ECTO- AND ENDO-PARASITES INFECTING THE BROOKE'S HOUSE GECKO *HEMIDACTYLUS BROOKII* (SAURIA: GEKKONIDAE) IN GHANA

[1]*Bethel Kwansa-Bentum, [2]Henrietta Terko Kwansa-Bentum, [1]Emmanuel Okorie Baah, [3]Joseph Otchere and [1]Fred Aboagye-Antwi

[1] *Department of Animal Biology and Conservation Science, School of Biological Sciences, College of Basic and Applied Sciences, University of Ghana*

[2] *Immunology Department, Noguchi Memorial Institute for Medical Research, College of Health Sciences, University of Ghana*

[3] *Parasitology Department, Noguchi Memorial Institute for Medical Research, College of Health Sciences, University of Ghana*

***Corresponding author**: Bethel Kwansa-Bentum; email: bkwansa-bentum@ug.edu.gh

Abstract

Introduction: *Wall geckos are known carriers of parasites. Limited information exists on the parasites that affect wall geckos in Ghana. This study investigated the incidence of ectoparasites and endoparasites in Brooke's house gecko on University of Ghana campus.* ***Methodology***: *Hemidactylus brookii were caught from Legon Botanical Gardens, Department buildings and Residential halls of University of Ghana. Parasites were stained, fixed and examined under a compound light microscope. Pictures taken with Leica EZ microscope. Morphological identification was done using appropriate identification keys.* ***Findings***: *Out of 136 H. brookii examined, 128 (92%) were infested with Geckobia leonilae and G. bataviensis. Endoparasites included Paradistomum sp., Oochoristica sp., Raillietiella sp. and Pharyngodon sp. All parasites were observed in only adult geckos. Parasite prevalence was not significantly different among the study areas, or sex of wall gecko.* ***Conclusions***: *Adult wall geckos are hosts to mites, trematodes and nematodes.*

Keywords

Hemidactylus brookii, Geckobia mites, pentastomid worms, nematodes, trematodes, Ghana

Introduction

Wall geckos are common household reptiles of the family Gekkonidae. They occur in the warmer regions of Asia, Africa, the Pacific, Mediterranean Europe and northern South America (Weterings and Vetter, 2017). In these tropical and sub-tropical parts of the world, wall geckos have a variety of habitats that include rocky deserts, mountains, jungles, rainforests and grasslands. These reptiles have also become attached to human dwellings to the extent that they are found in houses (Weterings and Vetter, 2017). Some wall gecko species such as *Hemidactylus brookii* and *H. mabouia* have been introduced into the New World tropics through human activities such as trading and transportation (Levins and Heatwole, 1963). Wall geckos have elongated body with feet covered with adhesive toepads. This adhesive apparatus is due to the presence of setae, a microscopic hair-like outgrowths of the superficial layer of the sub-digital epidermis (Autumn et al., 2006). Wall geckos are well known for their extraordinary clinging abilities as they easily scale vertical surfaces as smooth as glass, or even inverted surfaces (Gamble et al., 2012; Green, 1981; Irschick et al., 1996) as a result of these outgrowths. They are mostly nocturnal organisms, and are carnivores preying on insects such as ants, termites and beetles. Wall geckos on the other hand are chiefly preyed upon by snakes, but other animals such as large spiders, birds and some mammals also prey upon them (Weterings and Vetter, 2017).

Studies show that geckos are also known to host parasites that are of zoonotic importance such as *Salmonella typhi*, which causes typhoid fever (Whiley et al., 2017). Both *H. brookii* and *H. mabouia* harbour a wide range of parasites that include platyhelminthes, pentastomids, acanthocephalans,and acarines (Ali et al., 1985; Lainson and Paperna, 1999; Martinez-Rivera et al., 2003; Simonsen and Sarda, 1985). Obi et al. (2013) also identified species of tapeworms and ectoparasites such as ticks and mites in *H. frenatus* in Nigeria. Geckos also host a wide variety of gastrointestinal nematodes, which may be acquired through ingestion of an infected prey or integument penetration (Criscione and Font, 2001; Fontes et al., 2003; Goldberg and Bursey, 1992; Ribas et al., 1995; Sanchis et al., 2000). The level of infection has been attributed to habitat (Goldberg and Bursey, 1992), materials ingested (J., 1986; Kennedy et al., 1987), or age of individual lizards (Bundy et al., 1987; Pfaffenberger et al., 1986; Ribas et al., 1995; Vogel and Bundy, 1987).

