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Infectious Diseases of Six Non-Domesticated Neo-Tropical Animals In Trinidad and Tobago

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Abstract

This review serves to shed light on some common infectious diseases: their names, prevalence, site of infection and diagnostic tools for identificationof six (6) neo-tropical animals that are found in Trinidad and Tobago with the potential for domestication. These are theagouti(*Dasyprocta leporina/ D. agouti),* lappe/paca (*Cuniculus paca/ Agouti paca),* capybara (*Hydrochoerus hydrochaeris),* manicou/opossum *(Didelphis marsupialis insularis),* collared peccary (*Tayassu tajacu/ Peccari tajucu)* and red brocket deer (*Mazama americana).*There is over Ninety (90) references were used, with the earliest being 1951 and the most recent being in 2017.Where literature was lacking, information from other species within the same genus was incorporated and identified clearly. It was interesting to note that the majority of animals, despite being infected with pathogenic organisms were clinically healthy. In animals that showed clinical signs of disease there was a large quantity of pathogens present. This manuscript sheds some light on the pathogens that may use these animals as natural reservoirs. This review paper also includes many of the earliest identification of these pathogens in Neo-tropical animals in specific geographic regions.

Keywords: Dasyprocta leporina, Cuniculus paca, Hydrochoerus hydrochaeris, Didelphis marsupialis insularis, Tayassu tajacu, Mazama Americana.

Background

Neo-tropical animals possess the potential for domestication. These animals can be used as Mini-livestock and serve as a protein source for rural communities (Harduin et al. 1997). These animals are adapted to our environment and can be fed local feed stuff which made the production system sustainable (Miller and Miller 1986). These animals may also harbour diseases which are zoonotic or pathogens which can have devastating impact on domestic livestock. These pathogens may be present in Neo-tropical animals causing subclinical disease and decrease the productive efficiency. Obtaining information on the potential pathogens Neo-tropical non-domestic animals can harbour becomes important when considering these animals for intensive production.

Neo-tropical animals make reference to animals which originated from the new world between the tropic of cancer and the tropics of Capricorn. Animals which have the potential for domestication and belong to this group are *Dasyprocta leporina, Cuniculus paca, Hydrochoerus hydrochaeris, Didelphis marsupialis insularis, Tayassu tajacu,* and *Mazama Americana* Dasyprocta leporina (Brown-Uddenberg et al. 2004). Little attention have been given to these animals but in recent times authors have done work of specific factors affects their production. In Trinidad recent work has been done on the male reproductive system (Mollineau et al. 2006) and female reproductive system in the agouti (Singh et al. 2014). Recent work on the parasitic organisms found in the Agouti (Jones and Garcia 2017; 2018b). The digestive anatomy of the agouti (Garcia et al. 2000), digestive anatomy of the red brocket deer (Jones et al. 2018), the nutrition of specific neo-tropical animals (Lall et al. 2018) and reviews on the biology of the manicou (Tardieu et al. 2017). The purpose

of this paper is to compile information regardingcommon infectious diseases of the six neo-tropical animals with the potential for domestication.

Agouti (*Dasyprocta leporina)*

Parasitic pathogens in the Agouti

Brown-Uddenberg et al. (2004) stated that agouit rarely became diseased in captivity. Some protozoan infections that they are said to be susceptible to include Cocciodiosis, *Trypanosoma cruzi* (as a sylvatic host) and *Leishmania* spp. (as a reservoir). They are also said to be the intermediate host for Echinococcosis (*E. oligathus*). Helminths that could be found in the *D. leporina* include; Nematodes: Oxyuroidae, *Strongyloidesagouti*, Strongyloides ova, *Monodonius aguirari*, Trichostrongyles, *Physaloptherа torresi*, *Helminthoxys urichi*, *Trichuris* spp. And Trichostrongyles; and the cestode *Echinococcus* spp. Ectoparasites found included the mallophagas; *Gyropus* (2 species), *Macrogyropus amplexans*, *Amyblyomma* spp. and Amplexanas and the siphonapteras: *Rhopalopsyllus lugubris* and *R. australis australis*.

Cameron and Reesal (1951) reported that the free-ranging *D. leporina* in Trinidad contained *Stichorchis giganteus*, *Raillietina demerariensis var. trinitatae*, *Strongyloides agouti*, *Trichuris gracilis var trinitatae*, *Acanthocheilonema* spp., *Aspidodera binansata var. agoutiae*and *Helminthoxys urichi*. Suepaul et al. (2016) evaluated free-ranging *D. leporina* in Trinidad and found 4 nematodes: *Strongyloides agouti*, *Trichuris gracilis var trinitatae*, *Helminthoxys urichi* and Ascarid-type ova; *Eimeria* spp. and an unidentified trematode and cestode ova. More recently, Jones and Garcia (2017; 2018b) found in *D. leporina* intensively reared in Trinidad, *Strongyloides* spp., *Paraspidodera uncinata*, *Eimeria* spp. and *Trichuris* spp. were present in the caecum, colon and rectum, rectum and caecum respectively. These animals, however, showed no signs of being clinically ill and were in good body condition.

de Thoisy et al. (2000) evaluated the blood smears of 56 free-ranging *D. aguti* in French Guiana for haemoparasites and found*Babesia* spp., *Trypanosoma* spp. and filarial worms in blood smears. Zimmerman et al. (2009) examined two imported wild-caught agoutis (from Guyana to the U.S.A.) and found that despite appearing to be clinically healthy, subcutaneous cysts were present. One agouti was underweight and two months later an exploratory laparotomy revealed cysts along the abdominal wall. Over the following months, more cysts developed and she started showing difficulty in breathing and was lethargic. Radiographs revealed calcified cysts throughout the entire body. The second agouti was in a better body condition with a couple cysts. A diagnosis of *Echinococcusoligarthrus* hydatid cyst disease was confirmed via histopathology (agoutis act as intermediate hosts).

Sherlock (1996) suspected the presence of *Leishmanial* spp. in free-ranging *D. aguti* examined in Brazil, as leishmania amastigote structures were seen in the smears of liver and spleen, but he was unable to isolate and confirm it. In Brazil, Paçô, Campos and de Oliveira (1999) inoculated 5 captive agoutis (*D. aguti*) with *Lagochilascaris minor* infective eggs and upon necropsy found encysted L3 larva. Nodules were distributed throughout the body tissues, mainly subcutaneous, muscular and adipose. In the faeces egg shells were found. Clinical signs were observed in infected animals, including weight loss, raised hair, loss of appetite with CNS involvement manifesting as locomotor difficulties, loss of balance, mydriasis and head hanging. Gonçalves et al. (2006) captured and necropsied three free-ranging agoutis (2 *D. fuliginosa* and 1 *D. leporina*) in Brazil and found *Trichuris gracilis* in caecum, *Helminthoxys urichi* in the caecum, *Physaloptera torresi* in the stomach, *Physocephalus mediospiralis* in the stomach of and *Raillietina trinitatae* in the small intestine.

Lainson et al. (2007) in Northern Brazil captured free-ranging agoutis from Marajó and Outeiro and examined their faeces. *Eimeria aguti*, *Eimeria cotiae* and *Eimeria paraenis* based on the morphology of the oocysts was found, with the intestine being the development site. The agoutis that

had recovered were fed oocysts and subsequently wasshown to be re-infected 8 days later as all three types of oocysts were found in the faeces. Aogutis infected with *E. aguti*, *E. cotiae* and *E. paraenis* oocystsappeared clinically normal. da Silva et al. (2008) examinedfaecal samples from *D. leporina* in Brazil and found a high prevalence of nematodes (*Strongylida* and *Rhabditida*), with *Enoplida* eggs, *Eimeria* spp. oocysts and *Giardia* spp. Despite these findings, the animals appeared to be clinically healthy. Voltarelli et al. (2009) evaluated the serum of free-ranging *D. azarae* in Brazil using the direct agglutination test (DAT) to test *Leishmania* antibody titres and found that 75% of samples were positive. Minervino et al. (2010) tested the sera of captive agoutis (*D. aguti*) from Brazil for *T. gondii* antibodies using the modified agglutination test (MAT) and found that 18% were positive. Tenório et al. (2014) testedfree-ranging agoutis (*D. aguti*) in Brazil using blood cultures and polymerase chain reaction (PCR) and found that 6.25% was positive for *Trypanosoma cruzi* (Table 1).

