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U.S. Centers for Disease Control and Prevention in Haiti:

A National Rabies Prevention and Control Program Strategy

By

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U.S. Centers for Disease Control and Prevention in Haiti:

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An Abstract of

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Abstract

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By Sarah Ashley Schildecker

Introduction: An estimated 60,000 persons die of infection with the rabies virus annually, and dog bites are responsible for 95 percent of these deaths. Haiti is estimated to have a high incidence of canine and human rabies, and the Centers for Disease Control and Prevention (CDC) is assisting the Haitian government with prevention and control efforts. In order to reduce the burden of disease associated with rabies, a comprehensive strategy for prevention and control must be developed and implemented throughout the country.

Objective: This study aims to assess and describe animal welfare, animal vaccination, animal bite treatment among humans, and canine morbidity and mortality in Haiti in order to develop effective and efficient program recommendations for rabies prevention and control in Haiti.

Methods: A Knowledge, Attitudes and Practices (KAP) survey was used for data collection among dog owners during government-sponsored vaccination clinics at eight different randomly selected sites. 1,448 surveys were collected and analyzed using statistical analysis software.

Results: The majority of owned dogs (58 %) spend all or part of their time in the street. Thirteen percent of owned dogs received veterinary care. Lack of access to a rabies vaccine was the largest barrier to animal vaccination. Sixty-seven percent of respondents provided some form of care to community animals. Nearly a third of the dog population dies annually and five percent of the total dog population died of a canine rabies-like-illness in the past year. Four percent of our study population experienced a dog bite in the past year, a third of whom were children. One percent of respondents reported knowing someone who had died of rabies or a dog bite.

Discussion: The incidence of canine and human rabies in Haiti is high and the risk of infection is exacerbated by infrastructural barriers, the roaming nature of owned dogs, and poor animal welfare. Knowledge of prevention and treatment of human rabies is low and education of the public and healthcare providers is needed to address gaps in knowledge. Community-based initiatives endorsed and supported by the Haitian government are needed to tackle the burden of disease among animals and humans.

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Acknowledgements

This thesis is an end product of a journey of rabies prevention research that began in the CDC Tbilisi, Georgia office during my summer practicum in 2014. That experience directly led me to CDC Headquarters in Atlanta, where I have worked with the Rabies Program since October 2014. This thesis is a synthesis of established prevention and control strategies adapted to the Haitian context via quantitative and qualitative data obtained from CDC Atlanta's activities and efforts in that country.

I would like to first and foremost thank Dr. Deb McFarland at Emory University, who provided me with constant guidance since I came to this program. You connected me with CDC Georgia and endorsed me for the experience that has shaped my MPH and provided a foundation for my career at CDC. You have been a constant mentor and source of guidance for me during my 2 years at Rollins and I could not have done it without you.

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I: Introduction

1.1 Epidemiology and Transmission of Rabies

Rabies is an infection that poses a risk to human and animal populations alike, intricately linking the health of humans to the health of surrounding animals and the local environment. There are an estimated 15 million people treated for exposure to rabies annually worldwide [1]. Despite efforts to promote awareness of rabies and availability of post-exposure treatment for persons infected with the virus, nearly 60,000 people die annually worldwide due to infection with rabies [2]. Exposures from dogs, whether domesticated or stray, account for the vast majority of human cases of rabies, and it is estimated that around 95 percent of all rabies infections worldwide are transmitted via dog bites [1]. Over 3 billion of the world's 7 billion people live in areas where canine rabies is present [3]. Children under the age of 15 are most at risk of exposure from dog bites, since they experience around 40 percent of total reported animal bites worldwide [1].

Human rabies exposure is caused by contact with the bite, scratch, or lick of an infected animal. Whether via a direct bite or a pre-existing existing wound, animal saliva must penetrate the outer layer of the skin in order for exposure to occur. Once a human is exposed to rabies, immediate medical attention in the form of wound cleansing and post-exposure prophylactic (PEP) treatment is necessary in order to prevent the onset of disease. The incubation period of the rabies virus is generally from 11 days to 3 months, but can last as long as 18 months or more [4]. The virus attacks the nervous system and causes encephalitis, inevitably resulting in death to the infected individual. Once the virus reaches the nervous system and symptoms are visible, vaccination is ineffective and palliative care is the only course of action [4]. Symptoms may last

for 4 to 17 days and can include any of the following: fever or flu-like symptoms, headache, hydrophobia, delirium, and insomnia. Rabies is always fatal if left untreated, and almost always fatal if treated after symptoms appear. According to the CDC, less than 10 documented cases of rabies that were treated after the onset of symptoms resulted in survival [4].

