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Title: Leptospira **seroprevalence in animals in the Caribbean region: a systematic review.**

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Abstract

This systematic review summarises the data published on the *Leptospira* seroprevalence, serovar diversity and distribution among animal species in the Caribbean region. Following Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines, and checklist, relevant articles were identified and data were extracted and recorded. The review provided *Leptospira* seroprevalence data from 16 Caribbean islands (Barbados, Trinidad, Grenada, Puerto Rico, Saint Croix, St. Kitts and Nevis, Jamaica, Antigua, Carriacou, Dominica, Guadalupe, Martinique, Monserrat, St. Lucia, St. Maarten, and St. Vincent) in a variety of animal species. Reviewing the literature highlighted the limited amount of data available from limited number of islands. Many of the studies conducted have recorded seroprevalences based on variable and small samples sizes. Besides, serovar panels used for MAT were not consistent between studies. The review indicates that the *Leptospira* exposure in a given geographic location may change with time and climatic and environmental conditions, and highlights the need to conduct continual surveillance in tropical countries where the climate supports the survival of *Leptospira* in the environment. Specific attention must be given to standardization of MAT panels and protocols and providing training across laboratories involved in testing. Further, animal and environment testing to isolate and identify circulating *Leptospira* spp. in geographic region must actively be pursued. This knowledge is important to implement geographically specific control programs, as risk factors of *Leptospira* transmission is favoured by various factors such by change in climatic conditions, urbanization, encroachment of wildlife inhabitation, import/export of animals, increase in adventure travel, and water related recreational activities.

Key words: Leptospira, serovars, Seroprevalence, Animals, Caribbean, systematic review

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Introduction

Leptospirosis is a bacterial zoonotic disease, affecting both humans and animals. Leptospirosis, originally considered as an occupational disease affecting people in contact with animal tissues or urine, has increasingly been acknowledged as a neglected disease of poverty (Bharti *et al.,* 2003; Hotez *et al.*, 2008). Leptospirosis outbreaks usually occur after natural disasters such as hurricanes and flooding and in the tropics an increased incidence is often recorded coinciding with increased rainfall (Hagan *et al.,* 2016; Lau *et al.*, 2010b). Recently, leptospirosis has been emerging as a health threat in new locations as a result of climate change and globalization (Costa *et al.*, 2015; Hagen *et al.,* 2016; Lau *et al.,* 2010b; Hartskeerl *et al.,* 2011). There has been an upsurge in the number of travellers diagnosed with this disease (Lau *et al.,* 2010a; Hochedez *et al.*, 2011; Hochedez *et al.*, 2013, Bandara *et al.*, 2014). The rise in the popularity of adventure travel and extreme athletic events in tropical areas could result in increased incidence of this disease (Morgan *et al.,* 2002; Sejvar *et al.*, 2003; Monahan *et al.*, 2009).

Pathogenic *Leptospira* are maintained in the kidneys of many animal species, including cattle, dogs, horses, pigs and several wild animals (Ellis, 2015). These bacteria asymptomatically colonize the renal tubules of the reservoir animals and are shed into the environment through urine; if conditions are right, can survive for long periods, from weeks to months. Humans and animals may develop fatal life-threatening illness. Leptospirosis can cause economic losses in livestock due to its effects on production and reproduction (Ellis, 2015). The livestock and pets who are asymptomatic maintenance hosts, may serve as a source of infection to people in contact.

A recent systematic review pertaining to human leptospirosis (Costa *et al*., 2015), concluded that small tropical islands generally have the highest incidence of infection, with *Leptospira* infection being one of the major zoonotic cause of morbidity in these regions. Leptospirosis accounts for significant mortality and morbidity in humans in the Caribbean region (Pappas *et al.,* 2008; Costa *et al.*, 2015). In 2011, Desvar *et al.,* reviewed animal leptospirosis in small tropical areas including the Caribbean region and emphasized the presence of unique circulating serovars, which is linked to the region’s animal and environmental biodiversity. Another review article pertaining to animal leptospirosis in the region recorded incidence of leptospirosis outbreaks in animal populations, in the Caribbean and Latin America (Petrakovsky *et al.*, 2014). This systematic review was conducted using Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines and is solely focused on *Leptospira* seroprevalence studies on the islands of the Caribbean region to obtain a detailed overview.

Methods

Search Region

The Caribbean region situated on the Caribbean plate, an oceanic tectonic plate, consists of the Caribbean Sea, the surrounding coasts and the islands within. The area is north of South America, east of Central America and southeast of the North American mainland and the Gulf of Mexico (Figure 1). The Caribbean plate is approximately 3.2 million square kilometres in area. The area is comprised of more than 700 islands, reefs and cays. It consists of the Lesser Antilles to the south and east (including the Leeward Islands) and the Greater Antilles to the north.

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Literature Search
Following Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Moher *et al.*, 2009) and checklist, pertaining studies were identified. To find studies describing *Leptospira* seroprevalence on the islands of the Caribbean region, a literature search was conducted using the following electronic databases; EBSCOhost, Wiley-Blackwell, Springer Link, Science Direct, Wiley Online and PubMed Central. In addition to these databases, a search was performed using internet based search engines, including Google Scholar, Google, Yahoo and Bing. The scientific databases were searched for eligible citations that included the terms '*Leptospira*' or 'leptospirosis' AND 'animals' AND 'Caribbean'. A search was also performed using the term 'leptospi*' and the names of the individual islands present in the Caribbean region (Table 1). The titles and abstracts were then downloaded into EndNote (Thomson Reuters, Philadelphia, PA, USA). The titles and abstracts were reviewed against pre-determined abstract inclusion criteria to determine their suitability.

Inclusion and Exclusion Criteria
Abstracts were included if they described data relating to *Leptospira* spp. in animals from any country within the Caribbean region. Abstracts were excluded if they did not refer to original research data on animal leptospirosis or they did not describe naturally occurring *Leptospira* infections in animal populations on the islands. All articles that were considered to fit the inclusion criteria were retrieved as full text documents. The full text documents were then assessed against specific inclusion criteria. Documents containing data obtained using the microscopic agglutination test (MAT) were specifically included. The search performed focused on articles written in English, however although non-English studies were excluded, data was extracted from studies that had English abstracts. In cases were full articles could not be obtained, the article abstract was used. Publications were selected based on the methodology used in the study and the relevance of the information. Data considered relevant included 1) studies performed on islands of the Caribbean, 2) data from serological surveys in animal populations obtained using MAT or isolation, and 3) data concerning serovar circulation. Articles describing *Leptospira* infection using PCR were excluded as PCR generally cannot give information on serogroup/serovar involved. Full text articles were also excluded if they provided insufficient data to determine whether inclusion criteria were met. Table 2 lists the criteria used for the inclusion of the article.