Table 1. Parasitic organism at different predilection sites of the Agouti living in different geographical locations

Organism	Geographical location	Prevalence	Predilection site	Diagnostic tool	References
Gastrointestinal parasites					
Stichorchis giganteus	Trinidad	33% (2/6)	Digestive tract	Faecal analysis	Cameron and Reesal (1951)
Raillietina demerariensis var. *trinitatae*		33% (2/6)			
Strongyloides agouti		66% (4/6)			
Trichuris gracillis var. *trinitatae*		100% (6/6)			
Acanthocheilonema spp.		17% (1/6)			
Helminthoxy urichi		17% (1/6)			
Aspidodera binansata var. *agouti*		17% (1/6)			
Strongyloides agouti	Trinidad	38.6% (5/13)	Digestive tract	Faecal floatation	Suepaul et al. (2016)
Trichuris gracilis var. trinitatae		53.8% (7/13)			
Helmintoxy urichi		15.4% (2/13)			
Eimeria spp.		76.9% (10/13)			
Strongyloides spp.	Trinidad	36.9% (24/65)	Digestive tract	Faecal floatation	Jones and Garcia et al. (2017;2018b)
Paraspidodera uncinata		15.4% (10/65)			
Trichuris spp.		4.62% (3/65)			
Eimeria spp.					
Trichuris gracilis	Brazil	100% (3/3)	Caecum	Faecal examination	Gonçalves et al. (2006)
Helminthoxys urichi		33% (1/3)	Caecum		
Physaloptera torresi		100% (3/3)	Stomach		
Physocephalus mediospiralis		100% (3/3)	Stomach		

Raillietina trinitatae		66% (2/3)	Small intestines		
Eimeria aguti *Eimeria cotiae* *Eimeria paraenis*	Northern Brazil	50% (5/10)	Digestive tract	Faecal examination	Lainson et al. (2007)
nematodes, *Enoplida* (*Strongylida, Rhabditida*), *Eimeria* spp. *Giardia* spp.	Brazil	16.7% (24) 75% (24) 1% (24)	Digestive tract	Faecal examination	da Silva et al. (2008)
Parasites found in blood, glands and connective tissue					
*Leishmania*spp. *T. gondii* *Trypanosoma cruzi*	Brazil	75% (9/12) 18% (21/118) 6.25% (1/16)	Blood Serum Blood	Direct Agglutination test Modified Agglutination test Blood culture and Polymerase chain reaction (PCR)	Voltarelli et al. (2009) Minervino et al. (2010) Tenório et al. (2014)
Babesia spp. *Trypanosoma* spp. Filarial worms	French Guina	36% (20/56) 2% (1/56) 30% (17/56)	Blood	Blood smear	de Thoisy et al. (2000)
Eccinococcus oligarthus	Guyana		Subcutaneous	Exploratory laparotomy, Radiographs Histopathology	Zimmerman et al. (2009)
Leishmania spp.	Brazil	44% (4/9)	Liver and Spleen	Smears of the Liver and Spleen	Sherlock (1996)
Lagochilascaris minor (eggs and L_3 larvae)	Brazil		Subcutaneous, muscular and adipose tissue	Necropsy and faecal examination	Oliveira (1999)

Bacterial pathogens in the Agouti

Adesiyun et al. (1998) evaluated free-ranging *D. leporina* in Trinidad and found that 0.43% was positive for *Salmonella* spp., whereas in farmed agoutis, 2% were positive for *Salmonella* spp. and 9% were positive for *Campylobacter jejuni*. Dollinger et al. (1999) stated that 6 out of 29 *D. leporina* necropsied at the Basel Zoo from 1968 to 1988 died from yersiniosis (*Yersiniapseudotuberculosis*) but has had no cases since then. However, this still caused deaths in agoutis at the Zurich Zoo. At this zoo, fleas were also detected on 2 agoutis. Some bacterial infections that they are said to be susceptible to include Pasteurellosis (*Pasteurella pseudotuberculosis*), Tuberculosis (*Mycobacterium tuberculosis var. nominis*), *Klebsiella pneumonia*, *Streptococcus* spp. (viridian's group) and *Enterobacter* spp (Brown - Uddenberg et al 2004) (Table 2).

Viral Pathogens in the Agouti

In Trinidad a study done by Thompson et al. (2012) found that a juvenile *D. leporina* in Trinidad was positive for antibodies to the St. Louis encephalitis virus (SLEV) TBH-28 antigen via epitope-blocking enzyme-linked immunosorbent assays (ELISA), as well as using the hemagglutination inhibition assay (HIA). Brown-Uddenberg et al (2004) stated that they are susceptible to Foot and Mouth disease (FMD) (Table 2).

Table 2 Bacterial and Viral pathogens found in the Agouti at different geographical sites

Organism	Country	Diagnostic tool	Reference
Bacterial pathogens			
Salmonella spp.	Trinidad	Growth plates	Adesiun et al (1998)
Campylobacter jujeni	Trinidad	Growth plates	Adesiun et al (1998)
Yersinia pseudotuberculosis	Switzerland	Necropsy	Dollinger et al (1999)
Pasturella pseudotuberclosis *Klebsiella pneumonia* *Streptococcus* spp. *Entrobacter* spp.			Brown-Uddenberg et al (2004
Viral pathogens			
Foot and Mouth Disease			Brown-Uddenberg et al (2004)
St. Louis encephalitis virus	Trinidad	Enzyme linked Immunosorbent assay (ELISA)	Thompson et al (2012)

Lappe/Paca (*Cuniculus paca/ Agouti paca*)
Parasitic pathogens in the Lappe

Morales et al. (1979) evaluated free-ranging pacas in Colombia and based on gross and histological examination was able to identify polycystic hydatid cysts (*Echinococcus* spp.). Lesions were found in the liver parenchyma, except in one paca, which had a cyst in the peritoneum caudal to the right kidney. Gardner et al. (1988) reported the first record of the cestode, *Echinococcus vogeli* in Bolivia.Free-ranging pacashad the larval stage of *Echinococcus* spp. in their livers. The cysts in the liver, which when cut, stained and examined, had the larval stage of *E. vogeli* (identified based on morphology, proportions and dimensions of the rostellar hooks).

Tantaleán et al. (2012) made the first discovery of *Echinococcus vogeli* hydatid in Iquitos, Peru. The livers of pacas, bought from a market, were evaluated and had cystic structure, which when examined; a diagnosis of *E. vogeli* was made based on the morphology and dimensions of the rostellar hooks. Mayor et al. (2015) examined the viscera samples of free-ranging pacas from two regions in Peru, Nueva Esperanza and Diamante. Cysts were found in the liverand lung. Protoscolices from these cysts were examined and based on morphology, shape and size of the rostellar hooks, *E. vogeli* was identified

Matamoro et al. (1991) evaluated faecal samples from captive pacas in breeding cages in Costa Rica, which were never treated with anthelmintic. They found *Strongyloides*spp., Strongyloidea, *Eimeria aguti*, *Balantidium coli*, *Capillaria* spp., Ascaroidea, *Taenia* spp. and *Trichuris* spp. Gonçalves et al. (2006) captured and necropsied free-ranging pacas in Brazil and found *Physaloptera torresi* and *Physocephalus mediospiralis* in the stomach of pacas as well as *Raillietina trinitatae*in the small intestine. Almeida et al. (2013) examined the livers of free-ranging pacas from Brazil and found multiple spherical and sub-spherical lesions. Histopathology of the affected livers determined the presence of *Echinococcus vogeli* based on morphology, appearance and measurements. *Calodium hepaticum* eggs were also identifiedin pacas based on morphology and measurements. This was the first time *C. hepaticum* was found in that area and it was

also the first case of a mixed infection with these two helminths.

Carme et al. (2002) tested the sera of free-ranging pacas, in French Guiana, using the DAT and found some animals positive for *Toxoplasma gondii*. de Thoisy et al. (2000) evaluated the blood smears of free-ranging pacas in French Guiana for haemoparasites and found *Babesia* spp., and Trypanosomatidae. D'Alessandro et al. (1984) examined free-ranging pacas in Colombia and found *Trypanosoma cruzi*. Lopes et al. (2016) examined the ticks from free-ranging pacas in Belizeand found that *Amblyomma pacae* was present, with *Rickettsia amblyommii* found in a tick. This was the first documented case of *R. amblyommii* in *A. paca* (Table 3).

Wells et al. (1981) sampled free-ranging mammals in Carimagua, Colombia and found the hard tick, *Amblyomma pacae*; the haemoparasite, *Trypanosoma cruzi*; the fleas, *Rhopalopsyllus lugubris lugubris, R. australis tupinus* and *R. cacicus saevus* present on or in pacas. *Echinococcus* spp. cysts were also found liver of pacas.

Bacterial pathogen found in the Lappe

Adesiyun et al. (1998) evaluated free-ranging and captive wildlife in Trinidad and found that in captive pacas some were positive for *Salmonella* spp., while none were positve in the free-ranging ones (Table 3).

Table 3 Parasites and Bacteria present at different prediction sites in the Lappe housed in different geographical locations.

