PREVALENCE OF ENDOPARASITIC HELMINTHS OF THE SMALL INDIAN MONGOOSE (*HERPESTES AUROPUNCTATUS*) ON THE ISLAND OF PUERTO RICO

by

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LIST OF ABBREVIATIONS

Abbreviation	Description
EtOH	Ethanol
Sp	Species singular
Spp	Species plural
SD	Standard Deviation
~	Approximately
ha	Hectare

ABSTRACT

The small Indian mongoose (*Herpestes auropunctatus;* hereafter mongoose) has been widely introduced to islands around the world as a biological control agent. Species targeted for control were various rodents and venomous snakes. Follow-up research has been conducted on the role of the mongoose as a potential reservoir of diseases that might affect man and economically important animals. However, most of previous studies have focused on detecting rabies and leptospirosis, with reports of endoparasitic helminths being largely incidental. From 22 May to 12 August, 2015 I trapped mongooses from several sites on Puerto Rico and conducted standard necropsy techniques to survey for endoparasitic helminths in the viscera. My examinations of gastrointestinal tracts yielded two species of nematodes and one acanthocephalan. *Skrjabinocapillaria caballeroi* was found infecting 65 percent of mongoose stomachs while *Physaloptera* spp. were recovered from 18 percent of gastrointestinal tracts. *Oncicola venezuelensis* was recovered from the greater and lesser omenta, fascia of the skin and muscle, tissues of the small intestine, and the coronary ligaments of the liver and diaphragm of 36.6 percent of examined mongooses.

I. INTRODUCTION

In the family Herpestidae (Order Carnivora), the small Indian mongoose (*Herpestes auropunctatus*) is a diurnal omnivorous carnivore native to Iraq, Iran, Afghanistan, Pakistan, Kashmir, India, Nepal, Myanmar (Burma), Thailand (Siam), Malaysia, and southern China including the province of Hainan (Hinton and Dunn 1967, Veron et al. 2007, Patou et al. 2009, Bennett et al. 2011). The mongoose is characterized by a slender body with short legs, a tapered tail, an elongate skull with a narrow rostrum and dental formula of I3/3, C1/1, P4/4, M2/2 (Nellis and Everard 1983). Males and females are sexually dimorphic (males are scrotal) with mating occurring between February and October, while births mostly occur in March-April and July-August (Pearson and Baldwin 1953, Pimentel 1955, Nellis and Everard 1983). After a 7-week gestation period, females have litters sizes of 2 and 4 pups. Males reach sexual maturity in 4 months and females in 6 months after birth (Pearson and Baldwin 1953, Pimental 1955, Nellis and Everard 1983).

The mongoose is an opportunist and generalist forager capable of adapting to a wide range of food types ranging from plant matter to insects, crustaceans, reptiles, amphibians, small mammals, birds, and anthropogenic food (Nellis and Everard 1983, Nellis and Small 1983, Quinn and Whisson 2005, Lewis et al. 2011). The species readily exhibits prey switching in the face of limited food resources (Nellis and Everard 1983; Wiley 2003; Engeman et al. 2006; Lewis et al. 2011). A solitary predator in its hunting, the mongoose will pursue prey with inexhaustible tenacity (Nellis and Everard 1983, Nellis and Small 1983, Lewis et al. 2011). This relentless tenacity coupled with observed displays of food envy (when the foraging behavior of a mongoose attracts more

mongoose) can make management of protected species in the presence of mongooses very challenging (Nellis and Everard 1983, Nellis and Small 1983, Lewis et al. 2011).

In 1872 the small Indian mongoose was introduced to Jamaica to control introduced rodent species (*Rattus rattus* and *Rattus norvegicus*) which were damaging sugar cane crops (Nellis and Everard 1983). Within 30 years of the initial introduction small Indian mongooses were subsequently established on every island in the Caribbean engaged in sugar cane production (Nellis and Everard 1983). Since its introduction, the prevailing opinions regarding introductions of the mongoose as a biological control agent switched from positive to negative; a pest species because of its role in the endangerment and extirpation of island endemics as well as for its apparent role in spreading zoonotic diseases such as rabies and leptospirosis (Engeman et al. 2006, Barun et al 2011, Lewis et al 2011, Berentsen et al. 2018). However, while considerable research has been conducted on the ecology of the mongoose on Trinidad, Grenada, and St. Croix, little to no research has been reported on the community of endoparasitic helminths of the Puerto Rico mongoose population (Pimentel 1955; Webb 1972; Webb 1980; Nellis and Everard 1983).

