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Epidemiological Investigation of Gastrointestinal Helminth Infections in Domestic and Stray Pigeons (*Columba livia*) in Urban and Rural Areas of Borno State, Northeastern Nigeria

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ABSTRACT

This study conducted between June 2023 and May 2024 investigated the prevalence, intensity, species composition, and risk factors of gastrointestinal helminths in domestic and stray pigeons (*Columba livia*) from urban and rural areas of Borno State, Northeastern Nigeria. A total of 420 pigeons (323 domestic and 97 stray) were sampled during rainy and dry seasons. Gastrointestinal tracts were examined for helminths using standard parasitological techniques, and species were identified morphologically. Out of the pigeons examined, 227 were infected, giving an overall prevalence of 54.0% (95% CI: 49.3–58.8%) and mean intensity of 2.05 ± 0.93 . Stray pigeons showed significantly higher prevalence (81.4%) and mean intensity (2.71 ± 1.05) than pigeons from live bird markets (46.7%; 1.88 ± 0.72) and household flocks (44.8%; 1.45 ± 0.60) ($p < 0.0001$). Five helminths species were identified, comprising five single-species infections, *Ascaridia columbae* (18.8%), *Heterakis gallinarum* (10.0%), *Capillaria* spp. (4.3%), *Raillietina tetragona* (7.4%), and *Hymenolepis cantaniana* (6.9%), and three mixed-species combinations. Prevalence was significantly higher in rural (68.6%) than urban (39.9%) pigeons (OR = 3.29), females (61.4%) than males (44.1%) (OR = 2.01), adults (66.1%) than young (37.6%) (OR = 3.23), and during the rainy (72.9%) than dry (35.2%) season (OR = 4.93) ($p < 0.05$). The small intestine was the most common predilection site (63.9%), followed by ceca (22.5%), gizzard (17.2%), large intestine (11.5%), and crop/proventriculus (7.9%). The high burden, particularly in stray and rural pigeons, emphasizes the need for targeted parasite control, improved husbandry, and environmental hygiene to limit transmission risks to domestic flocks and mitigate potential zoonotic risks.

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INTRODUCTION

Pigeons (*Columba livia*), both domestic and stray, are ubiquitous avian species widely distributed across urban and rural settings globally. They have adapted remarkably well to human settlements, often coexisting closely with people, livestock, and other domestic animals (Iacob *et al.*, 2024; Hamza and Ndams, 2024; Sule *et al.* 2024). In many regions, particularly in developing countries, pigeons play important socio-economic and cultural roles, including use for meat, sport (racing), research, traditional medicine, and religious ceremonies (Chang *et al.*, 2023; Mostert and Donaldson, 2024). However, their close interaction with human habitats and agricultural environments raises significant public health and veterinary concerns, particularly with regard to their potential role as reservoirs and carriers of infectious pathogens, including gastrointestinal (GI) helminths.

Gastrointestinal helminth infections are among the most prevalent parasitic conditions affecting pigeons, often resulting in subclinical to overt disease (Shehu *et al.*, 2018; Magaji *et al.*, 2022). These parasites can negatively impact the host's health, leading to poor weight gain, reduced reproductive performance, lowered immunity, diarrhea, anemia, intestinal obstruction, and increased susceptibility to secondary infections (Salem *et al.*, 2022; Mohebaty *et al.*, 2024). Moreover, helminth infections in pigeons are not only of veterinary importance but also of public health significance, especially when zoonotic helminths are involved or when pigeons serve as mechanical vectors (Hamid *et al.*, 2023; Mohebaty *et al.*, 2024).

Among the commonly reported GI helminths in pigeons are nematodes such as *Ascaridia columbae*, *Capillaria* spp., and *Heterakis gallinarum*; cestodes like *Raillietina tetragona*, *Raillietina echinobothrida*, and *Hymenolepis* spp.; and trematodes such as *Echinostoma* spp. and *Prosthogonimus* spp. (Mijinyawa and Junaid, 2017; Salem *et al.*, 2022; Mohebaty *et al.*, 2024). The burden and diversity of these helminths are influenced by several epidemiological and ecological factors including geography, seasonal variation, host behavior, husbandry system, feeding habits, and level of exposure to intermediate or paratenic hosts (Adhikari *et al.*, 2022; Terfa *et al.*, 2024).

In Nigeria, and particularly in Borno State, pigeons are commonly kept by households in both urban

and rural communities for subsistence and ornamental purposes, often under low-input management systems with minimal veterinary intervention. Concurrently, stray pigeons roam freely in open environments, frequently foraging on food remnants and sharing spaces with domestic birds, thereby increasing the risk of cross-transmission of parasitic infections. Despite the significance of pigeons in these settings, there is a dearth of current, region-specific data on the prevalence, diversity, and intensity of GI helminth infections, especially with a comparative perspective between stray and domestic pigeon populations. This knowledge gap is a barrier to developing effective control and preventive strategies for parasitic diseases in pigeons and for mitigating the potential zoonotic risks they may pose.

Despite growing evidence of gastrointestinal (GI) helminth infections in pigeons across various parts of Nigeria, there remains a significant paucity of data from the northeastern region, particularly Borno State. This gap is critical given the region's unique ecological features, climatic variability, and evolving management systems, which differ markedly from those in other parts of the country. Furthermore, the resurgence of backyard poultry farming and the increasing use of pigeons for food, trade, and socio-cultural purposes in Borno State heighten the need for localized epidemiological surveillance. Previous studies of Mohammed *et al.* (2019), Magaji *et al.* (2022), and Hamza and Ndams (2024), has documented helminth infections in pigeons in Kano, Plateau, and Zaria respectively, all from northern Nigeria, while Nwadike *et al.* (2023) reported the presence of multiple helminth species infecting pigeons in southeastern Nigeria.