Organism	Location	Prevalence	Predilection site	Diagnostic tool	Reference
Endoparasites					
Echinococcus spp.	Colombia	47.3% (44/93)	Liver, kidneys, peritoneum	Gross and histological examination	Morales et al. (1979)
Echinococcus vogeli	Bolivia	50% (2/4)	Liver	Gross and histological examination	Gardiner et al. (1988)
Echinococcus vogeli	Peru	25% (1/4)	Liver	Gross and histological examination	Tantaleán et al. (2012)
E. vogeli	Diamante, Peru Nueva Esperanza, Peru	25% (2/8) 10.8% (13/120)	Liver and lungs	Gross and histological examination	Mayor et al. (2015)
Strongyloides spp. Strongyloidea *Eimeria aguti* *Balantidium coli* *Capillaria* spp. Ascaroidea *Taenia* spp. *Trichuris* spp.	Costa Rica	79.28% 66.42% 56.24% 5.71% 4.28% 2.85% 2.14% 2.14%	Digestive tract	Faecal Analysis	Matamoro et al. (1991)
Physaloptera torresi *Physocephalus mediospiralis* *Raillietina trinitatae*	Brazil	100% (2/2) 100% (2/2)	Stomach Stomach	Necropsy	Gonçalves et al. (2006)

		50% (1/2)	Small intestines		
Echinococcus vogeli *Calodium hepaticum*	Brazil	60% (3/5) 20% (1/5)	Liver	Gross and Histological examination Microscopic morphologic measurements	Almeida et al. (2013)
Toxoplasma gondii	French Guina	60.9% (14/23)	Blood	Direct Agglutination Test (DAT)	Carme et al. (2002)
Babesia spp. Trypanosomatidae.	French Guiana	44% (7/16) 6% (1/16)	Blood	Blood smear	de Thoisy et al. (2000)
Rickettsia amblyommii *R. amblyommii*	Columbia		Blood (Ticks)	Blood smear	Lopes et al. (2016)
Trypanosoma cruzi	Colombia				Wells et al. (1981)
Echinococcus spp.	Colombia	40.4% (38/94)	Liver	Gross and microscopic examination	Wells et al. (1981)
Ectoparasites					
Amblyomma pacae *Rhopalopsyllus lugubris lugubris* *R. australis tupinus* *R. cacicus saevus*	Colombia		Skin	Gross and microscopic examination	Wells et al. (1981)
Bacterial					
Salmonella spp.	Trinidad	20% (2/10)		Bacterial growth plates	Adesiyun et al. (1998)

Capybara (*Hydrochoerus hydrochaeris*)

Parasitic pathogen in the Capybara

Salas and Herrera (2004) evaluated the intestinal helminths in free-ranging capybaras from Venezuela and found *Monoecocestus macrobursatum*, *M. hagmanni*, and*Viannella hydrochoeri* in the small intesines. *Protozoophaga obesa* and *Taxorchis schistocotyle* were found in the caecum. Finally, *Hippocrepis hippocrepis*was found in the large intestine. This represented the first report of *M. macrobursatum* in Venezuela. Corriale et al. (2011) evaluated the prevalence of gastrointestinal parasites from faecal samples of free-ranging capybaras in Argentina. Gastrointestinal parasites found were *Taxorchis schistocotyle*, *Monoecocestus hydrochoeri*, *Capillaria hydrochoeri*, *Strongyloides* spp., *Protozoofaga obesa*, Trichostrongyloidea, *Huevo ascarideo*, *Eimeria* spp., *Blastocystis* spp. and *Balantidium coli*. This represented the first report of Ascaridea eggs in capybaras and the first report for *Balantidium coli* and *Blastocystis* spp. in Esteros del Iberá, Argentina.

Casas et al. (1995) presented the first report of intestinal helminths in capybaras from Bolivia. The following were found in free-ranging capybaras examined *Monoecocestus hagmanni, M. hydrochoerid, M. macrobursatum, Habronema clarki, Viannella hydrochoeri*, *Protozoophaga obesa*, *Taxorchis schistocotyle*and *Hippocrepis hippocrepis*. In Brazil, Santarém et al. (2006) presented a case report of a dead adult female capybara that was necropsied. The faecal egg count of eggs resembling trichostrongylidae was 500. *Eimeria* oocysts and *Strongloides* spp. Liver flukes were examined and based on morphology and size, was determined to be *Fasciola hepatica*. Faecal samples from

free-ranging capybaras in Brazil and found *Fasciola hepatica* eggs present (Bellato et al. 2009; Dracz et al. 2016). Urban areas in Brazil were studied and *Amblyomma cajennennse* and *A. dubitatum*ticks were collected.PCR determined that some adult *A. dubitatum* were positive for R. *bellii* (Pacheco et al. 2007; Queirogas et al. 2012; Brites-Neto et al. 2015).

Wells et al. (1981) sampled free-ranging mammals in Carimagua, Colombia and found the hard ticks; *Amblyomma cajennense, A. rotundatum, A. maculatum* and *Boophilus microplus*; the haemoparasite, *T. evansi*; and an unidentified helminth found commonly in the kidneys.Muñoz and Chávez (2001) examined clinically healthy captive capybaras in Peru, for *Trypanosoma* spp. Analysis of blood samples was done using the microhaematocrit, wide drop and Giema-stain methods and based on morphology and *T. evansi* was identified. Morales et al. (1976) discovered *Trypanosoma evansi* in free-ranging capybaras in Colombia via blood smears. However, they seemed to all be clinically normal and in good body condition. In Colombia, Morales et al. (1978) found that *Cruorifilariatuberocauda* damaged tissue in the kidney, lungs and myocardium (Table 4).

Arias et al. (1997) examined blood samples after microcentrifugation demonstrated active infection by *T. evansi* in capybaras from El Frio Ranch from El Cedral Ranch, Venezuela. Antibody testing of serum using the indirect immunofluorescent technique (IFAT) detected *T. evansi* in capybaras from El Frio Ranch also in capybaras from El Cedral Ranch.Caňon-Franco et al. (2003) reported the first prevalence of *Toxoplasma gondii* in capybaras. They used immunofluorescence antibody *test* (IFAT) and modified agglutination test (MAT) to analyse the sera from free-ranging capybaras in Brazil and found antibodies for *Toxoplasma gondii* in the serum samples. Pacheco et al. (2007) tested sera from free-ranging capybaras in Brazil using the indirect immunofluorescence assay (IFA) to identify rickettsial infection and found that they were positive to at least one *Rickettsia* species. The capybara sera reacted to *R. rickettsii, R. parkeri*and *R. bellii*. Truppel et al. (2010) evaluated free-ranging young and adult capybaras in Brazil for *T. gondii*. Serawas used for the indirect fluorescent antibody test (IFAT) and positive antibodies against *T. gondii*was found. Polymerase chain reaction (PCR) evaluated blood, liver, heart, lymph nodes, and spleen tissues and confirmed capybaras were seropositive to *T. gondii*. Free-ranging and captive capybara was identified in Brazil to have *T. gondii* antibodies (Ullman et al. 2017)

Valadas et al. (2010) evaluated sera from free-ranging capybaras in Brazil to find the prevalence of antibodies to *Trypanosoma cruzi, Leishmania infantum, Encephalitozoon cuniculi, Sarcocystis neurona* and *Neospora caninum*. Using an indirect immunofluorescent antibody test demonstrated antibodies to *T. cruzi, S. neurona* and *N. caninum*. da. Silva et al. (2014) evaluated wild animals in Brazil for antibodies to *T. gondii* and found that one capybara had antibodies to *T. gondii* using the modified agglutination test (MAT) (Table 4).

Table 4 Parasitic organisms at different predilection sites in the Capybara reared at different geographical locations

Organism	Location	Prevalence	Predilection site	Diagnostic tool	Reference
Gastrointestinal parasites					
Monoecocestus macrobursatum *M. hagmanni* *Viannella hydrochoeri*	Venezuela	98% (/40) 73% (/40) 100% (40/40)	Small intestine	Faecal analysis	Salas and Herrera (2004)
Protozoophaga obesa *Taxorchis schistocotyle*	Venezuela	100% (40/40)	Caecum	Faecal analysis	Salas and Herrera (2004)