Some parasites of wall geckos have zoonotic implications on the health of human and domestic animals (Ameh and Ajayi, 2005), and may transmit pathogens in their faecal matter to humans through contamination. There is a dearth of knowledge on infection by the pentastomid *Raillietiella* on geckos in Ghana even though the African pentastomids *Raillietiella frenatus* and *R. teagueselfi* were reported in the lungs of the exotic gecko Hemidactylus turcicus in Texas and Florida (USA) (Pence and Selcer, 1988; Riley et al., 1988, 1991). There is therefore the need to identify some of these parasites in wall geckos found in Ghana. The focus of the study reported in this paper was to identify ectoparasites and endoparasites that affect the wall gecko, *H. brookii* in Ghana.

Materials and Methods

Study sites

The wall geckos were collected from the University of Ghana main campus in Legon, Accra, Ghana. The area lies about 13 km northeast of the centre of Accra located at 05°39'03" North, 00°11'13" West, and has an elevation of about 97 m above sea level. The University has an estimated population of 29,750 people. Some of the wall geckos were collected from the Legon Botanical Gardens, which is home to an array of varying wildlife. It features uncompleted and abandoned buildings, with greatly reduced human activity. Others were collected from some departments on campus, which represent areas of high human activity during the day, but greatly reduced at night. The remaining wall geckos were collected from residential halls, representing areas that have relatively high human activity all day and night.

Collection of wall geckos

The wall geckos were collected from January to February 2015, between 19.00 – 22.00 hours from the walls of buildings in the study sites mentioned above. Opportunistic methods such as swatting them down from walls with a long broom were used. They were placed in an aerated plastic container using a pair of tongs. The geckos were euthanized with chloroform, identified and assigned to the different species and categories based on snout to vent length as adult, sub-adult and juvenile. Adult length ranges from 50.0 – 63.6 mm (Brown and Alcala, 1978). Sub-adult length ranges from 40 – 49.9 mm and juvenile length < 40 mm (Martinez-Rivera et al., 2003).

Collection and examination of ectoparasites

All collected *H. brookii* were sprayed with 70% ethanol to loosen the grip of ectoparasites on the skin and then gently stroked to get them off the skin with a pair of forceps into Petri dishes. The parasites were stored in sample tubes containing 70% alcohol and appropriately labelled with the site from where geckos were captured. Ectoparasites were mounted on a glass slide and morphologically identified under a compound light microscope using identification keys of Bertrand et al. (2012).

Collection and examination of endoparasites

All the 136 wall geckos were caught were euthanized, pinned onto dissecting boards and their body cavities opened by making mid-ventral longitudinal incisions from their throats to the vents. The gastrointestinal tract was removed by cutting across the oesophagus and rectum. The gut, lungs, gallbladder and the caecum of each gecko were excised into labelled Petri dishes. These were washed with 0.9% saline and examined separately for parasites under the compound light microscope. Isolated parasites were placed in glycerol and allowed to clear.

Staining and fixing of endoparasite groups (trematodes, cestodes, nematodes and pentastomes)

Trematodes collected from the gall bladder were placed in 2% chloral hydrate, and then fixed in alcohol-formalin-acetic acid (AFA) until they were opaque. This was done by transferring parasites onto a slide and gently pressing them with another slide to flood them in the fixative for 10 minutes. The parasites were washed gently with distilled water and stained with Gower's carmine for 30 minutes. The trematodes were then passed through a series of increasing concentrations (30%, 50%, 70%, 80%, 95% and 100%) of AFA. Trematodes were cleared in lactophenol for 10 minutes and then permanently fixed on a slide with Canada balsam.

Cestodes were pre-processed for permanent staining by placing them in cold distilled water and slightly pressing them between two glass slides. The cestode worms were subsequently fixed in AFA for 24 hours and transferred into 70% alcohol for another 24 hours. These specimens were stained with hematoxylin for 5 minutes. The preliminary processed cestodes, nematodes and pentastomes were dehydrated through increasing concentrations (10%, 30%, 50%, 70% and 90%) of alcohol. The cestodes were cleared in xylene, while the nematodes and pentastomes were cleared with lactophenol. Further staining of cestodes with eosin dye was carried out, following which permanent staining of both cestodes and pentastomes was done. Nematodes were temporarily mounted on a glass slide using glycerol.

Identification of parasites

Stained or fixed parasites were examined under a light microscope, and endoparasites identified using identification keys (Gerald, 1970; Schell, 1970). Images and measurements were taken with Leica EZ microscope application suite.

Data analyses

Differences in gecko numbers per site of collection as well as the numbers of parasites they harboured were assessed using the Kruskal-Wallis test. Student's T test was used to test for significant difference in parasite counts between male and female geckos. One-way ANOVA was also used to test for statistical significance in parasite counts among the sampling sites, with p value set at 0.05.