Data Extraction
The following data were extracted from the publications selected for inclusion, the author(s), year of publication, geographic location in which the study was conducted and the design of the study. Other extracted data included were the serovars used in the MAT panel, titre value considered positive, serovar prevalence recorded for each species tested and the animal species tested. Serovars are also recorded, when culture and characterization of isolates were available. A data extraction form was prepared and used to record relevant data.

Results
The database search resulted in a possible 95 articles using the criteria described in the methods. Of these, 18 did not fit the selection criteria, and 10 were rejected as duplicates. From the remaining articles, 25 studies examined the incidence in humans and another three documents used methods other than MAT and so did not fit the selection criteria. An additional three documents were excluded as they were review articles that described etiology and disease, leptospirosis or described leptospirosis in the Caribbean region in humans. Another nine studies

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were excluded as either no full text or abstract was available and six were excluded as they had been published in Spanish, with one in French, and no English abstract was available. A flow chart showing the selection of article is shown in the Figure 2. Twenty articles met the overall inclusion criteria, were selected and are listed (Table 3) with publication dates ranging from 1979 to 2014.

***Leptospira* Prevalence in various Caribbean islands:** The studies provided *Leptospira* seroprevalence data from 16 Caribbean islands. Much of the seroprevalence information came from a single study published by Levett *et al.*, in 1996 in livestock animals in the Lesser Antilles. This study encompassed 12 islands and used 22 *Leptospira* serovars for MAT testing. Variations in exposure to serovars were observed between islands in this study ranging from exposure to 0-9 serovars. Other relevant studies we identified are from Barbados (n=9), Trinidad (n=7) Grenada (n=3), Jamaica (n=2) Puerto Rico (n=1), Saint Croix (n=1). The number of serovars used in the MAT panel in these studies ranged from 2 to 23 (Supplemental Table 1.) The seroprevalence data for the individual islands are shown in tables 4-10.

Seroprevalence in animal species in the Caribbean: A list of various animal species and seroprevalence observed in various studies in the region are given in supplemental tables 2-16.

Cats: Only one study was identified in the region that surveyed cats on the island of Trinidad **(**Everard *et al*., 1979). A low seroprevalence in cats was observed 12.5% (5/40) for the serovars Shermani, Panama, Canicola and a mixed reaction of Canicola/Copenhageni was recorded. The serovar Canicola was isolated from a cat with a mixed serological reaction.

Cattle: Surveys on the Caribbean islands have recorded prevalence in cattle ranging from 0% in Nevis (Levett *et al.,* 1996) to 92% on the island of Trinidad (Everard *et al.*, 1985). On Trinidad, a second study conducted 25 years later found a reduced seroprevalence of 21.5% (Suepaul *et al.,* 2011).

Dogs: Canine seroprevalence studies conducted on Barbados, Puerto Rico and Trinidad, recorded seroprevalence in stray dogs to be 62% (48/78) (Weeks *et al*., 1997). This study found the most common serovars to be Autumnalis (45%), Icterohaemorrhagiae (16%), Australis (16%) and Pomona (13%). The study also tested acutely ill dogs that had been presented to a veterinary clinic on the island with a presumptive diagnosis of leptospirosis. The study found that 75% (46/61) of these animals tested positive by MAT. The most prevalent serovars being Icterohaemorrhagiae (36%), with Australis, Autumnalis and Ballum having little significance. In Puerto Rico, Farrington & Sulzer (1982), looked at leptospirosis in stray dogs and the seroprevalence was found to be 62.9% (73/116) with the serovar Icterohaemorrhagiae 72.6% (53/73) being the most common. Positive reactions were also recorded for the serogroups Andamana 8.2% (6/73) and Pyrogenes 4.1% (3/73). (Suepaul *et al.* 2010), conducted a further study in dogs and rodents on Trinidad. The group looked at two populations of dogs on the island. The first group were suspected cases of canine leptospirosis presented to local veterinarians, the frequency of isolation was found to be 18% (9/50) with the isolates been identified as the serovar Copenhageni. The second group studied were clinically healthy stray

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dogs, with the frequency of isolation found to be 3.4% (7/207) again with the serovar Copenhageni being identified.

In an earlier study looking at different populations of canines on Trinidad by Adesiyun *et al.,* (2006), the seroprevalence in the populations of suspected canine cases, stray dogs, hunting dogs, farm dogs and house dogs was found to be 48.0% (24/50), 4.4% (5/113) 25.5% (12/47), 20.4% (10/49) and 8.1% (13/160) respectively. The seropositivity of the dog populations as a whole was 15.3% (61/419). The serovars detected included Icterohaemorrhagiae 32.8% (20/61), Copenhageni 16.4% (10/61), Mankarso 47.5% (29/61), Bratislava 13.1% (8/61), Autumnalis 41% (25/61) and Ballum, Pomona, Georgia and Wolffi all at a prevalence of 1.6% (1/61) (Adesiyun *et al.,* 2006) with a number of dogs having positive reactions to more than one serovar. Seroprevalence studies looking at rats and studies involving isolation of *Leptospira* spp. from rats have shown them to be maintenance hosts and as such a source of infection for serovar Copenhageni in dogs on Trinidad (Suepaul *et al.,* 2010 and 2014). In an earlier study conducted on Trinidad by Everard *et al.* (1979), they found a seroprevalence of 20.0% in stray dogs with the predominant serovars being Canicola, Icterohaemorrhagiae and Hebdomadis, however, in the study by Adesiyun *et al.* (2006), the group recorded no positive reactors to the serovar Canicola in either stray dogs or in owned dogs suspected of having leptospirosis. This absence of the serovar Canicola has been noted in other countries. This change in predominant *Leptospira* spp. was also documented in a study by Weekes *et al.* (1997), on the island of Barbados. They reported that the serovar Autumnalis was the predominant serovar in canine *Leptospira* infection. However, in previous years (Damude *et al.*, 1997) it had never been recorded as the prevalent serovar. Serovar Bim also has been isolated from dogs in Barbados (Jones *et al.,* 1984). The difference in predominant serovar in the studies could indicate a similar change in the epidemiology of exposure. The prevalence was found to have increased during the second study (Suepaul *et al.,* 2010) where samples were collected at a time of higher temperatures and increased rainfall and mirrors the increase seen in prevalence in stray dogs at that time.

