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Research Article

Diversity and Composition of Gastrointestinal Helminths and Gram-Negative Bacteria of the West African Rainbow Lizard (*Agama picticauda*) in a Human-Modified Landscape: Implications for Conservation and Zoonosis

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Emerging infectious diseases are negatively impacting herpetofaunal populations globally, posing a major conservation threat. Anthropogenic perturbations of natural habitats may influence wildlife disease dynamics and spillover events. Although viral and fungal diseases of vertebrates have received considerable studies, there is scant information on the enteric bacteria and helminths of herpetofauna. Here, we assessed the gastrointestinal helminths and Gram-negative bacteria of the West African rainbow lizard (*Agama picticauda*) in a human-dominated landscape in Accra, Ghana. We used the flotation method and standard cultural, morphological, and biochemical methods, for helminths and bacteria, respectively. Four helminth species, *Ascaris* spp., *Enterobius* spp., *Pharyngodon* spp., and *Oxyurid* spp., were identified, with overall high (71.9%) prevalence. *Ascaris* spp. ($\chi^2 = 33.33$, $p < 0.001$) and *Pharyngodon* spp. ($\chi^2 = 14.5$, $p < 0.001$) were more prevalent in suburban lizards during the wet season than dry season. The prevalence of *Ascaris* spp. and *Enterobius* spp. was significantly higher ($\chi^2 = 12.34$, $p < 0.001$) in urban than suburban lizards, while *Oxyurid* spp. was more prevalent ($\chi^2 = 4.75$, $p = 0.03$) in the suburban lizards during the wet season. The gut bacteria identified (prevalence) were *Escherichia* spp. (86.5%), *Enterobacter* spp. (75.7%), *Proteus* spp. (67.6%), *Shigella* spp. (40.5%), *Klebsiella* spp. (21.6%), and *Salmonella* spp. (16.2%). The prevalence of *Escherichia* spp. and *Proteus* spp. was significantly higher ($\chi^2 = 5.77–7.34$, $p = 0.01–0.02$) in suburban lizards than urban lizards during the wet season. Some *Ascaris* spp., *Enterobius* spp., *Escherichia* spp., *Enterobacter* spp., *Shigella* spp., and *Salmonella* spp. are found in humans. Our data can serve as baseline information for long-term monitoring studies of reptile-parasites-environment interactions in the Accra plains of Ghana. Further studies using molecular techniques are needed to ascertain the zoonotic helminths and bacteria of *A. picticauda*.

1. Introduction

Emerging infectious diseases are on the rise and impacting negatively wildlife, particularly, herpetofaunal (reptiles and amphibians) populations globally. This poses a major conservation challenge, particularly in developing countries where natural habitats are being destroyed at alarming rates [1, 2]. Parasites influence host behaviour, resource utilization, body condition, population dynamics, and fitness [3, 4]. Infectious diseases result from the interactions of host and pathogens, and the interactions involve physiological and ecological mechanisms that have evolved over several years under a given set of environmental conditions [5]. Therefore, land use and other environmental changes that alter the structural and ecological conditions of the environment will modulate host-pathogen interactions, leading to altered disease risks [6].

Recently, human modification of the environment that has attracted high ecological interest is urbanization. Urbanization destroys natural habitats and dramatically alters the biotic and abiotic components of the environment [7], changing species richness, distribution, and community composition [8]. Rapid urbanization also causes dramatic changes in local climate, food and habitat availability, water flow, and waste accumulation, which directly or indirectly affect the composition of soil microbial and pathogen communities and their interaction with host species. This influences the distribution, intensity, and dynamics of infectious diseases [9]. Furthermore, the urban environment may pose serious and novel stressors to wildlife that may compromise their immunity and make them more susceptible to infectious diseases.

It is widely acknowledged that many emerging infectious diseases, such as those related to coronaviruses, are associated with anthropogenic modifications of the environment [10, 11]. Wildlife in their natural habitats may decrease the transmission of infectious diseases via the dilution or amplification effect. According to the dilution hypothesis, an increase in species diversity leads to a decrease in pathogen prevalence [12]. An increase in the number of nonhost species decreases the number of intraspecies encounters between infected and susceptible hosts, leading to a decrease in the pathogen transmission rate and prevalence [5]. The amplification effect, on the other hand, argues that there is a positive correlation among species diversity, disease risk, and infection prevalence [12].