Results

Distribution of wall geckos

A total of 136 wall geckos, all of which were *H. brookii* were caught. Twelve (9%) were juveniles and 124 (91%) adults of which 65 (48%) were males and 59 (43%) females (Figure 1). In terms of location, 50 (36.8%) *H. brookii* were caught from the residential halls, 75 (55.1%) from the departments, and 11 (8.1%) from the botanical garden (Table 1). *Hemidactylus brookii* has a concave forehead, and a pointed snout which is longer than the distance between the eye and the ear-opening. It has a grey brown colour on its dorsal part with darker spots, which are generally large and quadrangular, forming longitudinal and transverse series (or a ladder-like pattern) on the dorsal region. A dark streak on the side of the head passes through the eye.

Figure 1. Morphometric comparison of adult, sub-adult and juvenile *Hemidactylus brookii*

Distribution of ectoparasites

Ectoparasites were found primarily on the areas around the eye shield and anywhere from the rostrum to the tail. All the ectoparasites were mites of the genus *Geckobia*. Two species were identified; 1,392 (78.3%) were *G. leonilae* and 386 (21.7%) *G. bataviensis. Geckobia bataviensis* has a round posterior region, with a longer posterior scutum than the dorsal scutum. The ventral setae are similar to or shorter than the dorsal setae. The palp is long and slender in the first segment. All four pairs of legs are relatively of the same length, with short and stiff spur in the coxa. Mites were present on both the dorsal and ventral surfaces of the same geckos. Mites on the ventral surface were larger than those at the dorsum and were attached beneath the scales. Difference between the numbers of mites collected from the ventral and dorsal surfaces of wall geckos were statistically significant ($p < 0.05$). *Geckobia bataviensis* were smaller in size, ranging from 0.39 – 0.43 mm (Figure 2), with *G. leonilae* which is relatively larger in size, ranging from 0.45 – 0.62 mm. *Geckobia* mites were present only in adult and sub-adult *H. brookii*. Adult mites were particularly abundant in body parts that come in contact with the ground. No significant difference was observed between any of the ectoparasites counted and the study areas where geckos were caught ($p = 0.79$ for *G. leonilae*; $p = 0.05$ for *G. bataviensis*). None of the mite infestations was significantly different between the sexes of wall geckos.

Identification and morphometry of endoparasites

Endoparasites were found in the lungs, gallbladder, intestines and caecum. Platyhelminthes identified included Oochoristica

Figure 2. Dorsal view of Geckobia bataviensis

species (Cestoda: Linstowiidae) that were isolated from the lumen of the small intestine of *H. brookii*. Their length ranged from 29 – 32 mm (Figure 3). This delicate, whitish and opaque worm has a simple scolex with four rounded cuticular suckers, and lacks a rostellum. The scolex is joined to a long narrow neck. The strobili is widest at the mid-region and tapers both ends. Immature, mature and gravid proglottids are wider than long. Terminal proglottids are slightly longer than wide. The prevalence of this trematode was not significantly different among the three study areas where geckos were collected from ($p = 0.59$).

Figure 3. Adult Oochoristica tapeworm (left) showing the head, scolex and suckers (right)

Other trematodes included *Paradistomum* species (Trematoda: Dicrocoeliidae) found in the gall bladder and bile duct of geckos and ranging in length from 2.66 – 2.74 mm, with a width range of 1.58 – 1.61 mm at the widest area (Figure 4). The prevalence of Paradistomum species was significantly different between the three study areas ($p = 0.009$). Endoparasites were absent in all juvenile wall geckos but present in adults and sub-adults that were examined in this study.
Detailed morphological descriptions of the Raillietiella species and Pharyngodon species are shown in Figures 5 and 6 respectively. The female pentastomid worm has a fusiform or cigar-shaped body that is flattened ventrally (5a). The anus is terminal and the caudal segment is bifurcated (5b).

Table 1. Distribution and abundance of Hemidactylus brookii harbouring ectoparasites and/ or endoparasites

Site of gecko collection	Age/ sex	No. caught	No. of wall geckos harbouring				
			Ectoparasites	Endoparasites			
			Geckobia spp	Oochoristica spp	Pharyngodon spp	Paradistomum spp	Raillietiella spp
	Male	23	12	21	12	14	18
Residential	Female	21	9	19	10	11	12
	Juvenile	6	0	0	0	0	0
	Male	38	19	26	11	9	23
Department	Female	31	15	22	14	4	14
	Juvenile	6	0	0	0	0	0
	Male	4	3	1	1	2	0
Botanical garden	Female	7	5	5	2	6	3
	Juvenile	0	0	0	0	0	0
Total		136	63	94	50	46	70

