

Host-parasite dynamics and distribution of nematodes in insectivorous bats of Burkina Faso

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Abstract

Insectivorous bats can become contaminated with helminths through their diet, potentially impacting their immune systems. This study represents the first survey conducted in Burkina Faso, focusing on nematodes in insectivorous bats.

Bats were captured using mist-nets and sent to the laboratory for parasitological examination. We sampled 311 bats representing five species (*Mops condylurus*, *Mops midas*, *Pipistrellus nanulus*, *Rhinolophus alcyone* and *Scotophilus leucogaster*).

A total of 237 parasites were identified in 22.83% of the bats examined, encompassing five species: *Capillaria* sp., *Rictularia bovieri*, *Molinostrongylus* sp., *Parashistiostrongylus octacantus*, and *Physaloptera* sp. *R. bovieri* and *Molinostrongylus* sp. were the most widespread; they were found in four host species. The analyses showed that sex and age class did not influence the presence of nematodes. The sex index of nematodes was 0.69. *P. octacantus* had the highest sex index (1.14) followed by *R. bovieri* (0.67). This study highlights the need for further research on bat nematodes to better understand the impact of these parasites on bat physiology.

Keywords : Bats, Nematodes, Chiroptera, Prevalence, Burkina Faso

Dynamique hôte-parasite et distribution des nématodes des chauves-souris insectivores du Burkina Faso

Résumé

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Les chauves-souris insectivores s'infestent par des helminthes à travers leur régime alimentaire, ce qui peut altérer leur système immunitaire. Cette étude constitue la première enquête réalisée au Burkina Faso sur les nématodes des chauves-souris insectivores. Les chauves-souris ont été capturées à l'aide de filets japonais, puis transférées au laboratoire pour un examen parasitologique approfondi. L'étude a porté sur 311 chauves-souris appartenant à cinq espèces : *Mops condylurus*, *Mops midas*, *Pipistrellus nanulus*, *Rhinolophus alcyone* et *Scotophilus leucogaster*. Un total de 237 parasites ont été identifiés chez 22,83 % des individus examinés, comprenant cinq taxons : *Capillaria* sp., *Rictularia bovieri*, *Molinostrongylus* sp., *Parashistiostrongylus octacantus* et *Physaloptera* sp. Parmi eux, *R. bovieri* et *Molinostrongylus* sp. étaient les plus répandus, colonisant quatre espèces d'hôtes différentes. Les analyses statistiques indiquent que le sexe et la classe d'âge n'influencent pas la présence de nématodes. L'indice sexuel global des nématodes était de 0,69, *P. octacantus* présentant l'indice le plus élevé (1,14), suivi de *R. bovieri* (0,67). Cette étude révèle une diversité de nématodes jusqu'alors méconnue au Burkina Faso et souligne la nécessité de recherches futures pour élucider l'impact de ces parasites sur la physiologie et la conservation des chiroptères en Afrique de l'Ouest.

Mots-clés : Chauves-souris, Nématodes, Chiroptères, Prévalence, Burkina Faso.

Introduction

Within the class Mammalia, bats belonging to the order Chiroptera are the most diverse after rodents. Bats are also considered to be good indicators of environmental stress (Angoma *et al.*, 2020). They play a key role in the balance of biodiversity through insect regulation. Unfortunately, the insects consumed by bats often harbour helminths that can pass through and end up in bats (Lord, 2012). This happens because very often the prey species are stable hosts of the intermediate stages of some parasites. Most helminth parasites of wild insectivorous vertebrates are acquired through prey-predator relationships in the given micro ecological settings (Okafor *et al.*, 2008). However, studies on chiropteran endoparasites are limited around the world, which means that the diversity of bat's parasites is probably underestimated (Kirschbaum 2009; Lord *et al.*, 2012; Santos et Gibson, 2015). Although studies on the helminth fauna of bats are less represented in parasitology than those related to research on helminths of other mammalian groups, from the second half of the 20th century onwards they intensified (Okafor *et al.*, 2008).

Such studies indicate that bats are infected with a rich diversity of helminths, including trematode, cestode, and nematode species. However, there remains a paucity of data on parasite community composition and the factors that may influence community structure

(Santos et Gibson, 2015).

Among the helminths, nematodes are second only to arthropods in terms of number of species, with 25,000 species already described, 12,000 of which parasitise vertebrates (Poulin et Morand, 2000; Hugot *et al.*, 2001).

