Transboundary and Emerging Diseases

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ORIGINAL ARTICLE

Dog Ecology and Barriers to Canine Rabies Control in the Republic of Haiti, 2014-2015

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Summary

An estimated 59 000 persons die annually of infection with the rabies virus worldwide, and dog bites are responsible for 95% of these deaths. Haiti has the highest rate of animal and human rabies in the Western Hemisphere. This study describes the status of animal welfare, animal vaccination, human bite treatment, and canine morbidity and mortality in Haiti in order to identify barriers to rabies prevention and control. An epidemiologic survey was used for data collection among dog owners during government-sponsored vaccination clinics at fourteen randomly selected sites from July 2014 to April 2015. A total of 2005 surveys were collected and data were analysed using parametric methods. Over 50% of owned dogs were allowed to roam freely, a factor associated with rabies transmission. More than 80% of dog owners reported experiencing barriers to accessing rabies vaccination for their dogs. Nearly one-third of the dog population evaluated in this study died in the year preceding the survey (32%) and 18% of these deaths were clinically consistent with rabies. Dog bites were commonly reported, with more than 3% of the study population bitten within the year preceding the survey. The incidence of canine rabies in Haiti is high and is exacerbated by low access to veterinary care, free-roaming dog populations and substandard animal welfare practices. Programmes to better understand the dog ecology and development of methods to improve access to vaccines are needed. Rabies deaths are at historical lows in the Western Hemisphere, but Haiti and the remaining canine rabies endemic countries still present a significant challenge to the goal of rabies elimination in the region.

Introduction

Rabies is an invariably fatal encephalomyelitis caused by a group of neurotropic viruses in the genus Lyssavirus (family Rhabdoviridae). The most widely distributed species, *rabies virus*, is found on every continent except Antarctica and Australia, and circulates in more than 20 known terrestrial animals and 16 New World bat species. The broad range of reservoir animals and environments in which this virus is found creates a complex ecologic and epidemiologic dynamic that intricately links the health of humans, animals and the environment. As a result of this complex interaction, it is estimated that, globally, 20 million people are vaccinated as a result of rabies exposures each year, and an additional 59 000 people die (Hampson et al., 2015).

Domestic dogs are responsible for over 95% of the global human rabies burden (World Health Organisation, 2013). Effective canine rabies control and elimination programmes have been implemented since at least the 1960s through mass vaccination of dogs, dog population management and disease surveillance (Meslin et al., 1994; Velasco-Villa et al., 2008). North America, Western Europe and a host of island nations have successfully eliminated canine rabies (Vigilato et al., 2013a; Fooks et al., 2014). These efforts have also been successful in Latin and South America, where a Pan American Health Organization (PAHO) programme has supported the important tenets outlined above with a consequent 95% decline in dog-transmitted human rabies deaths in the Americas between 1980 and 2012 (Vigilato et al., 2013a,b).

Unfortunately, the successes observed in much of the Western Hemisphere have not been mirrored in several of the most economically unstable countries in the region, including Bolivia, Guatemala and Haiti (Vigilato et al., 2013b). Haiti is the poorest country in the Western Hemisphere and has been afflicted by natural disasters and political instability for decades (Alsan et al., 2011). The ensuing socio-economic instability has taken a toll on rabies prevention efforts, resulting in inconsistent mass rabies vaccination campaigns, limited capacity to perform human and animal rabies surveillance, and poor dissemination of rabies biologics for post-exposure prophylaxis (PEP) in humans (Vigilato et al., 2013a). As of 2015, Haiti has the highest burden of human rabies in the Western Hemisphere, at 130 estimated deaths per year (Hampson et al., 2015).