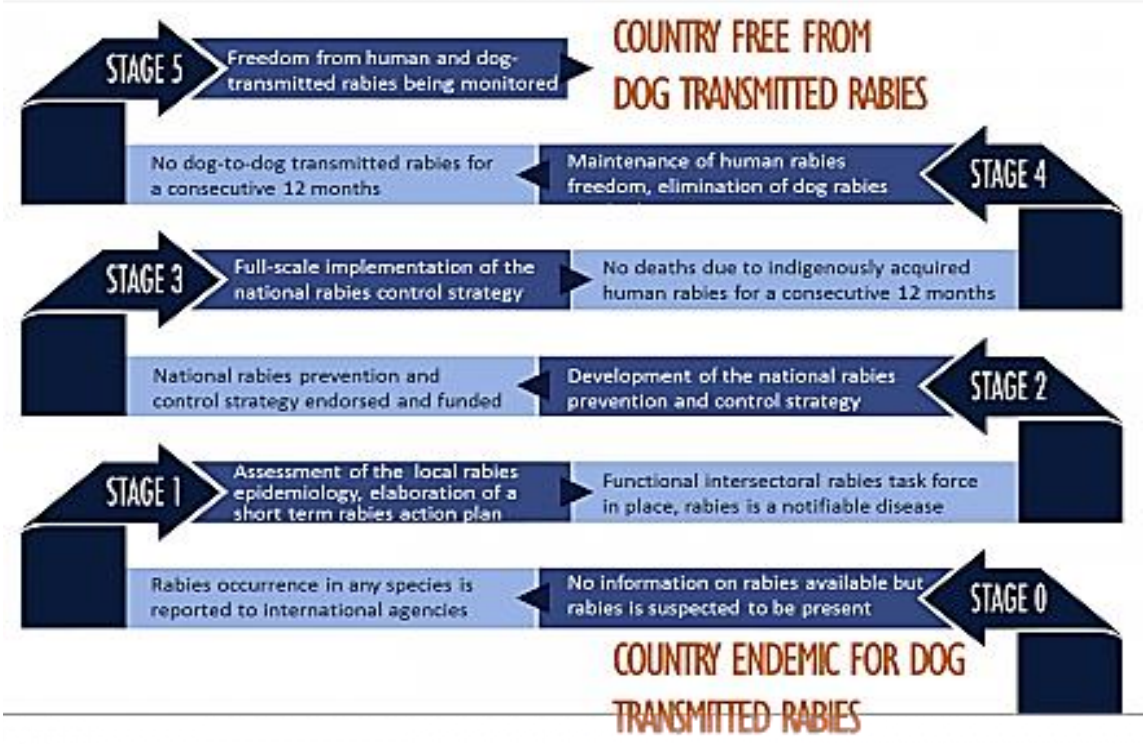
Preventing and controlling canine-transmitted rabies is crucial not only because it is responsible for the vast majority of human exposures to rabies, but also because dogs are a reservoir species for rabies [3]. Any mammal can become infected with rabies and transmit the virus to humans, but dogs are one of a few reservoir species [5]. In a reservoir host, the rabies virus develops its own species-specific variant. Dogs infected with the canine rabies variant may shed the virus for a longer period of time than other animals infected with the canine rabies variant, thereby allowing the virus to circulate widely within the dog population. Eliminating exposures in dogs is part of the One Health approach, which recognizes that the health of animals, humans, and the environment are interrelated and a holistic approach is crucial to both understanding the burden of disease as well as developing strategies to reduce and ultimately eradicate disease [6].

1.2 Disease Prevalence and Strategic Elimination Goals in the Americas

The Pan American Health Organization (PAHO) is a United Nations (UN) member agency specializing in disease prevention and control in the Americas. In 1982, PAHO initiated the effort to eliminate rabies in this region and publicly declared that canine-transmitted rabies will be eliminated in the Americas by 2015 [7]. Since the introduction of prevention and control efforts in 1980, canine-transmitted rabies declined in humans by 95 percent [8]. During the same time period, canine rabies in dogs declined by 98 percent [9]. The areas of action undertaken by

PAHO and its partners include human post-exposure prophylactic treatment (PEP), mass canine rabies vaccination campaigns, community education on prevention and treatment of rabies exposures, and disease surveillance in animals and humans. However, every year approximately 1 million people receive PEP treatment for exposure to rabies in the Americas region and several countries still report both canine and canine-transmitted human cases of rabies.

Figure 1: Stages of Rabies Elimination [a] [10]



[a] Figure obtained from the Global Alliance for Rabies Control's "Stepwise Approach Towards Rabies Elimination" at www.canineraviesblueprint.org

[b] Dark blue explains the rabies situation at each stage and light blue indicates what must occur in order to advance to the next stage

1.3 Haiti Background

Haiti is an underdeveloped country of 10 million people and one of 35 PAHO member states [11]. Geographically, it shares an island with the Dominican Republic in the Caribbean Sea and is divided into 10 governmental departments, hereafter referred to as departments. Haiti fares poorly in developmental, health and economic outcomes, as compared to other countries in the PAHO region. In 2012, the average life expectancy was 62 years, as compared to a regional average of 76 [12]. The per capita gross domestic product was around 332 USD and unemployment was as high as 49 percent in the capital commune of Port-au-Prince [11]. Development indicators also vary between rural and urban areas. The literacy rate in 2003 was 80 percent in urban areas, as compared to 47 percent in rural areas. Primary school enrollment nation-wide was 60 percent in 2001. Survey data estimates that the survival rate of primary school completion in all areas of the country from 2008-2012 was 85 percent [13]. Fifty-seven percent of years of life lost in 2012 were due to infection from communicable diseases, as compared to 16 percent for the Americas region. Vaccine coverage for vaccine-preventable diseases ranged from 45 percent to 75 percent in 2010.

1.4 CDC Presence and Ongoing Activities in Haiti

The CDC Atlanta Rabies Department is involved in various rabies prevention and control efforts in Haiti. In 2011, the Centers for Disease Control and Prevention in Atlanta (CDC) received funding to enhance surveillance capacity, train public health practitioners, and expand laboratory diagnostic resources in Haiti [14]. Prior to the CDC's involvement beginning in 2011, there was no formal surveillance system and laboratory diagnostic methods for rabies were outdated and inadequate.