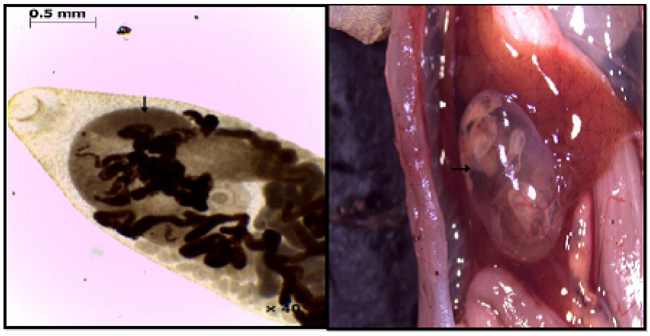

Figure 4. Adult Paradistomum trematode (left) inside the gall bladder of a dissected gecko (right). Arrow indicates inflated intestinal caeca

The anterior hook pair are sharp-tipped and contrast markedly with the posterior hooks which are about two and half times largerwith bluntly rounded tips (5c). The posterior hooks of the male is less blunt than those of the female and are twice as big as the sharp tipped anterior part (5d).

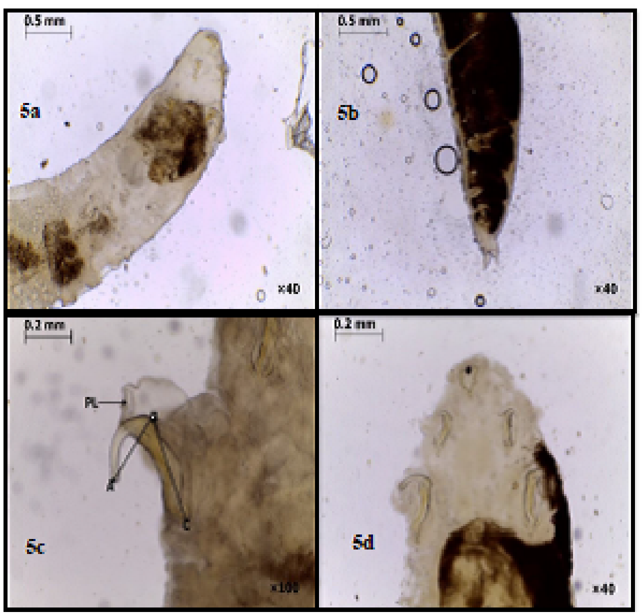

Figure 5. Morphology of the Raillietiella pentastomid worm

Raillietiella species (Pentastomida: Cephalobaenidae) were found in the lungs of *H. brookii*. The length of females ranged from 7.7 – 8.8 mm with males ranging from 4.5 – 6.4 mm. The prevalence of *Raillietiella* species was not significantly different among the three study areas where geckos were collected for the study ($p = 0.19$). Nematodes identified included *Pharyngodon* species (Nematoda: Oxyuridae) that were found in the lower gut (caecum) of the geckos. Length of male pinworms ranged from 1.82 – 2.44 mm, with females ranging from 4.10 – 6.02 mm. The male worm is smaller, and the mid-region gradually tapers towards the anterior and posterior ends. The anterior extremity is bluntly pointed, whereas the tail is constricted at the level of the cloaca and continues dorsally into a conical caudal appendage. Female worms are larger than male worms, cylindrical and tapers at both ends. The prevalence of this nematode was not significantly different among the three study areas where geckos were collected for the study ($p = 0.35$). None of the endoparasite infections was significantly different between the sexes of wall geckos.

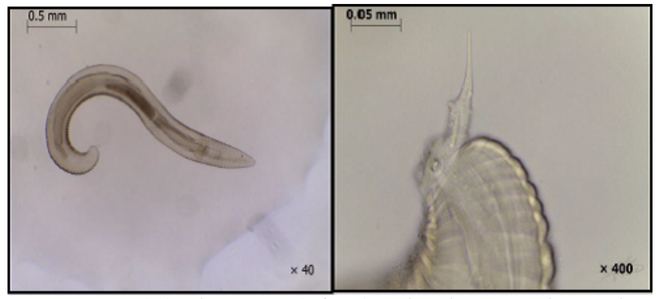

Figure 6. Adult pinworm (left) showing its posterior region (right).