However, these studies may not accurately represent the helminthological burden in pigeons within Borno State, where distinct environmental and management factors could influence parasite transmission dynamics. Generating region-specific data is therefore essential for targeted control measures and for enhancing understanding of pigeon health in the Nigerian context.

In addition, the growing recognition of the role of wildlife in the epidemiology of parasitic diseases, coupled with the close ecological interface between stray birds and domestic flocks in rural and peri-urban settings, makes helminth surveillance in pigeons imperative. This present study is particularly crucial in Borno State, which

shares borders with Cameroon, Chad, and Niger, where bird migration, trade, and informal poultry movements pose transboundary disease risks.

Therefore, this study was designed to investigate the prevalence, diversity, and intensity of gastrointestinal helminth infections in domestic and stray pigeons in selected urban and rural areas of Borno State, Northeastern Nigeria. The findings aim to provide baseline epidemiological data necessary for strategic control of gastrointestinal parasites, improve pigeon health and productivity, and offer insights into potential zoonotic threats of public health significance.

MATERIALS AND METHODS

Study Area

This study was conducted across selected urban and rural locations of Borno State, Northeastern Nigeria. Borno State lies between latitudes 10°N and 13°N and longitudes 11°30'E and 14°45'E, characterized by a semi-arid climate with distinct wet (June–September) and dry (October–May) seasons. Urban sites included Maiduguri, Bama, and Jere, while rural areas involved Konduga, Mafa, and Kaga Local Government Areas. The region supports both domestic and feral pigeon populations due to poultry-keeping practices and abundant food sources in urban marketplaces and rural settlements.

Study Design and Sampling Technique

This study was designed as a cross-sectional epidemiological survey conducted over a twelve-month period from June 2023 to May 2024. A purposive multistage sampling approach was employed to ensure broad representativeness of both ecological zones (urban and rural) and management systems (domestic and stray pigeons) within the study area. Although no formal statistical formula was used to predetermine the sample size due to logistical and ecological constraints associated with working on free-ranging and owner-managed pigeons, the total number of birds examined ($n = 420$) was determined pragmatically based on field availability, accessibility, and supporting evidence from previous studies conducted under similar conditions. This strategy ensured a sufficiently large sample to allow for meaningful comparative and statistical analyses and was adapted from the methodologies of Ko and Lim (2021), Cambrone *et al.* (2023), and Li *et al.* (2024). Such a pragmatic sampling approach is consistent with established practices in field-based parasitological and avian epidemiological research, particularly in

contexts where population frames are unavailable or difficult to construct, as previously documented by Campbell *et al.* (2020), Wu *et al.* (2023), and Ibitoye *et al.* (2024).

In the first stage, six distinct sampling sites were strategically selected, comprising three urban areas (Maiduguri, Bama, and Jere) and three rural communities (Konduga, Mafa, and Kaga). These locations were chosen based on the documented presence of large pigeon populations, accessibility, and prior reports of parasitic infections in avian species. Within each location, sampling units were stratified by pigeon type and capture setting. Domestic pigeons were sourced from backyard pigeon keepers and household aviaries, as well as live bird markets with the consent of owners. Stray (feral) pigeons, which had no identifiable ownership, were captured with the permission of local authorities and community leaders from congregation points such as mosque rooftops, public buildings, grain storage sites, and refuse disposal areas. Custom-designed grain-baited cage traps reinforced with nylon noose lines were used to humanely and selectively trap the stray pigeons without injury.

A total of 420 pigeons were examined during the study period, comprising 323 domestic and 97 stray pigeons. To minimize seasonal bias and enhance statistical robustness, birds were sampled equally across the two major climatic seasons: the rainy season (June–October) and the dry season (November–May). Efforts were also made to stratify the sampled population by sex (male and female) and age categories. Age estimation was based on morphometric criteria and plumage development, classifying birds as squabs or young (<6 months) and adults (>6 months).

Sample Collection, Processing, and Data Recording

Stray pigeons were humanely euthanized via cervical dislocation in accordance with institutional animal care and use guidelines to minimize distress, while domestic pigeons were obtained through two primary means: (i) live purchase from pigeon keepers and aviaries, where they were slaughtered under humane conditions, and (ii) post-slaughter sampling at live bird markets and processing slabs, where pigeons had been slaughtered as part of regular commercial operations. Immediately after death, each bird underwent thorough postmortem examination.

The entire gastrointestinal tract from the esophagus to the cloaca was carefully excised and ligated at

both ends to prevent leakage of contents. Each tract was placed into individually labeled sterile polyethylene bags and kept under cold chain (approximately 4°C) using ice packs. All specimens were transported within four hours to the Veterinary Parasitology Laboratory, Faculty of Veterinary Medicine, University of Maiduguri, for parasitological investigation.

In the laboratory, each gastrointestinal tract was anatomically segmented into: (i) crop and proventriculus, (ii) gizzard, (iii) small intestine (duodenum to ileum), and (iv) large intestine including the paired ceca. Segments were longitudinally incised using sterile scissors, and the contents flushed into clean glass Petri dishes using 0.85% normal saline. The mucosal lining and luminal contents of each segment were meticulously examined under a stereo dissecting microscope at $\times 40$ magnification for the presence of helminths. All observed parasites were carefully removed using fine-tipped forceps, counted, and preserved in 70% ethanol for taxonomic identification based on established morphological keys and helminthological guides.

