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Mini Elucidation on Some Parasites in bats

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Abstract.

Bats (Order Chiroptera) are ecologically important mammals providing pest control, pollination and seed dispersal, but they also harbor diverse parasitic fauna with zoonotic potential. This paper provides a mini elucidation on some parasites identified in bats with emphasis on epidemiology, taxonomy, life cycles and public health significance. Epidemiological surveys across Nepal, Iran, Ghana and Nigeria reveal high prevalence of gastrointestinal and haemo-parasites. In south-central Nepal (July 2018-Feb 2019), faecal analysis of frugivorous and insectivorous bats using wet mount, flotation, sedimentation, acid-fast staining and sporulation assay detected Entamoeba spp., Hymenolepis spp., Isospora spp., Oxyurid spp., Strongyle spp., Strongyloides spp., Eimeria spp., Capillarid_ spp., Cryptosporidium spp. and Ascarid spp., with higher threat in insectivorous bats. In Persian Gulf Coastal Iran, Rhinopoma muscatellum and R. microphyllum showed 26.7% helminth infection with Lecithodendrium spp. and Castoria spp. being most prevalent. In Ghana (480 bats, 2014), ectoparasites Spinturnix americana, Carpoglyphus spp., Ancystropus zeleborii dominated in adults, while haemoparasites occurred in 48%, with ticks transmitting Borrelia, Rickettsia, Ehrlichia, mites causing acariasis and bugs transmitting trypanosomes. In Amurum, Nigeria, Hepatocystis prevalence was 25-42% in fruit bats, while Anambra State survey identified Cimicidae, Nycteribiidae, Ixodes veretillomis, Leptotrombidium spp., Macronyssus spp., Plasmodium and Trypanosoma spp. This overview also details Penicillidia conspicua (Nycteribiidae), a wingless, hematophagous bat fly highly specific to Miniopterus schreibersii with obligate pseudo-placental unilarviparity, Hepatocystis spp. transmitted by Culicoides midges, Ascaridia spp., Eimeria spp. with 31 species in bats, and Cryptosporidium spp. with zoonotic species C. hominis and C. parvum reported globally at 0.7-50% prevalence. Bats play significant roles as reservoirs and vectors of zoonotic parasites.

1.INTRODUCTION

Bats belong to Order Chiroptera and are the second most diverse mammalian order after rodents, with over 1,400 species globally. They are found on all continents except Antarctica and are divided into frugivorous and insectivorous groups. Ecologically, bats are indispensable for agriculture through insect pest control, pollination and seed dispersal, contributing to ecosystem stability and food security (Boyles et al., 2011; Kasso & Balakrishnan, 2013; Kamani et al., 2022). Despite their ecological benefits, bats are important reservoir hosts for diverse parasites and pathogens including viruses, bacteria, helminths and protozoa (Calisher et al., 2006; Allocati et al., 2016). Their unique biological traits such as long lifespan, colonial roosting, flight ability and torpor/hibernation facilitate parasite maintenance and transmission. Parasitic fauna in bats include endoparasites (gastrointestinal helminths, protozoa, haemo-parasites) and ectoparasites (bat flies, ticks, mites, bugs). Epidemiological studies on bat parasites have been conducted in Nepal, Iran, Ghana, Burkina Faso and Nigeria. These studies employ parasitological techniques such as direct wet mount, saturated salt flotation, sedimentation, acid-fast staining, sporulation assay, microscopy, PCR and sequencing to detect prevalence and diversity (Adhikari et al., 2020; Atama et al., 2019; Okeke et al., 2020). Specific parasites of interest include Penicillidia conspicua, a highly specialized, wingless, blood-feeding bat fly of family Nycteribiidae associated with cave-dwelling Miniopterus schreibersii; Hepatocystis spp., a haemosporidian parasite transmitted by Culicoides midges with 25 species recognized affecting bats, primates and squirrels; Ascaridia and Eimeria spp. causing gastrointestinal infections; and Cryptosporidium spp., a zoonotic protozoan causing cryptosporidiosis with global prevalence ranging from 0.7% in Australia to 50% in USA. Understanding the epidemiology and life cycles of these parasites is crucial for assessing public health threats, bat conservation and One Health interventions, as ectoparasites serve as vectors for Borrelia, Rickettsia, Ehrlichia and Trypanosoma (Atama et al., 2019). This paper therefore presents a mini elucidation on parasitic fauna identified in bats, their epidemiology, morphology, life cycles and zoonotic implications.