With the help of CDC, the Haitian Ministry of Health established a reporting system for suspect rabid animals in the Port-au-Prince department [14]. Under this system, CDC-trained officers respond to reports of suspect rabid animals and follow a protocol to quarantine and euthanize animals if necessary. As of October 2014, animal surveillance is on-going in two out of ten departments, with the plan to expand to all ten in the future.

CDC assisted with the establishment of a national diagnostics laboratory and trained laboratory technicians to test samples of animal brain tissue for rabies. Brain samples from euthanized suspect rabid animals obtained from surveillance activities are regularly analyzed and tested for the rabies virus. Laboratory-confirmed cases are reported to CDC on an on-going basis.

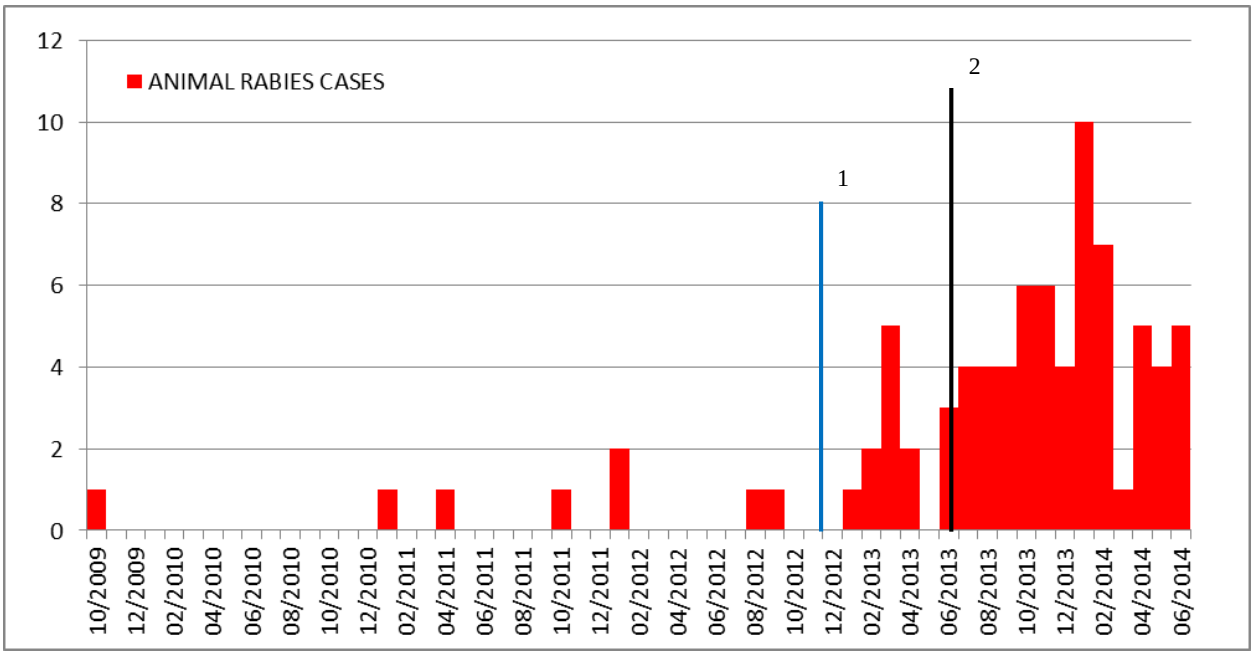
Education of public health professionals, veterinary workers, and the general public is another core CDC Rabies Program area. As of October 2014, education materials are under revision. Materials include pamphlets, flyers, and mural templates on rabies awareness, what to do after a dog bite, and how to treat wounds from animal bites. CDC plans to distribute these materials to healthcare providers and the general public.

1.5 Problem Statement

Haiti is a PAHO member state and has the highest estimated rate of canine rabies in the Americas [15]. Prior to 2012, Haiti reported an average of 5 cases of canine rabies annually. All human cases were clinically diagnosed without laboratory confirmation, but it is unknown how many cases were diagnosed using this method. Very few human cases were reported due to the lack of a laboratory diagnostic system for humans. The Ministry of Health reported only 1 case in 2010 [16]. After the introduction of a formal animal surveillance system in 2013, the reported

number of animal and human cases of rabies increased. Haiti reports an average of 5 canine rabies cases in the capital commune of Port-au-Prince monthly and 8 human cases annually within the two departments under active surveillance.

Figure 2: Reported Animal Rabies Cases in Haiti by Month, 10/2009-6/2014 [16]



[1] Formal Surveillance System established and Animal Rabies Control Officer hired
[2] Three additional Animal Rabies Control Officers hired to conduct surveillance

The incidence of animal and human rabies is traditionally underreported in all regions of the world [17]. There are varying estimates as to the incidence of canine rabies in Haiti. In order to estimate incidence, there must be a valid estimate of the total dog population. The dog population is unknown but current estimates range from 800,000 to 1,200,000 million, amounting to about 1 dog per 10 people [16]. Until the animal surveillance system is expanded to all departments, there will be no valid estimates of the true incidence of animal rabies in Haiti. Until a human surveillance system is established, the true incidence of human rabies will also be

unknown. Without this data, the actual burden of disease will remain unknown and efforts to prevent and control rabies will be difficult to achieve.

Because of limited surveillance data on rabies cases in humans and animals in Haiti, the economic burden of disease is also unknown. The country of Brazil donated 20,000 rabies vaccines in June of 2013, which Haiti currently uses as the only PEP treatment for human exposures to rabies [18]. These vaccine stores became depleted in January of 2015. Without more donations or governmental funding for vaccines, Haiti will not have access to life-saving treatment for individuals exposed to rabies.