Dog rabies vaccination is the primary component of a rabies control programme; however, reaching the recommended 70% vaccination levels in dogs can be challenging in resource-limited countries (Jackman and Rowan, 2007). To overcome these challenges, Kitala et al., 2000, 2001 proposed that surveys could be used to elucidate dog populations, dog distributions, turnover rates and access to vaccines, thereby opening inroads to address barriers to successful vaccination programmes (Kitala et al., 2000, 2001). These barriers are often addressed through animal welfare programmes, which monitor population health of domestic animals. However, animal welfare (i.e. the promotion of animal health through veterinary care, appropriate sheltering, management of nutrition and humane handling) is a concept that is rarely a primary focus of rabies control programmes and little information is available regarding welfare of dogs and its impact on rabies control in Haiti (World Bank, 2015). A study conducted directly after the 2010 earthquake in an urban Haitian community found that the majority of owned dogs were allowed to roam freely (65%), few had been sterilized (6%), and rabies vaccination rates were below the recommended threshold of 70% for herd immunity (42%) (Fielding et al., 2012). This study builds upon previous research by describing animal welfare, animal vaccination practices, human bite treatment, and dog morbidity and mortality in Haiti in order to identify barriers to rabies prevention and control.

Methods

Research design and population

An epidemiologic survey was administered to dog owners who participated in government-sponsored rabies vaccination clinics from July 2014 to April 2015. The survey tool consisted of 16 questions pertaining to animal care, rabies vaccination, the nature of deaths of owned animals, occurrences of dog bites and recognition of rabies in the community (Appendix S1). The survey was intentionally brief in order to capture basic data from a wide number of animal owners without delaying the primary goal of animal vaccination, thus allowing for a valid characterization of dog ownership practices and animal welfare in a spectrum of socio-economic communities in Haiti. Survey questions were administered orally in Creole and receiving the vaccine was not contingent on completing the survey. Surveyors were trained during the first survey day in the site of Delmas. Minor corrections in data collection were instituted based on findings from the training.

Haiti is politically divided into ten departments, which are further divided into 42 arrondissements and 147 communes. A random number generator was used to select 14 communes for participation in this study (Table 1). The fourteen sites were located in four departments: Ouest (west), Sud (south), Nord-Est (north-east) and Artibonite (geographically, central-north). The selected sites represented areas of rural, semi-urban and urban communities. Global Positioning System (GPS) coordinates were used to tag each site selected for data collection. The survey methodology used a convenience sample of offering participation to every person who brought his or her dog(s) to the vaccination clinic for rabies vaccination.

Data analysis

Survey data were entered into Microsoft Access. Data were exported to Statistical Analysis System (version 9.3, SAS Institute Inc., Cary, NC, USA), where the data were cleaned. Survey sites were classified according to population density: fewer than 200 persons per square kilometre were classified as rural, between 200 and 1000 as semi-urban and greater than 1000 as urban. Results were stratified and analysed according to rural, semi-urban and urban communities. Where affirmative responses were given by respondents but a requested numeric value was not

Table 1. Sites selected for data collection

Site	Department	Settlement type	Population density (Km2)	Date of collection	Surveys completed
Arcahaie	Ouest	Rural	175	4/7/2015	162
Carrefour	Ouest	Urban	7059	10/6/2014	136
Croix-des-Bouquets	Ouest	Rural	109	7/17/2014	191
Delmas	Ouest	Urban	5000	7/10/2014	258
Dessalines-Marchand	Artibonite	Semi-Urban	391	1/26/2015	106
Gonaïves	Artibonite	Urban	1429	1/27/2015	92
L'èstere	Artibonite	Rural	195	1/28/2015	54
La Chapelle	Artibonite	Rural	149	2/24/2015	10
Ouanaminthe	Nord-Est	Rural	132	12/17/2014	218
Port-au-Prince	Ouest	Urban	5000	10/1/2014	112
Saint-Marc	Artibonite	Urban	1834	12/15/2014	164
Sannet	Ouest	Semi-Urban	400	7/14/2014	348
Torbeck	Sud	Semi-Urban	291	10/15/2014	69
Verrettes	Artibonite	Urban	799	12/22/2014	85

provided, a value was imputed based on a calculated mean stratified by urban, semi-urban, rural values; however, if missing values comprised more than 10% of the overall dataset, values retained a value of 'missing' for analysis.