2. Survey on Epidemiology of Parasites in Bats

Epidemiology describes patterns, distributions, prevalence, determinants and likes of diseases. A study of prevalence of gastrointestinal parasites in the frugivorous and the insectivorous bats in south-central Nepal using direct wet mount technique, saturated salt flotation technique, sedimentation technique, acid-fast staining, sporulation assay, to study the prevalence of endoparasites of bats from July 2018 – February 2019. The parasites detected were: Entamoeba species, Hymenolepis species, Isospora species, Ozeyurid species, Strongyle species, and strongyloides species, from faecal analysis., Eimeria species, Entamoeba species, Capillarid species, Crystospridium species, Ascarid species, and hymenolepis species were detected in frugivorous bats. The study depicts that, the gastrointestinal parasites are a threatening factor in the insectivorous bats (Adhikari et al., 2020). In Iranian study of helminth parasites of Bats (hiroptera: Rhinopomatidae Bonaparte, 1838) from the Persian Gulf Coastal Area. The identification of helminths was carried out using morphological and morphometric characters, leading to the identification of 44R. Muscatellum and 6R Microphyllum species, among which 26.7% had infections with parasitic worms. Lecithodendrium species., Castoria species, were detected in the digestive tract of 8 and 4 individually observed R. Muscatellum bats, respectively. Furthermore, 3 R. Microphyllum bats had a few spirurid nematode with incomplete structures were detected. In the end Lecithodendrium species was the most prevalent (Atama et al., 2019, Guo et al., 2020). In Africa, particularly in Ghana, a study of parasites (ecto and endo) that infect bats and the potential public health threat assessed, in a sample of 480 bats in 2014 from blood, and faeces for helminthes was carried out. The most prevalent ectoparasites detected were Spinturnix americana, carpoglyphus species and Ancystropus zeleborii mostly found in adults. Haemoparasites are observed in very significant proportion (48%) of the bats, but specific parasites were never unveiled. Ectoparasites found that transmits pathogens were as follows; tick transmits Borelia species, Rickettsiae species, Ehrlichia species, Mite transmits enteric Acariasis, scrub typhus, and rickettsia pore; and bugs transmit trypanosomes. The study points to the possibility of the capacity of bats to play role in transmission of Zoonotic diseases in the study area or elsewhere (Atama et al., 2019). A

Nigerian study survey of hepatocystic parasites of fruit bats in the Amurum forest reserve, in Enugu reported in 2019, PCR and sequencing of blood lead to the discovery of hepatocystis with prevalence of 25% and 42%. In fruit bats (Atama et al., 2019). Progressively, in the year 2020, a survey of the ectoparasites and haemoparasites of bats trapped in Anambra State, Nigeria, was carried out using microscope and Identified Cimocidae, Nycteribiidae, Ixoodes Verertilomis, leptrombiodium species. and Macronyssus species. were the ectoparasites found, whereas, haemoparasites detected are Plasmodium and Trypanosoma species (Okeke et al., 2020).