Because of the diversity of its food habits, the mongoose has the potential to be exposed to infection with a diverse array of endoparasitic helminths (Acholonu 1976, Nellis and Everard 1983, Coomansingh et al. 2009). To date an infection with *Spirura* spp. in Iran is the only reported case of endoparasitic helminth infection in the mongoose from its native range (Rakhshandehroo et al 2014). However, in the Caribbean, Nellis and Everard (1983) recovered specimens of *Skrjabinocapillaria caballeroi* and *Physaloptera* sp. from the stomachs of mongoose examined from St. Croix, Trinidad, and

Grenada. While on St. Croix, Webb (1980) also recovered specimens of *S. caballeroi* and *Aspicularis* sp. from examined gastrointestinal tracts. Huizinga et al. (1976) reported finding *Capillaria* sp. infecting the kidneys of mongooses examined on St. Lucia. The community of helminths associated with the mongoose on Puerto Rico may have important disease management implications for humans and domestic animals, since recent findings indicate utilization of agricultural and human recreational sites by the mongoose (Siddiqui et al. 2003; Quinn and Whisson 2005; Quinn et al. 2006; Mahmood et al. 2011). However, the Puerto Rico population of the mongoose has not been systematically surveyed for helminths.

Because the small Indian mongoose is an opportunistic generalist with a diet including many animals capable of serving as intermediate hosts for economically important introduced endoparasitic helminths. I predict that the viscera of the Puerto Rico population of mongooses will contain endoparasitic helminthes and that some portion of the species found therein will have zoonotic implications pertaining to humans or economically important animals on Puerto Rico. As such, I conducted a systematic helminthological examination of the viscera from the Puerto Rico mongoose populations, with special attention to parasites that may pose risks to humans and domestic animals.

II. METHODS

Study Sites

Trapping occurred on five private properties in the municipalities of Naguabo, Isabela, San Sebastian, Lajas, and Sabana Grande, Puerto Rico from 22 May through 12 August 2015. All sites were active cattle farms with daily activities ranging from cattle pasture rotation to milking operations. Of the five farms, four were dairy farms (Lajas, Naguabo, Isabela, and San Sebastian), and one (Sabana Grande) was explicitly a beef cattle operation. All ranches were observed to have horses, dogs, and cats. Reference Figure 1 for all site locations relative to ecological life zones on Puerto Rico.

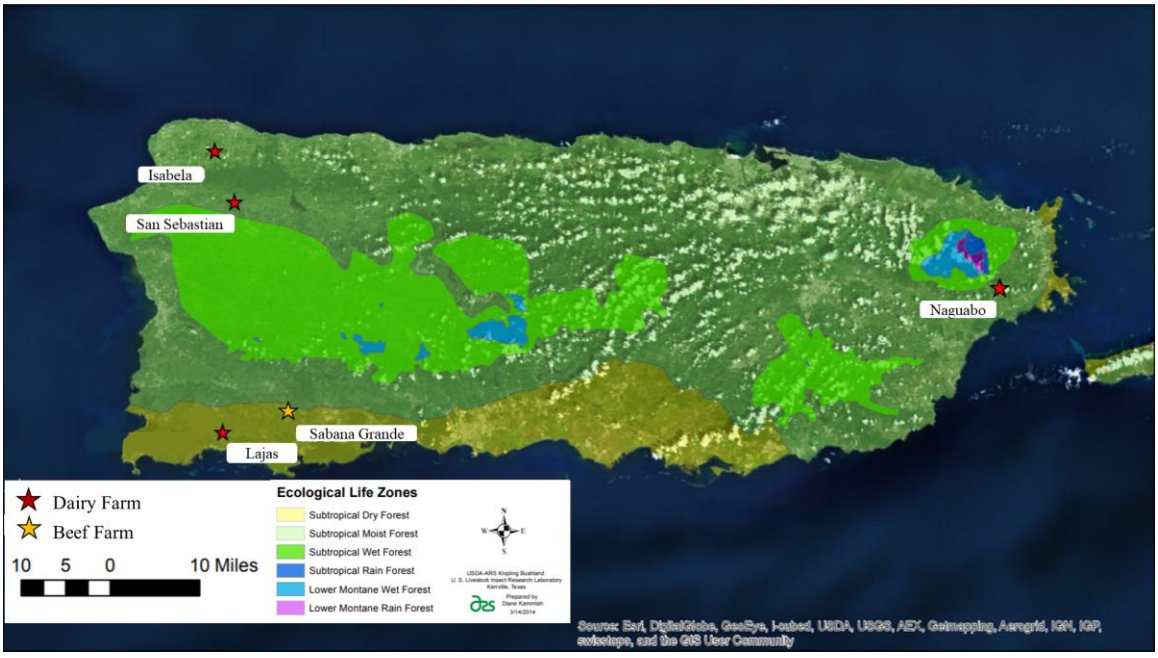

Figure 1: Trap site locations relative to ecological life zones on Puerto Rico.

Sites Lajas and Sabana Grande are located in the south-western region of Puerto Rico in the subtropical dry rain forest ecological life zone. Lajas itself was observed to