Horses In this review, in horses, seroprevalence ranged from 76% (66/87) horses and donkeys on the island of Trinidad (Everard *et al.,* 1985) to 61% on the island of Guadeloupe (Desvars *et al.,* 2011).

Mongoose: Mathias and Levett (2002) recorded the seroprevalence in mongoose on the island of Barbados as 40.7% (48/118) with positive reactors to the serogroup Autumnalis. They obtained isolates from four mongooses. The seroprevalence in mongoose was recorded as high (40.7%) but evidence of renal infection was found in only four animals (< 3%). In 1983, Everard *et al.,* recorded the seroprevalence of Grenadian mongoose to be 36% (71/200). *Leptospira* were isolated from the kidneys of 5.3% (10/190) of the mongoose, these isolates were identified as the serovars Copenhageni, Brasiliensis and Atchafalya (Tarassovi) (Everard *et al.*, 1983). On the island of Trinidad, the proportion of mongoose seropositive ranged between 33.3% and 51.1% (Everard & Green, 1976). In 1983, the seroprevalence in mongoose was recorded as 48% (Everard *et al.,* 1983). The serogroup Canicola was isolated from the kidneys of the captured mongoose (Everard *et al.*, 1976; Everard *et al.*, 1983) with an infectivity rate of 4.7% (5/106) (Everard *et al.*, 1976). These studies would seem to confirm that the mongoose is an infrequent

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carrier of *Leptospira* spp. on these islands. Within the Caribbean region, *Leptospira* spp. have been isolated previously from mongoose in Jamaica, Grenada and Trinidad (Everard & Everard, 1993).

Monkeys: In 1987, Baulu *et al.* recorded a seroprevalence of 42% in captured Vervet monkeys.

Pigs; In pigs seroprevalences ranged from 5% in Trinidad (Suepaul *et al.,* 2011) to 53%, again on Trinidad but several years earlier (Everard *et al.*, 1985).

Rodents: Suepaul *et al*., conducted a seroprevalence study on the island of Trinidad they found the seroprevalence in rats to be 16.5% (33/200) with all reactors to the Icterohaemorrhagiae serogroup. Suepaul *et al.* (2010), conducted a further study on the serovars that were isolated from dogs and rodents on the island. The study found that in rodents the frequency of isolation was 25.6%. This frequency of isolation was statistically greater than for the frequency of isolation in dogs (6.2%, 16/257) emphasising the importance of rodents as reservoirs of *Leptospira* on the island of Trinidad. The group found that the predominant serovar that was isolated was Copenhageni, 68.5% (37/54). However, this is contrast to the study conducted by Levett *et al.* (1998), who recorded a seroprevalence in Barbadian rats of 42%, and a frequency of isolation of *Leptospira* of 16%. Isolates were recovered from cultures of kidney, urine or blood. Using MAT that study also recorded the most prominent serovar as Copenhageni. The seroprevalence in rats on Barbados appears to have been slowly increasing over time. In the period 1964-1965 Taylor *et al.* (1991), recorded the seroprevalence in *Rattus rattus* as 33% (32.98) and 35% (48/138) in *Rattus norvegicus* and Levett *et al.* (1998), recording the prevalence as 42%. On the island of Barbados, Matthias & Levett (2002) recorded seroprevalence in mice to be 28.2% (24/85) with serogroups Ballum and Autumnalis being identified. *Leptospira* were isolated from the kidneys of 28 mice out of 97 tested and these isolates were identified as Arborea (n=17) and Bim (n=7).

Sheep and Goat: From the review, only limited studies were found on sheep on two separate occasions by two different groups of investigators. Damude *et al.* (1979), found the prevalence in sheep on the island to be 18% while Levett *et al.* (1996), recorded a prevalence of 4.3%. In goats, a prevalence rate as high as 40% was recorded in Belize, 19% in Barbados, (Damude *et al.*, 1979), while almost 20 years later a lower prevalence of 9.3% was found in goats (Levett *et al.*, 1996). A similar situation was documented on the island of Grenada where Everard *et al.* in 1985, recorded prevalence rates in goats of 35% and later Levett *et al.* (1996), recorded a prevalence of 19%.

Wildlife: Everard *et al.* (1983), recorded in the bats of the family *Pyllostomide*, on the island of Grenada, 21% (13/61) of *Anoura* spp. 8% (4/52) *Glossaphaga* spp. were found to be positive. None of the bat kidneys that were cultured gave a positive result. In the same study on the island of Trinidad, of the 8 species of bats caught, 4 species presented with a positive result using MAT (Everard *et al.*, 1983). Studies conducted on the island of Barbados, showed that amphibians there were carriers of *Leptospira* and from kidney tissue of toads (*Bufo marinus*) and frogs (*Eleutherodactylus johnstonei*) 2 pathogenic strains were isolated (Everard *et al.,* 1988, 1990; Gravekamp *et al.,* 1991). The studies showed that the most prevalent strain in amphibians was *L.*

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noguchii serovar bajan (Everard *et al.,* 1990; Gravekamp *et al.,* 1991), followed by the serovar bim (Everard *et al.*, 1988, 1990; Gravekamp *et al.,* 1991). These studies also noted that the serology of the toads from which isolates were recovered was not a good gauge of infection neither was it a reliable indicator of the infecting serogroup. On Grenada Everard *et al.* (1983), reported a seroprevalence of 15% (10/66) in the toad (*Bufo marinus*). From 2 of these animals the serovars navet (Tarassovi) and peruviana (Australis) were cultured. While on the island of Trinidad, Everard *et al*, (1983), showed that 25% (20/80) of the marine toads tested positive by MAT, whereas none of the lesser tree frogs captured (0/2) tested positive. Of other wildlife on the island of Trinidad, Everard *et al.* (1983), showed that of the family *Muridae*, 29% of rice rats (2/7) and 24% (4/17) of scaly-footed water rats were serologically positive.