Data were analysed for the following descriptive outcomes: dog confinement, resources provided to dogs, current dog health and the nature of previously owned-dog deaths, and frequency of dog bites. Respondents were asked to classify the confinement status of their dogs as: dogs which always stay at home, dogs which always roam unsupervised or dogs which roam unsupervised at least part of the time. Owners were asked about resources they provide to their dogs as well as resources provided to dogs they do not own, including food, water, shelter and veterinary care. Causes and frequency of household dog deaths during the year prior were requested with the following categories offered as owner-reported causes of death: disease, hit by car, intentionally killed, natural causes (old age), exposure and unknown. Dog owners were further queried about dog deaths within the year prior, for which the dog displayed at least two of the following clinical signs immediately preceding death: hypersalivation, aggressiveness, biting, difficulty walking or change in the dog's bark. These instances are referred to as deaths with 'rabies-like illness' (RLI). When applicable, Cochran's chi-square tests were calculated to determine associations between variables. When applicable, odds ratios (ORs) and Cochran tests for association were calculated to determine the relationship between variables.

Information on human household size and dog bite events in the past year was recorded to calculate the annual dog bite incidence in these communities. The size of household dog populations was enumerated by including all reported owned dogs among the survey population. This value – household dog population – was used as the denominator for rate calculations: dogs per person, dogs per household and dog vaccination rates (pre- and post-campaign). The total owned-dog population from the surveyed population segments was obtained through the sum of owned dogs (currently alive) and owned dogs reported to have died within the past year. Annual dog population turnover rates are displayed as dog deaths per total owned-dog population.

Results

Dog and household population overview

A total of 2005 respondents completed the survey, representing a study population of 12 073 when taking into account all members of the respondents' households (Table 2). The median age of respondents was 29 years and 63% were male (data not shown), compared to a national median age of 22.7 years and 49% male (ref CIA Fact-Book). The average household size was 6.0 persons. Roughly 38% (n = 762) of respondents were from urban communities, 30% (n = 608) were semi-urban, and 32% (n = 635) were rural. Survey respondents reported owning 3485 dogs at the time the survey was conducted (1.7 dogs per dog-owning household, approximately 1 dog for every 3 people in dog-owning households). Urban communities had an average of 1.5 dogs per household, while semi-urban and rural areas had averages of 1.8 and 1.9, respectively. Urban and semi-urban dog owners reported 54% and 62% of dogs were allowed to roam freely all or part of the time; dog roaming was more frequent in rural areas (70%, P = 0.002). Across all study sites, 14% of dogs were reported to roam streets at all times.

Table 2. Demographics of dog-owning households (n = 2005)

	Urban n (%)	Semi-Urban n (%)	Rural n (%)	Total N (%)
Dog-owning households	762 (38.00)	608 (30.32)	635 (31.67)	2005 (100.0)
Dogs per household	1.53	1.79	1.93	1.74
Household persons	4369 (36.18)	3772 (31.24)	3932 (32.57)	12 073 (100.0)
Dogs per person	0.27	0.29	0.31	0.29
Dog confinement status[c]				
Always home	501 (42.89)	385.5[b] (35.37)	359 (29.26)	1245.5 (35.74)
Always roam	160 (13.70)	189.5[b] (17.39)	131 (10.68)	480.5 (13.79)
Home and roam[a]	470 (40.24)	496 (45.50)	693 (56.48)	1659 (47.60)
Unreported status	37 (3.17)	19 (1.74)	44 (3.59)	100 (2.87)
Total owned dogs	1168 (100.00)	1090 (100.00)	1227 (100.00)	3485 (100.00)

[a]'Home and Roam' refers to dogs that were reported to spend part of their time at home and part of their time roaming unsupervised outside of the owner's property.
[b]As stated in methods, stratum-specific imputation methods were used when less than 10% of data were missing. This may result in non-integer values for dog counts.
[c]The Cochran chi-square test of association for dog confinement status showed a significant difference between confinement and rural–urban community status (value 92.0, P-value <0.001).

