 1):45-52.
PUBMED | CROSSREF
27. Júnior AF, Gonçalves-Pires MR, Silva DA, Gonçalves AL, Costa-Cruz JM. Parasitological and serological diagnosis of *Strongyloides stercoralis* in domesticated dogs from southeastern Brazil. Vet Parasitol. 2006;136(2):137-145.
PUBMED | CROSSREF
28. Paradies P, Iarussi F, Sasanelli M, Capogna A, Lia RP, Zucca D, et al. Occurrence of strongyloidiasis in privately owned and sheltered dogs: clinical presentation and treatment outcome. Parasit Vectors. 2017;10(1):345.
PUBMED | CROSSREF

29. Ngui R, Lim YA, Traub R, Mahmud R, Mistam MS. Epidemiological and genetic data supporting the transmission of *Ancylostoma ceylanicum* among human and domestic animals. PLoS Negl Trop Dis. 2012;6(2):e1522.
PUBMED | CROSSREF

30. Macpherson CN. The epidemiology and public health importance of toxocariasis: a zoonosis of global importance. Int J Parasitol. 2013;43(12-13):999-1008.
PUBMED | CROSSREF

31. Fan CK, Holland CV, Loxton K, Barghouth U. Cerebral toxocariasis: silent progression to neurodegenerative disorders? Clin Microbiol Rev. 2015;28(3):663-686.
PUBMED | CROSSREF

32. Mahdy MA, Lim YA, Ngui R, Siti Fatimah MR, Choy SH, Yap NJ, et al. Prevalence and zoonotic potential of canine hookworms in Malaysia. Parasit Vectors. 2012;5(1):88.
PUBMED | CROSSREF