be a typical dairy cattle operation with a large central milking station surrounded by supporting pens and pastures with derelict buildings scattered throughout the ranch. Pastures were a mixture of bare, overgrazed, and ungrazed sites with delineating barbed wire fencing enclosing each pasture. Pastures that were ungrazed contained dense vegetation dominated by 1 to 1.5 m tall grasses and scattered acacia shrubs. Surrounding the properties was bare agricultural land that appeared to have been tilled the week prior to trapping. Fence lines were overgrown with numerous grass and shrub species and the occasional acacia tree species. Man-made water sources were scattered throughout the ranch in the form of stock ponds and water troughs as well as at least one naturally occurring perennial creek. Vegetation along the creek was substantially denser with medium to large canopied acacia trees. There did not appear to be anyone living on the operating portion of the ranch. Sabana Grande was a typical beef cattle grazing operation with supporting facilities for loading cattle on and off of shipping trailers. Pastures were a mixture of overgrazed, bare, or ungrazed sites of grasses while containing pockets densely scattered scrub brush and lines of semi-riparian vegetation. Pastures were fenced with barbed wire and those fence lines were grazed down of grasses and cleared of any scrub brush. Water sources consisted of at least one man-made pond, raised concrete water troughs, and a heavy flowing perennial creek. In addition to horses and dogs, this ranch also kept free ranging pigs. The owners lived on the ranch at the entrance to the operational portion of the property.

Sites Isabela and San Sebastian are located in the north-western region of Puerto Rico in the subtropical moist forest ecological life zone. Isabela was a typical dairy cattle operation with the supporting buildings and structures. All structures (operational or

derelict) were confined to the operations section of the ranch. Pastures were bare of grasses and shrubs as a result of severe drought coupled with rotational grazing. Internal fence lines were all barbed wire and devoid of grasses and shrubs. The perimeter of the property contained a dense tree line of vertically mixed vegetation and understory. There was no observed source of naturally occurring water source, however, at the operations section of the ranch were two manmade ponds. One pond served as the waste collection for the milking station. No one appeared to live on the ranch during non-operating hours. Other domestic animals observed on the property were free ranging guinea fowl, peacocks, ducks, and chickens. San Sebastian was the largest of all the sampled dairy cattle operations. The operations portion consisted of a ~1 ha milking and housing facility with an accompanying tractor and equipment warehouse. Pastures ranged in size from 2 ha to 4 ha. The entirety of the property was not explored for logistical reasons but there appeared to be a perennial creek feeding into a manmade pond which had dense cattail clusters along its bank and 1to 2 m tall mixed grasses. Pastures had a mixture of open grass land and scattered clusters of dense acacia trees with substantial understory and grass growth along the property perimeter fence lines. Ungrazed pastures were observed to have 0.5 m to 1 m tall grasses.

Located on the eastern point of the island in the subtropical moist forest ecological life zone is Naguabo. The central milking facility covered ~1 ha and sat in the center of a valley with steep hills on three of its sides. Fences were a mixture of barbed wire and bailing wire with substantial vegetative grass growth along the fence lines. The vegetative growth of the perimeter fence lines were a mixture of acacia, avocado, and mango trees with the under story consisting of dense grass and shrub growth. Pastures

were on steep hills ~1 ha in size and consisted of short grasses. A single creek was located at the center of the property and appeared to be intermittent and rain fed.

Trapping Procedure

A research team trapped each site for a minimum of 2 weeks, logistics and farm operating hours permitting. Trap lines were placed along fence rows since they not only crossed ideal habitat profiles (such as natural water sources) and the vegetative undergrowth provided ideal foraging habitat, cover, and acted as "natural" corridors between pastures for mongooses. Each transect consisted of approximately 40 Tomahawk live traps (51x18x18 cm, Model #204, Tomahawk Live Trap Co, Hazelhurst, WI). Since some pasture layouts and vegetation didn't allow for a continuous 40 trap transect, two 20 trap transects were used to ensure as much varied habitat coverage as possible. Transect checks took place daily starting at 08:00 for regular intervals of 2 hours (depending on heat every hour) until approximately 1700 However, daily check start and finish times could vary depending on each farms operating hours. If by the last trap check the weather looked to be rain until the morning then traps were closed, otherwise traps were allowed to remain open until the morning check. Each trap was spaced approximately 15 to 20 paces apart and baited with canned tuna in oil. Efforts were made using canned tuna in water for bait, but it was discovered that the humidity and heat quickly evaporated the water out of the tuna lending itself to easy consumption by ants. If the vegetation was suitable, traps were placed into the cover of the understory and the floor grates lightly covered in leaf litter. In some cases the understory wasn't dense enough to adequately conceal traps, so natural debris and cover was added to conceal the trap and protect captured animals from exposure to the sun or view of dogs

and cats. Traps containing a mongoose were removed and the animal in its trap were placed into a duffel flight bag for ease of transportation to the mobile lab. This method also helped to reduce further induced stress in captured individuals.

Mongoose Processing Protocol

The handling of live mongooses in traps was conducted by teams of two technicians while wearing leather gloves at all times. Animals ready for processing were euthanized with a combined two-step process of isoflurane overdose and cervical dislocation (IACUC protocol #0514_0303_07). A canvas bag containing a jar of isoflurane-soaked cotton balls was used to administer the overdose. This was done by placing the mouth of the bag over the trap door side of the trap while ensuring the isoflurane jar was at the very bottom of the bag or furthest from the mongoose. Slack material around the opening of the bag was reduced by bunching and twisting the loose material towards the trap sides ensuring there were no gaps between the fabric and the trap through which the mongoose could escape. The trap door was then opened to allow the mongoose to voluntarily enter the bag. Once the mongoose was inside the bag, the bag was quickly raised (this ensured the mongoose was at the bottom of the bag near the isoflurane jar) and secured by tightly twisting all slack from the opening of the bag down to the animal. Once the canvas bag was secure, it is then placed into a heavy-duty trash bag and sealed as above. After approximately 20 to 25 minutes the unconscious mongoose was removed and checked for the absence of a blink response by lightly tapping on the eye. If a blink response was detected the animal was promptly returned to the bag for an additional 10 minutes. If no blink response was detected a cervical separation was conducted and the isoflurane kill jar was stored in a Ziploc® bag.