Animal ownership practices

The majority of respondents reported that they provided their dogs with food (93%) and water (77%) (Table 3). However, only 26% of dog owners provided shelter and only 15% provided any level of veterinary care to their dogs. Only 5% of dogs received the four basic resources of animal ownership measured in this study: food, water, shelter and veterinary care. Six per cent of dog owners reported that they do not provide their dogs with any of the four resources assessed. In addition to care for owned dogs, 62% (n = 1243) of respondents provided some form of care to dogs in the community that they did not own ('community dogs'); the most frequently reported resource was food (58%). Food was also the resource that showed the most variability in provision; the odds of a survey respondent providing food to an owned dog were 9.7 (95% CI: 8.0–11.8) times greater than the odds of providing food to a community dog. The odds of providing all four resources of care to an owned dog were 6.5 (95% CI: 3.8–11.1) times greater than the odds of providing these four resources to a community dog.

Dog morbidity and mortality

Over half of respondents (59%) reported at least one death of an owned dog in the year preceding the survey, a total of 1666 deaths among the study population (Table 4). The total 1-year dog population from the surveyed population segments was determined to be 5151 (deceased + alive dogs). These 1666 dog deaths represented a population turnover rate of 32.3%. The majority of owned-dog deaths were the result of disease or illness (25.5%), followed by intentional killings (24.4%). Death due to cars contributed to an additional 23.3% of dog deaths. Less than 1% of owned dogs were reported to have died due to natural causes (old age), and the circumstance of death was unknown for 21%. In semi-urban areas, dogs were most commonly reported to have died from intentional killings (27.7%) and disease was the most common cause of death in rural areas (31.8%). Disease was a significantly more commonly reported cause of death in rural communities ($P < 0.001$). Dogs in urban and semi-urban communities were significantly more likely to die from car accidents, as compared to rural settings ($P = 0.033$).

Dog deaths due to RLI were common, with 10% of dog-owning households reporting at least one RLI death in the year preceding the survey. A total of 306 owned dogs died of RLI (18.4% of all dog deaths). Rural areas experienced the highest rate of RLI, at 80.4 dogs per 1000 total owned dogs; the lowest RLI rate was observed in urban areas, at 43.5 RLI dogs per 1000 owned dogs ($P < 0.001$).

Dog vaccination

Official government statistics report vaccination coverage as the number of vaccinated dogs compared to the number of dogs reported owned by vaccination attendees. Per this method, rabies vaccination coverage was most successful in urban areas, as 94% of respondents' dogs were vaccinated during the campaign (Table 5). Rural areas experienced the lowest coverage; 82% of respondents' dogs were vaccinated. While these reported vaccination rates exceeded the established minimum coverage of 70% for achieving herd immunity against rabies, the proportion of household dog owners who did not participate in the vaccination campaign, and the total dog population in these communities,

Table 3. Care provided to owned and community dogs (N = 2004)

Type of care	Community dogs		Owned dogs[c]		Odds ratio
	Frequency	% of total respondents	Frequency	% of total respondents	(95% CI)[d]
Care combinations	*n*	%	*n*	%	
No care provided	747	37.28	116	5.80	40.2 (22.9 – 70.7)
Any care provided	1257	62.72	1884	94.20	4.2 (2.5 – 7.1)
Full care provided[b]	16	0.80	100	5.00	Ref
Total respondents[a]	2004		2000		
Type of care provided					
Food	1169	58.33	1863	93.15	
Water	771	38.47	1546	77.30	
Shelter	104	5.19	529	26.45	
Veterinary care	82	4.09	303	15.15	
Other (unspecified)	6	0.30	0	0.00	
Total respondents[a]	2004		2000		

[a]5 observations excluded from 'Owned Animals' and 1 observation excluded from 'Community Animals' because of missing data due to contradictory answers to survey questions 9 and 13, respectively.

[b]'Full care' is defined as providing all four measured forms of care: food, water, shelter and veterinary care.

[c]'Community dog' is defined as an animal that the respondent did not report as his/her own animal (see appendix S1, question 13).

[d]Tests of association could not be calculated for 'Type of Care Provided', as the survey respondent could select multiple responses.

are unknown. Therefore, only individual household vaccination rates can be determined; extrapolation to the broader community is not possible.