For each bird, detailed data were recorded to support comprehensive epidemiological and parasitological analyses. Pigeons were classified as either domestic or stray based on physical characteristics, behavioral patterns, and site of acquisition. Sampling locations were categorized into urban or rural zones using geopolitical demarcations within Borno State. Sex was determined through morphological assessment, and age was estimated based on plumage development, size, and behavior allowing categorization into juvenile or adult.

Seasonal variation in parasite burden was considered by documenting the season of collection as either wet (rainy) or dry, according to prevailing meteorological conditions. For every positive case, the specific segment(s) of the gastrointestinal tract from which helminths were recovered were noted to determine predilection sites. All helminths were counted to establish the worm burden per bird, and infection intensity was calculated as the mean number of helminths per infected bird. Prevalence was determined as the proportion of infected birds among the total examined per subgroup. Infection patterns were further categorized as single (infection with one helminth species) or mixed (infection with two or more helminth species).

Parasite Identification

Preserved nematode specimens were temporarily cleared in lactophenol solution to enhance the visibility of their internal anatomical structures, while cestodes were stained with carmine dye, dehydrated through a graded series of ethanol, cleared in xylene, and permanently mounted on glass slides using Canada balsam. These procedures facilitated optimal visualization of diagnostic morphological characteristics under light microscopy.

Species-level identification of helminths was based on comprehensive morphological examination using established taxonomic keys and descriptions provided by Soulsby (1982), Abdullah *et al.* (2021), and Shifaw *et al.* (2021). Diagnostic features considered included body size and shape, type and arrangement of the scolex, rostellum, and suckers (for cestodes), as well as cuticular structures, tail morphology, and configuration of reproductive organs such as spicules, vulval openings, uterus, and egg characteristics (for nematodes). Both male and female specimens were examined when available.

To ensure taxonomic accuracy and minimize observer bias, all identifications were conducted independently by two trained parasitologists, with each working in a blinded manner regarding the sample origin. In cases of discrepancy, a third expert was consulted, and consensus was reached through joint re-examination. Representative specimens were photographed and cross-referenced with standard helminthological atlases for further verification. Duplicate slide preparations were also used for a subset of samples to confirm consistency in morphological assessments. These quality control measures were implemented to enhance the reliability and reproducibility of parasite identification.

Data Analysis

All data generated were compiled into structured data sheets and analyzed to identify patterns, associations, and risk factors related to helminth infections across ecological zones, pigeon types, sex, age groups, and seasons. The data were entered into Microsoft Excel and subsequently analyzed using IBM SPSS Statistics Version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were employed to compute overall and stratified prevalence, mean worm burden, and frequency distributions. Associations between categorical variables such as infection prevalence and sex, age, habitat type (urban vs. rural), season,

and pigeon species were assessed using the Fisher's exact or Chi-square (χ^2) test. A p-value of

less than 0.05 was considered indicative of statistical significance.

Prevalence (%) was calculated using:

$$\text{Prevalence} = \frac{\text{Number of infected pigeons}}{\text{Total number of pigeons examined}} \times 100$$

Mean intensity of infection was calculated as:

$$\text{Mean intensity} = \frac{\text{Total number of helminths recovered}}{\text{Total number of infected pigeons}}$$

RESULTS

The prevalence of gastrointestinal helminth infections in pigeons across different sampling locations in Borno State, Nigeria, is presented in Table 1. Out of the 420 pigeons examined, 227 were found to be infected, giving an overall prevalence of 54.0% (95% CI: 49.3 – 58.8%). A total of 465 helminth parasites were recovered from the infected birds, with a mean intensity of 2.05 ± 0.93 helminths per infected pigeon. Considering location-wise prevalence, the highest prevalence was recorded among stray pigeons (81.4%; 95% CI: 75.4 – 87.5%), followed by pigeons from live bird markets (46.7%; 95% CI: 16.5 – 24.1%) and households (44.8%; 95% CI: 12.1 – 19.0%). Statistical analysis revealed that prevalence rates differed significantly among the three sampling locations ($p < 0.05$) (Table 1).

Table 1 also revealed that stray pigeons also harbored the highest total number of helminths ($n = 214$) and exhibited the greatest mean intensity (2.71 ± 1.05), suggesting a heavier parasitic load compared to pigeons sampled from live bird markets (1.88 ± 0.72) and households (1.45 ± 0.60).

A total of seven gastrointestinal helminth taxa, comprising three nematodes, two cestodes, and three mixed infections, were identified in the examined pigeons (Table 2). Among the single-species infections, *Ascaridia columbae* was the most prevalent, occurring in 79 pigeons (18.8%, 95% CI: 15.4 – 22.8%) with a relatively high mean intensity of 11.4 ± 3.6 worms. This was followed by *Heterakis gallinarum* (10.0%, 95% CI: 7.5 – 13.2%; mean intensity 8.3 ± 2.9) and *Raillietina tetragona* (7.4%, 95% CI: 5.3 – 10.3%; mean intensity 6.6 ± 2.1). *Hymenolepis cantaniana* showed a comparable prevalence of 6.9% (95% CI: 4.9 – 9.7%), though with a notably lower mean intensity (3.2 ± 1.2). *Capillaria* spp. recorded the lowest prevalence among the single infections

(4.3%, 95% CI: 2.7 – 6.7%; mean intensity 4.9 ± 1.7).