Parasitic nematodes rarely kill their hosts; as sublethal parasites, they primarily weaken the host immune system. Consequently, they play an essential role in host population regulation (Maizels & Yazdanbakhsh, 2003; Morand *et al.*, 2006). Because bat nematodes are not typically recognized as zoonotic agents, they remain understudied compared to viral and bacterial pathogens. While recent research in Burkina Faso has examined bat diversity and associated ectoparasites (Thiombiano *et al.*, 2019, 2021; Kangoyé *et al.*, 2022), data on endoparasitic nematodes remain scarce. To address this gap, the present study aims to identify bat-parasitic nematodes and evaluate the key factors influencing their infection dynamics.

I. Materials and Methods

I.1. Bat collection and helminth research

A survey was conducted to identify the preferred habitats of bats. These included water sources, which serve as drinking sites for bats; forest tunnels, which serve as feeding sites; and abandoned buildings, which serve as roosting sites for bats. Bats were collected in six sites across Burkina Faso: Ouagadougou, Bama, Diébougou, Gondogo, Bobo-Dioulasso, Manga, and Banzon (Figure 1).

- Capture and identification bats

Captures were conducted from December 2020 to September 2021. At each sampling site, six Vohwinkel-type Japanese nets (length: 6 or 12 m; height: 2.80 m; 5 pockets; mesh size: 16 mm; denier: 70/2) were deployed starting at 5:00 p.m. The nets were positioned in various microhabitats (near dwellings, in forest clearings, and along water sources) and secured using PVC pipes and nylon lines. They remained open from dusk (around 6:00 p.m.) until 5:00 a.m., depending on bat abundance. The nets were inspected every 15 minutes. Captured bats were removed and then transferred individually to a cotton bag until they were identified. To avoid any direct contact with bats, we have used Personal Protective Equipment in line with the "Code of ethics for

the practice of catching bats" designed as part of the National Plan of Chiroptera Actions 2009-2013.

Bat identification was based on several parameters: sex, age class (juvenile, subadult, adult), reproductive status, and standard morphometric variables. The mass of individuals (in grams) was measured using Pesola precision scales (accuracy of 0.25 g, 1 g, or 2 g depending on the specimen's size), in accordance with the method described by Epstein *et al.* (2016). Sex was determined by direct examination of the external genitalia. Age was assessed by observing the conjugation cartilages (epiphyseal plates) at the phalangeal joints, which allowed for the distinction between juvenile and adult individuals. The reproductive status of the males (breeding or non-breeding) was determined based on testicle size. The reproductive status of the females (nulliparous, pregnant, lactating, or post-lactation) was determined by abdominal palpation, observation, and squeezing of the mammary glands. We used calipers to measure standard morphometric variables in the bats. Bats were identified using the identification keys of Rosevear (1965), Hayman and Hill (1971); Bergmans (2002). This study was approved by the Ministry of the Environment, Green Economy, and Climate Change (MEECVCC) (authorization No. 21-091 MEECVCC/SG/DGEF/DFRC). It was also approved by the Animal Experimentation Ethics Committee at Joseph Ki-Zerbo University under number CEEA-UJKZ/2021-04. All work was conducted in accordance with applicable guidelines and regulations regarding the care and use of animals.

- Collection and Identification of Nematodes

To collect the nematodes, the bats were first euthanized by injection of a combination of medetomidine (50 µg/kg) and ketamine (5 mg/kg) in accordance with AVMA (2020) recommendations. The specimens were placed in the supine position and secured to a dissection board. The digestive tract and associated organs (esophagus, stomach, liver, small intestine, and large intestine) were dissected and then transferred to individual Petri dishes, labeled with the bat's identification number and containing 0.9% saline (Okafor *et al.*, 2008). Each organ was then sectioned longitudinally and examined separately under a Leica MZ8 binocular magnifying glass equipped with an ocular micrometer. The nematodes were examined on temporary slides after being clarified with lactophenol for five minutes between the slide and the coverslip.

Lactophenol makes the nematodes transparent and easy to observe under a microscope. This clearing agent allows for the observation of the nematodes' characteristics according to the protocol described by Okafor *et al.* (2008). The nematodes were identified using a Leica EZ4 binocular stereomicroscope at high magnification (100X and 400X). Identification was based on morphological and morphometric characteristics, using reliable reference keys (Yamaguti, 1941, 1961; Santos et Gibson, 2015).