Fifty-five per cent of respondents reported owning at least one dog that had never been vaccinated against rabies prior to the current vaccination campaign. In total, 81.2% of respondents with unvaccinated dogs cited a lack of available vaccine either at the veterinarian or from government-sponsored campaigns as the primary reason for having unvaccinated dogs. The vaccine may be more accessible in urban locations, where only 65.2% reported access as a reason for not vaccinating dogs. Semi-urban and rural respondents cited lack of access to vaccine as a reason for not vaccinating dogs 91.7% and 88.4% of the time, respectively. Lack of knowledge about the need for rabies vaccination was infrequently cited (4%).

Exposures and need for PEP

Respondents reported that 384 members of their households experienced a dog bite in the year preceding the survey (3.2% of study population) (Table 6). Bite incidence was higher in rural communities (4.0%) compared to urban (3.5%) and semi-urban (2.0%) communities ($P < 0.001$). Denominator data were not available to calculate an age-stratified bite rate; however, the proportion of total bites directed at children was calculated and varied from urban (19.7%) to rural (44.0%) communities ($P < 0.001$). Fifty-two respondents (2.5%) reported to have known 24 unique individuals who had died after being bitten by a dog or from a disease called 'rabies'. The majority of deaths from 'rabies' were reported from rural communities (n = 11).

Discussion

Epidemiologic surveys that focus on the demographics of dog populations and owner provision of care are useful for characterizing the human–animal relationship, which can vary greatly depending on cultural practices and beliefs (Arechiga Ceballos et al., 2014). Haiti is one of the poorest countries in the world, which may negatively impact domestic animal health (Vigilato et al., 2013a; World Bank, 2015). Understanding the human–dog relationship in Haiti is critical for the development of improved vaccination programmes, rabies surveillance and educational messaging. Barriers to rabies control in Haiti likely also exist in other developing countries; therefore, recommendations developed from this study are likely to be widely applicable to programmes in countries of similar socio-economic status in Africa, Asia and the rest of the developing world (Lembo et al., 2010; Arechiga Ceballos et al., 2014).

Table 4. Reported dog owned deaths and all-cause mortality in the past year by settlement type (N = 2005)

Cause of death	Urban		Semi-Urban		Rural		Total	
	Freq.	Col[f]%	Freq.	Col %	Freq.	Col %	Freq.	Col %
Hit By Car	157	26.08	130	25.34	101	18.33	388	23.29
Intentional killing[a]	129	21.43	142	27.68	135	24.50	406	24.37
Disease[j]	117	19.44	133	25.93	175	31.76	425	25.51
Natural causes	1	0.16	6	1.17	3	0.54	10	0.60
Exposure[b]	1	0.16	3	0.58	11	2.00	15	0.90
Other	26	4.32	18	3.51	26	4.72	70	4.20
Unknown cause	171	28.41	81	15.79	100	18.15	352	21.13
Total dog deaths[d, e]	602	100.00	513	100.00	551	100.00	1666[h]	100.00
RLI deaths[c, e, g]	77	4.35	86	5.36	143	8.04	306[i]	5.94
Non-RLI causes of death	525	29.66	427	26.64	408	22.95	1360	26.40
Living dog population	1168	65.99	1090	68.00	1227	69.01	3485	67.66
Total Est. dog population	1770	100.00	1603	100.00	1778	100.00	5151	100.00

[a]Specific listed causes of mortality due to 'killing' included 'shot', 'electrified,' poisonings, death due to a knife or lethal injections.

[b]'Exposure' refers to environmental or accidental causes of death, such as heat, starvation or dog injuries resulting in death.

[c]Rabies-like illness (RLI) measured as responding positively to at least 2 of the following clinical signs: *Hypersalivation, Aggressiveness, Biting people or animals, Difficulty Walking or Change in the Dog's Voice.*

[d]Where a positive response to a cause of death was indicated but no dog count was given, a response of '1' was substituted for the number of dog deaths for the indicated cause of death.

[e]Cochran's chi-square test of association was applied to type of dog death as well as Rabies-like illness (RLI), as compared to rural–urban community type. For dog deaths, the Cochran value was 71.0 (P-value <0.001). For RLI, the Cochran value was 34.5 (P-value <0.001).