Once the subject was euthanized standard mammalian measurements were recorded: Sex, total body length (tip of rostrum to tip of tail), tail length, left hind foot length, left ear length, and weight (units in mm and g). Measurements and weights are reported as means followed by standard deviation in parentheses.

Using standard necropsy techniques, I collected the following visceral organs and tissues: lungs with attached trachea, heart, liver with attached gallbladder, gastrointestinal tract (esophagus to rectum) with associated mesenteric tissues, and bladder. I sealed organs separately in Whirl-Pak® sample bags before collectively sealing them in a gallon Ziploc® bag and finally placing them on ice for later examination. I only conducted a gross examination of kidneys for signs of parasitic infection. Blood was not examined for the presence of endoparasitic helminths in this study.

If it was possible, I examined the visceral samples on the same day they were excised in a controlled environment with the use of a dissecting microscope. Techniques for examination, fixation, staining, and clearing were adapted from those recommended by Gardner (1996). Retained organs were separated into glass petri dishes containing a 0.9% physiological saline solution while relevant samples and tissues were fixed in 70% EtOH.

It was not possible to conduct a thorough same-day examination of the gastrointestinal tract without risk of sample decay while maintaining a rigorous trap schedule. To compensate, the gastrointestinal tract was separated into 3 primary regions: stomach (cardiac sphincter to pyloric sphincter), the small intestine (duodenum to ileum), and the large intestine (including the cecum). Each section was placed into 125 ml Nalgene wide mouth jar and fixed in 70% EtOH for the purposes of examination back at

Texas State University. Multiple EtOH replacements were made to ensure complete fixation of samples. The complete stomach (tissue and contents) was retained while only the contents of the small intestine and large intestine were retained. Prior to fixation, a small test sample was scraped from the stomach wall and examined for the presence of parasitic helminths. Contents from the small and large intestine were collected using the edge of a microscope slide to carefully scrape or scoop the mucus and chyme from the respective tissue onto the slide for transfer to a 125 ml Nalgene bottle. At our laboratory at Texas State University, I examined samples in glass petri dishes that had pie-slice grids drawn onto the bases. Approximately 8 ml to 10 ml (or that can be reasonably examined effectively) of sample contents would be transferred to a prepared petri dish containing 70% EtOH. I systematically examined each pie slice of the petri dish for the presence of parasitic helminths before moving on to the next pie slice.

Parasite Processing Protocol

I processed nematode specimens collected in Puerto Rico by relaxing and killing them in hot 0.9% physiological saline (saline was heated using a microwave for ~30 seconds) and then promptly placing the specimens in a 2 ml cryotube filled with 70% EtOH. Additional specimens were found in samples while working in the lab at Texas State University. These specimens were placed into 2 ml cryotubes of 70% EtOH.

I identified nematodes in the well of a depression slide containing 70% EtOH and a drop of lactophenol/cotton blue. Observations were made with the use of a compound scope.

I identified specimens of *Skrjabinocapillaria caballeroi* by following the species description made by Khalil (1977). Identification of nematodes belonging to the genus

Physaloptera were made with the assistance of Dr. Francisco A. Jimenez-Ruiz and his lab at Southern Illinois University.

I placed excysted acanthocephalan specimens in distilled water to relax and kill them, as well as forcing proboscis eversion. Once the proboscis was completely everted, I then placed specimens into a 2 ml cryotube of 70% EtOH. The only acanthocephalan species I recovered was *Oncicola venezuelensis*, and identifications of specimens were made following the species descriptions by Nickol et al. (2006). I stained acanthocephalan specimens with acetocarmine red for ~45 minutes. After the allotted staining time the specimen was introduced to a series of three chemical washes: first a wash of 70% EtOH to halt the staining process, then a 5% Acid-EtOH destainer for ~1 minute, and finally a 70% EtOH wash to halt the destaining. I then slowly introduced stained specimens to increasing concentrations of EtOH from 70% to 100% EtOH in 10% increments. Finally, to clear the specimen, it was introduced to 100% terpineol. Approximately 2 hours and 45 minutes were needed for the terpineol to completely replace the EtOH within the specimen. Once cleared the specimen could be positioned on a depression slide for viewing under a compound microscope.

III. RESULTS

Mongoose Data

Between 22 May and 12 August 2015, the research team caught 61 (20 females and 41 males) mongooses over 2,320 trap nights on the island of Puerto Rico across five cattle ranches (Table 1). The sample sex ratio was biased in favor of males at 2:1. The most mongooses trapped were at the Lajas site (23 total; 7 females and 16 males; sex ratio 2.2:1). Pregnant females (7 total) were caught on Lajas, Naguabo, San Sebastian, and Sabana Grande (1, 2, 2, and 2 respectively; while no pregnant females were caught on Isabela. Only two lactating females were caught, each on Isabela and San Sebastian.