Haiti has an array of infrastructural barriers to implementing measures to prevent cases of human rabies and control the spread of animal rabies. No enforceable, modern legislation concerning rabies exists, there are no animal control measures for stray animals, and there is poor support for individuals bitten or otherwise exposed to rabies [19]. Although the country implemented mass vaccination campaigns for dogs and cats several times in the past two decades, coverage did not reach the target of 70 percent of the animal population and campaigns were not conducted consecutively each year [19]. Prior to the CDC's involvement in Haiti, there were no healthcare provider trainings, animal surveillance network, or proper lab diagnostic methods. CDC became involved with Haiti after the 2010 Earthquake, which claimed the lives of at least 230,000 individuals and displaced another 1.5 million persons [20]. The earthquake resulted in an increase in the number of street dogs as homes were destroyed and families were displaced. Despite the earthquake's devastating effects on the local population and existing infrastructure, international aid agencies pledged billions of dollars to assist the country with emergency aid relief and longer-term rebuilding efforts. CDC's involvement in this region aligns

with the international effort to assist Haiti in repairing and improving public health infrastructure, thereby reducing the burden of disease.

1.6 Significance of Project

National strategies to control and prevent rabies synthesize available data, offer project-specific recommendations to stakeholders, and provide a concrete platform for organizing resources and implementing activities. A comprehensive collaborative strategy presents the reasons why prevention and control efforts are needed, provides an impetus to initiate efforts among stakeholders, and ensures that efforts are targeted to the region(s) and population(s) at risk of infection. The goal of developing a National Prevention and Control Strategy for Haiti is to reduce the burden of rabies in Haiti through the proposal of collaborative projects among international and national stakeholders, targeted to the Haitian context via the synthesis of available data.

This special studies project will use surveillance data and results from a Knowledge, Attitudes, and Practices (KAP) survey administered among dog owners in 8 sites in Haiti during June 2014-January 2015 to inform the development of the national strategy. This project analyzes, discusses, and references survey data in order to develop project-specific recommendations for the core areas of surveillance, routine animal vaccination, animal welfare and control methods, and public communication. Recommendations for existing projects, such as animal surveillance and laboratory diagnostics, take the form of suggestions to scale-up, modify, or improve on-going activities.

II: Literature Review

2.1 Introduction

In order to develop recommendations for prevention and control strategies, it is essential to review and synthesize current peer-reviewed literature on rabies control and elimination. This literature review focuses on establishing the key components of rabies prevention, control, and eventual elimination. Before Haiti can tackle rabies elimination, essential groundwork on prevention and control measures must be in place. The first part of the review presents a synopsis of key components in Table 1 followed by an in-depth discussion of these measures. The second part of the review presents current elimination strategies adopted by other countries. The aim of the review is to bridge the gap between control and elimination by establishing key foundational components of the prevention and control process and offer examples from other countries to substantiate the path that Haiti will need to follow in order to achieve elimination in the future.

2.2 Peer-Reviewed Literature on Rabies Control

Table 1: Core Components of a Rabies Prevention and Control Strategy

Component	Summary
Surveillance and Laboratory Diagnostics	This component is the foundation of the strategy and is critical to identifying outbreaks of disease, quarantining suspect rabid animals, and testing for rabies
Animal Vaccination	Annual mass vaccination campaigns reaching at least 70 % of dog population
Animal Welfare and Population Control	Humane canine population reduction in the form of sterilization; routine veterinary care for stray and owned dogs

Human Pre and Post Exposure Prophylactic Treatment	PreP for high-risk individuals, a full course of PEP (5 vaccines + immunoglobulin when available) immediately after a potential exposure to rabies
Education and Communications	Three-tiered communications campaign: general public, healthcare and veterinary workers, and school-aged children
Legal Frameworks and Inter-Sectoral Collaboration	Establish a legal basis for intervention and employ a One Health approach that unites veterinary, human, and environmental sectors of government to reduce the incidence of disease
Monitoring and Evaluation	Use surveillance data and population surveys to monitor and evaluate prevention and control efforts
Sustainability	On-going surveillance, 'reactive' canine vaccination after 'rabies-free' status achieved, continued efforts to reduce wildlife disease burden, and continued political support

Surveillance and Laboratory Diagnostic Capacity

The foundation of a successful rabies prevention and control strategy is a functioning, comprehensive surveillance system. The World Organization for Animal Health (OIE) defines surveillance as 'the systematic ongoing collection, collation, and analysis of information related to animal health, and the timely dissemination of that information so that action can be taken' [21]. Surveillance systems are important for several reasons. Firstly, they provide an evidence base for estimates on disease prevalence and canine demographics. Without evidence, it is not possible to prove that there is a burden of disease. Secondly, the data obtained from surveillance can be used to generate community and governmental support for rabies prevention and control programs [22]. The evidence obtained from surveillance data can be used to make arguments for generating awareness among the public and implementing interventions. Thirdly, surveillance data are critical to the timely identification and handling of suspect infected humans and animals.

Surveillance is particularly important to rabies because of the fatal nature of the disease. Reporting cases early allows for quick responses and informed decision-making [23]. Reports of potential human exposures to rabies or of suspect rabid animals require a quick response in order to treat human exposures to rabies or diagnose and quarantine suspect rabid animals [24]. Poor surveillance can impact program performance by failing to identify and treat suspect exposures to rabies, which ultimately hinders progress towards rabies elimination.