Clearing of forests and other natural habitats for urbanization destroys wildlife habitats and reduces species richness as habitat specialist species become extirpated [13]. However, habitat degradation and fragmentation could also increase species richness by adding new habitats, such as forest edges that attract invasive or generalist species [8]. The increase or decrease in species richness as a result of anthropogenic habitat modifications may lead to the loss or gain of particular host or vector species, which can affect disease exposure and transmission [12]. Therefore, in principle, loss of biodiversity due to rapid urbanization could either increase or decrease disease transmission. However, mounting evidence indicates that biodiversity loss frequently increases disease transmission [5].

The complex social-ecological system and several characteristics of the urban environment, including high human population densities, loss of natural habitats, and humans' close proximity to wildlife, increase human interactions with wild animals and their pathogens [9]. Urban areas are therefore key venues for potential spillover events because of the presence of zoonotic pathogens transmitted by hosts and vectors living in close proximity to dense human settlements [5, 9]. Already, it is estimated that zoonotic diseases account for about 2.5 billion cases of infections and 2.7 million deaths annually, with substantial socioeconomic consequences [14]. The ongoing COVID-19 pandemic is also a stark reminder of the devastating consequences of pathogen spillover from wildlife to human hosts in urban areas [9].

The rapidly expanding cities in developing tropical countries and the ever growing human populations in urban areas enhance human-wildlife interactions, which increase the risks of infectious zoonotic diseases of wildlife origin. The prevention of future zoonotic disease is contingent on a better understanding of host-parasite interactions as well as informed surveillance for known and novel threats across diverse human-wildlife interfaces, particularly in human-dominated landscape [9].

The African rainbow lizard (*Agama agama complex*) is the most abundant and widespread lizard species in rural, suburban, and urban areas of sub-Saharan Africa [15, 16]. *Agama agama* plays a fundamental role in ecosystem structure and functioning. They form an integral part of animal biomass and important actors in the energy flow and materials cycle of natural and human-modified landscapes. They feed on insects and other arthropods, thereby controlling insect population to prevent them from becoming a nuisance in the ecosystem. They also serve as food for several birds of prey, snakes, and other reptilian, mammalian, and even arthropod predators, especially when the lizards are young. *Agama agama* is a rich source of protein for some local communities [17, 18] and a model organism for scientific research.

Agama lizards have been the subject of many ecological, physiological, and epidemiological studies [19–28]. Oyekunle et al. [29] assessed the suitability of using Agama lizards as a biomarker for environmental pollution of some heavy metals and concluded that the liver and kidney of Agama lizards are suitable for the study of cadmium, zinc, arsenic, barium, manganese, and lead contamination in soils. Despite the extensive distribution and abundance of *A. picticauda* (a member of the *Agama agama* complex) in West Africa, data on its population ecology and life history are scant. Anthropogenic induced land-use change such as urbanization may influence the species' interactions with pathogens and humans. This necessitates studies of the parasite community in the species across its geographic range in order to understand how it adapts to human-modified environment to facilitate its conservation. Also, data on the zoonotic risk potential associated with the lizards are vital for effective mitigation.

To the best of our knowledge, no study has simultaneously assessed the enteric bacteria and helminths of *Agama picticauda* in human-dominated landscape in Ghana and West Africa. Therefore, the present study assessed the diversity, prevalence, and composition of enteric bacteria and helminths of *A. picticauda* in urban and suburban areas of the Accra plains of Ghana. We hypothesized that the prevalence of enteric helminths and bacteria will be higher in male lizards than females, in the wet season than dry season in the suburban area. We also expected the prevalence of helminths and bacteria to be higher in the urban area than suburban area during the wet season. We also expected some genera of the bacteria and helminths found in the lizards to be present in humans and therefore potentially zoonotic. Our findings can serve as baseline information for long-term monitoring studies of reptile-parasite-environment interactions in the rapidly urbanizing Accra plains of Ghana as these parasites are good bio-indicators of environmental change.

2. Materials and Methods

2.1. Study Area. The study was carried out in developed urban area and suburban area in the Greater Accra Region of Ghana (Figure 1). Urbanization can be defined by population size, population density, or impervious surface area or built structures [30]. In this study, urbanization was defined *a priori* using the proportion of impervious surface, i.e., roads and buildings within the surrounding landscape [31]. Urbanization increases the coverage of impervious surface with a corresponding decrease of the original vegetation cover. The suburban area was defined to cover areas with about 40 to 70% of impervious surface, while the urban area was characterized by more than 70% of impervious surface. In the urban area, samples were collected within the developed areas of the University of Ghana, Legon main campus (N 05.650°, W 00.186°), which is located about 8 km north of the Central Business District (CBD) of Accra. For the suburban area, samples were collected at Oyibi (N 5.808°, W −0.118°), which is about 27 km northeast of the CBD of Accra.