Discussion

The main goal of this study was to characterise parasites of *H. brookii* on the University of Ghana main campus. Based on morphological characteristics, all observed mites were classified as Pterygosomatidae according to Krantz (1978). Further, genus level characteristics of the mites showed the presence of dorsal scutum, gnathosoma, coxa with rigid setae (spur) distributed on the body, giving credence to their characterisation as *Geckobia*. According to Lawrence (1936), these characteristics are unique to members of the genus *Geckobia*. Moreover, fused coxae 1 and 2 (anterior coxae), and fused coxae 3 and 4 (posterior coxae), variation setae at tarsus and distinct body size also affirmed their status as *Geckobia* species (Soleha, 2006).

Mites of the genus *Geckobia* have previously been identified in other geckos and lizards (Bauer et al., 1990). In their list of *Geckobia* mites that infest geckos, Bertrand et al. (1999) observed that *Cosymbotus platyurus* gecko was infested with *G. clelandi, G. cosymboty* and *G. glebosum; H. frenatus* gecko was infested with *G. andoharonomaitsoensis, G. bataviensis, G. nepali, G. cosymboty, G. ifanadianaensis, G. philippinensis, G. himalayensis* and *G. samanbavijinensis*. An earlier study on *C. platyurus, H. frenatus* and *H. garnotii* geckos in Bogor (Indonesia), also indicated that these geckos were infested by *Geckobia* mites (Hanley et al., 1998). In this present study, more *G. leonilae* were collected from the wall geckos. Perhaps these mites have a higher fecundity rate than *G. bataviensis*. The relatively larger size of *G. leonilae* may have enabled them to out-compete *G. bataviensis* for space on their common host (Persson, 1985). Transmission of mites from one gecko to another may thus be through communal nesting and fighting. Mites have no adaptation for climbing or clinging to passing hosts so it is unlikely that geckos acquire mites from substrates (Kearney et al., 2001). It has been observed that juvenile geckos seldom forage or rest in the same areas as adults do since they risk physical aggression and possible cannibalism (Aho, 1990; Floyd and Jenssen, 1983). This might have contributed to the absence of mites on juvenile geckos.

In their study, Anjos et al. (2008) observed no parasite in juvenile geckos, which is similar to the findings of this present study. This may be as a result of older geckos having had a longer time of exposure and contact with infection sources Cunha-Barros et al. (2003); Vogel and Bundy (1987). It has been reported that adult and sub-adult geckos occupy niches where they come into contact with parasites and their vectors (Obi et al., 2013). The juvenile geckos were probably outcompeted by adults to suboptimal areas with limited contact with the parasites and their agents. On the other hand, longer exposure to infections may have influenced adult geckos in harbouring more parasites, presenting a great difference in prevalence and intensity between them and the juvenile geckos (Barden and Shine, 1994). Lizards can become infected by nematodes, cestodes, trematodes etc., via ingestion of arthropods infected with larvae of these parasites (Goldberg and Bursey, 1992; Ribas et al., 1995). Juvenile geckos, however, are too small to prey on matured arthropods that may carry these parasites, leaving matured arthropod prey for adult and sub-adult wall geckos. Juvenile geckos feed on immature arthropods that are unlikely to carry parasites that may eventually infect the geckos. This could probably account for why there were no endoparasites recorded in juvenile geckos in this study. It has been observed that parasite infection intensity increases with age and size and that there is a positive correlation between intensity of parasites and snout-vent length. Larger body size of host supports a larger number of parasites and tolerates the nutritional drain from a given number of parasites (Riley et al., 1988).

Even though the number of wall geckos collected from the three different study sites varied greatly, the presence of parasites on/in the geckos was not statistically significant. This suggests that human activities which was assumed during the selection of study sites may not be a factor for the presence of parasites in wall geckos. Wall geckos are nocturnal and forage for arthropods at night due to the presence of light. Like the botanical garden, the departments experience minimal human activities during the night. However the presence of light at the departments attract insects, and eventually having more wall geckos foraging in the departments. Studies show that the diets of males and females of some species of lizard differ qualitatively and quantitatively (Riley, 1998), and that these do influence prevalence and intensity of helminths between the sexes (Ribas et al., 1995). Bundy et al. (1987) in their study observed that among the *Anolis* species of lizards, those that are active foragers appear to have more helminth infection. Likewise, active foragers such as *C. ocellifer* show a high intensity of nematode infection (Ribas et al., 1995). Other activities such as basking or mating behaviours in lizards serve as opportunities for infection by egg ingestion or larvae penetration (Ribas et al., 1995). In our study, difference in infection prevalence and intensity between sexes of *H. brookii* was not statistically significant even though males are more active foragers than females.