Hippocrepis hippocrepis		83% (/40) 80% (/40)	Large intestines		
Taxorchis schistocotyle *Monoecocestus hydrochoeri* *Capillaria hydrochoeri* *Strongyloides* spp. *Protozoofaga obesa* Trichostrongyloidea *Huevo ascarideo* *Eimeria* spp. *Blastocystis* spp. *Balantidium coli*	Argentina	1.51% (2/200) 11.06% (22/200) 4.02% (8/200) 8.04% (16/200) 1.01% (2/200) 27.64% (54/200) 1.01% (2/200) 39.7% (58/200) 1.01% (2/200) 1.01% (2/200)	Digestive tract	Faecal analysis	Corriale et al. (2011)
Monoecocestus hagmanni *M. hydrochoerid* *M. macrobursatum* *Habronema clarki* *Viannella hydrochoeri* *Protozoophaga obesa* *Taxorchis schistocotyle* *Hippocrepis hippocrepis*	Bolivia	12% (5/41) 12% (5/41) 34% (14/41) 2% (1/41) 2% (1/41) 100% (41/41) 12% (4/41) 20% (8/41)	Digestive tract	Faecal analysis	Casas et al. (1995)
Trichostrongylidae *Eimeria* spp. *Strongloides* spp. *Fasciola hepatica*	Brazil		Digestive tract Liver	Necropsy, morphological and microscopic analysis	Santarém et al. (2006)
Fasciola hepatica	Brazil	9.1% (1/11)		Faecal analysis	Dracz et al. (2016)
F. hepatica	Brazil	8.96% (12/134)		Faecal analysis	Bellato et al. (2009)
Ectoparasites					
Amblyomma cajennense *A. rotundatum* *A. maculatum*	Colombia		Skin	Skin examination	Wells et al. (1981)

Boophilus microplus					
Amblyomma cajennennse *A. dubitatum*	Brazil	77.3% (494/639) 22.7% (145/639)	Skin	Skin examination	Queirogas et al. (2012, 80)
A. cajennense *A. dubitatum*	Brazil		Skin	Skin examination	Pacheco et al. (2007)
Amblyomma sculptum *A. dubitatum*	Brazil		Skin	Environmental collection	Brites-Neto et al. (2015)
A. cajennense *A. dubitatum*	Brazil		Skin	Skin examination	Pacheco et al. 2007)
Parasites in blood, glands and connective tissue					
T. evansi	Colombia		Blood	Blood smear	Wells et al. (1981)
T. evansi	Peru	28%(14/50)	Blood	Blood smear	Muñoz and Chávez (2001)
Trypanosoma evansi	Columbia	26.6% (8/33)	Blood	Blood smear	Morales et al. (1976)
Cruorifilariatuberocauda	Columbia		Kidney, lungs and myocardium	Necropsy	Morales et al. (1978)
T. evansi	Venezuela (El Frio Ranch) (El Central Ranch)	9% (38/444) 9% (10/115)	Blood	Blood smears	Arias et al. (1997)
T. evansi	Venezuela (El Frio Ranch) (El Central Ranch)	47% (207/444) 63% (72/115)	Blood	Immunofluorescent technique (IFAT)	Arias et al. (1997)
Toxoplasma gondii	Brazil	69.8% (104/149) 42.3% (63/149)	Blood	IFAT MAT	Caňon-Franco et al. (2003)
R. rickettsia *R. parkeri* *R. bellii*	Brazil	26% (19/73) 34.2% (25/73) 68.5% (50/73)	Blood	IFAT	Pacheco et al. (2007)
T. gondii.	Brazil	61.5% (16/26)	Liver, heart, lymph nodes and Spleen	PCR	Truppel et al (2010)
T. gondii.	Brazil	61.5% (16/26)		IFAT	Truppel et al. (2010)

Trypanasoma. cruzi *Sarcoyst. neurona* *Neospora. caninum.*	Brazil	8% (5/63) 3% (2/63) 1.16% (1/63)		IFAT	Valadas et al. (2010)
T. gondii	Brazil	25% (1/4)		MAT	da Silva et al. (2014)
T. gondii	Brazil	19% (4/31) wild 10% (1/10) captive reared		MAT	Ullman et al (2017)

Bacterial pathogens in the Capybara

Tonin et al. (2016) investigated the seroprevalence of *Leptospira* spp.in Brazil and approximately twenty five percent of the samples were positive. Sero-groups found included Sejroe, Icterohaemorrhagiae and Grippotyphosa. Ullmann et al. (2017) evaluated free-ranging and captive capybaras in Brazil for leptospirosis but no positive animal was identified..Jorge et al. (2012) isolated and identified *Leptospira interrogans* serovar Icterohaemorrhagiae from a juvenile free-ranging capybara in Brazil, using molecular techniques.In Brazil, Marvulo et al. (2009) experimentally infected sevencaptive young capybaras with *Leptospira interrogans* serovar*pomona* and found, using the microagglutination test (MAT), that it persisted for eighty three days and was confirmed in five animals. Shedding of *L. interrogans* serovar *pomona*in the urine occurred between days nine and days fourty three, however no lesions (gross or histological) were indicative of leptospirosis (Table 5).

Mol et al. (2016) isolated tuberculosis (*Mycobacterium bovis*) from lung samples upon post-mortem examination of an adult female capybara from a park in Brazil.Lord and Flores (1983) evaluated two hundred and one capybaras from three ranches in Venezuela. Their spleens and mesenteric and submaxillary lymph nodes were examined and twenty three isolations of *Brucella* spp. (*B. abortus* [8] and *B. suis* [15]) were made via oxidative metabolic techniques.

Viral pathogen in the Capybara

Roeder (2009) stated that capybaras are susceptible to foot-and-mouth disease. Likewise, Anderson (2017) stated that capybaras, despite not showing clinical signs, harbour the foot-and-mouth virus. Delpietro et al. (2009) observed for sylvatic rabies in free-ranging capybaras in Northern Argentina. One capybara was seen with neurological problems and was subsequently found dead a couple days later. Bites from the Vampire Bats *(Desmodus rotundus*) and isolation of rabies from the brain confirmed rabies in this capybara.

Table 5 Bacterial pathogen in the capybara reared in different geographical locations

	Location	Prevalence	Diagnostic test	Reference
Leptospira interrogans serovar *sejroe* *Leptospira interrogans* serovar *icterohaemorrhagiae* *Leptospira interrogans* serovar *grippotyphosa*	Brazil	16.9% (29/172) 4.07% (7/172) 0.58% (1/172)	MAT	Tonin et al. (2016)
Leptospira spp.	Brazil	0% (0/31)	MAT	Ullmann et al. (2017)
B. abortus	Venezuela	3.46% (8/231)	Oxidative metabolic	Lord and Flores (1983)

B. suis		6.49% (15/231)	techniques	

Manicou/Opossum*(Didelphis marsupialis*)
Parasitic pathogen on Manicou

Nettles et al. (1975) examined an ill free-ranging opossum in Georgia. The adult female opossum was emaciated and displayed circling, with weakness in the hindlimbs and frequent falling over. Necropsy revealed *Physaloptera turgid* (stomach worm), *Brachylaima virginianum* (intestinal flukes); *Cruziaamericana* (roundworm), *Capillaria aerophile* in the lungs and metastrongyloid nematodes. Holsback et al. (2013) evaluated the faeces of free-ranging *D. marsupialis* in Brazil using sedimentation and flotation-centrifugation methods and found eggs of Oxyuroidea.

Chero et al. (2017) examined dead opossums in a jungle in Peru for helminths. Trematodes and nematodes were found in the gastrointestinal tract during necropsy. Based on morphology via microscopy helminths were identified as the following; *Plagiorchis didelphidis*, *Rhopalias caballeroi*, *Rhopalias coronatus*, *Aspidodera raillieti*, *Cruzia tentaculate*, *Gongylonemoides marsupialis*, *Physaloptera mirandai*, *Turgida turgid*, *Trichuris marsupialis*, Viannaia hamata and *Viannaia viannaia*. The presence of *V. hamata*, *V. viannaia* and *G. marsupialis* represented the first records for Peru, while all parasites in the study were recorded for the first time in the San Martín region. Jiménez et al. (2011) examined free-ranging opossums in French Guinana for parasites and found cestodes; *Mathevotaenia bivittata*; Nematoda: *Aspidodera raillieti*, *Capillaria eberthi*, *Cruzia tentaculate*, *Spirura guianensis*, *Travassostrongylus paraquintus*, *Trichuris reesali* and *Viannaia viannai*. Acanthocephala: *Oncicola campanulata* was also seen.

Deane et al. (1984) found numerous *Trypanosoma cruzi* epimastigotes and trypomastigotes, of the metacyclic type, in sections and lumen of the anal glands in 75% of experimentally infected *D. marsupialis* in Brazil. Morphological diagnosis of *T. cruzi* flagellates were made using fresh and Giemsa stained films and it showed the stages, previously mentioned, which typically is found in the invertebrate host, thus *T. cruzi* was shown to perform the vertebrate and invertebrate cycles in the opossums. In Brazil, Carreira et al. (1996) found *T. cruzi* and *T. (Megatrypanum) freitasi* in the bladder, ureter, heart, stomach and oesophagus. Experimentally inoculated opossums (with *T. cruzi*) showed amastigote nests from ten days to two months post-inoculation in striated muscles and the central nervous system. Parasites were found in the abdominal wall, tongue, heart and cranial muscle five months post-inoculation and in the scent glands, seven to twelve months post-inoculation.