The climate of the study area is typical of that of the Accra plains. The mean annual rainfall ranges from 733 to 1118 mm, and the mean annual temperature is 25 to 28°C. The vegetation is mainly coastal savanna comprising shrubs interspersed with thickets, woodland, and forest [32].

2.2. Study Species. Agama lizards are diurnal insectivores that range in snout-vent length from approximately 47 mm to 133 mm [33]. The distribution of the species extends from Mauritania and Sierra Leone in the west to Ethiopia and Kenya in the east [34]. The species is highly territorial with dominant males, particularly conspicuous, having blue-black bodies, orange-yellow heads, and tricolored tails [16, 35]. Females, immatures, and subdominant males are uniformly greenish brown [16, 24]. Agama lizards reproduce all year round, but reproduction peaks in the wet season [36]. The female lizards become sexually matured in 14 to 18 months, while it takes about 24 months for males to become sexually matured [36]. They are strictly diurnal [33], with bimodal peak activity occurring in the morning and late afternoon [16]. They are sit-and-wait predators, with ants, beetles, and grasshoppers being the most common consumed prey item [37]. *Agama* lizards are highly adapted to human-dominated landscape, with their continental distribution coinciding strongly with human settlements [37].

2.3. Lizard Sampling. Lizard capturing and handling followed recommended guidelines for the use of live amphibians and reptiles in field research by the American Society of Ichthyologists and Herpetologists (ASIH), Herpetologists' League (HL), and Society for the Study of Amphibians and Reptiles (SSAR). The lizards were captured by hand and transported to the Department of Animal Biology & Conservation Science laboratory, University of Ghana, Legon, in cotton bags, with each individual in a separate bag. The lizards were sacrificed humanely by refrigeration and freezing as recommended by ASIH, HL, and SSAR.

Overall, 57 adult Agama lizard individuals were captured and analyzed from the developed urban area and suburban area. In the developed urban area, 16 lizards (10 males and 6 females) were captured during the wet season only. In the suburban area, a total of 41 individual lizards were captured. Of these, 21 adult lizards (12 males and 9 females) were captured during the wet season and 20 (7 males, 13 females) were captured during the dry season. We searched for the lizards at random in both the urban and suburban areas, and when they were found, we captured at most three individuals (one adult male and two adult females) where possible, from a family group. Family groups were easily identifiable because Agama lizards are territorial and usually live in a family group of up to 11 individuals (personal observation). We measured the snout-vent length (SVL) of all the captured lizard individuals using a meter rule. We analyzed all the 57 individuals for enteric helminths, but only the 37 individuals captured during the wet season (16 in the urban area and 21 in the suburban area) were analyzed for enteric bacteria.

2.4. Sample Collection and Gastrointestinal Helminth Identification. The guts of the Agama lizards were sectioned, and its content was emptied into dry cleaned labeled Petri dishes containing physiological saline. The mixture was mixed with a stirrer and then observed under a dissecting microscope for the presence of adult helminths. After, the mixture was transferred into labeled 15 ml tubes and centrifuged at 1500 rpm for two minutes. The supernatant was discarded, and 5 ml of zinc sulfate ($ZnSO_4$, 33% v/v, specific gravity, 1.180) solution was added and capped. The mixture was then reconstituted and centrifuged for two minutes at 1500 rpm. Following this, a Pasteur pipette was used to collect part of the topmost supernatant onto a microscope glass slide, covered with a cover slip, and observed under a Leica 2000 compound microscope with a magnification of ×10 and ×40 for parasite ova. Parasites detected were confirmed by a chief microscopist.

2.5. Bacterial Sampling and Isolation. Buccal, cloacal, and faecal swabs were collected from lizards with sterile cotton swab and stored in Eppendorf tubes containing 200 μl phosphate buffered saline. Each swab was streaked on MacConkey agar and incubated at 37°C for 18 to 24 hours aerobically. For enrichment and purification, morphologically similar colonies were transferred onto soft nutrient agar plate and incubated at 37°C for 18–24 hrs. The pure bacteria isolates were identified by morphological characteristics, Gram staining, motility test, and biochemical tests (indole, catalase, oxidase, urease, Triple Sugar Iron (TSI), Methyl-Red-Voges-Proskauer, and citrate). Table 1 shows a summary of how the Gram-negative bacteria were identified (biochemical profile).