3. Penicillidia conspicua

This is an ectoparasite found parasitizing bats fauna. They are regarded as bat flies belonging to the Kingdom Animalia, Phylum Arthropod, Class Insecta, Order Diptera, Family Nycteribiidae, Genus Penicillidia. These specific flies are flattened in shape, spiderlike flies that have no eyes or wings. They also have insignificant resemblance with the other Dipterans. Penicillidia conspicua flies are not mostly affected by general collectors, because as they are mostly dwelling in their hosts. They consume blood, thus are considered as real parasites (Gustavo and Carl, 2008; Petersen et al., 2017). One key morphological feature of penecillidia is having a backward folded legs that resembles that of spider and a dorsally inserted head (Gustavo and Carl, 2008; Bajić et al., 2023). Bat ectoparasites have certain potential to act as vectors, parable, Polychromophilus species are transmitted by Nycteribiids (Gardener and Molyneux, 1988; Petersen et al., 2017). Batronella was identified among the bat flies populations and their host in the Madagascarn fruit bat delineating the significant crucial role of bat flies in Batronella transmission (Brooks et al., 2018). The bat fly Penicillidia conspicua is a highly specialized, hematophagous, obligate ectoparasite that is closely associated with its bat hosts. It emanates from the Nycteribiidae family, which is characterized by its wingless nature and marked sexual dimorphism. P. conspicua has a unique reproductive strategy, known as obligate pseudo-placental unilarviparity, in which a single larva develops inside the female. Certainly, the larva has to be placed during the third instar, and instantly undergoes pupation. The pupae are typically found on cave walls near the hosts. This bat fly species is highly specific to the cave-dwelling Miniopterus schreibersii, also known as the common bent-wing bat. However, sometimes it can be often located be found on other bat species. Interestingly, P. conspicua sometimes co-exists along with other bat fly species, Nycteribia schmidlii, which is also very specific to M. schreibersii. Geographical areas (distributions) where of P. conspicua is located is resembling that of its host, therewith it can be from the Mediterranean region (Europe), northern part of Africa, and moreover, the Middle East. Recent studies have discovered the presence of endosymbionts in P. conspicua, although the biological role of these endosymbionts remains to be explored. Overall, P. conspicua is a fascinating example of a highly specialized parasite that has evolved to thrive in a specific ecological niche. Further research is needed to fully understand the biology and ecology of this intriguing species (Szentiványi et al., 2020).

4. Hepatocystis species

Hepatocystis species is a genus of parasites transmitted due to the midges of the genus Culicoide. Their host includes the bats, primates, hippopotamus, and as well squirrels. Hepatocystis belonging to the Domain Eukaryota, Kingdom Alveolata, Phylum Apicomplexa, Class Aconoidosida, Order Haemospororida, Family Plasmodidae, Genus Hepatocystis. Presently, there exists about 25 recognized species that are of this genus. Certainly, an infection with Hepatocystis may not elicite fever, but it can instigate anaemia in the host (Tung et al., 2009; Jones et al., 2019). Microscopically, the exclusive stage detected in the blood are gametocytes. The microgamete stained less densely, is biscuit coloured and measures 9.5 micrometres in diameter. The nucleus is found as the big oval pale pink area situated on the third to one half portion of the parasite (Schaer et al., 2017). Insect vectors are responsible for transmitting this protozoa through the bite. The sporozoites shuttle from the liver (where merocysts are made) within the confine of the parenchyma tissue. They may also develop within the lungs and spleens. Macroscopically, they may occur as white or gray nodular focus (within the confine of the tissue). Leading to the formation of well-circumscribed focal fibrosis, hemosiderosis (hemorrhage), histiocytes and eosinophils gathering, and the lost if normal structure (Tung et al., 2009; Ejotre et al., 2021). The cysts-like exoerythrocytic schizoants exist within the