D'Alessandro et al. (1984) performed epidemiological studies in Colombia, which included the evaluation of free-ranging *D. marsupialis* as a reservoir host of trypanosomiasis. A total of 43% were positive for *Trypanosoma* spp. (*T. cruzi*, *T. rangeli*). Travi et al. (1994) examined the function of *D. marsupialis* as a reservoir host of zoonotic hemoflagellates in a tropical rainforest and a tropical dry forest in Colombia. Free-ranging opossums were evaluated and it was found that they were infected with *T. cruzi*, *T. (Herpetosoma) rangeli* and *T. (H.) leeuwenhoeki*. No trypanosomes were found in the anal gland contents of opossums. In the tropical dry forest, *T. cruzi* and *Leishmania chagasi* was found, with none showing clinical signs. Cantillo-Barraza et al. (2015) performed an eco-epidemiological study in Colombia and found that 61.5% free-ranging *D. marsupialis* were positive for *T. cruzi* (xenodiagnoses and haemocultures).

Morales and Nironi (1996) captured free-ranging *D. marsupialis* in Venezuela. Based on morphology of the flagellates *T. (Schizotrypanum) cruzi* was confirmed, with two showing trypanosomes in samples of fresh blood and epimastigotes in anal glands. Experimentally infected opossums showed amastigote nests in cardiac and skeletal tissues. Schallig et al. (2007) investigated the potential of the *D.*

marsupialis as a reservoir host for zoonotic leishmaniasis in Brazil. All free-ranging animals appeared clinically healthy. Analysis using IFAT and DAT identified several sero-positive animals (Table 5). Everard (1975) found *Hamanniellami-crocephala* in opossums in Trinidad.

Wells et al. (1981) examined free-ranging *D. marsupialis* in Colombia and found the presence of the following ectoparasites; hard ticks - *Amblyomma cajennense* and *Ixodes luciae*; and fleas - *Rhopalopsyllus lugubris lugubris* and *R. australis tupinus*. They also found low titres of *Leptospira sejroe* and *L. tarassovi*. Haemoparasite infections found were *T. cruzi*, *T. rangeli*, *Trypanosoma* spp. and a piroplasm. In the livers of opossums, a parasite and lesions resembling *Capillaria hepatica* was noted. Murgas et al. (2013) evaluated the presence of *Amblyomma ovale* in Panama and found that out of the *D. marsupialis* examined had the larval and nymphal forms of *A. ovale*. Durden and Richardson (2013) examined *D. virginiana* in Nebraska for ectoparasites and found the American dog tick (*Dermacentor variabilis*), fur mites (*Didelphilichus serrifer*) and fleas (*Pulex simulans*). This study presented the first record of *D. serrifer* in Nebraska.

Whitaker Jr., Jones and Goff (1976) examined the hair and skin (using a zoom dissecting microscope) of free-ranging *D. virginiana* in Indiana. The main ectoparasites that were discovered included four types of mites (*Marsupialichus brasiliensis, Archemyobia inexpectatus, Ornithonyssus wernecki* and *Didelphilicus serrifer*), a chigger (*Neotrombicula whartoni*) and a flea (*Ctenocephalides felis*).

Table 5 Parasitic organials at different prediction sites in the Manicou reared in different geographical locations

Organism	Location	Prevalence	Predilection site	Diagnostic tool	Reference
Endoparasites (Lungs and Digestive)					
Physaloptera turgid *Brachylaima virginianum* *Cruziaamericana* *Capillaria aerophile* Metastrongyloid	Georgia		Stomach Small Intestines Small Intestines & Caecum Lungs	Faecal analysis	Nettles et al. (1975)
Oxyuroidea.	Brazil			Faecal sedimentation, floatation and centrifugation	Holsback et al. (2013)
Plagiorchis didelphidis *Rhopalias caballeroi* *Rhopalias coronatus* *Aspidodera raillieti* *Cruzia tentaculate* *Gongylonemoides marsupialis* *Physaloptera mirandai* *Turgida turgida*	Peru	25% (2/8) 50% (4/8) 25% (2/8) 63% (5/8) 63% (5/8) 25% (2/8) 25% (2/8) 13% (1/8) 50% (4/8)	Digestive tract	Morphology and microscopy	Chero et al. (2017)

Trichuris marsupialis Viannaia hamata *Viannaia viannaia*		38% (3/8) 25% (2/8)			
Mathevotaenia bivittata *Aspidodera raillieti* *Capillaria eberthi* *Cruzia tentaculate* *Spirura guianensis* *Travassostrongylus paraquintus* *Trichuris reesali* *Viannaia viannai* *Oncicola campanulata*	French Guiana	25 (1/4) 100% (4/4) 50% (2/4) 25% (1/4) 50% (2/4) 100% (4/4) 50% (2/4) 100% (4/4) 50% (2/4)	Small intestine Caecum and large intestine Small intestine Caecum and large intestine Stomach Small intestine Large intestines and caecum Small intestines Small intestines	Morphology and microscopy	Jiménez et al. (2011)
Parasites in blood, glands and connective tissue					
Trypanosoma cruzi	Brazil	75% (6/8)	Anal glands (Epimastigote, trypomastigoe)	Morphology (Giamsa stain)	Deane et al. (1984)
T. cruzi *T. (Megatrypanum) freitasi*	Brazil	63% (10/16) 19% (3/16)	Bladder, ureter, heart, stomach and oesophagus.		Carreira et al. (1996)
T. cruzi *T. rangeli* *Trypanosoma* spp.	Colombia	29% (18/62) 3% (2/62) 6% (4/62)			D'Alessandro et al. (1984)
T. cruzi *T. (Herpetosoma) rangeli* *T. (H.) leeuwenhoeki*.	Colombia	72% (13/18) 17% (3/18) 6% (1/18)			Travi et al. (1994)
T. cruzi	Columbia	61.5% (8/13)		Xenoculture and Haemoculture	Cantillo-Barraza et al. (2015)
T. (Schizotrypanum) cruzi	Venezuela	33% (4/12)	Blood, Anal glands	Microscopy	Morales and Nironi (1996)
Leishmania spp.	Brazil	(24/111)	Blood	IFAT	Schallig et al. (2007)
Leishmania spp.	Brazil	8.1% (9/111)	Blood	DAT	Schallig et al. (2007)
Leishmania chagasi	Columbia	22.7% (5/22)	Blood	Microscopy	Travi et al. (1994)
Ectoparasites					
Amblyomma ovale	Panama	15.3%	Skin	Morphologic	Murgas et al.

		(15/98)		analysis	(2013)
Dermacentor variabilis *Didelphilichus serrifer* *Pulex simulans*	Nabraska	83% (5/6) 17% (1/6) 83% (5/6)	Skin	Morphologic analysis	Durden and Richardson (2013)
Marsupialichus brasiliensis *Archemyobia inexpectatus* *Ornithonyssus wernecki* *Didelphilicus serrifer* *Neotrombicula whartoni* *Ctenocephalidesfelis*	Indiana		Skin	Microscopy	Whitaker Jr., Jones and Goff (1976)

Bacterial pathogens present in the Manicou

In Iowa, Diesch et al. (1970) observed leptospires in kidney suspensions in opossums using darkfield microscopy examination. Positive *Leptospira* samples were also found using macroscopic slide agglutination, isolation, macroscopic pathologic lesion, microscopic pathologic lesion and Warthin-Starry stain. The species found upon isolation was *Leptospira ballum.* Cordeiro et al. (1981) captured free-ranging *D. albiventris* in Brazil and found that they were infected with the serovars Mangus and Pomona.

Jorge et al. (2012) captured free-ranging *D. albiventris* in Brazil and evaluated urine and blood samples. *Leptospira borgpetersenii* was isolated from urine samples and was identified using rpoB gene sequencing and was found to belong to the serovar Castellonis, using Multilocus Variable-Number Tandem-Repeat Analysis. Upon the microscopic agglutination test (MAT), 36.4% had antibody titres against the *Leptospira* isolate. This paper represents the first report of *Leptospira* spp. in *D. albiventris* in Brazil. de Hidalgo and Sulzer (1984) discovered three new serovars of *Leptospira interrogens* in free-ranging *D. marsupialis* in Peru, which were isolated from the kidneys. The suggested names, strains and serogroups of these new serovars were *huallaga* M-7 Diasiman, *rupa rupa* M-3 Sejroe and *tingomaria* M-13 Cynopteri. Adesiyun et al. (1998) evaluated seventeen free-ranging *D. marsupialis insularis* in Trinidad and found that 29% were positive for *Salmonella* spp. and 6% was positive for *Campylobacter jejuni* (Table 6).