2.6. Data Analysis. Data were compiled and tabulated using Microsoft Excel 2016 software. The diversity (richness) of enteric helminths infections was estimated as the number of

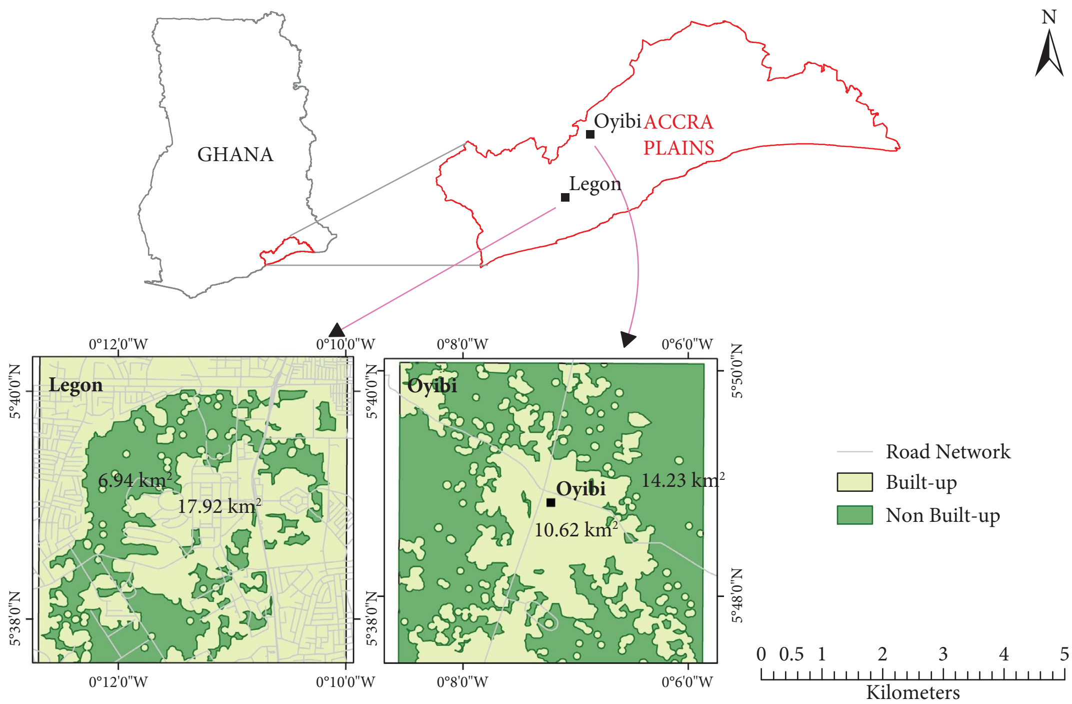

Figure 1: Map of the Greater Accra Region showing the sampling locations.

Table 1: Biochemical profile of the Gram-negative bacteria.

	TSI	Indole	MR	VP	Citrate	Urease	Motility
E .coli	A/A, gas	+ve	+ve	−ve	−ve	−ve	Motile
Citrobacter freundii	A/A or K/A, gas, H_2S	+ve	+ve	+ve	−ve	−ve	Motile
Klebsiella pneumoniae	A/A, gas (++), H_2S	−ve	−ve	+ve	+ve	+ve	Nonmotile
Enterobacter cloacae	A/A, gas (++)	−ve	−ve	+ve	+ve	+ve	Motile
Salmonella typhi	k/A, H_2S (weak)	−ve	+ve	−ve	+ve	−ve	Motile
Shigella boydii	K/A, no gas, no H_2S	−ve	+ve	−ve	−ve	−ve	Nonmotile
Proteus mirabilis	K/A, gas, H_2S	−ve	+ve	−ve	+ve	+ve	Motile (swarming)

helminth genera found in each specimen. The prevalence of helminth and bacterial infections in lizards was calculated as

$$\text{Prevalence} = \frac{\text{Number of infected lizards}}{\text{Total number of examined lizards}} \times 100. \tag{1}$$

The chi-square test was used to determine the statistically significant difference of the prevalence of parasites between sites (suburban vs. urban, for the wet season data only), season (wet vs. dry, for the suburban data only), and sexes (male vs. female, for both wet and dry season data for suburban and urban areas) of the lizards. Pearson's correlation coefficient (r) was used to assess the correlation between the snout-vent length (SVL) of lizards and diversity (richness) of enteric helminths infestations in the lizards after log-transforming the data. The analysis was conducted using the R software (Version 4.0.5), and significance was set at an alpha level of 0.05.

2.7. Ethical Approval. This study was approved by the University of Ghana College of Basic and Applied Sciences Animal Care and Research Ethics Committee (Ref. no. ECBAS 024/18-19).