Measurements from 60 mongooses (20 females and 40 males) caught across all trap sites were used for the purposes of this study. Values inside parentheses represent standard deviation. Observations of the data in Table 2 indicate that males display a trend towards being larger than females in all measurement categories. Mean measurements and body mass of 40 males were: total length 596.6 mm (49.7 mm), tail length 257.3 mm (27 mm), left hind foot length 62.1 mm (4.3 mm), left ear length 18.7 mm (3.9 mm), and body mass was 720 g (174.8 g). Mean measurements of 20 females were: total body length 550.4 mm (24 mm), tail length 245.9 mm (10.9 mm), left hind foot length 57.1 mm (3 mm), left ear length of 17.6 mm (3.5 mm), and body mass 530.2 g (60.5 g). When looking at just pregnant females (7 total) across all sites the mean total length was 545.2 mm (28.7 mm), tail length of 246.2 mm (11.5 mm), left hind foot length of 56.7 mm (3.1 mm), left ear length of 18.1 mm (3.4 mm), and weight of 561 g (40.2 g) at a max weight of 605 g (Table 2).

When mean measurement data is observed by site and sex (Table 3) Naguabo

displays a trend of having the largest males (means body mass 787 g and total length 616.7 mm), while the largest bodied females were caught in Sabana Grande (mean body mass 585 g and total length 573.5 mm). The smallest bodied females were caught at San Sebastian (means 498 g and 528.2 mm), however, the males with lightest body mass caught were in San Sebastian (mean 691 g) while the shortest males were caught in Lajas (mean 591.9 mm).

Parasite Data

I examined the major organs (heart, liver, lungs, bladder, and gallbladder) and gastrointestinal tract of 60 mongooses for the presence of endoparasitic helminths. There were no observable signs of infection from Trematoda or Cestoda in the viscera of any of the examined mongooses. Examination of major organs yielded a 0% prevalence for endoparasitic helminths, while the overall helminth prevalence in the gastrointestinal tracts was 87%.

Nematodes. The helminth most frequently found in the stomachs of mongooses (n = 39, 11 females and 28 males) was *Skrjabinocapillaria caballeroi*. This represented 65% of all individuals (55% of all females and 70% of all males) (Table 4). Males had a higher mean intensity of *S. caballeroi* per individual than females (35.8 per male and 33.5 per female). Pregnant females (n = 5) had a mean of eight worms per individual. Intensities ranged from 1 worm to 175 worms in a single individual with a mean intensity across all infected individuals of 35 worms. The male *S. caballeroi* membranous alate were measured to be 0.11 mm in length, while total body length was approximately 4.19 mm. Female total body length was approximately 8.38 mm with eggs measuring approximately 0.04 mm in length and 0.02 mm in width. I made Identification of

specimens following the species description made by Khalil (1977).

I found nematodes belonging to the Genus *Physaloptera* in the stomachs, small intestine, and colon of 11 mongooses (4 females and 7 males) with the intensities ranging from 1 to 11 worms.

Acanthocephalans. *Oncicola venezuelensis* was the only acanthocephalan I recovered from mongooses. I excysted specimens from the small intestine, coronary ligament of the liver and diaphragm, bladder, the fascia of the skin and muscle, greater and lesser omenta, and mesenteric tissues of the colon and small intestine. No adult forms of *O. venezuelensis* were found, and all recovered specimens were cystacanth larvae. Twenty-two samples from mongooses (36.6% of all mongooses, 25% of females and 42.5% of males) were found to contain this parasite with an intensity ranging from 1 to 11 worms and a mean intensity of 4 worms per infected individual (Table 4). The proboscis contained 36 hooks arranged in six rows/rings of six hooks per ring. Unique to the species *O. venezuelensis* was the presence of a pair of long, convoluted lemnisci running the full length of the trunk and containing six nuclei per lemnisci (Marteau, 1977). Unfortunately, many of the specimens collected were substantially compromised by host reactive tissue resulting in severe calcification and disfigurement of specimens making positive identification of many individuals very difficult.

Table 1: Mongooses caught at each site by sex, pregnant, and lactating females.

Sites	Total caught	Females	Males	Preg. Females	Lact. Females
Isabela	12	3	9	0	1
Lajas	23	7	16	1	0
Naguabo	6	3	3	2	0
Sabana Grande	7	2	5	2	0
San Sebastian	13	5	8	2	1

Table 2: Morphometry means for 60 mongooses by sex and pregnant females.

Sex	Total (mm)	Tail (mm)	Foot (mm)	Ear (mm)	Weight (g)	Max weight (g)
Female	550.4	245.9	57.1	17.6	530.2	630.0
Male	596.6	257.3	62.1	18.7	720.5	1,010
Preg. Female	545.2	246.2	56.7	18.1	561.0	605.0

Table 3: Morphometry means for 60 mongooses by site and sex (mm and g).