Discussion

Reviewing the literature highlighted the limited amount of data available from a limited number of islands. Many of the studies conducted have recorded seroprevalences based on variable and small samples sizes. Besides, serovar panels used for MAT were not consistent between studies. MAT detects agglutinating antibodies to *Leptospira* generated mainly towards the lipopolysaccharide component of this bacterium. Although considered as serovar specific, cross reactivity, paradoxical reactions, false negative results in the early stages of infection and in the maintenance hosts are the common limitations of this test (Goris & Hartskeerl, 2014). These issues related to MAT testing are often underestimated when results are interpreted and reported. Therefore, combination of testing protocols targeting organism detection and exposure is needed to understand the true distribution of *Leptospira* within a population.

Successful *Leptospira* isolations were reported from few islands (isolations are indicated in tables when data is available). Two manuscripts reviewing *Leptospira* isolates from the region (Everard *et al.,* 1980; Jones *et al*., 1982) described the presence of diverse serogroups. Everard *et al*. (1980), described 80 *Leptospira* isolates belonging to 10 serogroups in Trinidad, 20 isolates belonging to 5 serogroups in Grenada and 2 isolates belonging one serogroup in St. Vincent from animals. Among 11 different serogroups described in this study, six were first discovered from the region emphasizing the presence of unique types of *Leptospira* in the insular locations described in these studies. Another important concern this review highlights, is the role of amphibians in the environmental contamination and transmission of *Leptospira* (Everard *et al.,* 1980). New serovars such as Bim and Bajan were isolated from Whistling frogs and Marine toads which are commonly found in the region and their role *Leptospira* maintenance and water contamination needs to be explored.

This review suggests that the *Leptospira* exposure in animals in a given geographic location may change with time and with climatic and environmental conditions, and highlights the continual need to conduct surveillance studies in tropical countries where the climate supports the survival of *Leptospira* in the environment. Our recent studies have recorded a high seroprevalence in vervet monkeys on Saint Kitts with significant difference in exposure and serovar exposed (Rajeev *et al*., 2016). While implementing these studies, specific attention must also be given to standardization of MAT panels and protocols and training across laboratories involved in testing. Further, animal and environment testing to isolate and identify circulating *Leptospira* spp. in a

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geographic region must be attempted. This is important as risk factors of *Leptospira* transmission changes and are favoured by change in climatic conditions, urbanization, human encroachment of wildlife inhabitation, import/export of animals, increase in travel, tourism, and water related recreational activities.

As much as animals and the environment can play a crucial role in the transmission of leptospirosis to humans, leptospirosis can have a negative impact on production and reproduction in animals and can affect livelihood of people especially those using the animals for subsistence. Future studies must be targeted to investigate the impact of animal leptospirosis in both human, animal and environmental health. This knowledge is important to implement geographically specific control programs to improve animal and human health.

Conclusion:

Leptospirosis is a leading zoonotic cause of morbidity and mortality and an underecognized public health issue in the Caribbean region where environmental and social conditions favors disease clusters occurring during adverse weather related events. Animal surveillance is vital in prevention and control of human leptospirosis but relevant studies are very limited. This review summarising the seroprevalence data in animal species in the Caribbean region highlighted the scarcity of data from the region and need for active animal surveillance.

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Figure 1: Map of the Caribbean region

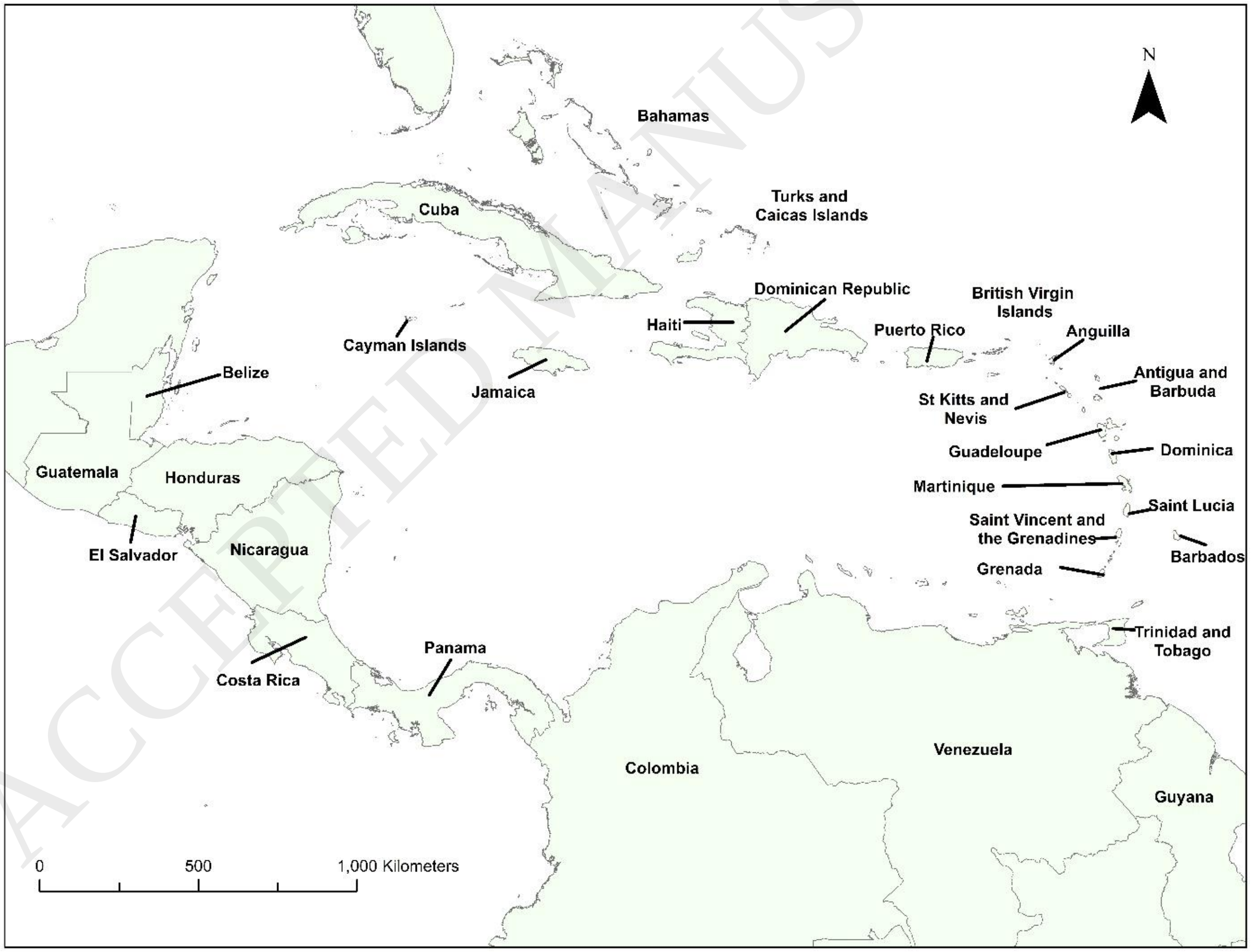

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Figure 2. Flow chart for the selection of articles.