3. Results

3.1. Prevalence and Zoonotic Risk Potential of Enteric Helminths in Agama Lizards. Fifty-seven Agama lizard individuals, 41 from the suburban area and 16 from the urban area, were analyzed for enteric helminths. A total of at least four helminth parasite genera, *Ascaris* spp., *Pharyngodon* spp., *Enterobius* spp., and *Oxyurid* spp., were detected. The overall prevalence of enteric helminth infections in the lizards at the study area was high (71.9%), with *Oxyurid* spp. being the most (59.6%) prevalent and *Enterobius* spp. the least (8.8%) prevalent (Table 2). In the suburban area, the overall prevalence of enteric helminth was 68.3%, while in the urban area, it was 81.3%. The prevalence of enteric helminths in the lizards was significantly higher ($\chi^2 = 5.25$–33.3, $p \leq 0.02$) in the wet season than dry season. Although the prevalence of enteric helminths was higher in lizards from the urban area than the suburban area during the wet season, the difference was statistically significant ($\chi^2 = 12.34$, $p < 0.001$) for *Ascaris* spp. only. *Oxyurid* spp. was significantly more prevalent ($\chi^2 = 4.75$, $p = 0.03$) in lizards from the suburban area than the urban area during the wet

Table 2: Overall prevalence of enteric helminths in lizards from suburban (wet season-SWS and dry season-SDS) and urban (wet season-UWS) areas in Accra, Ghana.

Species	Overall (%) prevalence				
	SDS	SWS	UWS	χ^2, p value (SDS vs. SWS)	χ^2, p value (SWS vs. UWS)
Ascaris spp.	0	33.3	68.8	33.3, <0.001	12.34, <0.001
Pharyngodon spp.	20	52.4	56.3	14.50, <0.001	0.14, 0.71
Oxyurid spp.	60	66.7	43.8	0.35, 0.55	4.75, 0.03
Enterobius spp.	15	4.8	6.3	5.25, 0.02	0.20, 0.65

Table 3: Prevalence of enteric helminths in male (M) and female (F) lizards from suburban and urban areas in Accra, Ghana.

Species	(%) prevalence								
	Suburban		Wet season	Suburban		Dry season	Urban		Wet season
	M	F	χ^2, p value	M	F	χ^2, p value	M	F	χ^2, p value
Ascaris spp.	50	11	24.93, <0.001	0	0	—	60	83	3.70, 0.05
Pharyngodon spp.	58	44	1.92, 0.17	29	15	4.45, 0.04	50	67	2.47, 0.12
Oxyurid spp.	75	56	2.76, 0.10	86	46	12.12, <0.001	50	33	3.48, 0.06
Enterobius spp.	8.3	0	8.3, 0.004	29	7.7	12.36, <0.001	10	0	10.00, 0.002

season (Table 3). Interestingly, *Ascaris* spp. was not observed in the lizards captured during the dry season at the suburban area. Also, the prevalence of enteric helminths was significantly higher in male than female lizards from the suburban area for both wet and dry seasons. For the lizards from the urban area, enteric helminths were generally more prevalent in female than male lizards (Table 3).

We found a positive but statistically insignificant correlation between SVL and diversity of enteric helminths for male lizards captured in the suburban and urban areas. However, for female lizards, we found a negative correlation between SVL and diversity of enteric helminths for the individuals captured at the suburban area and positive correlation for the individuals captured at the urban area (Figure 2). *Ascaris* spp. and *Enterobius* spp. may pose potential zoonotic risks to humans.

3.2. Prevalence and Zoonotic Risk Potential of Enteric Bacteria in Agama picticauda. All the 37 Agama lizard individuals analyzed showed positive cases for one or more Gram-negative bacteria, giving overall prevalence of 100%. The bacteria and their overall prevalence were *Escherichia* spp. (86.5%), *Enterobacter* spp. (75.7%), *Proteus* spp. (67.6%), *Shigella* spp. (40.5%), *Klebsiella* spp. (21.6%), and *Salmonella* spp. (16.2%). Generally, the prevalence of the identified Gram-negative bacteria was slightly higher in males than females, but the difference was not statistically significant ($\chi^2 = 0.02–1.89$, $p = 0.17–0.90$; Figure 3). *Escherichia* spp. was the most prevalent bacteria in male (90.9%) and female (80%) lizards, while *Salmonella* spp. was the least prevalent species, with 18.2% and 13.3% in male and female lizards, respectively. Also, the prevalence of enteric bacteria was higher in lizards from the suburban area than urban area, but the difference was not statistically significant ($\chi^2 = 0.59–3.34$, $p = 0.07–0.44$). However, the prevalence of *Escherichia* spp. and *Proteus* spp. was significantly higher ($\chi^2 = 5.77–7.34$, $p = 0.01–0.02$; Figure 3) in lizards from the suburban area than the urban area. Again, *Escherichia* sp. was the most prevalent bacteria in lizards from both suburban and urban areas, while *Salmonella* sp. was the least prevalent species (Figure 3).