Surveillance systems differ widely across the world. Surveillance in developing regions is often scarce due to infrastructural limitations, resulting in an underreporting and underestimation of cases [24]. This underreporting can become further exacerbated with zoonotic diseases such as rabies, as the nature of zoonotic disease transmission involves interactions between animals and humans, thus necessitating a larger, wider, and more complex population coverage for surveillance. There are varying estimates as to the underreporting of the true burden of rabies. One study in Manila, Philippines, concluded that human rabies might be 10-50 percent higher than that reported [23]. Another estimated that the true incidence of rabies might be 100 times that which is reported [23].

Surveillance in canine enzootic areas generally consists of passive reporting of suspect human and/or animal cases, followed up by laboratory diagnosis of suspect animal cases [24]. Passive reporting is essentially the reporting of diseases by diagnostic laboratories as they occur [23]. According to Banyard et al, this type of surveillance should be the minimum standard. Active surveillance, which involves surveillance staff actively searching and screening for cases, should also be a key component present within the surveillance system [23]. Although most rabies programs are based on passive surveillance only, the addition of active surveillance contributes to disease estimates and can provide a greater breadth of data.

Surveillance systems should be designed and implemented homogeneously in the target region [24]. Failing to detect cases in certain areas impacts disease estimates and can hinder the success of rabies control activities. The example of mass animal vaccination campaigns illustrates this point effectively. Non-uniform animal vaccination coverage can foster the persistence of disease in certain pockets and contribute to its migration into other geographic areas [24]. Surveillance is the principal tool for detecting these cases and informing the follow-up of vaccination efforts, which enables persons responsible for the vaccination activities to target the under-vaccinated areas and populations.

Townsend et al. recommend implementing targeted surveillance in addition to traditional surveillance methods [24]. Targeted surveillance involves collecting data on a specific disease within a certain population in order to measure its prevalence [25]. In the context of rabies, targeted surveillance is a process by which clinical symptoms of rabies in animals are reported as a means of identifying suspect rabid cases [25]. These animals are then captured and monitored to screen for rabies. This method can be used to augment disease detection.

A key complementary component of a surveillance system is laboratory diagnostics. Clinical diagnosis tends to underestimate the burden of disease, particularly when there is no formalized system for reporting cases. Laboratory confirmation of disease in animals is a core part of diagnosing disease and estimating rabies prevalence among the animal population(s). Poor laboratory diagnostic capacity often results in higher costs because individuals may demand life-saving treatment after bites, even when it is unconfirmed whether the biting animal was infected with rabies [26]. The use of laboratory diagnostics enables public health and veterinary workers to confirm whether a suspect animal was infected with rabies, and therefore determine if an individual needs PEP treatment for exposure. However, in areas where canine rabies is

prevalent, prompt and proper laboratory diagnostics may not be available [17]. Worldwide, the estimated costs of the 7.5 million PEP rounds delivered are around $1.5 billion annually [27]. Establishing laboratories and testing suspect rabid animals obtained from surveillance is a necessary component of diagnosing animal rabies cases, determining the administration of PEP, and ultimately reducing the economic burden of PEP.

Once an animal surveillance system is established, it can be modified to support the elimination of both animal and human rabies [23]. Human surveillance data are critical to justifying the importance of prevention and control measures. If governments do not see that there is a human rabies problem, it is extremely unlikely that any steps will be taken to remedy it. Cleaveland et al. recommend joint laboratory facilities for both humans and animals in order to foster integration of laboratory-based surveillance for rabies and other zoonotic diseases [26]. Pooling resources and coordinating prevention and control efforts can be an efficient and economical strategy for addressing rabies and building a platform for addressing other zoonotic diseases as well.

Animal Vaccination

Dogs constitute the principal source of human exposure to rabies. There is evidence that canine-transmitted rabies can be controlled and eventually eliminated via the mass vaccination of dogs [26]. Mass vaccination can in turn reduce the disease burden among wildlife by reducing the overall prevalence of disease [27]. Because dogs are a reservoir species, disease prevalence is strongly maintained within under-vaccinated populations. Reducing the prevalence within this core target group in turn reduces the spread of the disease to wildlife and other mammals. Vaccination should be sustained over several years in order to maintain herd immunity and

prevent epizootics (outbreaks of a disease among an animal population) due to in-migration of the virus across geographic borders [27].

Primary prevention of canine-transmitted rabies among humans can be achieved by vaccinating dogs annually. Mass vaccination campaigns must achieve vaccination coverage of 70 percent or greater among dog populations in order to be considered effective in reducing canine rabies and maintaining herd immunity among dog populations [22, 24, 28]. However, demographic, behavioral, and spatial characteristics of the dog population can influence the necessary coverage rate [29]. In one study that analyzed the impacts of vaccination campaigns, there appeared to be an inverse relationship between vaccination coverage levels and the likelihood, severity, and duration of a rabies outbreak [28]. The largest outbreaks occurred in villages with 20 % coverage or less and no outbreaks occurred in regions with greater than 70 % coverage. This data suggests that even if 70 percent coverage cannot be achieved, the incidence of rabies can still be reduced with lower levels of coverage. In order for mass vaccination campaigns to be successful, vaccines must be handled and administered correctly, and all affected communities must be reached [30]. Vaccination should re-occur annually in order to maintain protection against rabies.

Animal vaccination is widely used as a method of primary prevention of rabies among humans, but it is also a financially beneficial strategy to reducing the overall burden of disease [26, 30]. In one study that evaluated the cost-effectiveness of various rabies control measures in Flores Island, the mean cost of conducting mass rabies vaccination campaigns was estimated to be 2.49 USD per dog [31]. By contrast, the estimated average cost of a full course of human PEP treatment in Tanzania was 111.29 USD [27]. In a study conducted in rural Tanzania, mass canine vaccination was determined to be an optimal strategy for the prevention of human rabies [27].