[f]'Col %' refers to the relative proportion of the row within each column.

[g]Rates: 59 per 1000 dogs have RLI; 184 per 1000 dog deaths attributable to RLI.

[h]The 1666 owned-dog deaths were reported from 1183 households (59% of survey respondents).

[i]The 306 RLI owned-dog deaths were reported from 205 households (10% of survey respondents).

[j]84 reported RLIs were cleaned to be reported as 'disease/illness' because they exceeded the total number of reported dog deaths (5.04% of total dog deaths).

Animal welfare and population management

Dog ownership rates have previously been described in a focal urban population in Haiti, where prior to the 2010 earthquake it was estimated that there were 1.83 dogs per household. That figure fell to 1.40 in the year after the disaster (Fielding et al., 2012). This decline in dog ownership was attributed to displacement of both people and animals in the months after the earthquake, which resulted in an increase in the street dog population. We report that in 2014–2015, 5 years after the earthquake, the average number of dogs per household was 1.53 in urban communities. This intermediate ratio may indicate that urban owned-dog populations are increasing back to pre-earthquake levels. The owned-dog population had never been described in non-urban settings prior to this study, which found that rural homes kept 25% more dogs, on average, compared to urban homes. This finding is important to consider for planning vaccination campaigns and suggests that simplistic dog population extrapolations based on human density may be inaccurate if generically applied across all rural–urban settings.

In 2012, the World Organization for Animal Health (OIE) Pathway for Effective Veterinary Services (PVS) reported that veterinary resources in Haiti were inadequate to effectively fight animal diseases, including zoonoses (OIE, 2011; Fermet-Quinet, 2012). Consistent with the findings in this report, veterinary care was rarely accessed by dog owners, at only 15% of respondents. Low accessibility to veterinary care is likely associated with the dearth of qualified veterinarians in Haiti, with only 43 registered with the Ministry of Agriculture as of 2013 (0.4 veterinarians per 100 000 people). In comparison with other developing countries, the number of veterinarians per capita in Haiti is among the lowest in the world. Programmes to promote veterinary education and retain qualified veterinarians should be considered in Haiti and other countries which lack adequate veterinary infrastructure.

The One Health Theory supports the inextricable connection between the health of animals, humans and the environment (Osburn et al., 2009). Enzootic diseases, such as rabies, are most commonly spread outside of the home among dogs in the local community. Although humans can contract these diseases outside of the home, owned dogs

Table 5. Reported reasons for owning dogs without a history or rabies vaccination[a] among participants of a government-sponsored canine rabies vaccination clinic (*n* = 1095)[b]

Dog vaccination coverage	Urban *n* (%)	Semi-Urban *n* (%)	Rural *n* (%)	Total *N* (%)
Pre-vaccination rate	551 (47.2)	543 (49.8)	619 (50.4)	1713 (49.2)
Post-vaccination rate[d]	1092 (93.5)	940 (86.2)	1002 (81.7)	3034 (87.1)
Reason for not vaccinating				
No money to vaccinate	105 (27.6)	44 (16.0)	10 (2.3)	159 (14.5)
No vaccine available from vet	178 (46.84)	180 (65.5)	239 (54.3)	597 (54.5)
No vaccine available from government	70 (18.4)	72 (26.2)	150 (34.1)	292 (26.7)
Lack of knowledge	11 (2.9)	13 (4.7)	14 (3.2)	38 (3.5)
Other reason	50 (13.2)	22 (8.0)	40 (9.1)	112 (10.2)
Total respondents[c]	380	275	440	1095

[a]Owners who reported that their dogs were too young to vaccinate were excluded from this table because their dogs were ineligible for vaccination.
[b]910 (45.39% of total) observations excluded from table because no reasons were reported.
[c]Multiple responses were indicated among some respondents, so column frequencies do not equal column total, and responses total more than 100%.
[d]The Cochran chi-square test of association for dog vaccination showed a significant difference between rural–urban community status (value 125.0, *P*-value <0.001)

Table 6. Reported incidence of dog bites among household members within the year preceding the survey and ever-known human deaths due to rabies (*n* = 2005)