Site	Body length		Tail		Foot		Ear		Weight	
	F	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**
Isabela	561.3	602.9	250.3	262.1	58	62.4	18.3	19.7	498.3	749.0
Lajas	551.1	591.9	243.4	248.6	57.3	61.1	18.6	19.6	540.4	697.5
Naguabo	559.3	616.7	252.3	270.7	54.3	62.7	21.7	19.3	555.3	787.0
Sabana Grande	573.5	594.6	251.5	247.2	60.5	61.6	18.5	17.0	585.0	744.2
San Sebastian	528.2	592.3	240.8	269.6	56.6	63.6	13.2	16.8	498.0	691.9

Table 4: Prevalence and mean intensity of parasite species in mongooses by sex.

Parasite sp.	Infected			Mean Intensity			Max Intensity		Pregnant Females	
	F	**M**	**Total**	**F**	**M**	**Total**	**F**	**M**	**Total Inf.**	**Mean Int.**
S. caballeroi	11	28	39	33.5	35.8	35.1	175	143	5	8.0
O. venezuelensis	5	17	22	6.4	3.5	4.1	11	8	3	6.3
***Physaloptera* sp.**	4	7	11	2.2	3.4	3	3	11	0	0

IV. DISCUSSION

Since its introduction, the mongoose has demonstrated a high level of adaptability by colonizing and establishing itself in every ecological life zone on Puerto Rico as well as the ecological life zones of islands in the Caribbean to which the mongoose has been introduced (Pimentel 1955, Nellis and Everard 1983, Vilella 1998, Johnson et al. 2016). Although I trapped mongooses at cattle farms, the sites were located in representative ecological life zones across the island of Puerto Rico; however, the mongoose will still readily inhabit cattle pastures and other anthropogenically disturbed areas (Pimentel 1955, Siddiqui et al. 2003, Quinn and Whisson 2005, Quinn et al. 2006). Yet, I trapped at Lajas 44% of the total individuals caught. In Pakistan, the preferred habitat of the mongooses was dry forest scrub land with tall dense grass cover (Mahmood et al. 2011). Similarly, the Puerto Rico and Caribbean mongoose populations apparently prefer habitat in dry areas containing tall dense grasses with scattered scrubs (Pimentel 1955, Nellis and Everard 1983, Vilella 1998). This reported preferred habitat may reflect why I caught so many mongooses at Lajas, since its ungrazed pastures exhibited all the local environmental and climate conditions preferred by the mongoose.

Mean mongoose body measurements were within reported limits for the introduced species on Puerto Rico as well as for reports for this species from other islands in the Caribbean (Pimentel 1955, Nellis and Everard 1983, Vilella 1998, Guzmán-Colón 2014). However, the sex ratio (2.05:1) was biased in favor of males and contrasting to those reported in studies from Puerto Rico and other Caribbean islands (Pimentel 1955, Nellis and Everard 1983, Guzmán-Colón 2014). Although, studies in which trapping occurred during the spring dry season March through July (I trapped 22

May through 12 August 2015), sex ratios were reported between 2.09, 2.6, and even 3.36 biased towards males (Vilella 1998, Johnson et al. 2016). Similarly, though, the spring dry season for Puerto Rico is in line with the reported time frame in which females are birthing and nursing (March to April and July to August),perhaps indicating a maternal component because females are staying nearer to offspring. This may elucidate the male biased sex ratios (Pimentel 1955, Johnson et al. 2016).

Examination of the major organs from 60 mongooses (heart, lungs and trachea, liver, gallbladder, and bladder) were found to be free of endoparasitic helminth infections. My results reflect similar findings reported in studies from other Caribbean islands (Webb 1972, Nellis and Everard 1983). Gross examinations of aforementioned organs yielded no signs of lesions, signs of liver damage, presence of granulomas, and lungs were bright pink. Because the kidneys needed to be removed aseptically for a leptospirosis study, only a gross examination of the kidneys was conducted. For the gross inspection I looked for signs of infection and disease, although did not observe any signs of infection. However, from a parasitic survey conducted on St. Lucia, a new species of *Capillaria* sp. was discovered in the pelvic fornices from 28 of 30 examined small Indian mongooses (Huizinga et al. 1976). The kidneys were observed to exhibit seemingly mild host reactions to the parasitic infection with little to no signs of inflammation suggesting that my gross examination of kidneys was not sufficient for infection detection (Huizinga et al. 1976). There were no observable signs of infection by cestodes, although the visceral cavity of a small Indian mongoose examined in Burma yielded cestode specimens *Oochoristica amphisbeteta* and *Sparganum* sp. (Meggitt 1924). Despite the cestode specimens recovered in the Burma mongoose, I failed to find

literature reporting cestode infection of mongooses on Puerto Rico or elsewhere in the Caribbean where the mongoose has been introduced.