The diet composition of the gecko could also influence infection parameters (Anjos et al., 2008; Rocha and Anjos, 2007). The diet of *H. mabouia* juveniles usually includes only ants and termites, but the stomachs of adult geckos consist of all kinds of arthropods, including larger ones such as spiders, cockroaches and moths (Vitt, 1995). Other authors suggest that host specificity of parasites is ecological rather than physiological (Rocha and Anjos, 2007); therefore, differences in endoparasitic fauna composition among geckos is likely to depend on where they inhabit rather than the type of prey the geckos feed on. Differences in infection prevalence was not significantly different between the study areas where wall geckos were collected from. This could probably be due to closeness in proximity between the sites, as they are on the same campus. These intermediate hosts may be adapted to specific habitats making the parasites they harbour specific to those habitats. The prevalence of a particular parasite in the gecko could thus mean that the gecko had fed on a respective insect from a particular habitat. Although the complete life cycles of many species of *Raillietiella* are yet to be determined, insects are probably the intermediate hosts in the life cycles of all lizard pentastomes (Ali and Riley, 1983; Jeffery et al., 1985). The *Raillietiella* species were identified based on morphometrics, annulus count and length, and shape of posterior hooks (Ali et al., 1981). The *Pharyngodon* species were identified based on the characteristics described by Bursey et al. (1994). Whereas the genus *Raillietiella* which was found in this study are not known to cause human disease, some pentastomid species have, on rare occasions caused human disease (Tappe and Büttner, 2009; Tappe et al., 2013).

Conclusion

Wall geckos, particularly adults are hosts to mites, trematodes and nematodes. Mites encountered were *Geckobia* species. Trematodes identified include the pentastomid *Raillietiella* species. Harbouring of parasites was not significantly different between study areas. Neither was harbouring of parasites significantly different between sexes of the wall geckos.

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References

Aho, J. M. (1990). Helminth communities of amphibians and reptiles: comparative approaches to understanding patterns and processes. In *Parasite communities: patterns and processes*, pages 157–195. Springer.

Ali, J. H. and Riley, J. (1983). Experimental life-cycle studies of Raillietiella gehyrae Bovien, 1927 and Raillietiella frenatus Ali, Riley and Self, 1981: pentastomid parasites of geckos utilizing insects as intermediate hosts. *Parasitology*, 86(1):147–160.

Ali, J. H., Riley, J., and Self, J. T. (1981). A revision of the taxonomy of the blunt-hooked Raillietiella, pentastomid parasites of African, South-East-Asian and Indonesian lizards, with a description of a new species. *Systematic Parasitology*, 3(4):193–207.

Ali, J. H., Riley, J., and Self, J. T. (1985). A review of the taxonomy and systematics of the pentastomid genus Raillietiella Sambon, 1910 with a description of a new species. *Systematic Parasitology*, 7(2):111–123.

Ameh, I. and Ajayi, J. (2005). Morphology and significance of some helminth parasites of the wall gecko. *Jour. Biol Sci.*, 5:141–144.

Anjos, L. A., Almeida, W. O., Vasconcellos, A., Freire, E. M. X., and Rocha, C. F. D. (2008). Pentastomids infecting an invader lizard, Hemidactylus mabouia (Gekkonidae) in northeastern Brazil. *Brazilian Journal of Biology*, 68(3):611–615.

Autumn, K., Dittmore, A., Santos, D., Spenko, M., and Cutkosky, M. (2006). Frictional adhesion: a new angle on gecko attachment. *Journal of Experimental Biology*, 209(18):3569–3579.

Barden, G. and Shine, R. (1994). Effects of sex and reproductive mode on dietary composition of the reproductively bimodal scincid lizard, Lerista bougainvillii. *Australian Zoologist*, 29(3-4):225–228.

Bauer, A. M., Russell, A. P., and Dollahon, N. R. (1990). Skin folds in the gekkonid lizard genus rhacodactylus: a natural test of the damage limitation hypothesis of mite pocket function. *Canadian Journal of Zoology*, 68(6):1196–1201.

Bertrand, M., Paperna, I., and Finkelman, S. (1999). Pterygosomatidae: descriptions et observations sur les genres Pterygosoma, Geckobia, Zonurobia et Hirstiella (Acari: Actinedida). *Acarologia*, 40(3):275–304.

Bertrand, M., Pfliegler, W. P., and Sciberras, A. (2012). Does the African native host explain the African origin of the parasite? The Maltese Geckobia estherae n. sp. parasitic on Tarentola mauritanica (Acari: Raphignathoidea: Pterygosomatidae). *Acarologia*, 52(4):353–366.

Brown, W. C. and Alcala, A. C. (1978). *Philippine lizards of the family Gekkonidae*. Number 1 in Silliman University Natural Science Monograph Series. Silliman University.