Escherichia spp., *Enterobacter* spp., *Shigella* spp., and *Salmonella* spp. could be of a potential zoonotic risk to humans.

4. Discussion

4.1. Diversity, Prevalence, and Zoonotic Risk Potential of Enteric Helminths in A. picticauda. Parasitic infections are ubiquitous in wildlife, and healthy ecosystems are often parasite rich. Parasites play an important role in natural communities, influencing host behaviour, resource utilization, predation risks, body condition, population dynamics, and fitness [2–4, 38]. Infected reptiles may also pose a serious threat for public health because it may be a source of zoonotic pathogens for humans and livestock. We identified four genera of enteric helminths in *A. picticauda* from suburban and urban areas in Accra, Ghana. The number of genera of enteric helminths that was recovered from *A. picticauda* was similar to what was found (4 genera) in *Agama agama* from the Nsugbe, Anambra State, Nigeria [39], but it was higher than that observed (2 genera) in *Agama agama* from Ibadan, Nigeria [40], and lower than that observed (7 genera) in *Agama agama* from Legos, Nigeria [41].

All the helminths recovered from *A. picticauda* were nematodes, and this finding corroborates the findings of other studies that suggest that nematodes form the bulk of the enteric helminths of *Agama* species [39–42]. Likewise, Rataj et al. [43] found that most of the 18 parasite taxa in specimens of lizards imported into Slovenia were nematodes. Similarly, the endoparasites of reptiles in Namibia were mostly nematodes [44].

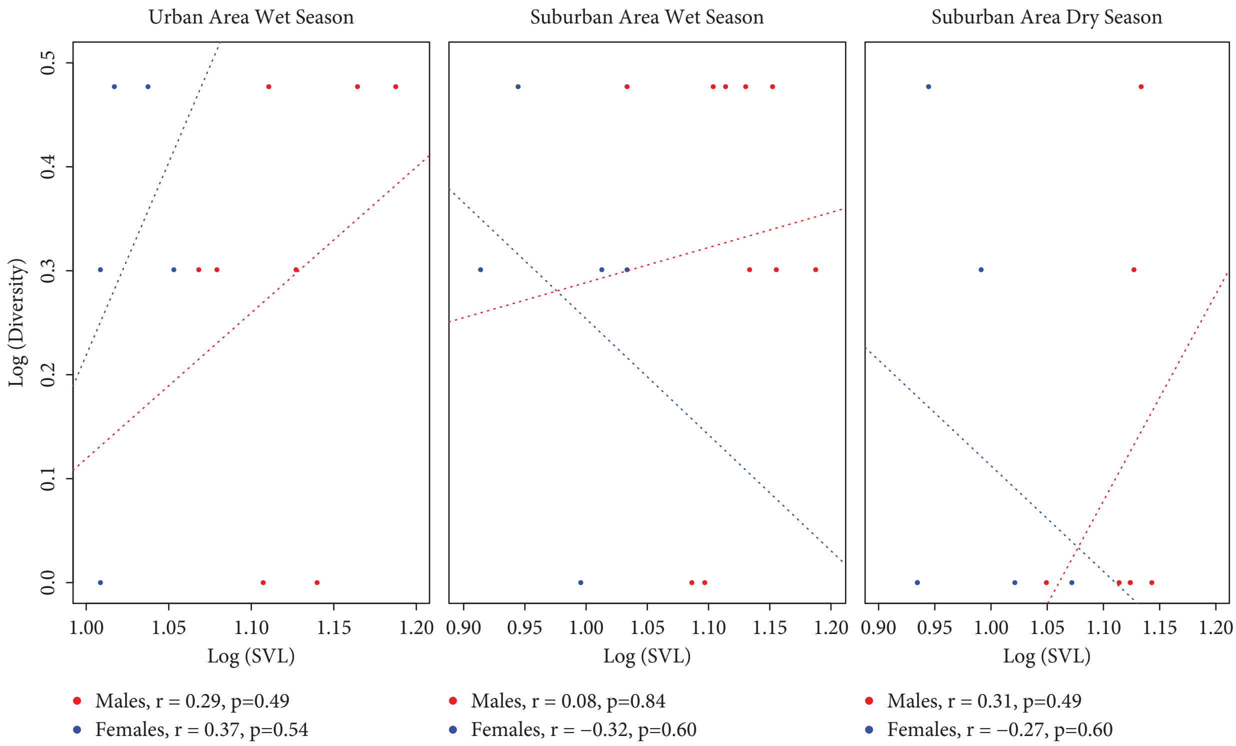

Figure 2: Correlation between SVL and diversity of enteric helminths infestations for male and female Agama lizards from the suburban and urban areas in Accra, Ghana.