confine of the merocysts. They are detected (found) in large number in the edges of the merocystes. The principal central core in the cyst compose of (non) granular material. The divulged merozoites are left with the option to invade erythrocytes or hepatocytes, where they transform into rings, and to the trophozoites, and resultantly into gametocytes. Gametocytes are described as large, due to their ability to fill the entire space of the erythrocyte. They have nuclei that are Feulge negative, and haemozoin may be traced (Atama et al., 2019). The infected erythrocytic cells are consumed by the insects through the feeding mode on the host, therewith, within the insect sporogonic cycle exits between five-to-six days. Near the eye and brain, the oocysts become developed (in the haemocoele specifically) (Tung et al., 2009; Ejotre et al., 2021). The mature merocysts are visible to the naked eye on the hepatic surface. These appear as raised, grayish-white to translucent foci with a central accumulation of fluid. Multiple, depressed areas of fibrosis with calcification representing healed lesions may also be found (Tung et al., 2009; Ejotre et al., 2021). Microscopically, the liver cysts contain an irregular core space occupied by faintly eosinophilic (acellular), flocculent material. In the surrounding there exist a peripheral rim of round, huge, and lightly basophilic merozoites measuring about ~1.0–2.0 mm (in diameter). The cysts are distinguished using the thin, acellular, convoluted, hyaline capsule. Significantly, an inflammatory response upon the merocysts may be experienced or may not be present. The presence of the reaction indicates, it is granulomatous with combination of lymphocytes and eosinophils (Tung et al., 2009; Ejotre et al., 2021). The initial display in the blood is noticed two months after infection, but the stage noticed in the blood are gametocytes (They doubled in number in the initial three days and become matured). After reaching maturity, they tend to decline in number and therewith disappear after a month. Some secondary events may take place at variable intervals. The early gametocytes are in possessing of tiny dense spots of chromatin with a tiny loop of cytoplasm. “As the parasite grows, the chromatin tends to spread in a semicircle or into multiple dots. There is no stippling of the erythrocyte” (Olival et al., 2007; Schaer et al., 2017; Ejotre et al., 2021). “Mature gametocytes are larger than a normal erythrocyte stain poorly compared to other protozoa. In both male and female gametocytes, the nucleus consists of two portions. The macrogametocyte is a steel blue color measuring 9.5 micrometres in diameter. The nucleus has a pale pink area with dense chromatin in the middle and is much smaller than that of the microgametocyte. The microgametocyte stains less densely, is biscuit-colored and measures 9.0 micrometres in diameter. The nucleus is a large, oval, pale pink area occupying one-third to one-half of the parasite” (Olival et al., 2007; Schaer et al., 2017; Ejotre et al., 2021).

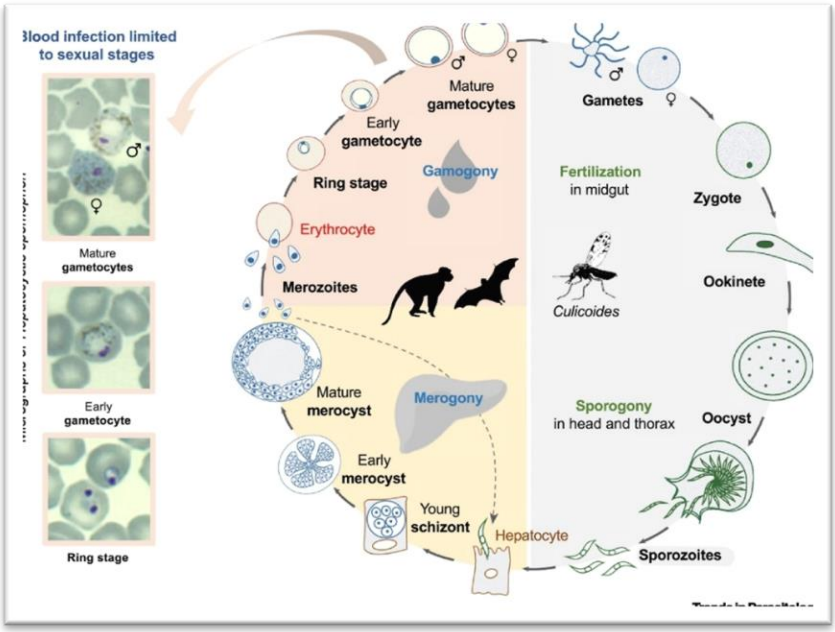


Figure 1: Life cycle of Hepatocystis species; Source: Ejotre et al., (2021)