Type of bite	Urban *n* (%)	Semi-Urban *n* (%)	Rural *n* (%)	Total *N* (%)	Cochran chi-square test of association (*P*-value)[c]
Total household bites[b]	152 (3.48)	75 (1.99)	157 (4.00)	384 (3.18)	27.1
Adult bites	122 (80.26)	54 (72.0)	88 (56.01)	264 (68.75)	2
Child bites[a]	30 (19.74)	21 (28.0)	69 (43.95)	120 (31.25)	<0.001
No reported bites	4217 (96.52)	3697 (98.01)	3775 (96.01)	11 689 (96.82)	
Total population	4369 (100.00)	3772 (100.00)	3932 (100.00)	12 073 (100.0)	
Type of human death					
Deaths from dog bites	4	0	5	9	
Deaths from 'Rabies'	3	1	11	15	
Total human rabies deaths	7	1	16	24	
Total respondents reporting known human rabies death	7	1	44	52 (2.6)	

[a]'Child' is defined as any respondent or household member under the age of 18.
[b]Bite rate: 32 per 1000 population.
[c]The Cochran chi-square test of association for household bites showed a significant difference between rural–urban community type (value 27.1, *P*-value <0.001)

that roam can carry diseases contracted in the community into the household, increasing the potential for exposure to disease among household members. Therefore, proper shelter and animal movement control are critical to limiting the risk of disease exposures and improving the overall health of the owned-dog and human populations. Dogs that are allowed to roam freely face numerous health threats such as malnutrition, starvation, disease, intentional killing and accidental death. Free-roaming dogs impact human health through increased rates of bite events, road accidents and the spread of zoonotic diseases (Beck, 2000; Reece, 2005). This study reports that over half of the owned dogs in Haiti were allowed to roam freely all or part of the time. Rural areas experienced a higher frequency of dog roaming than urban, which corresponds with findings from similar studies in other developing countries (Acosta-Jamett et al., 2010; Rinzin et al., 2016). These communal interactions, combined with an absence of veterinary care and poor access to animal vaccines, contribute to the transmission of a multitude of zoonotic diseases, particularly rabies. Implementation of educational and legislative programmes to improve owners' knowledge about these risks of disease transmission associated with free-roaming dog populations are important concepts in rabies control (Lapiz et al., 2012; Lembo, 2012). Further research is needed to understand why dogs are allowed to freely roam in Haiti in order to develop interventions that aim to reduce this free movement. Humane solutions to roaming freely, such as adequate provision of sustenance and shelter, and humane methods of population management, should be considered.

Dog morbidity and mortality

Dog population turnover is a critical measure to monitor when planning rabies vaccination programmes (Beran, 1982; Kitala et al., 2001; Jackman and Rowan, 2007; Acosta-Jamett et al., 2010; Davlin and Vonville, 2012; Morters et al., 2014). High death rates negatively impact the population vaccination coverage and increase the likelihood of introduction of diseases like rabies (Jackman and Rowan, 2007; Davlin and Vonville, 2012). Countries experiencing high population turnover rates often have to rely on more resource-intensive vaccination methods such as bi-annual vaccination campaigns. The owned-dog population turnover rate in Haiti was 32%, a finding that would likely be higher had other sectors of the dog population been assessed. This finding was consistent with ecological studies on dogs in similar developing countries in Africa and Latin America (Cleaveland, 1998; Kitala et al., 2001; Acosta-Jamett et al., 2010; Davlin and Vonville, 2012). Nearly a quarter of the dog deaths recorded in this study were preventable – the result of intentional killings, often through suspected poisonings. A cost-effective and sustainable model for population management, including reducing population turnover rates via humane methods of animal control (i.e. sterilization) and providing education on basic animal welfare (adapted to the cultural and socio-economic aspects of Haiti), is necessary to prevent and control the spread of rabies in Haiti (World Health Organisation, 2001).