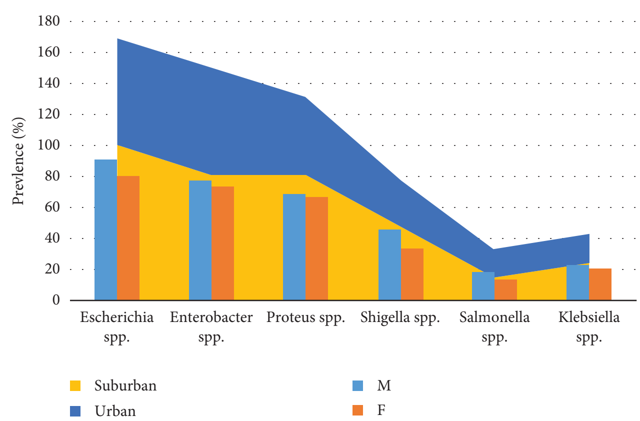

Figure 3: Comparison of the prevalence of Gram-negative bacteria isolates from male ($n = 22$) and female ($n = 15$) lizards (cluster column) and lizards captured from suburban ($n = 21$) and urban ($n = 16$) areas (stacked area) in Accra, Ghana.

The prevalence of helminth infections in *A. picticauda* was high and supports information in the literature, which suggests that helminth infection among lizards can be high [45]. For instance, high prevalence of enteric helminths has been reported in *Agama agama* from Legos, Ibadan, Ile-Ife, Anambra State, Okrika Rivers State, and Southwest Nigeria [39–46]. Furthermore, studies on house lizards (Gekkonidae): *Cosymbothus platyurus* and *Hemidactylus frenatus* from Thailand revealed high levels of infection [47].

We found higher prevalence of enteric helminths in male lizards than their female counterparts, and this corroborates the findings of Robert et al. [46] who reported higher prevalence of enteric helminths in male *Agama agama* than females from the Okrika Rivers State in Nigeria. However, the prevalence of enteric helminths in *Agama agama* from Lagos and Anambra State, Nigeria, was similar for male and female lizards [39, 41]. Adeoye and Ogunbanwo [41] and Sowemimo and Oluwafemi [42] reported significantly higher mean intensity of helminth infection in male than female *Agama agama*, but the present study did not consider helminth intensity in *A. picticauda*. This indicates that both male and female lizards are susceptible to helminth infection, but the larger and highly active males are more prone to infections because of increased contact with parasites during feeding.

Also, we found higher prevalence of enteric helminths in *A. picticauda* during the wet season than dry season and in suburban area than urban area. This was expected given that most parasitic helminths are transmitted through soil and become abundant during the wet season when the environment is warm and humid [48]. The urban area had a greater percentage of impervious surfaces that were not favourable for helminth growth and survival. Therefore, the Agama lizards in this area encountered less helminths compared to those in the suburban area. This finding supports the results of some studies in the literature; for instance, Dugarov et al. [49] found that the prevalence, intensity, and diversity of helminths in the Mongolian racerunner (*Eremias argus*; Lacertidae, Reptilia) decreased with the increasing degree of urbanization. Also, Sitko and Zaleśny [50] found that urbanization significant reduced the helminth fauna of the Eurasian blackbird (*Turdus merula*).

We found a positive correlation between SVL and diversity of enteric helminths for male lizards captured in the suburban and urban areas, but for females, we found a negative correlation between SVL and diversity of enteric helminths for the individuals captured at the suburban area and positive correlation for the individuals captured at the urban area. Sowemimo and Oluwafemi [41] found a positive correlation between the SVL and helminth prevalence and intensity in *Agama agama* from Nigeria. Mature female Agama lizards in the suburban area where food resources are abundant perhaps use a small area, usually around the center of the dominant male's territory and therefore encounter less helminths during feeding. In the urban area where food resources are less, females extend their feeding ground in order to meet their energy requirement and thus encounter more helminths while feeding.