5. Ascaridia species

It is a known parasitic roundworm belonging to Kingdom Animali, Phylum Nematoda, Class Chromadorea, Order Ascaridida, Family Ascaridiidae, and Genus Ascaridia (Schaer et al., 2017). It causes ascaridiasis in animals with symptoms such as anorexia, diarrhea, stunted growth, listleness, change in behaviour and enteritis. Heavy infection can cause a partial or total obstruction of the gastrointestinal tract (Schaer et al., 2017). Nevertheless, small intestine are the locations of the adult worms, therewith, a female can be able to make about 200,000 eggs (per day), which are divulged through the faeces. Ingestion of unfertilized portions of the divulged eggs may not cause infection. After spending 18 days or several weeks, the larvae transform to infectivity (while in the fertile eggs); therewith, transformation is dependent on favorable environment (Schaer et al., 2017). After infective eggs are swallowed, the larvae hatch, invade the intestinal mucosa, and are carried through the vital portal vein. In turn into the systemic circulation, and subsequently reaching the lungs. The transformation into mature form by the larvae (in the lungs) occur in 10 to 14 days; thereby infusing into the alveolar walls, passing to the bronchial tree, to the throat, and be swallowed). After dwelling the small intestine, they become adult worms. There is need for two or three months for the ingestion to reach the infective eggs, and to oviposition (by the adult female). Noteworthy, adult worms can stay for about one or two years (Schaer et al., 2017).

6. Eimeria species

Eimeria belongs to the genus known as "Apicomplexan" that encompasses several species that are of the potential to instigate coccidiosis in domestic animals like dogs, poultry, and cattle. Others affected include, cat, sheep, goat (Schaer et al., 2017; Miles et al., 2019). Eimeria is from the Phylum "Apicomplexa," Class" Conoidosida," and the Order is "Eucoccidiorida." The Family of Eimeria is "Eimeriidae," and the Genus is " Eimeria." Eimeria species ability to finish (complete) life cycle within a single host. They are stenoxenous for being host-specific (despite some often exceptions). Species in this genus infect a variety of hosts populations. About 31 species affect (occur in) bats, 2 are detected in turtles, and certainly 130 are detected in fishes 2 species infect seals, 5 species are able to infect Ilamas and alpaces E. alpacae, E. ivitaensis, E. lamae, E. macusaniensis, and E. punonensis. A number of species infect rodents, including E. couesii, E. kinsellai, E. palustris, E. ojastii and E. oryzomysi (Fayner, 1980; Barbosa et al., 2023). Eimeria is a genus of Apicomplexan parasites that includes various species capable of causing the disease coccidiosis in animals such as cattle, poultry, dogs (especially puppies), cats (especially kittens), and smaller ruminants including sheep and goats (Schaer et al., 2017; Miles et al., 2019). Eimeria belongs to the Phylum Apicomplexa, Class Conoidosida, Order Eucoccidiorida, Family Eimeriidae, and Genus Eimeria. Eimeria species are considered to be monoxenous because the life cycle is completed within a single host, and stenoxenous because they tend to be host specific, although, a number of exceptions have been identified. Species of this genus infect a wide variety of hosts. Thirty-one species are known to occur in bats (Chiroptera), two in turtles, and 130 named species infect fish. Two species (E. phocae and E. weddelli) infect seals. Five species infect llamas and alpacas: E. alpacae, E. ivitaensis, E. lamae, E. macusaniensis, and E. punonensis. A number of species infect rodents, including E. couesii, E. kinsellai, E. palustris, E. ojastii and E. oryzomysi (Fayner, 1980; Barbosa et al., 2023). However, the microbe follows a direct life cycle where, an infected host sheds unsporulated oocysts in their feces. Oocysts sporulate in the environment becoming infectious and if ingested by a new host can cause intestinal coccidiosis. In the gastrointestinal tract, sporozoites are divlged from the oocyst and invade intestinal epithelial cells to form trophozoites, and eventually undergo several cycles of asexual multiplication (merogony, schizogony). Merozoites released from asexual stages within the host cell will infect new enterocytes to form the female sexual stage, a macrogamete, or a male sexual stage, a microgamete, which unite to form oocysts (Merck, 2016; De Santana Miglionico et al., 2020). Diarrhea and decreased growth are the main clinical signs of coccidiosis and typically occur in young, infected animals. In severe cases, dysentery, dehydration, and tenesmus can occur. Some infections are asymptomatic and self-limiting (Merck, 2016). Destruction of infected intestinal cells and surrounding tissue can result in necrosis, hemorrhage, and inflammation. Diagnosis can be made via oocyst identification in feces using sugar flotation methods (or salt flotation methods), direct