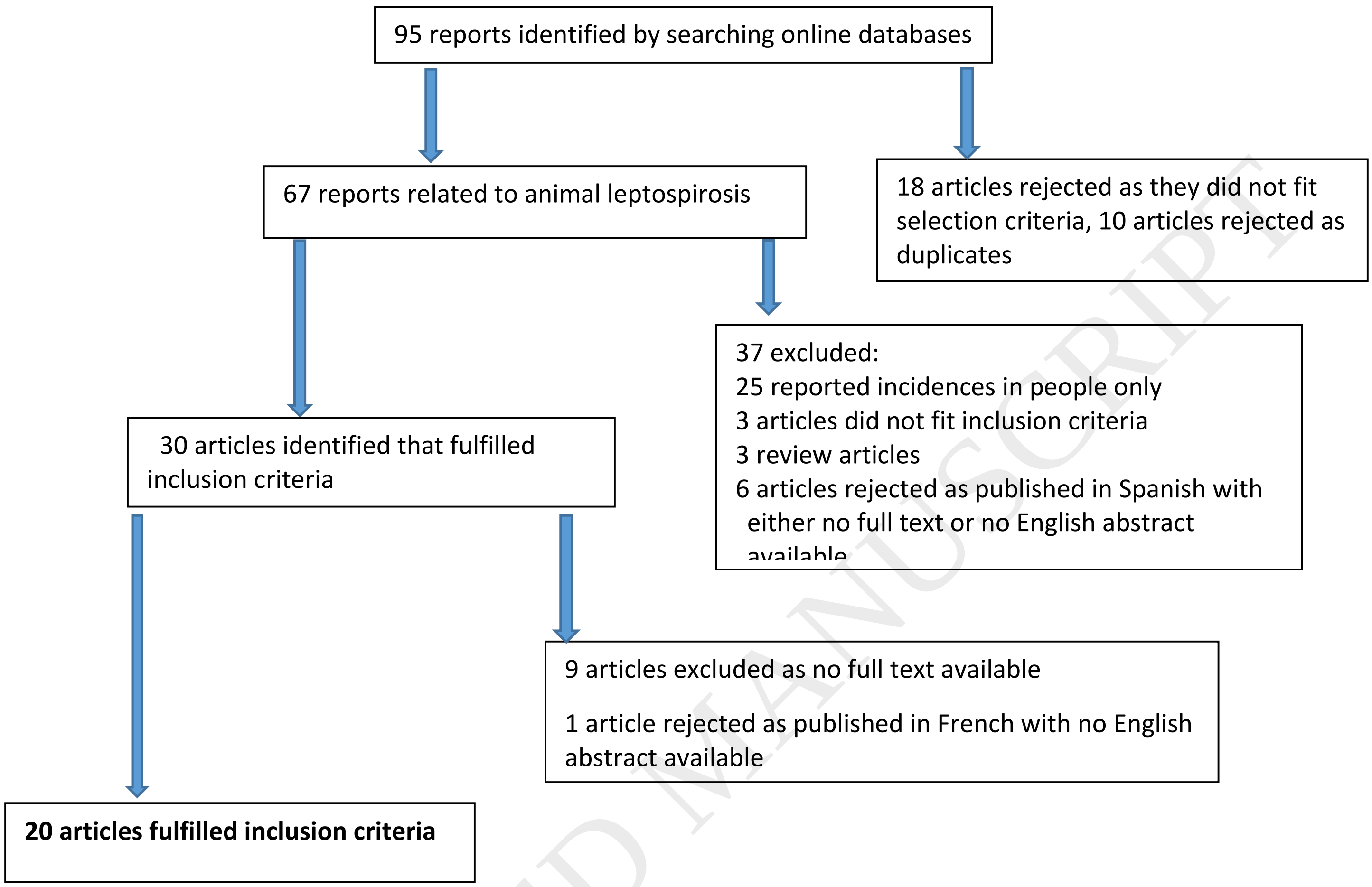

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Table 1. Full search terms used for database search. The search was conducted using the search string 'Leptospirosis' OR '*Leptospira*' and 'Caribbean'.

Database	Publication Date Limits	Search Strategy
EBSCOhost	1950 - Present	leptospira' OR 'leptospirosis' AND 'Caribbean' * AND 'animals'
PubMed Central	1950 -Present	(('leptospir*) AND Caribbean *
Science Direct	1950 - Present	leptospira' OR 'leptospirosis' AND 'Caribbean' * AND 'animals'
Springer Link	1950 -Present	leptospira' OR 'leptospirosis' AND 'Caribbean' * AND 'animals'
Wiley-Blackwell	1950 - Present	leptospira' OR 'leptospirosis' AND 'Caribbean' * AND 'animals'
Wiley Online	1950 -Present	leptospira' OR 'leptospirosis' AND 'Caribbean' * AND 'animals'
Bing	No limit	leptospira' OR 'leptospirosis' AND 'Caribbean' * AND 'animals'
Google	No limit	leptospira' OR 'leptospirosis' AND 'Caribbean' * AND 'animals'
Google Scholar	No limit	leptospira' OR 'leptospirosis' AND 'Caribbean' * AND 'animals'
Yahoo	No limit	leptospira' OR 'leptospirosis' AND 'Caribbean' * AND 'animals'

* a search was also conducted using the names of the individual islands; Bahamas, Turks & Caicos Islands, Cayman Islands, Cuba, Hispaniola (Haiti & Dominican Republic), Jamaica, Puerto Rico, Saint Croix, Saint Thomas, Saint John, Water Island, Tortola, Virgin Gorda, Aneyada, Jost Van Dyke, Anguilla, Barbuda, Redonda, Saint Maarten, Saba, Saint Eustatius, Saint Barthelemy, Saint Kitts & Nevis, Montserrat, Guadeloupe, Dominica, Martinique, Saint Lucia, Saint Vincent & the Grenadines, Grenada, Carriacou & Petite Martinique, Barbados, Trinidad & Tobago

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Table 2. Definitions of selection criteria. Full text articles were assessed with the above criteria to determine their suitability for inclusion.