This study found that 70 percent vaccination coverage in canine populations was a cost-effective strategy to reducing the burden of rabies. Moreover, repeated annual vaccinations were found to be cost-saving. Vaccinating beyond 70 percent was still found to be cost-effective and cost-saving because greater vaccination coverage results in wider control over rabies and better primary prevention of human cases. There is evidence that animal vaccination over the course of several years can yield economic benefits in the form of reducing the cost of treating rabies [26].

Animal Welfare and Population Control

While animal vaccination is critical to reducing the incidence of canine rabies, managing the dog population is also important for controlling canine rabies [30]. Dog culling, which is the systematic mass elimination of dogs, comes up frequently in the literature as an ineffective, costly and inhumane strategy for controlling rabies [22, 26, 30]. This method of animal control does not ultimately impact the dog population density because the remaining dogs reproduce and repopulate the area [32]. Moreover, this strategy requires eliminating 50 to 80 percent of dogs annually, which is a largely expensive and unethical approach [22].

Various humane methods of dog population control exist. The Animal Birth Control (ABC) approach, or Trap Neuter Release (TNR), involves capturing, sterilizing, and vaccinating stray dogs against rabies [32, 33]. These animals are then released where they were captured. The ABC approach is practiced to varying degrees in many countries but has been widely adopted throughout India as a strategy to reduce the densities of local dog populations. While this method has seen a decline in the stray dog population in various cities throughout India, there is little research and evidence about its effectiveness [33]. According to some models, around 90 percent of stray dogs should be reached in order to maintain effective vaccination

coverage [33]. This approach may therefore be challenging and costly to maintain [22]. Moreover, it may simply be ineffective with stray animal populations [34].

Chemical sterilization is another possible method for animal control. This method involves injecting calcium chloride into unsterilized males. Males are capable of producing greater numbers of offspring than females, and may therefore be a more efficient target group for population control than females if resources are limited [34]. However, Franka et al. points out that females should also be targeted to achieve comprehensive and effective population management [22]. Chemical sterilization is a quicker and less involved procedure than surgical sterilization, and carries a lower risk of pain and infection for the animal. In a study conducted by Jana and Samanta, chemical sterilization in a group of male dogs did not show any chronic stress from the procedure [34]. This method may be ideal when traditional surgical sterilization is not economically or logistically feasible.

Animal shelters, public sanitation, and the promotion of responsible pet ownership contribute to animal welfare. Humane methods of animal control and the provision of animal shelters can improve the health and control the population of stray animals, which is likely to benefit human populations in turn [32]. Proper waste disposal discourages free-roaming animals from entering and residing in populated urban areas [32]. Awareness and communication with the public about animal welfare can be conducted in conjunction with vaccination campaigns [30]. Conducting joint awareness and vaccination campaigns can also provide an opportunity for community engagement, which fosters sustainability and the uptake of the promoted practices [26]. Public engagement facilitates the promotion of responsible animal ownership, which is essential to animal health and welfare.

Pre and Post-Exposure Prophylactic Treatment

Human rabies fatalities occur because of exposure via an infectious animal and a subsequent lack of treatment [17]. Pre-exposure prophylaxis (PrEP) consists of a series of 3 vaccinations that are administered over the course of a month. PrEP impacts the number of PEP vaccines needed after a potential exposure, and is therefore recommended for healthcare workers or veterinary workers who are likely to come into contact with rabid animals [17, 22]. If an exposure occurs, an individual who received PrEP will need fewer vaccine doses and will not need immunoglobulin [17]. The administration of rabies vaccines can be costly and should always be done with a proper risk assessment [22].

Human vaccination in the form of post-exposure prophylactic treatment (PEP) reduces the number of human rabies cases by preventing the onset of disease [22]. PEP treatment consists of a series of 5 vaccinations over the course of 1 month as well as the administration of immunoglobulin (human antibodies) [17]. PEP administration should always be performed in conjunction with routine animal vaccination to avoid an over-reliance on PEP treatment and to promote sustainability of prevention and control measures [22].

Vaccine quality is a critical issue in PEP treatment. In some developing countries vaccines are manufactured from nerve cells of infected animals. These vaccines are unsafe and their use should be avoided and discontinued [17]. Safe vaccines are obtainable from international manufacturers and can also be produced in country with appropriate modern technology. These vaccines use an inactivated viral strained obtained from cell cultures or avian embryos [17]. Stakeholders should ensure that safe and efficacious vaccines are procured and

administered to exposed individuals. This quality standard will prevent disease and build trust in the effectiveness of vaccination among the public.

Education and Communications

The average rabid dog bites 4-7 people during its infectious stage, which can last up to 10 days [3]. An infection can take up to 60 days to fully develop from the initial exposure [3]. Without proper and timely administration of PEP vaccines, those bitten will die of infection with rabies. Without communication to the public and healthcare workers about the importance of routine animal vaccination, identifying potential exposures to rabies, and proper and timely treatment of animal bites, efforts to reduce or prevent infection among both canine and human populations will be unsuccessful.

In order to explain the theories behind behavior change in health communications, it is important to understand the concepts underlying cognitive-behavioral theory. Under cognitive-behavioral theory, three important concepts exist: that what people know and believe has an impact on their actions, that knowledge is necessary but not sufficient to effect most behavior modifications, and that the social environment is a key influence on behavior [35].