intestinal smears, or a McMaster counting chamber, histopathology, and PCR (Gardiner et al., 1998; Barbosa et al., 2023). Wildlife population impacts have been recognized for long, because, while mortality can occur in severely infected animals, infections are usually self-limiting. Coccidia observed in this case were an incidental finding (De Santana Miglionico et al., 2020). The life cycle of Eimeria species primarily occurs within the intestines of bats. The infectious stages of Eimeria are oocysts, which are dispensed in an unsporulated state. These oocysts develop outside the host's body, forming four sporocysts that each contain two sporozoites. When a suitable host ingests these sporulated oocysts, the sporozoites penetrate the intestinal cells and initiate their life cycle within a parasitophorous vacuole (Mehlhorn, 2015).

7. Cryptosporidium species

Cryptosporidium is described as a microscopic parasite that is responsible for triggering cryptosporidiosis, and diarrhea. The disease cause by this parasite, and the entire parasite are called as " Crypto" (CDC, 2019). Cryptosporidium is described as a zoonotic parasite (able of instigating) gastrointestinal problem officially regarded as cryptosporidiosis. The parasite has the potential of infecting livestock and humans, spurring diarrhea and is basically a major health problem affecting children (under the age of five) and as well affect people with compromised immunity. The disease has limited treatment options, and as well often goes undiagnosed. This has led to diarrhea-bases morbidities and mortalities in various parts of the world (CDC, 2019). It emanates from the famous Kingdom Potozoan, Phylum Apicomplexa, and as well the Class is Conoidosida, Order Eucoccidiorida, Family Cryptosporididae, and Genus Cryptosporidium (Tyzer, 1912; Silva-Ramos et al., 2023). Bats are regarded as players in the transmission of Cryptosporidium species that cause gastrointestinal disease in humans. The prevalence of zoonotic infections of Cryptosporidium was only studied in about only 3% of bats that exist. It was reported from Brazil, China, Japan, Costa Rica, Nigeria, and relations. About 2.1 % to 16.3% of prevalence was reported as shown in Table 1. Indeed, C. hominis, and C. parvum act as potential parasites of public health significance because they cause gastrointestinal disease. Evidence show that, this is achieved through bats as contributor or vectors or reservoirs (Silva-Ramos et al., 2023).

Table 1:Prevalence of Some Species Cryptosporidium of bats across Some Parts of the World

Species	Country	Prevalence
C. hominis	Australia	0.7%
C. parvaum	USA	50.0%
	Czech Republic	9.1%

(Barbosa et al., 2023)

The lifecycle of Cryptosporidium (Figure 2.1) can be described in 6 stages as follows:

- Encystation, where infective sporozoites are divulged
- Merogony, an asexual multiplication undergone in cells of host organism
- Gametogony involving the making of macrogametes and microgametes
- Fertilization consisting of fusion of two micro and macro gametes
- Synthesis of oocyst wall, so that resistance is conferred
- Sporogony involving the synthesis of infective sporozoites inside the oocyst wall (Bamaiyi and Redhuan, 2016; CDC, 2019).