Table 2 also reveals that mixed infections were less frequent, with *Ascaridia* + *Raillietina* being the most common (3.8%, 95% CI: 2.4 – 6.1%; mean intensity 4.0 ± 1.5), followed by *Heterakis* + *Hymenolepis* (2.1%, 95% CI: 1.1 – 4.0%; mean intensity 3.3 ± 1.1), and *Capillaria* + *Raillietina* (0.7%, 95% CI: 0.2 – 2.1%; mean intensity 2.1 ± 0.6).

Table 3 presents the some risk factors associated with gastrointestinal helminth infections in pigeons from Borno State. Location-wise, the rural pigeons exhibited a markedly higher infection rate (68.6%; 95% CI: 29.5 – 38.5%) compared with the urban pigeons (39.9%; 95% CI: 16.7–24.3), with the difference being statistically significant ($\chi^2 = 34.8$; $p < 0.0001$). Rural location was associated with a higher risk of infection (RR = 1.77; reciprocal of urban RR = 0.5646; OR = 3.29).

Table 3 also reveals sex-wise prevalence, indicating that females pigeons were significantly more infected (61.4%; 95% CI: 30.8 – 39.9%) than males (44.1%; 95% CI: 15.4 – 22.8%) ($\chi^2 = 12.34$; $p = 0.0004$), with a 1.49-fold higher risk (reciprocal of male RR = 0.6717; OR = 2.01), indicating possible sex-related behavioural or physiological predispositions. Adult pigeons recorded a higher prevalence (66.1%; 95% CI: 33.6 – 42.8%) compared with young (37.6%; 95% CI: 12.8 – 19.8%) ($\chi^2 = 33.48$; $p < 0.0001$), with adults being 1.66 times more likely to be infected (OR = 3.23) as presented in Table 3.

Seasonal-wise prevalence was evident as also present in Table 3, with infections peaking during the rainy season (72.9%; 95% CI: 32.0 – 41.1%) compared to the dry season (35.2%; 95% CI: 14.3 – 21.6%) ($\chi^2 = 59.83$; $p < 0.0001$). Rainy season conferred over a twofold increased risk (RR = 2.07; OR = 4.93).

Table 4 presents the anatomical distribution of helminths within the gastrointestinal tract of infected domestic and stray pigeons in Borno State. The highest prevalence of helminth recovery was recorded in the small intestine, with 145 (63.9%) pigeons harbored helminths predominantly *Ascaridia columbae* and *Raillietina* species. The ceca were the second most affected site, with 51 pigeons (22.5%) pigeons infected, primarily by *Heterakis gallinarum*. The gizzard

was found to be infected in 39 (17.2%) pigeons, with *Raillietina tetragona* and *Capillaria* species. Infections of the large intestine was found in 26 (11.5%) pigeons, dominated by the cestode *Hymenolepis cantaniana*. The crop and proventriculus had the lowest prevalence, with 18 (7.9%) pigeons infected with *Capillaria* species.

Table 1: Prevalence of Gastrointestinal Helminths in Pigeons (*Columba livia*) in Borno State, Nigeria

Location	Number of Pigeons sampled	Number (%) of Pigeons infected	Prevalence (%)	95% CI: (LL – UL)	Total Helminths Recovered	Mean Intensity \pm SD
Live birds markets	180	84 (46.7)	20.0 ^a	16.5 – 24.1	158	1.88 \pm 0.72
Households	143	64 (44.8)	15.2 ^b	12.1 – 19.0	93	1.45 \pm 0.60
Stray	97	79 (81.4)	18.8 ^c	5.4 – 22.8	214	2.71 \pm 1.05
Overall	420	227 (54.0)	54.0	49.3 – 58.8	465	2.05 \pm 0.93

$\chi^2 = 38.23$, degrees of freedom (df) = 2, $p < 0.0001$

Key: CI= Confidence Interval; LL – UL = Lower limit – Upper limit

^{a,b,c} Values with different superscripts indicate significant ($p < 0.05$) difference in prevalence rates

Table 2: Frequency of Identified Gastrointestinal Helminths Species in Infected Pigeons (*Columba livia*) in Borno State, Nigeria

Helminth Species	Helminth Types	Number of Pigeons infected	Prevalence (%)	95% CI: (LL – UL)	Mean Intensity \pm SD
<i>Ascaridia columbae</i>	Nematode	79	18.8	15.4 – 22.8	11.4 \pm 3.6
<i>Heterakis gallinarum</i>	Nematode	42	10.0	7.5 – 13.2	8.3 \pm 2.9
<i>Capillaria</i> spp	Nematode	18	4.3	2.7 – 6.7	4.9 \pm 1.7
<i>Raillietina tetragona</i>	Cestode	31	7.4	5.3 – 10.3	6.6 \pm 2.1
<i>Hymenolepis cantaniana</i>	Cestode	29	6.9	4.9 – 9.7	3.2 \pm 1.2
<i>Ascaridia</i> + <i>Raillietina</i>	Mixed	16	3.8	2.4 – 6.1	4.0 \pm 1.5
<i>Heterakis</i> + <i>Hymenolepis</i>	Mixed	9	2.1	1.1 – 4.0	3.3 \pm 1.1
<i>Capillaria</i> + <i>Raillietina</i>	Mixed	3	0.7	0.2 – 2.1	2.1 \pm 0.6

Table 3: Risk Factors Associated with Gastrointestinal Helminth Infections in Pigeons (*Columba livia*) in Borno State, Nigeria