The Health Belief Model underlies much of the application of cognitive behavior theory in the field of public health. Six factors are of particular importance to this model, including the perception of risk of contracting disease, the perception of severity of the outcome, the perception of the benefits of taking action, the belief that the benefits of taking action outweigh the costs of not taking action, the existence of cues to take action, and the individual's belief that he or she is capable of taking action [35].

A well-structured rabies communications campaign can address all six of these tenants holistically. The key messages must communicate that rabies is fatal if untreated, the routes of transmission and thereby the risk of infection from potential exposures such as dog bites or scratches, and that rabies is fully preventable if timely treated. The campaign itself provides the cue to action, and the benefits of state-sponsored PEP treatment as well as the low cost of pet vaccination fully outweigh the cost of death due to infection with rabies. A well-organized campaign supported at all levels of government and implemented in all regions of the country will reinforce the belief that the individual can take action because institutional support in the form of human and animal vaccinations is available, accessible, and affordable. There must be a framework by which the public can receive ongoing information on pet vaccination and human PEP treatment in order for that belief to sustain itself over time.

In addition to using the Health Belief Model theory to inform campaign development, it is also important to consider that humans of all ages are at risk of infection with rabies and that the communications campaign should therefore target all age groups. Social cognitive theory maintains that observational learning is the foundation for modeling [36]. According to the model of observational learning, humans acquire socially acceptable behaviors by observing the example set by others in their environment [35]. By this logic, children follow the influence of adult models, whether negative or positive. Therefore, the example set by parents can be a predictor for the behavior that children will adopt. However, children also have the ability to bring lessons learned at school home to their parents, thus providing the potential to influence the behavior of adults in turn. This cycle can positively reinforce behavior modification in both age groups.

Using the model of observational learning, it is clear that parents with young children and youth themselves are important target groups for education. Children can serve as an integral communication channel for reaching adults. Moreover, modifying the behavior of youth to adopt positive health behaviors creates a healthier population that in turn sets the foundation for their children and future youth to adopt the same habits moving forward.

Education of healthcare providers is also essential to successful treatment of exposures. Physicians may administer PEP unnecessarily if they are unsure of whether an individual was exposed to rabies [29]. Conversely, they may fail to administer life-saving PEP for the same reason. A health professional's confidence in the choice of administration or non-administration of PEP is reinforced by quarantine of a suspect animal, laboratory diagnosis of a tissue sample from the animal, and accurate information on the animal's vaccination status and the context of the exposure [26]. Accurate treatment of potential exposures is not only cost-effective, but also important in building trust in healthcare providers among the public. Moreover, education of healthcare providers can also be an ideal platform for secondary sources of education to the public and the reinforcement of key communications messages.

Legal Frameworks and Inter-Sectoral Collaboration

A key challenge to implementing an effective prevention and control strategy is the interdisciplinary and ongoing nature of rabies interventions. According to Cleaveland et al, the veterinary or agricultural sector generally is responsible for canine rabies control measures, but these measures can be costly and difficult to incentivize in low-income or low-resource countries [26]. Dogs do not carry a tangible economic benefit like that of livestock or cattle, and veterinarians might have little experience or confidence with handling dogs because of cultural

norms on dog ownership [26]. Moreover, governments and policy makers in low-income countries might not recognize the value of rabies prevention and control because of competing disease burdens [27, 29]. Rabies control measures can take several years to produce lasting results and must be sustained into the future in order to prevent re-introduction of disease from wildlife, imported animals, or persisting pockets of disease in stray animals. In addition, resources in developing countries are scarce and communication among government ministries can be complex and challenging. Because of the necessarily interdisciplinary nature of rabies prevention and control measures, joint efforts among government ministries as well as the public and private sectors are critical to organizing, implementing, and sustaining interventions [17]. Trust, responsibility, adequate resources, and effective communication are core components of ensuring cooperation and progress [26].

A foundational component of achieving and maintaining prevention and control measures is the establishment and enforcement of a legal framework. Part of the establishment of a legal framework is the identification and institutionalization of defined roles and responsibilities for all components of prevention and control efforts [37]. The ability of a governmental authority to respond to rabies problems is critical to reinforcing this system. Governments should be able to implement control measures and respond promptly to potential outbreaks with surveillance measures, vaccination campaigns, and adequate supplies of safe and efficacious PEP [26]. Both the tangible response and perceived support on behalf of authorities motivates healthcare workers, veterinarians, and the public to report human cases of rabies, identify suspect animals, and obtain proper treatment. Engaging the public and the community in these efforts promotes sustainability [37], and sustainability is the key to moving towards elimination.

Monitoring and Evaluation

Surveillance data is an essential component of monitoring program progress and evaluating its impact. Without surveillance data, programs would not be able to justify their need or measure their impact. It is necessary for sustainable interventions and assessing the impact of control and elimination efforts [23, 24]. Diagnostic capacity is essential to achieving and maintaining vaccination coverage [23]. It is also a core means of verification of the impact of prevention and control strategies [23]. Moreover, it is impossible to estimate the true burden of disease without laboratory confirmation of disease. Surveillance and laboratory diagnostics allow for the rapid identification of areas of disease, enabling and enhancing prevention, control, and elimination efforts. Equally important is the use of KAP surveys or other population surveys to assess the effectiveness of education and communications activities among the general public.