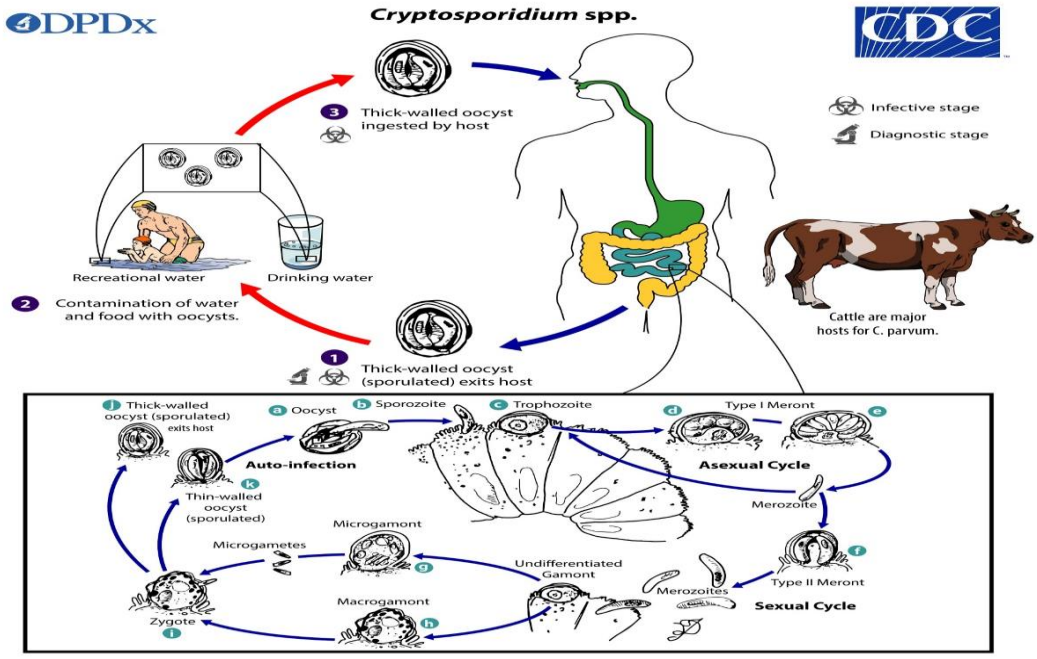


Figure 2:Cryptosporidium species (CDC, 2019)

8.Conclusion

This mini review has demonstrated that bats harbour a rich diversity of parasitic fauna comprising gastrointestinal parasites (Entamoeba, Hymenolepis, Isospora, Oxyurid, Strongyle, Strongyloides, Eimeria, Capillarid, Ascarid, Lecithodendrium, Castoria), haemo-parasites (Hepatocystis, Plasmodium, Trypanosoma, Polychromophilus), protozoan zoonoses (Cryptosporidium hominis, C. parvum with 0.7-50% global prevalence) and ectoparasites (Penicillidia conspicua, Nycteribia schmidlii, Spinturnix americana, Carpoglyphus spp., Ancystropus zeleborii, Cimicidae, Ixodes, Leptotrombidium, Macronyssus). Penicillidia conspicua exemplifies high host specificity to Miniopterus schreibersii with unique pseudo-placental unilarviparity, while Hepatocystis shows exoerythrocytic merocysts in liver parenchyma and gametocytes in blood. Eimeria xhibits monoxenous, stenoxenous life cycles with 31 species in bats, and Cryptosporidium follows a six-stage life cycle (excystation, merogony, gametogony, fertilization, oocyst wall synthesis, sporogony) with both thick-walled and thin-walled oocysts. Epidemiological evidence from Nepal, Iran, Ghana and Nigeria indicates prevalence rates of 25-48% for haemoparasites and helminths, with insectivorous bats more threatened. Ectoparasites play dual roles as parasites and vectors transmitting Borrelia, Rickettsia, Ehrlichia, Bartonella and Trypanosoma, highlighting zoonotic risk. Bats' role as reservoirs for emerging diseases necessitates integrated surveillance under One Health framework, balancing conservation (bats provide vital ecosystem services) with public health protection. Future studies should focus on molecular characterization, vector competence of bat flies, and long-term monitoring of parasite dynamics in diverse roosting habitats in Nigeria and across Africa.

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