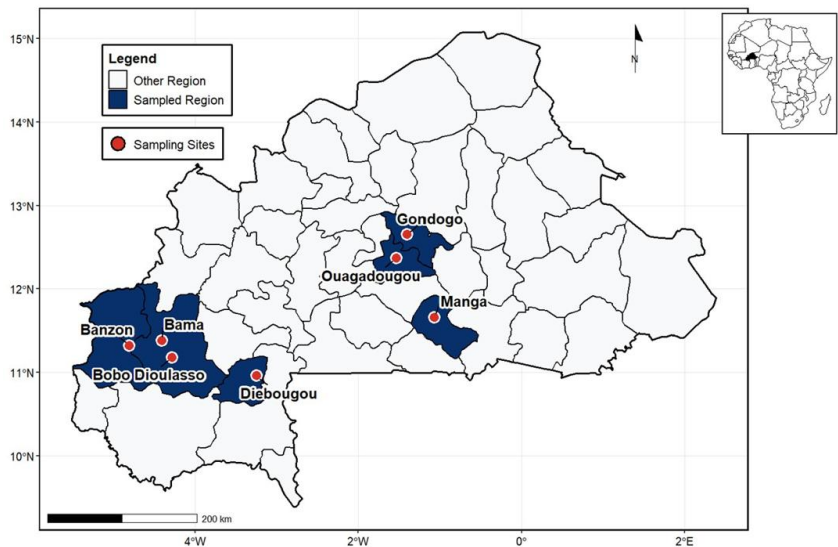


Figure 1: A map of Burkina Faso highlighting the sites of bat collection

1.2. Data analysis

Data was analyzed statistically using the statistical software R, version 4.5.2. A Shapiro-Wilk test was used to check the normality of the data; this test showed that the data was not normally distributed. Consequently, nonparametric tests were used for data analysis. Epidemiological indices were calculated to characterize the infestation of bats: Prevalence was calculated by dividing the number of infected bats by the total number of bats; Average abundance was calculated by dividing the number of nematode individuals by the total number of bats examined; Mean intensity is a key indicator calculated by dividing the total number of nematodes of a given species collected by the number of infested bats (Bush *et al.*, 1997). These epidemiological

indicators were analyzed by sex and bat order using the chi-square test and Fisher's exact test at a significance level of 0.05. The host-parasite network was mapped using Sankey diagrams to identify primary reservoirs and “pivotal” species, while community diversity was quantified using the Shannon-Wiener (H') and Pielou’s evenness (J) indices to assess stability and dominance patterns among host species.

II. Results

II.1 Species diversity of captured bats by sex and age class

A total of 311 specimens of insectivorous bats, representing five species, were subjected to helminthological analysis: *Mops condylurus* (A. Smith, 1833), *Mops midas* (Sundevall, 1843), *Pipistrellus nanulus* (Thomas, 1904), *Rhinolophus alcyone* (Temminck, 1853), and *Scotophilus leucogaster* (Cretzschmar, 1826). Among the captured bats, there were 169 females (54.34%) and 142 males (45.66%). Adult bats were the most represented with 284 specimens (91.31%), followed by 25 subadults (8.03%) and 2 juveniles (0.66%).

II.2. Structure of the nematode according to bat species

An overall prevalence of nematode infection of 22.8% (71/311) was recorded among all bats sampled. Prevalence varies significantly by host species ($p < 0.05$). The highest infection rate was observed in *Mops midas* (48.0%, group a), followed by *Mops condylurus* (31.0%, group b) and *Rhinolophus alcyone* (20.0%, group ab). In contrast, *Scotophilus leucogaster* (7.0%) and *Pipistrellus nanulus* (5.3%) showed significantly lower prevalence rates (group c) (Table I).

Table I: Structure of the nematode according to bat species

Bat species	Examined bats	Infected bats	Prevalence	Statistical group
<i>Rhinolophus alcyone</i>	20	4	20.0%	ab
<i>Mops midas</i>	25	12	48.0%	a
<i>Pipistrellus nanulus</i>	38	2	5.3%	c
<i>Scotophilus leucogaster</i>	57	4	7.0%	c
<i>Mops condylurus</i>	158	49	31.0%	b
Total	311	71	22.8%	

II.3. Prevalence and Mean intensity of nematodes infection of bats

A total of 237 nematodes (five species) were collected, representing

0.76 parasites per bat examined and 3.38 parasites per infected bat. Four species were found exclusively in the intestine: *Capillaria* sp., *Rictularia bovieri*, *Molinostrongylus* sp., and *Parashistiostrongylus octacanthus*. In contrast, *Physaloptera* sp. was the only adult parasite present in the stomach. *Rictularia bovieri* was the dominant species. *Physaloptera* sp. had the highest prevalence (9.6%) coupled with the lowest MI (1.63), in contrast to *R. bovieri*, whose moderate prevalence (4.8%) was associated with the highest

Table II: Nematode species of bats and their ecological index in the different host species