The gastrointestinal tracts of 60 mongooses were examined for the presence of endoparasitic helminths. The major organs of all examined mongooses and gastrointestinal tracts of 8 mongooses were observed to be free of the presence of parasitic infection. However, the stomachs of 39 mongooses were found to contain *Skrjabinocapillaria caballeroi* in intensities ranging from 1-175 worms. My findings contrast starkly with those found in the only study on Puerto Rico in which the examination of mongoose gastrointestinal tracts was conducted and in 210 mongooses no endoparasitic helminths were found (Pimentel 1955). My results also contrasted with a study on Grenada in which 4.9% of 1,117 mongoose were infected, on Trinidad where 12.5% of 80 mongooses were reported to be infected, and 21 individuals out of 100 examined mongooses on St. Croix (Webb 1980, Nellis and Everard 1983). It is important to note that the infection prevalence reported for the studies conducted on Grenada and Trinidad reflect shared infections by two other nematodes (*Physaloptera* sp. and *Capillaria* sp.) suggesting that the specific detected prevalence of *S. caballeroi* may be lower in those studies. A comparison of examination techniques could elucidate the disparities in *S. caballeroi* findings. In the studies conducted on Trinidad and Grenada, the gastrointestinal contents were brushed out and it is unclear if the mucosa of the stomach was examined. I effectively scraped contents out ensuring to free any attached worms from the mucosa (Nellis and Everard 1983). In research on St. Croix, the gastrointestinal tracts of 30 mongooses were examined macroscopically for endoparasitic helminths and the contents of another 55 mongooses were filtered through a 100 mesh

sieve. Both of these methods provide opportunities to miss or even lose large numbers of worms leading to the under reporting of relative infection densities and prevalence (Webb 1972, 1980). The methods used in the only other study on Puerto Rico (Pimentel 1955, 210 mongoose gastrointestinal tracts) were not reported, and a comparison of techniques could not be made to determine why my findings were so different. To my knowledge no information on the specific life history of *S. caballeroi* could be found in the literature besides its description (Khalil 1977, Webb 1980, Nellis and Everard 1983). Information regarding the parasites of the small Indian mongoose in its native range is lacking; however, representative members of the Genus *Skrjabinocapillaria* are reported to infect *Gerbilis* spp. and murid rodents that have native ranges overlapping with that of the small Indian mongoose (Wertheim and Chabaud 1979). It is unlikely that *S. caballeroi* is spread through direct transmission since mongooses are solitary in nature, congregating only when there is a consistent centralized food supply (food envy), only to re-disperse once that food supply is exhausted (Nellis and Everard 1983, Nellis and Small 1983, Quinn and Whisson 2005). It is more likely that the parasite is transmitted through an arthropod intermediate host since the hosts of other representative members of the genus *Skrjabinocapillaria* are partly or obligate insectivores feeding on a varied diet of arthropods (Wertheim and Chabaud 1979). Mongooses on Puerto Rico and other Caribbean islands were found to feed heavily on centipedes (specifically *Scolopendra subspinipes*) and various species of Orthoptera, Coleoptera, and Diptera, with insects in one study accounting for 56.4% of animal food items in examined stomachs (Wolcott 1953, Pimentel 1955, Nellis and Everard 1983).

Physaloptera spp. nematodes were found throughout the gastrointestinal tracts of

11 (18%) of the mongooses, at a mean intensity of 3 worms per infected individual and an observed max intensity of 11 worms in a single infected individual. Again, my findings conflict with the only study on Puerto Rico in which mongooses were surveyed for endoparasitic helminths and no infections were detected (Pimentel 1955). To my knowledge my findings are similar to and within reported infection limits of those studies conducted on other islands in the Caribbean for the exception of one study conducted on St. Croix in which no *Physaloptera* spp. were reported (Webb 1980, Nellis and Everard 1983). There is only one reported case of a nematode from the family Spiruridae infecting the small Indian mongoose from its native range (Rakhshandehroo et al. 2014). Adult forms of *Physaloptera* spp. parasitize the stomachs of vertebrate definitive hosts by attaching to the mucosa resulting in inflammatory responses at attachment sites. Eggs are shed through the host feces with invertebrate species acting as intermediate hosts for transmission (Goldberg and Bursey 1989, Naem et al. 2006). I did not observe any signs of inflammation or thickening of stomach walls in those mongoose stomachs containing *Physaloptera* spp. individuals. Furthermore, specimens were recovered from throughout the gastrointestinal tract. It is likely that the presence of *Physaloptera* spp. is an artifact of feeding on arthropod (Orthoptera) and vertebrate (*Bufo marinus*) intermediate hosts, on which the mongoose is recorded to feed (Erickson 1944, Nellis and Everard 1983, Galicia-Guerrero et al. 2000,). To my knowledge *Physaloptera praeputialis* is the only representative specimen recorded on Puerto Rico to have disease implications for domestic animals, although identification of my specimens to species level was not made as a result of noted inconsistencies in identification from macro-examinations (De Leon and Kolodziej 1969, Tiekotter 1981).