Table 6 Bacterial organism at different predilection sites in the Manicou reared at different geographical locations

Organism	Location	Prevalence	Predilection site	Diagnostic tool	Reference
*Leptospira*spp.	Iowa	17% (2/12)	Kidneys	Dark Field Microscopy	Diesch et al. (1970)
		25% (3/12)		Macroscopic agglutination	
		8% (1/12)		Gross Pathologic lesion	
		33% (4/12)		Microscopic lesions	
Leptospira ballum		8% (1/12)		Warthin-Starry	

				stain	
Leptospira interrogens serovar*mangus* *Leptospira interrogens* serovar*Pomona*	Brazil	8.69% (8/92)			Cordeiro et al. (1981)
Leptospira borgpetersenii serovar *castellonis*	Brazil	36.4% (12/33)	Blood and Urine	Genetic sequencing	Jorge et al. (2012)
Salmonella spp.	Trinidad	29% (5/17)		Bacterial culture	Adesiyun et al. (1998)
Campylobacter jejuni.	Trinidad	6% (1/17)		Bacterial culture	Adesiyun et al. (1998)

Collared peccary (*Tayassu tajacu/Pecari tajacu*)

Parasitic pathogens in the Collared peccary

Parasitic diseases such as mange, intestinal nematodes, trichinellosis, stomach worms, trypanosomosis, cryptosporidiosis and coccidiosiswere found in the collared peccary (Fowler 1996). *Balantidium* spp., *Dirofilaria acutiuscula*, *Gongylonema baylisi*, *Parabronema pecariae*, *Parostertagia heterospiculum*, *Physocephalus* spp. and *Texicospirura turki*, *Moniezia benedeni* and *Fascioloides magna*. This study reported *D. acutiuscula, G. baylisi* and *F. magna* for the first time in North American peccaries (Samuel and Low (1970). Corn et al. (1985) examined free-ranging collared peccaries in Texas for helminths. The parasites that were found were; *Physocephalus sexalatus, Texicospirura turki*, *Gongylonema pulchrum*and *Parabronema pecariae*and *Moniezia* spp. This was the first recorded case of *G. pulchrum* in collared peccaries.

Romero-Castañón et al. (2008) examineddigestive tracts and faecal samples of free-ranging collared peccaries for endoparasites andcollared peccaries for ectoparasites in Mexico. The endoparasites, including site of infection were *Globocephalus urosubulatus* (stomach), *Oesophagostomum* spp. eggs, *Parabronema pecariae* (stomach), *Paraostertagia* spp. eggs *Texicospirura turki* (stomach), *Paramphistomum* spp. (stomach, large intestine) and *Moniezia benedeni* (small intestine). *G. urosubulatus* and *Paramphistomum* spp. were found for the first time in collared peccaries, while *P. pecariae*, *T. turki*, *M. benedeni*, *A. cajennense* and *A. inornatum* represent the first records in Mexico.

Herrera et al. (2008) examined eight clinically healthy free-ranging collared peccaries for *Trypanosoma evansi* and *T. cruzi* and found that one was positive for *T. evansi* using polymerase chain reaction (PCR), while using the immunofluorescence antibody test (IFAT) three were positive *T. evansi*and two were positive for *T. cruzi* using IFAT. In Brazil, Ullmann et al. (2017) surveyed twenty-two captive collared peccaries in Brazil for antibodies to *Leptospira* spp. and *Toxoplasmagondii*. The microscopic agglutination test (MAT) revealed 31.8% to be seropositive for *T. gondii*.

Gruver and Guthrle (1996) examined fifty-five free-ranging collared peccaries in Texas and found that sera from 2% had antibodies against *Borellia bugdorferi*, while sera from 5% had antibodies to *Yersinia pestis*. Of the fifty-five peccaries, forty-seven were examined for ectoparasites and it was found that 2% had the cat flea, 25% had the javelina flea, 40% had sucking louse (*Linognathida* spp.) and 2% had the black-legged tick. This was the first record for *Borellia* spp. and *Yersinia s*pp. in collared peccaries in the Trans-Pecos region of Texas. Samuel and Low (1970) surveyed parasites of free-ranging collared peccaries in south and west Texas. The species and prevalence of parasites in south Texas were; Acarina: *Amblyommacajennense* (98%), *Amblyomnma inornatum* (5%), *Dermace-*

ntor variabilis (78%) and *Haemaphysalis leporis palustris* (7%); Siphonaptera: *Pulex porcinus* (100%). The species and prevalence of parasites in west Texas were;Anoplura: *Pecaroecus javalii* (88%); and Siphonaptera: *Pulex porcinus* (77%). Romero-Castañón et al. (2008) found ectoparasites, Arthropoda: *Amblyomma cajennense* (20%), *A. inornatum* (60%) and *A. pecarium* (40%) (Table 7).

Table 7 Parasitic organism at different prefilection sites in the Manicou reared at different geographical locations

Organism	Location	Prevalence	Predilection site	Diagnostic test	Reference
Gastrointestinal parasites					
Balantidium spp.	Texas	4%		Necropsy	Samuel and Low (1970)
Dirofilaria acutiuscula		27%			
Gongylonema baylisi		4%			
Parabronema pecariae		36%			
Parostertagia heterospiculum		91%			
Physocephalus spp.		86%			
Texicospirura turki		48%			
Moniezia benedeni		9%			
Fascioloides magna		1%			
Physocephalus sexalatus	Texas	90% (52/58)		Necropsy	Corn et al. (1985)
Texicospirura turki		83% (48/58)			
Gongylonema pulchrum		33% (19/58)			
Parabronema pecariae		3% (2/58)			
Moniezia spp.		2% (1/58)			
Globocephalus urosubulatus	Mexico	23% (6/28)	Stomach	Faecal analysis	Romero-Castañón et al. (2008)
Oesophagostomum spp.		13% (4/28)			
Parabronema pecariae		31% (9/28)			
Paraostertagia spp.		7% (2/28)			
Texicospirura turki		8% (2/28)			
Paramphistomum spp.	Mexico	61% (17/28)	Stomach and Large intestine	Faecal Analysis	Romero-Castañón et al. (2008)
Moniezia benedeni	Mexico	8% (2/28)	Small Intestine	Faecal Analysis	Romero-Castañón et al. (2008)
Parasites in the blood, gland and connective tissue					
Trypanosoma evansi	Brazil	13% (1/8)		PCR	Herrera et al. (2008)
Trypanosoma evansi	Brazil	38% (3/8)		IFAT	Herrera et al. (2008)
T. cruzi	Brazil	25% (2/8)		IFAT	Herrera et al. (2008)

T. gondii	Brazil	31.8% (7/22)		MAT	Ullmann et al. (2017)
Borellia bugdorferi *Yersinia pestis*.	Texas	2% (1/55) 5% (3/55)			Gruver and Guthrle (1996)
Ectoparasites					
Amblyommacajennense *Amblyomnma inornatum* *Dermacentor variabilis* *Haemaphysalis leporis palustris* *Pulex porcinus* *Pecaroecus javalii* *Pulex porcinus*	Texas	98% 5% 78% 7% 100% 88% 77%	Skin	Gross and Microscopic identification	Samuel and Low (1970)
Ctenocephalis felis Javelina flea *Linognathida* spp. *Ixodes scapularis*	Texas	2% (1/47) 25% (12/47) 40% (19/47) 2% (1/47)	Skin	Gross and microscopic identification	Gruver and Guthrle (1996)
Amblyomma cajennense *A. inornatum* *A. pecarium*	Mexico	20% (1/5) 60% (3/5) 40% (2/5)	Skin	Gross and microscopic identification	Romero-Castañón et al. (2008)

Viral and Bacterial pathogens in the Collared peccary

Fowler (1996) stated that they were susceptible to; Viral diseases: Foot-and-mouth disease, vesicular stomatitis, vesicular exanthema (clinical disease), rinderpest (clinical disease), rabies (clinical disease), pseudorabies (serological response) and classical swine fever (clinical disease and serological response); Fungal and bacterial diseases: Ringworm (clinical disease), coccidioidomycosis, crypto-coccosis (clinical disease), salmonellosis (clinical disease) and colibacillosis (clinical disease). Similarly, Roeder (2009) stated that they were susceptible to foot-and-mouth disease infection.

Corn et al. (1987) tested two hundred and eighteen sera samples from free-ranging collared peccaries in Arizona and found that 8% had antibodies against vesicular stomatitis virus (VSV) New Jersey (NJ) type, less than 1% had antibodies against pseudorabies virus and 23% had antibodies against a number of different *Leptospirainterrogans* serovars.