Nematodes	<i>Mops condylurus</i>	<i>Mops midas</i>	<i>Pipistrellus nanulus</i>	<i>Rhinolophus alcyone</i>	<i>Scotophilus leucogaster</i>	n _h
<i>Capillaria</i> sp	+		+	-	-	2
<i>Molinostrongylus</i> sp.	+		+	-	+	4
<i>Parashistiostrongylus octacanthus</i>	+		+	-	-	2
<i>Physaloptera</i> sp	+		+		+	3
<i>Rictularia bovieri</i>	+		+	+	-	4
n _n	5		5	1	2	2
H'	1.34		1.31	0	0.6	0.56
Equitability J	0.83		0.82	-	0.86	0.81

n_n: number of nematodes species per host species of bat; n_h: number of bat host species of each nematode; H': Shannon-Wiener index; **Equitability J**: Pielou uniformity index

II.5. Structure of the nematode according to sex and age class

Analysis of the biotic parameters of the bats revealed that neither age group nor sex significantly influenced the presence of nematodes (P > 0.05). Adults comprised most of both infected and uninfected individuals, showing a prevalence of 92.96% among positive cases; however, no statistical difference was found between age class (p = 0.88). Notably, juveniles showed no infections while subadults exhibited a stable prevalence of 20%. Similarly, nematode prevalence was symmetrically distributed between the sexes (p = 0.87), with females and males demonstrating nearly identical infection rates of 22.48% and 23.24%, respectively (Table III).

II.6. Distribution of nematode across host species and sex

The Sankey diagram illustrates an asymmetry in the distribution of nematodes based on bat sex (Figure 4b).

Table III: Structure of nematodes according to sex and age class of bats

Age class	Absence %	Presence	Prevalence	P-value
Adulte	218 (90.83%)	66(92.96%)	23.24%	0.88 ¹
Juvenile	2(0.83%)	0 (0%)	0%	
Subadulte	20 (8.33%)	5 (7.04%)	20%	
Sex				
Female	131 (54.58%)	38(53.52%)	22.48%	0.87 ²
Male	109 (45.42%)	33(46.48%)	23.24%	

Female individuals carry a total parasite load that is significantly higher than that of males ($P = 0.35$) (Figure 4a). Some species are stenoxenous to the genus *Mops*. For example, *Parashistiostrongylus octacantus* is found exclusively in the genus *Mops* (primarily *M. condylurus*). In contrast, *Rictularia bovieri* has a more euryxene distribution, occurring in nearly all the host species sampled, including less common hosts such as *Pipistrellus nanulus* and *Scotophilus leucogaster*. To assess the effect of host sex on nematode burden, parasite abundance was compared between males and females. Although a higher absolute number of parasites was counted in females (145 parasites) compared to males (92 parasites), this difference was not statistically significant (Wilcoxon signed-rank test, $W = 18$, $p = 0.21$).

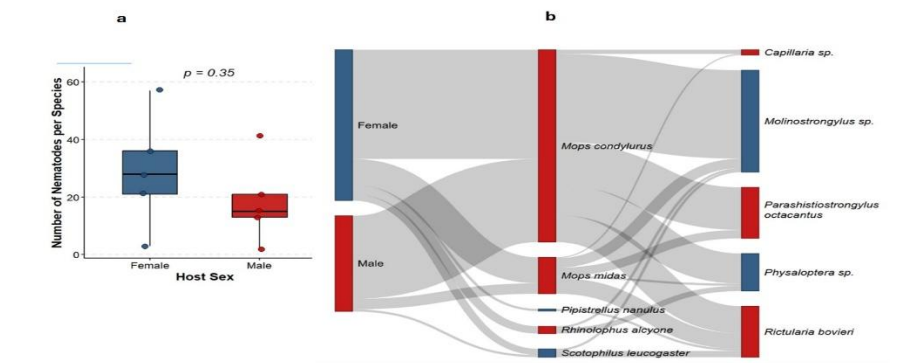


Figure 4: Distribution of nematode across host species and sex

a: Distribution of the number of nematodes by host sex (bats); *b*: Distribution of nematode species by bat species and sex.

II.7. Sex structure of bat nematodes

A total of 237 adults nematode individuals were isolated from the parasitological examination. Female nematodes were the most abundant 164 (69.20%) compared to male nematodes 73 (30.80%) males. The sex index of the total sample was 0.69.

It was higher in *P. octacantus* ($S = 1.14$) while *R. bovieri*,

Molinostrongylus sp., *Physaloptera* sp. and *Capillaria* sp. had indices of 0.67, 0.24, 0.11, and 0.02 respectively. In *Capillaria* sp. the presence of males was not determined.