Bundy, D. A. P., Vogel, P., and Harris, E. A. (1987). Helminth parasites of Jamaican anoles (Reptilia: Iguanidae): a comparison of the helminth fauna of 6 Anolis species. *Journal of Helminthology*, 61(1):77–83.

Bursey, C. R., McAllister, C. T., Freed, P. S., and Freed, D. A. (1994). Oochoristica ubelakeri n. sp.(Cyclophyllidea: Linstowiidae) from the South African rock agama, Agama atra knobeli. *Transactions of the American Microscopical Society*, pages 400–405.

Criscione, C. D. and Font, W. F. (2001). The guest playing host: colonization of the introduced Mediterranean gecko, Hemidactylus turcicus, by helminth parasites in southeastern Louisiana. *Journal of Parasitology*, 87(6):1273–1278.

Cunha-Barros, M., Van Sluys, M., Vrcibradic, D., Galdino, C. A. B., Hatano, F. H., and Rocha, C. F. D. (2003). Patterns of infestation by chigger mites in four diurnal lizard species from a restinga habitat (Jurubatiba) of Southeastern Brazil. *Brazilian Journal of Biology*, 63(3):393–399.

Floyd, H. B. and Jenssen, T. A. (1983). Food habits of the jamaican lizard anolis opalinus: resource partitioning and seasonal effects examined. *Copeia*, pages 319–331.

Fontes, A. F., Vicente, J. J., Kiefer, M. C., and Van Sluys, M. (2003). Parasitism by helminths in Eurolophosaurus nanuzae (Lacertilia: Tropiduridae) in an area of rocky outcrops in Minas Gerais state, southeastern Brazil. *Journal of Herpetology*, pages 736–741.

Gamble, T., Greenbaum, E., Jackman, T. R., Russell, A. P., and Bauer, A. M. (2012). Repeated origin and loss of adhesive toepads in geckos. *PLoS One*, 7(6):e39429.

Gerald, D. (1970). How to know the tapeworm. *Dubuque, Iowa: W M. C. Brown Company Publishers*.

Goldberg, S. R. and Bursey, C. R. (1992). Prevalence of the nematode Spauligodon giganticus (Oxyurida: Pharyngodonidae) in neonatal Yarrow's spiny lizards, Sceloporus jarrovii (Sauria: Iguanidae). *The Journal of Parasitology*, pages 539–541.

Green, D. M. (1981). Adhesion and the toe-pads of treefrogs. *Copeia*, pages 790–796.

Hanley, K. A., Petren, K., and Case, T. J. (1998). An experimental investigation of the competitive displacement of a native gecko by an invading gecko: no role for parasites. *Oecologia*, 115(1-2):196–205.

Irschick, D. J., Austin, C. C., Petren, K., Fisher, R. N., Losos, J. B., and Ellers, O. (1996). A comparative analysis of clinging ability among pad-bearing lizards. *Biological journal of the Linnean Society*, 59(1):21–35.

J., R. ((1986)). The biology of pentastomids. *Adv Parasitol*, 25:45–128.

Jeffery, J., Krishnasamy, M., Oothuman, P., Ali, J. H., Bakar, E. A., and Singh, I. (1985). Preliminary observations on the cockroach intermediate host of a house gecko raillietiellid in peninsular Malaysia. *Malaysian Journal of Medical Sciences*, 2(2):82–84.

Kearney, M., Shine, R., Comber, S., and Pearson, D. (2001). Why do geckos group? An analysis of" social" aggregations in two species of Australian lizards. *Herpetologica*, pages 411–422.

Kennedy, M. J., Killick, L. M., and Beverley-Burton, M. (1987). The prevalence of Paradistomum geckonum, Mesocoelium sociale, and Postorchigenes ovatus (Digenea) in lizards (Sauria) from Indonesia. *Canadian Journal of Zoology*, 65(5):1292–1294.

Krantz, G. W. (1978). *A manual of Acarology.* Oregon, USA: Oregon State University Book Stores, 2nd edition.

Lainson, R. and Paperna, I. (1999). Re-descriptions of Isospora ameivae Carini, 1932 in the Teiid Lizard Ameiva ameiva and Isospora hemidactyli Carini, 1936 in the Gecko Hemidactylus mabouia, with Particular Reference to their Endogenous Stages. *Memórias do Instituto Oswaldo Cruz*, 94(4):459–466.

Lawrence, R. F. (1936). The prostigmatic mites of South African lizards. *Parasitology*, 28(1):1–39.

Levins, R. and Heatwole, H. (1963). On the distribution of organisms on islands. *Caribbean Journal of Science*, 3:173–177.