Noon et al. (2003) conducted a serological survey for canine distemper virus (CDV) antibodies in three hundred and sixty-four free-ranging collared peccaries in Arizona. Serum neutralization (SN) revealed that 58% samples had neutralizing antibodies to CDV. Shender et al. (2009) necropsied thirty-four dead free-ranging collared peccaries that were clinically ill in Arizona. Clinical signs exhibited, before death, included emaciation, dehydration, lethargy, hindlimb weakness, laboured breathing and diarrhoea. In 47% of necropsied animals, *Salmonella* spp. was isolated from the small intestines, large intestines, liver, lung, spleen and stomach. With Anatum, Muenchen, Panama, Montevideo, Typhimurium and Oranienburg serotypes being identified in 67% of the isolates. Upon pulsed-field gel electrophoresis (PFGE), *Clostridium perfringens* was isolated in60% of the animals and was found in the small

intestine, faeces, large intestine and mesenteric lymph node, with 8 cases genotyped as type A. *Escherichiacoli* was isolated in 67% animals and was found in the lung, liver, small intestine, large intestine and spleen. This was the first recorded case of widespread salmonellosis in free-ranging collared peccaries.

Lord and Lord (1991) investigated brucellosis in collard peccaries from two ranches in Venezuela. 31% of animal tissues cultured had *Brucella suis*biovar 1, while antibodies to *Brucella* spp. was found in 87.8% samples. This represented the first case of *Brucella suis*biovar 1 in Venezuela from collared peccaries. Galvez et al. (2006) conducted a serological study in a collared peccary farm in the Peruvian Amazon to examine leptospiral seroprevalence. In the 2003 survey of twenty-seven clinically healthy collared peccaries, nine different *Leptospira* spp. serovars were identified: Varillal 010 (100%), Bratislava (19%), Borincana (19%), Tarassovi (11%), Autumnalis (11%), Icteroheamorragiae (7.4%), Ballum s102 (7.4%), Bataviae (7.4%) and Copenhagenii (3.7%). As compared to the 2005 survey of twenty-two clinically healthy collared peccaries, six different *Leptospira* spp. serovars were identified: Icteroheamorrhagiae (50%), Cynopteri (32%), Varillal 010 (27%), Bratislava (23%), Tarassovi (4.5%) and Panama (14%) (Table 8).

Mendoza et al. (2007) conducted a serological survey of ninety-six clinically healthy collared peccaries from four experimental farms in Peru for antibodies to *Leptospira* spp. Microscopic agglutination test (MAT) revealed the following serovars: In Loreto (BIOAM), the serovars and prevalence for twenty-seven collared peccaries were; total (100%), Var10 (100%), Australis (18.5%), Hebdomadis (18.5%), Icterohaemorrhagiae (7.4%), Autumnalis (11.1%), Bataviae (7.4%) Tarassovi (11.1%) and Ballum (7.4%). In the Ucayali area (Pucallpa Natural Park), the serovars and prevalence for six collared peccaries were; Total (16.6%) and Var10 (16.6%). In the Ucayali area (San Juan), the serovars and prevalence for fifty-seven collared peccaries were;Total (51.9%), var10 (36.5%), Australis (17.3%), Hebdomadis (3.8%), Icterohaemorrhagiae (3.8%), Autumnalis (1.9%), Bataviae (3.8%), Djasiman (3.8%), Grippothyphosa (3.8%), Canicola (1.9%) and Mini (1.9%); and In the Ucayali area (Club Divina Montaña), the serovars and prevalence for eleven collared peccaries were;Total (63.6%), Var10 (63.6%) and Australis (9.1%).Mayor et al. (2006) serologically tested forty-one clinically healthy collared peccaries from an experimental breeding farm in Brazil and found that 4.9% had antibodies to *Brucella* spp., while 9.8% had antibodies to *Leptospira* spp. serovars Butembo and Autumnalis (Table 8).

Table 8 Bacterial and Viral organisms at different predilection sites in the Collared peccary reared at different geographical locations

Organism	Location	Prevalence	Predilection site	Diagnostic tool	References
Viral					
Vesicular stomatitis virus Pseudorabies virus	Arizona	8% (18/218) 0.08%(1/218)		Serology	Corn et al. (1987
Canine distemper virus (CDV)	Arizona	58% (212/364)		Serum Nuetralization (SN)	Noon et al. (2003)
Bacterial					
Salmonella spp.	Arizona	47% (16/34)	Small intestines, liver, lungs, spleen and stomach	Bacterial culture	Shender et al (2009)
Clostridium perfringens	Arizona	60% (12/20)	Small intestines,	Bacterial culture	Shender et al (2009)

			faeces, large intestine and mesenteric lymph nodes		
Escherichiacoli	Arizona	67% (8/12)	Lungs, liver, small intestine, large interstine and spleen	Bacterial culture	Shender et al. (2009)
*Brucella suis*biovar 1	Venezuela	31% (43/139)		Animal tissue culture	Lord and Lord (1991)
Brucella spp.	Venezuela	87.8% (122/139)		Serology	Lord and Lord (1991)
Leptospira spp. serovar Varillal 010	Peru (2003)	100% (27/27)	,	Serology	Galvez et al. (2006)
Leptospira spp. serovar *Bratislava*		19% (5/27)			
Leptospira spp. serovar Borincana		19% (5/27)			
Leptospira spp. serovar Tarassovi		11% (3/27)			
Leptospira spp. serovar Autumnalis		11%(3/27)			
Leptospira spp. serovar Icteroheamorragiae		7.4% (2/27)			
Leptospira spp. serovar Ballums102		7.4 (2/27)			
Leptospira spp. serovar Copenhagenii		3.7% (1/27)			
Leptospira spp. serovars Icteroheamorrhagiae	Peru (2005)	50% (11/22)			
Leptospira spp serovar Cynopteri		32% (7/22)			
Leptospira spp. serovars Varillal 010		27% (6/22)			
Leptospira spp. serovars *Bratislava*		23% (5/22)			
Leptospira spp. serovars Tarassovi		4.5% (1/22)			
Leptospira spp. serovars Pamona		14% (3/22)			
Leptospira spp. serovar Varillal 010	Peru (Loreto)	100% (96/96)		MAT	Mendoza et al. (2007)
Leptospira spp. serovar Australis		18.5% (18/96)			
Leptospira spp. serovar Hebdomadis		18.5% (18/96)			
Leptospira spp. serovar Icterohaemorrhagiae		7.4% (7/96)			
Leptospira spp. serovar Autumnalis		11.1% (11/96)			
Leptospira spp. serovar Bataviae		7.4% (7/96)			
Leptospira spp. serovar Tarassovi		11.1% (11/96)			
Leptospira spp. serovar Ballum		7.4% (7/96)			
Leptospira spp. serovar Varillal 010	Peru (Pucallpa Natural	16% (1/6)			

	Park)				
Leptospira spp. serovar Varillal 010	Peru (Club Divina Montana)	63.% (4/6)			
Leptospira spp. serovar Australis		9.1% (1/6)			
Varillal 010	Peru (San Juan)	36.5% (19/52)			
Leptospira spp. serovar Australis		17.3% (9/52)			
Leptospira spp. serovar Hebdomadis		3.8% (/252)			
Leptospira spp. serovar Icterohaemorrhagiae		3.8% (2/52)			
Leptospira spp. serovar Autumnalis		1.9% (1/52)			
Leptospira spp. serovar Bataviae		3.8% (2/52)			
Leptospira spp. serovar Djasiman		3.8% (2/52)			
Leptospira spp. serovar Grippothyphosa		3.8% (2/52)			
Leptospira spp. serovar Canicola		1.9% (1/52)			
Leptospira spp. serovar Mini		1.9% (1/52)			
Leptospirainterrogans	Arizona	23% (48/218)		Serology	Corn et al. (1987)
Brucella spp.	Brazil	4.9% (2/41)		Serology	Mayor et al. (2006)
Leptospira spp. serovars Butembo *Leptospira* spp. serovar Autumnalis.	Brazil	9.8% (4/41)		Serology	Mayor et al. (2006)

Red brocket deer (*Mazama americana*)

Parasitic pathogen in the Red brocket deer

Cysts were found in 47% of the deer, in lung, liver, omentum and mesentery and based on the gross findings, the most likely cause was *Taenia hydatigena*. Faecal examination was conducted to investigate endoparasites and 64% deer were positive, with four having *Moniezia* spp., one having *Eimeria* spp., one having *Eimeria* spp. and strongyles and one having *Moniezia* spp., strongyles, and *Trichurisovis* (Deem et al 2004). Romero-Castañón et al. (2008) examined four free-ranging deer for endoparasites and ectoparasites in Mexico. The only endoparasite, including site of infection and prevalence found was; Trematoda: *Paramphistomum cervi* (rumen and abomasum;100%).