Variable	Category	Number of Pigeon Examined	No. (%) Infected	Prevalence (%) 95% CI: (LL – UL)	χ^2	<i>p</i> -value	RR	OR
Location Type	Urban	213	85 (39.9)	20.2 ^a (16.7 – 24.3)	34.8	<0.0001	0.5646	0.3040
	Rural	207	142 (68.6)	33.8 ^b (29.5 – 38.5)				
Sex	Male	179	79 (44.1)	18.8 ^a (15.4 – 22.8)	12.34	0.0004	0.6717	0.4964
	Female	241	148 (61.4)	35.2 ^b (30.8 – 39.9)				
Age	Adult	242	160 (66.1)	38.1 ^a (33.6 – 42.8)	33.48	<0.0001	1.659	3.233
	Young	178	67 (37.6)	16.0 ^b (12.8 – 19.8)				
Season	Rainy	210	153 (72.9)	36.4 ^a (32.0 – 41.1)	59.83	<0.0001	2.068	4.933
	Dry	210	74 (35.2)	17.6 ^b (14.3 – 21.6)				

Key: CI= Confidence Interval; LL – UL = Lower limit – Upper limit; χ^2 = Chi – square; OR = Odd ratio; RR = Relative risk

^{a,b} Values with different superscripts indicate significant ($p < 0.05$) difference in prevalence rates

Table 4: Anatomical Distribution of Helminths within the Gastrointestinal Tract of Infected Pigeons in Borno State, Nigeria

Gastrointestinal Recovery Segment	Number of Pigeons Infected	Percentage of Infected Pigeons (227)	Dominant Helminth Species Recovered
Crop/Proventriculus	18	7.9	<i>Capillaria</i> spp.
Gizzard	39	17.2	<i>Raillietina tetragona</i> , <i>Capillaria</i> spp.
Small Intestine	145	63.9	<i>Ascaridia columbae</i> , <i>Raillietina</i> spp.
Ceca	51	22.5	<i>Heterakis gallinarum</i>
Large Intestine	26	11.5	<i>Hymenolepis cantaniana</i>

DISCUSSION

This study recorded an overall prevalence of 54.0% for gastrointestinal (GI) helminths among pigeons (*Columba livia*) sampled from diverse environmental settings across Borno State, Northeastern Nigeria. This relatively high prevalence reflects a substantial parasitic burden within the pigeon population in the region, likely attributable to the availability and abundance of infective stages of helminths, coupled with environmental conditions favorable for their survival and transmission. Such conditions facilitate the proliferation of these parasites, with significant implications for avian health and

productivity. Moreover, the findings emphasize the potential role of pigeons as reservoirs and sources of helminth infections, posing transmission risks not only to other avian species but also to livestock and, potentially, humans.

The detection of gastrointestinal helminth infections in pigeons in the present study agrees with findings from previous research conducted in Nigeria. However, comparison with similar studies within the country, the prevalence recorded in this study was lower than the 78.3% reported in Jalingo Metropolis, Taraba State (Umaru *et al.*, 2017), 64.1% in Ilorin, Kwara State (Ola-Fadunsin *et al.*, 2019), 60.0% in Awka, Southeastern Nigeria

(Nwadike *et al.*, 2023), and 88.7% in Makurdi, Benue State (Terfa *et al.*, 2024). Conversely, it was higher than the 46.7% reported in Owerri, Imo State (Opara *et al.*, 2012), 48.3% in Zaria, Kaduna State (Adang *et al.*, 2008), 50% in Port Harcourt, Rivers State (Laku *et al.*, 2018), 27.7% in Kano State (Mohammed *et al.*, 2019), 23% in Katsina State (Abdullahi *et al.*, 2019), and 47.5% in the southern parts of Plateau State (Magaji *et al.*, 2022). Variations were also evident when compared with studies conducted outside Nigeria, such as 68% in Sylhet District, Bangladesh (Islam *et al.*, 2017), 72.8% in YSR Kadapa District, Andhra Pradesh (Sivajothi *et al.*, 2015), 55% in Nepal (Gurung *et al.*, 2018), and 43.63% in Zabol, Iran (Mohebati *et al.*, 2024). These differences in prevalence rates across studies are likely attributable to a combination of factors, including geographical location, climatic conditions, seasonal variations, sample size, sampling intensity, management practices, diagnostic techniques employed, and the extent to which parasite control measures are implemented in different regions.

The findings of the present study reveal that stray pigeons exhibited the highest prevalence, mean intensity, and total helminth burden compared to domestic pigeons and those obtained from live bird markets. This trend may be attributed to their unrestricted scavenging and foraging habits, frequent contact with contaminated environments, and the absence of routine deworming. Such conditions facilitate repeated exposure to infective stages, while malnutrition and concurrent stressors can compromise immune function, rendering stray pigeons more susceptible to gastrointestinal helminths (Kommu *et al.*, 2016; Aldamigh *et al.*, 2023). These results agree with earlier reports that documented higher parasite loads in stray pigeons than in owned ones (Mohebati *et al.*, 2024; Magaji *et al.*, 2022).

Conversely, the lower helminth burdens observed in domesticated pigeons support the hypothesis that improved husbandry practices, partial confinement, and access to moderate veterinary care can reduce the risk of parasitic infections. Similar observations have been reported by Adhikari *et al.* (2022) in Nepal and Albogami *et al.* (2023) in Saudi Arabia, where domestic breeds showed lower helminth burdens than pigeons dwelling in temples or non-residential areas. Nevertheless, the detection of helminth infections in household pigeons in this study suggests

potential gaps in parasite control programs or the possibility of emerging resistance to commonly used anthelmintics (Aldamigh *et al.*, 2022).