The acanthocephalan *Oncicola venezuelensis* was my second most encountered parasitic worm. Although I did find some live specimens, the vast majority of specimens collected were dead. Dead specimens ranged from a state of extreme desiccation to completely calcified and compromised with host reactive tissue. Desiccated individuals could often be reconstituted by placing them in distilled water. Samples that were compromised with host tissue, though collected, were in most cases identifiable only by the hook arrangement and count of the proboscis. The majority of cystacanths collected were from the greater and lesser omenta, but individuals were also recovered from the fascia of the skin and muscle, the coronary ligaments of the liver and diaphragm, as well as from the small intestine. My findings are in contrast to Pimentel (1955) which found no acanthocephalans in mongooses examined on Puerto Rico. *Oncicola venezuelensis* wasn't described until 1977 and its first case infecting a mongoose in the Caribbean until 1983, thus it is conceivable that the absence of records for acanthocephalans infecting mongooses resulted in the mesenteric tissues being overlooked (Pimentel 1955, Marteau 1977, Nellis and Everard 1983). It wasn't until 2011 that the complete life cycle of *O. venezuelensis* was described: the intermediate host (the Caribbean termite *Nasutitermes acajutlae*) consumes *O.* venezuelensis eggs, the encysted acanthellae modify the infected termite's colors and manipulates its behavior in such manner that the infected termite exposes itself for consumption by *Anolis* spp (paratenic host) that in turn is consumed by domestic cats (definitive hosts) (Marteau 1977, Fuller et al. 2003, Nickol et al. 2006, Fuller and Nickol 2011). Puerto Rico has no extant native non-volant mammals that could potentially prey on the mongoose, and because recovered *O. venezuelensis* are in the cystacanth form, there is no means of transmission of the parasite to cats suggesting

that the mongoose is an incidental or dead-end host (Fuller et al. 2003, Nickol et al. 2006, Fuller and Nickol 2011).

Because the small Indian mongoose has such a large native range and is an omnivorous generalist, it would follow that the mongoose would have a greater species-richness of native endoparasitic helminths associated to it (Blaustein et al. 1983, Clay 1995, Torchin et al. 2004). However, it is difficult to say what endoparasitic helminths the small Indian mongoose is susceptible to without a systematic survey of the community of endoparasitic helminths associated from its native range (Webb 1972, Nellis and Everard 1983). Often parasites do not invade with their introduced hosts because founding host populations tend to carry a limited subset of parasites found in native ranges, resulting in a decrease in diversity of native parasites and number of hosts infected in the introduced range (Torchin et al. 2002, Torchin et al 2003, Torchin and Mitchell 2004). None the less, introduced hosts often have approximately half of the native endoparasite helminth species in the introduced range than host populations of the native range (Blaustein et al. 1983, Torchin et al. 2003, Torchin and Mitchell 2004, Mastitsky et al. 2010). Without knowing the parasites native to the mongoose, this may elucidate why there is a lack of endoparasite species diversity found therein. This is observed in examined cane toads (*Bufo marinus*) introduced to Australia that were reported to have 16 endoparasitic helminth species in the introduced range as compared to the 59 endoparasitic species reported in their native range (Barton 1997, Torchin and Mitchell 2004). Similarly, endoparasitic surveys conducted on European starlings introduced to the United States were reported to be infected by 9 endoparasitic helminths as compared to the 44 reported from the starlings' native range (Torchin et al. 2003). The

founding population of small Indian mongoose on Jamaica consisted of nine individuals from which the subsequent progeny were systematically introduced and established to islands throughout the Caribbean (Nellis and Everard 1983). Founding host densities in introduced ranges are often below a parasites host density threshold to establish self-sustaining populations since bottle necks of host populations after introduction tend to break parasitic transmission (Torchin et al. 2002, Torchin and Mitchell 2004). Additionally, many endoparasitic helminths have complex life cycles often requiring multiple intermediate hosts, that if not present in the introduced range will prevent the establishment of that parasite (Torchin et al. 2002).

Thus the low diversity of endoparasitic helminths I found in the Puerto Rico population of mongooses may be explained by the compounding effects of: founding population bottlenecks, parasite host density requirements not being met, disruptions in complex parasite life cycles, and introduced host populations containing a small subset of infective native parasites (Torchin et al. 2002, Torchin et al. 2003, Torchin and Mitchell 2004). Lastly, *Skrjabinocapillaria caballeroi* was the only parasite I found to be potentially using the small Indian mongoose as a definitive host from the presence of egg bearing adult females. However, a fecal float analysis would need to be conducted to detect for the presence of egg shedding to support reproduction in the mongoose. For the acanthocephalan *Oncicola venezuelensis* the mongoose may serve as an incidental or dead end host for the following reasons: individuals found only in the cystacanth larval stage, absence of adult forms, and lack of method for transmission of cystacanth larva to domestic cats (Nellis and Everard 1983, Fuller et al. 2003, Nickol et al. 2006, Fuller and Nickol 2011). The distribution in the gastrointestinal tracts, lack of adults, and presence

of mastication and digestion of *Physaloptera* spp. may suggest that the presence of the nematode is likely an artifact of consumed intermediate arthropod and vertebrate hosts. To my knowledge I am the first to report these three endoparasitic helminth species in the Puerto Rico population of small Indian mongooses. However, to fully elucidate the parasite host relationships of the mongooses in the Caribbean, a systematic survey of the native community of endoparasitic helminths from the mongoose's native range needs to be conducted.

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