Reginatto et al. (2010) reported the first case of cryptosporidiosis in *M. gouazoubira*. Analysis of the faeces from a male and female deer, in Brazil, via the centrifugal floatation method yielded a high infection by *Cryptosporidium parvum* (more than three hundred oocysts/slide), which was associated with diarrhoea in both deer. It was shown to be self-limiting however, as after ten days, without treatment, the faeces returned to normal and there were less than ten oocysts per slide. Lux Hoppe et al. (2010) evaluated the helminths in ten free-ranging *M. gouazoubira* in Brazil and found; Strongylida: *Trichostrongylus axei* (40%), *Haemonchus contortus* (80%), *Haemonchus similis* (60%), *Cooperiapunctata* (60%) and *Bunostomumphlebotomum* (10%); Spirurida: *Physocephaluslassancei* (10%) and *Pygarginemaverrucosa* (10%); and Enoplida: *Capillariabovis* (20%).

In Brazil, Zimpel et al. (2015) found that25% deer was positive for antibodies against *T. gondii* using the indirect fluorescent antibody test (IFAT). da Silveira et al. (2011) evaluated fifteen free-ranging and two captive *M. gouazoubira* in Brazil for *Theileria* and *Babesia* and found that

18% were positive for *Theileria* spp., 53% were positive for *T. cervi*, 6% was positive for *B. bigemina*, 33% were positive for *Rhipicephalus microplus*, 33% was positive for *Dermacentor nitans* and 27% were positive for *Amblyomma cajennense*. This represented the first report of *Theileria* spp. in cervids in Brazil. The ectoparasites of free ranging deer in Mexico, including site of infection and prevalence found were; Arthropoda: *Amblyomma americanum* (25%), *A. pseudoconcolor* (25%), *Anocentor nitens* (25%), *Dermacentor albipictus* (75%), *Haemaphysalis* spp. (25%), *Ixodes scapularis* (50%), *Ixodes* sp. (25%) and *Lipoptena mazamae* (100%). *P. cervi*, *A. americanum*, *A. pseudoconcolor*, *A. nitens*, *D. albipictus* and *I. scapularis* were found for the first time on *Mazama americana*. *L. mazamae* was found for the first time in Mexico (Romero-Castañón et al. 2008) (Table 8).

Fifty percent (50%) of the deer sampled had ectoparasites; *Amblyomma* spp. ticks were found on 41% deer (*Amblyomma parvum* and *A. pseudoconcolor* adults and *Amblyomma* spp. nymphs and larvae), *Lipoptenamazamae* flies 35% and unidentified lice on 35% (Roeder 2009). Tiemann et al. (2005) evaluated the sera of one hundred and fifty captive *Mazama* spp. in Brazil for *Neospora caninum* antibodies, using IFAT and found that 44% from the captive herd and 39% from the zoohad antibodies. Gomez-Puerta and Mayor (2017) examined thirty-seven apparently healthy foetuses and found *Setaria bidentate* (nematoda) in 32%. Each fetus had one to seven filaria and the majority was found in the peritoneal cavity and one was found in the thoracic cavity. This finding represented the first study to show *S. bidentate* in cervid foetuses and it was also the first finding in Peru (Table 8)

Table 8 Parasitic organisms at different predictions sites of the Red brocket deer reared at different geographical locations

Organisim	Location	Prevalence	Predilection	Diagnostic tool	Reference
Endoparasites					
Taenia hydatigena.		12% 18% 17%	Lung Liver Omentum and Mesentry	Necropsy	Deem et al (2004)
Moniezia spp. *Eimeria* spp. Strongyles *Trichurisovis*		36% (4/11) 9% (1/11) 9% (1/11) 9% (1/11)	Digestive tract	Faecal examination	Deem et al. (2004)
Paramphistomum cervi	Mexico	100% (4/4)	Rumen and Abomasum	Goss findings	Romero-Castañón et al. (2008)
Cryptosporidium parvum	Brazil	100% (2/2)		Faecal analysis	Reginatto et al. (2010)
Trichostrongylus axei	Brazil	40% (4/10)		Faecal analysis	Lux Hoppe et al. (2010)
Haemonchus contortus		80% (8/10)			
Haemonchus similis		60% (6/10)			
Cooperiapunctata		60% (6/10)			
Bunostomumphlebotomum		10% (1/10)			
Physocephaluslassancei		10% (1/10)			
Pygarginemaverrucosa		10% (1/10)			
Capillariabovis		20% (2/10)			
Parasites of blood, connective tissue and glands					
Theileria spp.	Brazil	18% (3/17)	Blood	Microscopy	da Silveira et al. (2011)

T. cervi *B. bigemina*		53% (9/17) 6% (1/17)			
T. gondii	Brazil	25% (1/4)		IFAT	Zimpel et al. (2015)
Setaria bidentate		32% (10/25)		Microscopy	Gomez-Puerta and Mayor (2017)
Neospora caninum	Brazil	38/86 (Captive herd) 25/64 (Zoo)		IFAT	Tiemann et al. (2005)
Ectoparasites					
Rhipicephalus microplus *Dermacentor nitans* *Amblyomma cajennense*	Brazil	33% (5/15) 33% (5/15) 4/15	Skin	Gross observation	da Silveira et al. (2011)
Amblyomma americanum *A. pseudoconcolor* *Anocentor nitens* *Dermacentor albipictus* *Haemaphysalis* spp. *Ixodes scapularis* *Ixodes* sp. *Lipoptena mazamae*	Mexico	25% (1/4) 25% (1/4) 25% (1/4) 75% (3/4) 25% (1/4) 50% (2/4) 25% (1/4) 100% (4/4)	Skin	Gross observation	(Romero-Castañón et al. 2008).
Amblyommaparvum *A. pseudoconcolor* *Lipoptenamazamae* Unidentified lice		41% (7/17) 41% (7/17) 35% (6/17) 35% (6/17)	Skin	Gross and Microscopic observation	Roeder et al. (2009)

Bacterial and Viral pathogens of the Red brocket deer

Delpietro et al. (2009) observed three ill deer in Argentina displaying clinical signs. One deer was excessively salivating while being recumbent and the other had difficulty walking and keeping balance, however samples could not have been taken from them for diagnostic testing. The third deer was recumbent with paralytic signs, excess salivation, opisthotonous, slow micturition and pedalling of the hindlimbs. Vampire bat (*Desmodusrotundus*) bite marks around the ears were observed upon euthanasia of this deer and rabies virus was detected in the brain. 45% of deer had antibodies to four serovars of *Leptospira interrogans*: Autumnalis, Ballum, Icterohae-morrhagiae, and Sejroe (Deem et al 2004).

Roeder (2009) stated that the *Mazama* spp. was susceptible to foot-and-mouth disease infection. Deem et al. (2004) conducted a survey of seventeen clinically healthy free-ranging Grey Brocket Deer *(Mazama gouazoubira*) in Bolivia. Bovine respiratory syncytial virus (13%), Epizootic hemorrhagic disease virus serotypes 1 and 2 (7%) and *Leptospirainterrogans*, eighteen serovars (45%), were found using serum neutralization (SN), agar gel immunod-iffusion (AGID) and microagglutination respectively (Table 9).

Table 9 Bacterial and Viral organisms at different predilection sites in Red brocket deer reared at different geographical locations

Organism	Location	Prevalence	Predilection site	Diagnostic tool	Reference
Bovine respiratory syncytial virus	Bolivia	13% (2/15)		SN, AGID,	Deem et al. (2004)
Epizootic hemorrhagic disease virus serotypes 1& 2		7% (1/15)			
Leptospirainterrogans		33% (5/15)			

Discussion

This literature review showed that it was possible for most of these neo-tropical animals to be infected by pathogens yet appear clinically healthy. Infectious diseases are disorders caused by pathogenic organisms and could be directly or indirectly transmitted, versus other types of diseases, such as nutritional diseases. A parasitic relationship occurs when one organism, the parasite, gains from the relationship, usually at the expense of the other, the host (Jones and Garcia 2018a). An endoparasite is one that lives within the host's body, while an ectoparasite is one that lives on the surface of the host. The finding of this review shows that most of the pathogenic organism found in Neo-tropical animals was similar at different geographical locations. This will suggest that these organisms were present in the environement at various geographical locations.

These findings are of major importance as these animals could act as reservoirs and spread zoonotic diseases without us knowing as they appear clinically healthy. The effects of these organisms on the six neo-tropical aniamls listed should be further investigated. It is clear that there is a lot of information lacking in this subject area of infectious diseases in these neo-tropical animals that were reviewed and more research is needed to understand exactly how they could harbour parasitic, bacterial and viral organisms yet appear clinically healthy, which in other domesticated animals may debilitate or even cause death of those animals. Thus animals will not show overt clinical signs and economic losses attained may be sub-clinical. However these Neo-tropical animals can serve as reservoirs for diseases which are pathogenic to domesticated animals. At present further work must be done to investigate the economic effect these pathogens have on Neo-tropical non-domesticated animals

Conclusion

Neo-tropical non domesticated animals have the ability to harbour various amount of pathogens. However, these pathogens don't seem to have harmful effects on the animals but can spread diseases to domesticated animals.

Conflict of interest Statement

The authors declare that they have no conflict of interest.

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