Criteria for Inclusion
Pathogenic *Leptospira* spp. detected in animal populations
Pathogenic *Leptospira* spp. detected using MAT/isolation
Original study conducted on an island of the Caribbean
Animal populations including domestic and wild animals

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Table 3. The list of articles meeting inclusion criteria

Author	Study
Damude *et al.* (1979)	A study of leptospirosis among animals in Barbados W.I.
Everard *et al.* (1979)	Leptospirosis in dogs and cats on the island of Trinidad: West Indies
Farrington *et al.* (1982)	Canine leptospirosis in Puerto Rico
Everard *et al.* (1983)	Leptospirosis in wildlife from Trinidad and Grenada
Jones *et al.* (1984)	Bim, a new serovar of *Leptospira interrogans* isolated from a dog in Barbados
Everard *et al.* (1985)	Serological studies on leptospirosis in livestock and chickens from Grenada and Trinidad
Baulu *et al.* (1987)	Leptospires in vervet monkeys (*Cercopithecus aethiops Sabaeus*) on Barbados
Everard *et al.* (1988)	Leptospires in the marine toad (*Bufo marinus*) on Barbados
Everard *et al.* (1990)	Leptospires in the whistling frog (*Eeutherodactylus johnstonei*) on Barbados
Johnachan *et al.* (1990)	Serological survey for leptospiral antibodies in goats in St Elizabeth Parish, Jamaica, 1985-1986
Taylor *et al.* (1991)	Lepospires in *Rattus* spp. on Barbados
Ahl *et al.* (1992)	*Leptospira* serology in small ruminants on St Croix, U.S. Virgin Islands
Levett *et al.* (1996)	Serological survey of leptospirosis in livestock animals in the Lesser Antilles

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Weekes *et al*. (1997)	Seroepidemiology of canine leptospirosis on the island of Barbados
Levett *et al*. (1998)	Surveillance of leptospiral carriage by ferel rats in Barbados
Matthias & Levett (2002)	Leptospiral carriage by mice and mongooses on the island of Barbados
Adesiyun *et al*. (2006)	Sero-epidemiology of canine leptospirosis in Trinidad: Serovars, implications for vaccination and public health
Suepaul *et al*. (2010)	Serovars of *Leptospira* isolated from dogs and rodents
Suepaul *et al*. (2011)	Seroepidemiology of leptospirosis in livestock in Trinidad
Suepaul *et al*. (2014)	Seroepidemiology of leptospirosis in dogs and rats in Trinidad

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Table 4. Summary of *Leptospira* seroprevalence and serovars in animals on the island of Barbados.

Author	Species	Prevalence	Serogroup/Serovar
Damude *et al*. (1979); Study 1971-1972	Cattle	51% (571/1110)	Autumnalis, Hebdomadis, Ballum, Pyrogenes, Pomona, Canicola, Icterohaemorrhagiae, Tarassovi and Bataviae (NID)
	Pigs	13% (29/219)	Autumnalis, Australis, Ballum and Pyrogenes (NID)
	Sheep	18% (13/70)	Autumnalis, Pyrogenes, Bataviae and Ballum (NID)
	Horses	64% (28/44)	Pyrogenes, Autumnalis, Icterohaemorrhagiae and Pomona (NID)
	Goats	19% (5/26)	Autumnalis (NID)
Damude *et al.* (1979); Study 1975-1976	Clinically ill Cattle	81% (60/74)	Autumnalis, Hebdomadis, Ballum, Pyrogenes, Pomona, Canicola and Icterohaemorrhagiae (NID)
Jones *et al.* (1984)	Dogs	1.5% (2/130)*	Bim (50%) and Copenhageni (50%)
Baulu *et al.* (1987)	Vervet Monkeys	28.5% (184/646)	Ballum (61%), Icterohaemorrhagiae (16%), Autumnalis (15%), Pomona (1%), Pyrogenes (3%), Panama (2%), Canicola (1%) and Tarassovi (1%)
Everard *et al.* (1988)	Marine Toad	22% (47/211)	Australis (38.3%), Autumnalis (23.4%), Panama (10.6%), Canicola (4.3%) and Icterohaemorrhagiae (2.1%)
		1.9% (4/211)*	Bim (50%) and Australis (50%)
Everard *et al.* (1990)	Whistling frog Group I	6% (6/99)*	Bim (16.7%) and bajan (33.3%), 2 isolates died
	Group II	2.6% (3/117)*	Bajan (100%)
		12.8% (15/117)	Austrlis, Pyrogenes, Toad strain 60, Bratislava, Panama, Toad strain 60/67 and Copenhageni (NID)
Taylor *et al.* (1991); Study (1964-1965)	*Rattus norvegicus*	34% (47/138)	Icterohaemorrhagiae (recorded as predominant)
	Rattus rattus	30% (30/98)	Autumnalis (recorded as predominant)
Weekes *et al.* (1997)	Stray dogs	62% (48/78)	Australis (16%), Autumnalis (45%), Icterohaemorrhagiae (16%) and Pomona (13%)
	Acutely ill dogs	75% (46/61)	Icterohaemorrhagiae (36%), Australis (13%), Autumnalis and Ballum (NID)

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Levett *et al*. (1996)	Sheep	4.3% (1/23)	Cynopteri (100%)
	Goats	9.3% (4/43)	Cynopteri (100%)
Levett et al. (1998); First study 1986/87; Second study 1994/95	*Rattus rattus*	19% (12/63)*	Copenhageni (91.7%), Arborea (8.3%)
	Rattus norvegicus	16% (16/100)*	Copenhageni (56.2%), Arborea (31.2%) and Bim (6.2), 1 isolate lost
	Rattus spp.	19.1% (31/162)**	Icterohaemorrhagiae (60.3%), Ballum (23.3%), Autumnalis (9.8%), Canicola (3.2%) and Pyrogenes (3.2%)
Matthias & Levett (2002)	Mongoose	40% (48/118)	Autumnalis (recorded as predominant serovar)
		2.9% (4/136)*	No data on isolates
	Mice	28.2% (24/85)	Autumnalis (45.8) and Ballum (52%)
		28.9% (28/97)*	Arborea (61%) and Bim (25%) (4 isolates lost)

NID No individual data

* indicates the data from studies that have performed cultures and and characterized the isolates by serogrouping

** Serovars recorded in first study (1986/87) and the second study (1994/95)

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Table 5. Summary of *Leptospira* prevalence in various species on the island of Grenada.