Animal vaccination

More than 80% of respondents with unvaccinated dogs reported a lack of access to vaccine as the primary barrier to prior animal vaccination. Rural and semi-urban areas were much more likely to report no access to a vaccine (90% of respondents) than were urban (60%), likely reflecting a barrier to vaccine distribution channels and access to veterinary care. Underlying these results is the reality that vaccines are typically only available during government-sponsored campaigns. Therefore, improved access to veterinary care may not result in improved access to the vaccine. Because this study only captured data from dog owners who participated in the vaccination campaign, the frequency of reported reasons likely reflects a segment of the Haitian population that is more proactive in providing care to animals than the general population when access to the vaccine is not a barrier to vaccination. The development of a system whereby the canine rabies vaccine can be acquired year-round, combined with programmes to vaccinate free-roaming dogs, would likely improve community-level dog vaccination rates. Consistent access to affordable animal vaccines has the potential to improve the health of both animals and humans alike.

Dog rabies-like illness (RLI)

Laboratory confirmation of the rabies virus is the preferred standard for surveillance programmes; however, many resource-limited countries do not have this capacity. Several studies conducted in canine rabies endemic countries have found very high levels of community recognition for rabies in animals based on clinical signs, with 51–67% of clinically diagnosed dogs later confirmed positive for the virus (Kitala et al., 2000; Cleaveland et al., 2002; Tenzin et al., 2011). Rabies diagnosis based on clinical signs is often one of the only methods available for surveillance programmes in resource-limited communities. Dog deaths preceded by signs consistent with rabies were frequently reported by the study population (5.9% of deceased and living dog population), perhaps indicating a high rate of rabies in these communities. However, in the absence of diagnostic confirmation, at best one can conclude that neurologic causes of death are common among Haitian dogs.

Need for post-exposure prophylaxis

The annual incidence of household dog bites among our study population was 3.2%, with significantly higher bite rates identified in semi-urban communities. Children accounted for 32% of dog bite cases, which is slightly lower than worldwide estimates of 40% (World Health Organisation, 2013). There were no estimates available for the number of bites occurring among non-dog-owning households, and the ownership status of the offending dogs was not collected. Still, these rates provide a baseline estimate of the incidence of dog bites among the dog-owning Haitian population and can be used to plan for effective human rabies vaccination distribution programmes. Further bite characterization studies are needed to gain a better understanding of frequency in non-dog-owning households, causes of bites, severity of bites and post-bite healthcare seeking behaviours.

Limitations

This study focused on owned dogs and therefore has limited applicability to community and stray dogs. Furthermore, the reasons for not vaccinating dogs may have differed if the total dog-owning population in these sites had participated in the survey. Proactive and concerned owners may be more likely to participate in this type of study. Consequently, findings are likely to be biased towards better care and higher vaccination coverage than dog-owning households that did not attend clinics. In this sense, findings may represent a 'best case scenario' for dogs and rabies control in Haiti (Davlin and Vonville, 2012).This study did not assess owners' attitudes towards their dogs or beliefs about rabies, so qualitative research is needed to better inform prevention and control programmes in Haiti. Additionally, there were no attempts made to minimize recall bias.

Conclusion

The findings gathered through this cross-sectional survey demonstrate that numerous factors in Haiti contribute to the enzootic transmission of rabies in the local dog population. Concepts of animal welfare are not well adopted by the general population and dog mortality rates are high, when compared to the developed world. Access to veterinary care and rabies vaccines for dogs appears to be a limiting factor towards rabies control in Haiti and must be addressed if success is to be achieved. These barriers may be more pronounced in rural areas, where a higher rate of bites and RLI was also observed; therefore, programmes to further understand rabies control and bite prevention in these communities should be undertaken. The findings from this study suggest that rabies in both dogs and humans is likely a larger problem than is currently recognized, and numerous barriers to effective control exist. Programmes to improve animal welfare will likely have a positive impact on vaccination coverage and population turnover in dogs. Concurrent programmes to better understand the dog population distribution and the development of methods to improve access to vaccines are needed. Rabies deaths are at historical lows in the Western Hemisphere, but Haiti and the remaining canine rabies endemic countries still present a significant challenge to the goal of rabies elimination in the region.

Disclaimer

The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the Centers for Disease Control and Prevention (CDC).

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Data collection instrument (English).