Pigeons sampled from live bird markets exhibited moderate helminth prevalence, likely due to their heterogeneous origins, varied pre-sale management practices, the mixing of different species and breeds from diverse sources in close proximity, and stress associated with handling and transportation. Such stressors can suppress host immunity and increase vulnerability to infections, including gastrointestinal helminths. These findings align with the reports of Adang *et al.* (2008) and Arfin *et al.* (2019), who identified live bird markets as focal points for pathogen amplification due to overcrowding, poor hygiene, and the intermingling of birds from multiple sources. Consequently, these trading hubs may facilitate the exchange of diverse parasite strains between bird populations.

The significant variation in helminth prevalence among pigeon groups observed in this study reinforces the view that ecological exposure and lifestyle are critical determinants of infection risk. Stray pigeons were significantly more infected than domestic and market pigeons, a pattern consistent with the findings of Albogami *et al.* (2023), who reported higher infection rates in stray Pakistani breeds (54.7%) compared to more confined or genetically adapted breeds. The elevated helminth burden in stray pigeons also raises important public health concerns, particularly in urban settings where these birds frequently inhabit areas near human dwellings and food sources.

The present study identified five distinct helminth species, comprising both nematodes and cestodes, occurring either as single or mixed infections. This diversity reveals the substantial parasitic burden and ecological complexity of helminthiasis in the examined pigeon populations. These findings suggest that the ecological adaptability of these parasites, coupled with the complexity of their life cycles, which often involves intermediate hosts, enables them to thrive under the prevailing climatic and environmental conditions of the study area, which appear suitable for their survival and transmission. The findings of the present study are consistent with previous studies, such as those of Mohebati *et al.* (2024) and Adang *et al.* (2008), who each reported nine helminth species of gastrointestinal helminth infections in pigeons. Comparable studies have documented varying

species richness: Mijinyawa and Junaid (2017) and Albogami *et al.* (2023) recorded six species. Other reports include, two species each by Aldamigh *et al.* (2022) and Magaji *et al.* (2022), while Islam *et al.* (2017) and Ashfiyah *et al.* (2022) identified three species each. Similarly, Kommu *et al.* (2016) and Nwadike *et al.* (2023) documented four species each, whereas Terfa *et al.* (2024) identified as many as 13 species, highlighting marked regional variation. Such discrepancies in the number of helminth species reported across studies may be attributed to several factors, including differences in the sensitivity and specificity of diagnostic techniques employed, geographic and ecological variations, host population density, sample size, and the season during which sampling was conducted.

Interestingly, nematode species were more prevalent than cestodes in this study, contrasting with earlier findings of Adang *et al.* (2008) and Aldamigh *et al.* (2023) that reported higher cestode burdens in pigeons from northern Nigeria and parts of the Middle East. Such discrepancies may be due to variations in climatic conditions, host feeding behavior, environmental sanitation, sampling season, and the abundance of intermediate hosts necessary for cestode transmission. Collectively, these observations highlight the multifactorial nature of helminth transmission dynamics in avian populations, shaped by ecological, biological, and management-related determinants.

The helminth species identified in this study include *Ascaridia columbae*, *Heterakis gallinarum*, *Raillietina tetragona*, *Hymenolepis cantaniana*, and *Capillaria* spp. in single and mixed infections. This finding concurs with previous reports documenting these gastrointestinal helminth species in pigeons (Islam *et al.*, 2017; Das *et al.*, 2020; Ara *et al.*, 2021; Abubakar and Muhammad, 2024).

In the present study, *A. columbae* was the most prevalent helminth species detected in infected pigeons, emphasizing its epidemiological significance in the study area. This high prevalence may be attributed to its direct life cycle, transmission via the fecal–oral route, adaptability to diverse environmental conditions, and the remarkable resilience of its eggs, which enhances environmental persistence. The high mean intensity recorded further suggests a well-established environmental transmission cycle, likely aggravated by suboptimal hygiene, the scavenging behavior of stray pigeons, and

persistent contamination of the surroundings with infective stages. Such conditions may pose a continuous transmission risk to domestic birds and, potentially, to humans, particularly children who may be exposed to contaminated environments (Cantin-Rosas *et al.*, 2025). The findings of the present study are consistent with previous research from other parts of Nigeria, which similarly identified *A. columbae* as the most prevalent helminth species in pigeons, especially in those allowed to scavenge freely or reared under extensive or semi-intensive management systems (Nwadike *et al.*, 2023; Abubakar and Muhammed, 2024; Terfa *et al.*, 2024).

Heterakis gallinarum emerged as the second most prevalent nematode species detected in infected pigeons in this study, with a mean intensity of 8.3 ± 2.9 . Its detection is of particular concern for other avian species, especially turkeys and chickens, because the eggs of *H. gallinarum* play a crucial role in the transmission cycle of *Histomonas meleagridis*, the protozoan responsible for histomoniasis (blackhead disease) in susceptible birds. *H. meleagridis* can cross species barriers, thereby posing a substantial threat to mixed-species flocks (Beer *et al.*, 2022).

It has been documented that *Heterakis gallinarum* is widely distributed across domestic and wild avian hosts and has been reported in diverse ecological settings worldwide (Radfar *et al.*, 2012; Ashfiyah *et al.*, 2022; Terfa *et al.*, 2024). Although often regarded as mildly pathogenic when occurring alone, its veterinary significance lies primarily in its role as a biological vector for *H. meleagridis*. While *H. meleagridis* infections in pigeons are generally not acutely fatal, they may impair physiological functions, suppress immune responses, reduce reproductive performance, and predispose birds to opportunistic infections (Salem *et al.*, 2022). Chronic helminthiasis in pigeons has been associated with clinical signs such as emaciation, diarrhea, poor body condition, and lethargy (Albogami *et al.*, 2023).