Author	Species	Prevalence	Serogroup/Serovar
Everard *et al.* (1983)	*Anoura* spp. (Bats)	21% (13/61)	Icterohaemorrhagiae (8%), Hebdomadis (38%), Autumnalis (8%), Panama (23%), Tarassovi (8%), Bataviae (8%) and Canicola (8%)
	Glossophaga spp. (Bats)	8% (4/52)	Hebdomadis (25%), Autumnalis (25%), Tarassovi (25%) and Shermani (25%)
	Asian mongoose	36% (71/200)	Icterohaemorrhagiae (63%), Autumnalis (11%), Pryogenes (7%), Panama (8.5%), Bataviae (1.4%), Shermani (2.8%), Grippotyphosa (2.8%) and Javanica (2.8%)
	Marine toad	15% (10/66)	Hebdomadis (30%), Icterohaemorrhagiae (20%), Ballum (10%), Autumnalis (10%), Panama (20%) and Shermani (10%)
Everard *et al.* (1985)	Cattle	25% (80/324)	Icterohaemorrhagiae (26%), Autumnalis (23%), Hebdomadis (11%), Panama (3%), Canicola (6%), Pyrogenes (9%), Bataviae (1%), Ballum (4%), Tarassovi (3%), Javanica (4%) and Shermani (4%)
	Pigs	35% (45/130)	Autumnalis (27%), Icterohaemorrhagiae (24%), Hebdomadis (4%), Canicola (2%), Pyrogenes (2%), Grippotyphosa (2%), Ballum (7%) and Shermani (7%)
	Sheep	35% (51/146)	Autumnalis (55%), Icterohaemorrhagiae (10%), Pyrogenes (12%), Tarassovi (2%) and Canicola (2%)
	Goats	23% (10/44)	Autumnalis (30%), Pyrogenes (50%), Tarassovi (10%) and Grippotyphosa (10%)
	Chickens	11% (19/175)	Autumnalis (5%), Hebdomadis (42%), Grippotyphosa (5%), Tarassovi (5%) and Shermani (32%)
Levett *et al.* (1996)	Cattle	13.5% (5/37)	Pomona (20%), Sejroe (20%) and Pyrogenes (40%)
	Sheep	8.5% (6/71)	Autumnalis (17%), Bataviae (33%), Pomona (33%), Cynopteri (33%) and Pyrogenes (17%)
	Goats	19% (7/36)	Autumnalis (71%) and Cynopteri (29%)

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Table 6. Summary of *Leptospira* prevalence in dogs on Puerto Rico.

Author	Species	Prevalence	Serogroup/Serovar
Farrington & Sulzer (1982)	Stray dogs	62.9% (73/116)	Icterohaemorrhagiae (72.6%), Andamana (8.2%), Canicola (2.7), Australis (1.4%) and Pyrogenes (2.7%)

Table 7. Summary of *Leptospira* prevalence sheep and goats on Saint Croix.

Author	Species	Prevalence	Serogroups/Serovars
Ahl *et al.* (1992)	Goats	26% (11/42)	Autumnalis (31%), Ballum (14.3%), Bataviae (4.8%), Bratislava (28.6%), Canicola (7.1%), Copenhageni (2.4%) and Pyrogenes (11.9%)
	Sheep	32% (8/24)	Autumnalis (29.3%), Ballum (12.5%), Bataviae (4.2%), Bratislava (12.3%), Canicola (12.5%), Copenhageni (8.3%), Hardjo (12.5%) and Pyrogenes (8.3%)

Table 8. Summary of *Leptospira* prevalence in various species on Saint Kitts.

Author	Species	Prevalence	Serogroups/Serovars
Levett *et al.* (1996)	Cattle	4.8% (1/21)	Cynopteri
	Sheep	1.6% (1/62)	Cynopteri
	Goats	23.8% (5/21)	Autumnalis, Ballum, Cynopteri and Grippotyphosa

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Table 9. Summary of *Leptospira* prevalence in various animal species on Trinidad.

Author	Species	Prevalence	Serogroups/Serovars
Everard *et al*. (1979)	Stray Canines	20% (10/50)*	Canicola (20%), Icterohaemorrhagiae (10%), Portland-Vere (60%) and Hebdomadis (10%)
		55% (53/96)	Canicola (40%), Copenhageni (30%), Pyrogenes (15%), Hebdomadis (6%), Tarassovi (6%), Autumnalis (2%) and Grippotyphosa (2%)
	Cats	2.5% (1/40)*	Canicola (100%)
		12.5% (5/40)	Canicola (20%), Panama (20%) and Shermani (40%)
Everard *et al*. (1983)	Seba's short-tailed bat	11% (2/19)	Cynopteri (100%)
	Greater spear-nosed bat	27% (13/48)	Hebdomadis (53.8%), Autumnalis (7.5%), Cynopteri (15.2%), Tarassovi (7.5%) and Javanica (7.5%)
	Giant velvety-tailed bat	10% (2/20)	Javanica (100%)
	Jamaican fruit bat	0% (0/15)	
	American phyllotomine bats	0% (0/3)	
	Little big-eared bats	0% (0/8)	
	Asian Mongoose	46% (17/37)	Icterohaemorrhagiae (5.9%), Canicola (35.3%), Javanica (5.9%), Panama (11.8%), Pyrogenes (23.5%), Ballum (11.8%) and Bataviae (5.9%)
	Common opossum	5% (1/22)	Bataviae (100%)
	Woolly Opossum	5.5% (4/73)	Hebdomadis (25%), Javanica (50%) and Ballum (25%)
	Delphidia	7% (1/14)	Javanica (100%)
	Marsoma fuscata	0% (0/73)	
	Black Rat	16% (5/32)	Icterohaemorrhagiae (40%), Hebdomadis (20%) and Autumnalis (40%)
	Brown Rat	43% (3/7)	Autumnalis (33.3%) and Javanica (66.6%)
	Spiney Rats	22% (8/37)	Hebdomadis (12.5%), Javanica (37.5%) and Pyrogenes (50.0%)
	Kangaroo Rat	5.9%% (1/17)	Autumnalis (100%)
	Unidentified Rattus species	0% (0/7)	
	House Mouse	29% (2/7)	Icterohaemorrhagiae (100%)
	Climbing Mouse	0% (0/2)	
	Short-tailed Mouse	0% (0/1)	