III. Discussion

This study was conducted on bat nematodes in Burkina Faso. The prevalence obtained in this study (22.83%) is like that found in other studies (Nogueira *et al.* 2004; Lord *et al.*, 2012, Horvat *et al.*, 2017; Kazemirad *et al.*, 2020). This prevalence is lower than that of the studies of Okafor *et al.* (2008) carried out in Nigeria where the prevalence was 76.78%. The achievement of such a prevalence could be due to the non-proliferation of insects that are consumed by the bats in our study. Insects are the intermediate hosts of nematodes. The nematodes pass through the insects to infest the bats which are their final hosts (García-Vargas, 1996; Moguel-Chin *et al.*, 2025). Also, according to Salinas-Ramos *et al.* (2017) the transmission, development and distribution of parasites can be regulated by abiotic factors such as ambient temperature, humidity and rainfall.

Five species of nematodes were isolated from insectivorous bats in this study. This is a first in Burkina Faso. However, other studies in Africa have already reported the presence of these species in bats. In Gabon, Justine (1989) described a new species of nematode belonging to the family Capillaridae parasite bat *Rhinolophus silvestris*. Similarly, nematodes of the family Rictulariidae have been reported in India, Nigeria, Japan, and the Americas, and have been detected in the intestines of rodents (Park, 2021). The high Shannon-Wiener diversity ($H' > 1.30$) observed in these molossid bats suggests that their resting ecology provides a stable niche allowing multiple nematode taxa to coexist without competitive exclusion.

The small intestine was the attachment site for four nematode species. This is due to the abundance of nutrients in the gut of bats (Okafor *et al.*, 2004). Thus, the nutrients and metabolites necessary for the growth, development and maintenance of these helminths are readily available in the small intestine (Okafor *et al.*, 2004). The stomach was infested only with *Physaloptera* sp. as in other studies (Lord *et al.*, 2012).

In this study, the nematode species showed euryxene specificity to all parasitized bat species. The only species (*M. pumilus*) not parasitized is due to the low number of specimens captured compared to the other

species. Indeed, only two specimens of *M. pumilus* were captured during our study. However, other studies have already isolated helminths from this bat species (Melaun et al., 2014). Statistical analyses showed that sex, age class, and capture site were not factors influencing the presence of nematodes on bats. Other authors have also found similar results (Shimalov et al., 2011; Lord et al., 2012). This is due to the gregarious lifestyle of bats, giving all bats the same chance of being infested regardless of sex, age class and housing. However, the highest prevalence of adult bats is explained by their longer life span compared to sub-adults and juveniles. Indeed, the adults being the oldest have had the chance to consume the intermediate host insects of the nematodes than the sub-adults and juveniles. The sexual index of nematofauna was in favour of female bats. The most pronounced dominance of females over males was found in the species *P. octacantus* in which the calculated sexual index was 1.14. The dominance of female nematodes in this study is consistent with the reproductive strategy of nematodes. According to Lewis (1987) quoted by Horvath et al. (2015), the role of male nematodes is limited to copulation, and the task of females is to lay as many fertilised eggs in which they will lay under the influence of environmental conditions favourable for the development of infective larvae. Also, according to Horvath et al. (2015), bat nematodes have a higher production of females, and the reason for this is a more successful reproduction, leaving a greater number of offspring and ensuring the survival of the species.

The observed contrast between parasite abundance and prevalence suggests distinct host-parasite strategies. While *M. condylurus* serves as a biomass reservoir, *M. midas* exhibits higher transmission efficiency. This phenomenon could be explained by a specific compatibility between the host and the parasite or by certain behavioral traits, such as social grooming (allogrooming), which can limit the total parasite load but fails to prevent the initial infection, as noted by (Zuk and Stoehr, 2002).

Furthermore, the broad host range of *Molinostrongylus* sp. and *Rictularia bovieri* (n = 4) underscores their status as ecological generalists. This plasticity is often linked to indirect life cycles involving common intermediate hosts among arthropods, which allows these parasites to bypass phylogenetic barriers between different bat families (Moguel-Chin et al., 2023).

Conclusion

This study provides the first characterisation of nematodes in

insectivorous bats in Burkina Faso (22.83% prevalence in 311 bats). Infection is independent of the host's sex and age, with *M. condylurus* acting as the main reservoir. These data highlight the importance of including wildlife parasites in 'One Health' eco-epidemiological monitoring for the conservation of West African ecosystems.

Ethical Statements

This study was approved by the Ministry of the Environment, Green Economy, and Climate Change (MEECVCC) (approval no. 21-091 MEECVCC/SG/DGEF/DFRC). It was also approved by the Animal Experimentation Ethics Committee of Joseph Ki-Zerbo University (No. CEEA-UJKZ/2021-04).

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