The identification of *Raillietina* spp. in pigeons in this study indicates the presence and likely abundance of suitable intermediate hosts in the environment, facilitating the transmission of the infective stages of these cestodes to the pigeon population. This finding is consistent with earlier reports in pigeons from similar ecological contexts (Abubakar and Muhammad, 2024; Mohebaty *et al.*, 2024). Species such as *Raillietina echinobothrida* and *R. cesticillus* can induce granulomatous

enteritis and intestinal obstruction, leading to reduced digestive efficiency, impaired nutrient absorption, and compromised health and productivity (Aldamigh *et al.*, 2022; Salem *et al.*, 2022). Heavy infestations with *R. tetragona* are known to cause severe enteritis, progressive emaciation, and even fatal intestinal blockage (Nwadike *et al.*, 2023). Such pathological changes can weaken pigeon's immune system, increase susceptibility to secondary infections, and exacerbate flock health challenges.

Although *Capillaria* species were the least prevalent nematodes detected in this study (4.3%) with a mean intensity of 4.9 ± 1.7 , their pathological significance remains considerable. The relatively low prevalence agrees with previous findings of Ashfiyah *et al.* (2022) and Terfa *et al.* (2024), which attribute their restricted distribution to the requirement for specific intermediate hosts such as earthworms and the need for particular environmental conditions for larval development. Despite their infrequency, *Capillaria* infections can cause marked pathology, including chronic enteritis, anemia, and growth retardation, particularly in immunocompromised birds (Salem *et al.*, 2022).

The detection of *Hymenolepis cantaniana* in infected pigeons aligns with earlier reports by Mohammed *et al.* (2019) and Terfa *et al.* (2024), who documented its occurrence in pigeons and rural poultry flocks. The low mean intensity observed in this study may suggest subclinical infections or reduced exposure to arthropod intermediate hosts such as beetles and fleas, whose population densities are influenced by environmental and seasonal factors.

Mixed infections of gastrointestinal helminths were also identified in the present study, with the most frequent combination involving *Ascaridia columbae* and *Raillietina tetragona*. Although relatively uncommon, such co-infections may exert synergistic pathological effects, including nutrient malabsorption, increased metabolic demands, and immunosuppression. Less frequent pairings, such as *Heterakis gallinarum* with *H. cantaniana* and *Capillaria* spp. with *Raillietina* spp., reflect the ecological diversity of helminth fauna in pigeons. These results emphasize the contribution of inadequate biosecurity, environmental contamination, and suboptimal pigeon management systems in sustaining helminth co-infections, as similarly reported by Hananeh *et al.*

(2022) and Dakheel Kremsh Alasadiy *et al.* (2022).

The present study revealed significantly higher prevalence of gastrointestinal helminths in pigeons sampled from rural areas compared to their urban counterparts corroborates previous findings by Mohammed *et al.* (2019) in Kano, Adang *et al.* (2008) in Zaria, and Aldamigh *et al.* (2023) in Saudi Arabia. These studies similarly reported increased parasitic loads in birds from rural or peri-urban areas, as well as higher infection rates compared to those reared in the cities or urban regions. The rural predominance may be attributed to several risk-enhancing factors such as lack of awareness, poor housing conditions, limited access veterinary care, inadequate sanitation, and frequent contact with intermediate hosts or contaminated environments. Stray pigeons, which are commonly found in rural areas particularly around markets, refuse dumps, and open fields, often scavenge in unhygienic surroundings, cohabit with wild birds, and have unrestricted movement, all of which increase their exposure to infective helminth stages (Magaji *et al.*, 2022; Mohebaty *et al.*, 2024). Conversely, domesticated pigeons in urban areas are more likely to benefit from confinement, improved hygiene, and restricted access to intermediate hosts such as insects or annelids, which are essential for the life cycles of many helminth species (Salem *et al.*, 2022).

In this study, female pigeons exhibited a higher prevalence of gastrointestinal helminths than males, aligning with findings reported by Radfar *et al.* (2012), Muhammad *et al.* (2022), and Abubakar and Muhammad (2024), although the latter observed a non-significant difference. The higher infection rates in females may be influenced by sex-based physiological differences, particularly those associated with reproductive stress, hormonal modulation, and immunosuppression. Estrogen, for instance, has been implicated in reducing immune efficiency, especially during egg-laying periods, when nutritional resources are diverted toward reproduction (Mohebaty *et al.*, 2024; Terfa *et al.*, 2024; Pilarczyk *et al.*, 2025). Additionally, the nesting behavior commonly observed in females may increase prolonged exposure to contaminated substrates or materials harboring infective larval stages.

However, some previous studies have reported higher helminth prevalence in male pigeons. For instance, Aldamigh *et al.* (2024), Ashfiyah *et al.*

(2022), and Qureshi and Aziz (2023) all observed a male-biased infection pattern. This discrepancy in the various studies could be attributed to behavioral differences such as increased territorial aggression, frequent roaming in search of mates, or dominance-related feeding behavior, which may expose males to greater environmental contamination in some contexts.

Age-related differences in infection burden were also observed in the present study, with adult pigeons exhibiting significantly higher prevalence than younger ones. The cumulative exposure theory provides a plausible explanation: older birds, due to prolonged environmental interaction and foraging over wider areas, are more likely to ingest infective stages. In contrast, younger pigeons, especially squabs may benefit from maternal immunity, reduced mobility, and restricted diets, all of which potentially limit their exposure to helminth infections. This pattern concurs with reports by Magaji *et al.* (2022) and Salem *et al.* (2022), who noted higher helminth loads in adult birds.