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	Northern Grass Mouse	0% (0/1)	
	Other Mouse species	24% (4/17)	Hebdomadis (25%), Ballum (25%), Grippotyphosa (25%) and Javanica (25%)
	Capuchin Monkey	0% (0/2)	
	Black Vulture	0% (0/6)	
	Tupinabis lizard	45% (5/12)	Icterohaemorrhagiae (40%), Ballum (20%), Autumnalis (20%) and Javanica (20%)
	Ground Lizard	100% (4/4)	Icterohaemorrhagiae (100%)
	Green Iguana	100% (1/1)	Autumnalis (100%)
	Cane Toad	25% (20/80)	Icterohaemorrhagiae (10%), Hebdomadis (25%), Autumnalis (35%), Javanica (10%), Panama (5%) and Tarassovi (15%)
	Tree Frog	0% (0/2)	
	Semi-aquatic Rodents	28.6% (2/7)	Canicola (50%) and Javanica (50%)
Everard *et al*. (1985)	Cattle	92% (24/26)	Grippotyphosa (25%), Autumnalis (17%), Hebdomadis (33%), Grippotyphosa (25%) and Ballum (4%)
	Pigs	53% (65/122)	Icterohaemorrhagiae (56%) and Autumnalis (29%)
	Horses/Donkeys	76% (66/87)	Panama (23%), Icterohaemorrhagiae (15%), Canicola (9%) and Hebdomadis (9%)
	Chickens	11% (16/87)	Autumnalis (6%), Hebdomadis (25%), Canicola (6%), Tarasovi (13%) and Shermani (50%)
	Ducks/Geese	0% (0/8)	
Adesiyun *et al*. (2006)	Suspected Canine Cases	48% (24/50)	Autumnalis (41.7%), Bratislava (20.8), Copenhageni (29.2), Icterohaemorrhagiae (50%) and Mankarso (62.5%),
	Stray canines	4.4% (5/113)	Autumnalis (40%), Ballum (20%), Icterohaemorrhagiae (40%) and Mankarso (40%)
	Hunting Canines	25.5% (12/47)	Autumnalis (70%), Bratislava (30%), Pomona (10%) and Wolffi (10%)
	Farm Canines	20.4% (10/49)	Autumnalis (30%), Ballum, Georgia (10%) and Mankarso (60%)
	House Canines	6.25% (10/160)	Autumnalis (40%), Ballum (2.7), Bratislava (8.1%), Copenhageni (8.1%), Georgia (2.7%), Icterohaemorrhagiae (21.6%), Mankarso (37.8%), Pomona (2.7%) and Wolffi (2.7%)
Suepaul *et al*. (2010)	Rodents	2.4% (5/211)*	Copenhageni (79.1%), Icterohaemorrhagiae (2.3%), Mankarso (11.6%), Inconclusive (7 %)***
	Suspected Canine Cases	18% (9/50)*	Copenhageni (100%)***
	Healthy Stray Canines	3.4% (2/207)*	Copenhageni (50%), Inconclusive (50%)***

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Suepaul *et al.* (2011)	Cattle	21.5% (127/590)	Icterohaemorrhagiae (4.4%), Copenhageni (1.5%), Mankarso (3.4%), Bim (0.68%), Hebdomadis (1.0%), Bratislava (0.17%), Arborea (1.0%), Ballum (3.1%), Autumnalis (1.2%), Panama (0.34%), Hardjo (3.9%) and Sejroe (0.17%)
	Sheep	5% (11/222)	Icterohaemorrhagiae (1.4%), Copenhageni (0.45%), Mankarso (0.45%), Bim (1.4%) and Autumnalis (1.4%)
	Goats	3.3% (6/180)	Icterohaemorrhagiae (0.56%), Copenhageni (1.7%) and Mankarso (1.1%)
	Pigs	5% (10/200)	Icterohaemorrhagiae (0.5%), Copenhageni (0.5%), Mankarso (1.5%), Bratislava (2.0%) and Ballum (0.5%)
Suepaul *et al.* (2014)	Stray dogs	15.5% (32/207)	Icterohaemorrhagiae (31%), Mankarso (25%), Copenhageni (38%), Bim (3%) and Hebdomadis (3%)
	Suspected cases	72% (36/50)	Icterohaemorrhagiae (3%), Copenhageni (61%), Mankarso (19%), Bim (6%), Bratislava (3%), Arborea (6%) and Ballum (3%)
	Rats	16.5% (32/200)	Icterohaemorrhagiae (34%), Copenhageni (59%) and Mankarso (9%)

*indicates the data from studies that have performed cultures and and characterized the isolates by serogrouping

***indicates the isolates were grouped in to serogroup/serovars using the monoclonal antibodies

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Table 10. Summary of seroprevalence of *Leptospira* in goats on the island of Jamaica

Author	Species	Herds	Serogroup/Serovar
Johnachan *et al.* (1990)	Goat	21 Family Herds	Canicla (57%), Icterohaemorrhagiae (18%) Jules (22%), Pomona (14%), Grippotyphosa (6%), Portland-Vere (54%) and Hardjo (20%)
		5 Commercial Herds	Canicola (55%), Icterohaemorrhagiae (9%), Jules (22%), Pomona (0.3%), Portland-vere (61%) and Hardjo (6%)
		ADC Facility	Canicola (39%), Icterohaemorrhagiae (6%), Jules (11%), Grippotyphosa (4%), Portland-vere (41%) and Hardjo (0.6%)
	Sheep	ADC Facility	Canicola (76%), Icterohaemorrhagiae (18%), Jules (15%), Pomona (4%), Grippotyphosa (nt), Portland-vere (51%) and Hardjo (0.5%)

(nt) - not tested

ADC Facility - Agricultural Development Corportation Hounslow

Data represents averages of all sampling

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