Martinez-Rivera, C. C., Negron, A. G., Bertrand, M., and Acosta, J. (2003). Hemidactylus mabouia (Sauria: Gekkonidae), host of Geckobia hemidactyli (Actinedida: Pterygosomatidae), throughout the Caribbean and South America. *Caribbean Journal of Science*, 39(3):321–326.

Obi, Z. C., Anyaegbunam, L. C., and Igboanugo, N. (2013). The house gecko (hemidactylus frenatus) and parasitaemia. *International Journal of Fauna and Biological Studies*, 1(2):13–15.

Pence, D. B. and Selcer, K. W. (1988). Effects of pentastome infection on reproduction in a southern Texas population of the Mediterranean gecko, Hemidactylus turcicus. *Copeia*, pages 565–572.

Persson, L. (1985). Asymmetrical competition: are larger animals competitively superior? *The American Naturalist*, 126(2):261–266.

Pfaffenberger, G. S., Best, T. L., and de Bruin, D. (1986). Helminths of collared lizards (Crotaphytus collaris) from the Pedro Armendariz lava field, New Mexico. *The Journal of Parasitology*, 72(5):803–806.

Ribas, S., Rocha, C., Teixeira-Filho, P., and Vicente, J. (1995). Helminths(Nematoda) of the lizard Cnemidophorus ocellifer(Sauria: Teiidae): Assessing the effect of rainfall, body size and sex in the nematode infection rates. *Ciencia e Cultura(Sao Paulo)*, 47(1):88–91.

Riley, J. (1998). A new blunt-hooked pentastomid belonging to the genus Raillietiella Sambon, 1910, from two species of agamid lizards in Namibia. *Systematic Parasitology*, 41(1):41–46.

Riley, J., McAllister, C. T., and Freed, P. S. (1988). Raillietiella teagueselfi n. sp.(Pentastomida: Cephalobaenida) from the Mediterranean gecko, Hemidactylus turcicus (Sauria: Gekkonidae), in Texas. *The Journal of Parasitology*, pages 481–486.

Riley, J., Powell, R., and Smith, D. D. (1991). Further observations of blunt-hooked pentastomids belonging to the genus Raillietiella Sambon, 1910 infecting Hemidactylus brookii (Sauria: Gekkonidae) in Africa and the Caribbean: comparison with closely related Raillietiella spp. from an African skink (Mabuya perrotetii). *Systematic Parasitology*, 20(1):47–57.

Rocha, C. F. D. and Anjos, L. A. (2007). Feeding ecology of a nocturnal invasive alien lizard species, Hemidactylus mabouia Moreau de Jonnès, 1818 (Gekkonidae), living in an outcrop rocky area in southeastern Brazil. *Brazilian Journal of Biology*, 67(3):485–491.

Sanchis, V., Roig, J. M., Carretero, M. A., Roca, V., and Llorente, G. A. (2000). Host-parasite relationships of Zootoca vivipara (Sauria: Lacertidae) in the Pyrenees (North Spain). *Folia Parasitologica*, 47(2):118–122.

Schell, S. C. (1970). How to know the trematodes. *Brown Comp. Pub. Dubuque Iowa*, pages 236–237.

Simonsen, P. E. and Sarda, R. K. (1985). Helminth and arthropod parasites of Hemidactylus mabouia from Tanzania. *Journal of Herpetology*, 19(3):428–430.

Soleha, I. (2006). Ectoparasite mites in Geckos in Borgor [thesis]. *Borgor Agricultural University, Borgor.*

Tappe, D. and Büttner, D. W. (2009). Diagnosis of human visceral pentastomiasis. *PLoS Neglected Tropical Diseases*, 3(2):320.

Tappe, D., Haeupler, A., Schäfer, H., Racz, P., Cramer, J. P., and Poppert, S. (2013). Armillifer armillatus pentastomiasis in African immigrant, Germany. *Emerging Infectious Diseases*, 19(3):507.

Vitt, L. J. (1995). *The ecology of tropical lizards in the Caatinga of northeast Brazil*. Number 1 in Occasional Papers. Oklahoma Museum of Natural History.

Vogel, P. and Bundy, D. A. P. (1987). Helminth parasites of Jamaican anoles (Reptilia: Iguanidae): variation in prevalence and intensity with host age and sex in a population of Anolis lineatopus. *Parasitology*, 94(2):399–404.

Weterings, R. and Vetter, K. C. (2017). Invasive house geckos (hemidactylus spp.): their current, potential and future distribution. *Current Zoology*, 64(5):559–573.

Whiley, H., Gardner, M. G., and Ross, K. (2017). A review of *Salmonella* and squamates (lizards, snakes and amphisbians): implications for public health. *Pathogens*, 6(3):38.