Seasonal variation was another significant factor, with the highest prevalence of gastrointestinal helminths recorded in pigeons during the rainy season. This may be associated with the fact that the rainy season promotes favorable conditions for the development and survival of free-living infective stages and increases the activity and abundance of intermediate hosts such as earthworms and insects. This observation is consistent with earlier studies by Adang *et al.* (2008) and Mohammed *et al.* (2019), which documented increased helminth transmission during wet periods. Moreover, high humidity and moisture has been reported to improve egg viability in the environment and facilitate the dispersal of infective stages, while increased contact with contaminated water, feeds, and substrates during this season may further heighten infection risks (Shearer and Ezenwa, 2020).

This study reports the anatomical distribution of gastrointestinal helminths in pigeons from urban and rural areas from study area, revealing significant variation in species predilection sites and highlighting complex host-parasite interactions. The small intestine emerged as the predominant site of helminth colonization, with a high infection prevalent rate. This observation is in line with previous studies by Mohebati *et al.* (2024) and Terfa *et al.* (2024), who identified the small intestine as a preferred habitat for numerous

helminth species due to its favorable conditions for nutrient absorption, parasite attachment, and growth. The predominance of *Ascaridia columbae* and *Raillietina* spp. in this segment corroborates earlier findings by Adang *et al.* (2008) and Salem *et al.* (2022), who reported similar site preferences among pigeons in Northern Nigeria.

The confinement of *Heterakis gallinarum* to the ceca is consistent with its known biological characteristics. The cecal environment provides optimal conditions for the development and reproduction of this nematode, commonly referred to as the cecal worm. This designation reflects its role in the epidemiological transmission of *Histomonas meleagridis*, the causative agent of blackhead disease in turkeys and chickens (Daş *et al.*, 2021; Morales-Barrera *et al.*, 2025). Although pigeons are not recognized as primary hosts for *H. meleagridis*, their potential to disseminate infective ova into the environment raises concerns, particularly in areas where they coexist with domestic poultry.

The gizzard was parasitized in 17.2% of the pigeons, with *Raillietina tetragona* and *Capillaria* spp. being the principal helminths recovered. These parasites are known to cause mechanical irritation of the gizzard lining, potentially impairing its grinding function, which is essential for proper digestion. Similar anatomical localization was reported by Salem *et al.* (2022) and Mohebati *et al.* (2024), who also identified the gizzard as a common site for cestode attachment in both pigeons and chickens.

Helminth infections recovered from the large intestine and crop/proventriculus were relatively less frequent. These findings likely reflect the comparatively unsuitable physiological conditions in these regions for helminth establishment and development. Nonetheless, the detection of *Hymenolepis cantaniana* in the large intestine is notable, as it highlights the broad ecological adaptability of some cestodes in avian hosts. Likewise, the presence of *Capillaria* spp. in the crop and proventriculus despite the short retention time and high enzymatic activity of these segments has been documented in previous studies (Salem *et al.*, 2022; Forssten *et al.*, 2023), suggesting intermittent colonization in less favorable niches.

Overall, the distribution patterns observed in this study highlight the organotropism of helminths within the avian host, which may be influenced by factors such as parasite-specific nutrient requirements, morphological adaptations for

attachment, local immune responses, and evolutionary co-adaptation (Mijinyawa and Junaid, 2017; Varyani *et al.*, 2017; Grondin *et al.*, 2024). The anatomical site of infection is critically important, as it often determines the pathological outcome and the severity of clinical manifestations. *A. columbae* can induce enteritis and nutrient malabsorption, whereas cestodes such as *Raillietina* spp. may cause pressure necrosis, intestinal blockage, and impaired digestive function when present in large numbers (Bobardt *et al.*, 2020; Usang *et al.*, 2025).

CONCLUSION

This epidemiological investigation demonstrates that gastrointestinal helminth infections are widespread among domestic and stray pigeons in Borno State, with substantial variation in prevalence and intensity influenced by ecological, host-related, and seasonal factors. Stray pigeons, particularly those in rural settings, exhibited markedly higher parasite burdens, underscoring the role of free-ranging behaviour and limited health interventions in facilitating parasite transmission. Among the eight identified helminth infection types recovered, the predominance of *Ascaridia columbae*, *Heterakis gallinarum*, and *Raillietina tetragona*, together with the occurrence of mixed infections, reflects a diverse helminth fauna capable of affecting pigeon health and potentially serving as reservoirs for cross-species transmission. The higher susceptibility observed in adult and female pigeons suggests possible age- and sex-related behavioural or physiological predispositions, while the rainy season peak highlights the influence of environmental conditions on parasite survival and transmission dynamics. Anatomical localisation patterns, with the small intestine and ceca as major sites of infection, emphasise the need for targeted diagnostic and control measures focusing on these predilection sites.

RECOMMENDATIONS

The findings of this study reveal high burden of gastrointestinal helminths in pigeons and important epidemiological drivers that should inform integrated parasite control strategies, particularly for stray and rural pigeon populations, emphasizing the need for targeted control measures. Therefore, regular parasitological surveillance should be instituted to monitor infection trends and detect emerging zoonotic risks. Integrated control strategies combining improved housing and hygiene, controlled feeding,

and restricted intermingling between domestic and stray pigeons are essential. Strategic, evidence-based anthelmintic treatments should be implemented, particularly before and during the rainy season when infection risk is highest. Public awareness campaigns targeting pigeon owners, live bird market operators, and rural communities will enhance compliance and sustain long-term parasite control efforts are recommended.

CONFLICT OF INTEREST

The authors declare they have no conflict of interest.

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