4.2. Diversity, Prevalence, and Zoonotic Risk Potential of Enteric Bacteria in A. picticauda. Bacteria are receiving increasing attention for the role they play in host ecology. Reptiles harbour and excrete a large number of bacteria, even though they may be asymptomatic. The prevalence and composition of enteric bacteria in reptiles may vary considerably with geographic area, species, sex, diet, and altitude [38, 51, 52]. The most common bacteria isolate from reptiles include *Salmonella* sp., *Mycobacteria* spp., *Chlamydia* spp., and *Leptospira* spp. [53]. In the present study, we isolated six genera of Gram-negative bacteria in *A. picticauda*, including *Escherichia* spp., *Salmonella* spp., *Shigella* spp., *Proteus* spp., *Enterobacter* spp., and *Klebsiella* spp., with *Escherichia* spp. being the most prevalent and *Salmonella* spp. the least prevalent. Casey et al. [54] isolated eight genera of enteric bacteria, *Citrobacter* spp., *Enterobacter* spp., *Serratia* spp. *Salmonella* spp., *Klebsiella* spp., *Escherichia* spp., *Kluyvera* spp., and *Pantoea* spp. from the Tokay geckos (*Gekko gecko*), with the three most prevalent genera being Citrobacter (55%), Klebsiella (20%), and Enterobacter (10%). Bastos et al. [55] also isolated several genera of the Enterobacteriaceae family from adult Jararacas (*Bothrops jararaca*), a venomous snake that is found in Brazil. The bacteria included *Citrobacter* spp., *Enterobacter* spp., *Escherichia* spp., *Klebsiella* spp., *Kluyvera* spp., *Morganella* spp., *Proteus* spp., *Providencia* spp., and *Salmonella* spp., with Salmonella, Citrobacter, and Escherichia being the most frequent isolates. *Escherichia* spp. and *Salmonella* spp. have also been isolated from the faeces of land iguanas (*Conolophus* sp.), marine iguanas (*Amblyrhynchus cristatus),* and giant tortoises (*Geochelone nigra*) [56].

We found higher prevalence of bacteria in male than female lizards, but both sexes had similar genera richness and composition. This contrasts with the results of Martin et al. [57], who found sex asymmetry in microbial community structure and composition of free-ranging striped plateau lizards (*Sceloporus virgatus*), with males having significantly higher microbial diversity and richness than females. Sex bias in susceptibility to parasitic infection may be linked to sex differences in the production of sexual hormones that affect directly or indirectly the host's immunological response [58, 59]. The males, which are the larger sex, are more active and invest more energy into vigilance and territory defense. This may reduce the efficacy of their immune function, and so, the males tend to be more exposed to parasitic infections [60]. The larger home range of the males might also enhance their exposure to parasites [61].

Also, we found higher prevalence of bacteria in lizards from the suburban area than urban area, but the genera richness and composition did not change. Changes in community composition and behavior, such as a switch in diet to include more anthropogenic food associated with urbanization, might have led to the lower parasite prevalence in the suburban lizards. Modupe al. [62] isolated 10 bacteria genera including *Shigella* spp., *Yersinia* spp., *Salmonella* spp., *Citrobacter* spp., *Enterobacter* spp., *Klebsiella* spp., *Proteus* spp., *Pseudomonas* spp., *Serratia* spp., and *Escherichia* spp. from birds in a protected forest in Ghana. The fact that *A. picticauda* shared all the six bacteria genera with wild-caught birds from Ghana suggests that these bacteria genera are common in the environment and are easily picked up by individual animals during foraging.

5. Conclusion

Our study highlights the parasite-host and environment relationship in *A. picticauda* and is the first to assess simultaneously the enteric bacteria and helminths of *A. picticauda* from Ghana. Our results showed that enteric helminths and bacteria were more prevalent in males than females, in the wet season than dry season and in the suburban area than urban area. We found a positive correlation between SVL and diversity of helminths in male lizards. The helminths *Ascaris* and *Enterobius* and bacteria *Escherichia*, *Enterobacter*, *Shigella*, *Klebsiella*, *Proteus,* and *Salmonella* are all potentially pathogenic to humans. This raises public health concerns given the close association of the rainbow lizards with human dwellings. Low sample sizes and lack of replication were the main limitations of the present study. The methods we used to identify helminths and bacterial could only identify to the genus level and not species. Therefore, future studies should increase the number of lizard individuals captured from each site, and also, several urban and suburban sites should be considered to increase the power of the statistical analysis. Molecular techniques should be used in future studies to determine the identity the actual species of enteric helminths and bacteria of *A. picticauda* in order to establish their zoonotic status.

Data Availability

The data that support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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