Sustainability and Elimination of Rabies

All of these aforementioned components contribute equally to the goal of rabies prevention and control. Each of the focus areas are required links in the chain of progress towards elimination. However, a successful prevention and control strategy necessitates that these components be adapted to the target area or country in order to ensure success [38]. Banyard et al recommends the following steps for moving towards the ultimate goal of elimination: that rabies be made a notifiable disease in all countries, that pet owners practice 'sensible' pet care, and that surveillance data be used to monitor progress and influence policy [23]. Limiting factors can be the absence of coordination among countries, lack of financial support, and not enough surveillance data. A One-Health approach can help coordinate efforts among stakeholders by overcoming institutional barriers to eliminating rabies and providing a

foundation for the prevention and control of other zoonotic diseases as well. A major challenge in meeting the goal of elimination is to sustain financial, political, and infrastructural commitments to preventing and controlling cases of rabies over time [38]. Resource scarcity is a persistent issue in developing countries [30], which further underlines the need for governmental support of sustainable prevention and control efforts.

Maintaining herd immunity among dog populations is a core component of controlling canine rabies [30]. To move towards the elimination of canine rabies, the level of 70 percent vaccination coverage among dog populations should be sustained [24]. There is evidence that after this threshold is reached, it may be more cost-effective and efficient to vaccinate on a case-by-case basis, or 'reactively', rather than 'proactively', as in the case of mass vaccination campaigns [24]. Townsend et al recommends the implementation of 2 years of mass vaccination campaigns after a 6-month period free of cases detected through surveillance [24]. However, this approach is contingent upon the surveillance system's ability to detect areas of circulating disease. Without a sustained surveillance system, efforts to eliminate canine-transmitted rabies via reactive vaccination will not be effective.

To move towards true rabies elimination, measures should also be taken to control rabies in wildlife. Oral vaccination of wildlife, trap-vaccinate-release (TVR), and ongoing passive surveillance of wildlife are different methods that can be used to reduce the prevalence of rabies in wild reservoir species [17]. Once canine-transmitted rabies is controlled and herd immunity is achieved, there is still a risk of the re-introduction of rabies into domesticated mammals via wildlife. Annual rabies vaccination of domesticated and stray animals protects against this risk and sustains existing progress towards the elimination of rabies.

A final important factor to consider in the elimination of canine-transmitted rabies is geography. Regional initiatives and inter-sectoral collaboration are critical to maintaining prevention and control methods [39]. If one country with contiguous borders in a region fails to uphold these measures, elimination efforts can be affected in bordering countries. Island nations are at an advantage because of natural barriers to free-roaming animals, but the importation of rabies can still occur and measures should be in place to verify the vaccination status of imported animals.

2.3 Experience in Different Countries and Current Strategies

While a discussion of core prevention and control components is central to the development of a rabies prevention and control strategy, it is also useful to investigate and analyze global efforts at reducing and eliminating rabies nations in order to supplement a sustainable prevention and control strategy for Haiti. The following table presents a synopsis of rabies elimination strategies at provincial, national, and regional levels in selected countries. Strategies were selected based upon the diversity of their issuing organizations and overall geographic scope. The main prevention and control components are listed in the furthest left column, and their program-specific activities are outlined within each row.

Table 2: Components of Rabies Elimination Strategies in Selected Countries or Regions

Area	Kenya [40]	North Gondar Zone, Ethiopia [41]	Southeast Asia [42]	Bohol Province (Island), Philippines [37]
Timeframe	2014-2030	2014-2020	2012-2016	2007-2010
Level of Strategy	National	District	Regional	Provincial
Issuing Organization(s)	Ministry of Health and Ministry of Agriculture, Livestock and	Ohio State University, Ethiopian Public Health Institute, Centers for	World Health Organization Regional Office for South-East Asia	Bohol Rabies Prevention and Elimination Project,

	Fisheries, Kenya	Disease Control and Prevention		Bohol Provincial Government
Surveillance	Strengthen linkage between veterinary and human surveillance systems, establish cross-border surveillance	Quarantine of suspect rabid animals, standardized protocol for animal management, passive surveillance	Establishment of surveillance systems in all regions, with rabies as a notifiable disease	Established human and animal systems with active and passive elements
Laboratory Diagnostics	Strengthen capacity for field sample collection and lab diagnosis	Establishment of regional laboratory	Improvement in laboratory diagnostic capacity and training of lab staff	Island rabies diagnostic facility established
Animal Vaccination	3 years of mass campaigns at 70% coverage and ongoing maintenance afterwards	Regular mass campaigns promoted by advertising and leash distribution	Mass campaign covering 70% or greater in all countries	2 mass campaigns at 70% coverage and 'catch-up' campaigns
Animal Welfare and Population Control	Animal control and promotion of responsible dog ownership, to be conducted during vaccination campaign	Surgical or chemical sterilization, waste removal, humane euthanasia, promotion of responsible dog ownership	Promotion of responsible pet ownership, surgical/chemical sterilization of 70% or greater of animal population	Minor owner's fee for dog registration, partnerships with animal welfare organizations, improved spay, neuter and euthanasia methods in 3rd year
Pre and Post-Exposure Treatment	PreP, bite wound management, RIG, PEP, HC professional trainings	Wound treatment, RIG and PEP vaccines, HC professional trainings	PreP for schoolchildren in high-risk areas, intradermal rabies vaccines replace nerve-tissue vaccines, PEP available in peripheral areas	Bite management trainings for healthcare staff, government-subsidized PEP, additional Animal Bite Treatment Centers built
Education and Communications	Improve public awareness and educate at-risk professional groups	Education and training to HC providers, schoolchildren and teachers, policymakers, local healers, and general public; promotion of community engagement	Advocacy on cleaning bite wounds and promotion of community-based elimination efforts	Handbooks given to field units for reference, community and school-based education campaigns
Legal Frameworks and Inter-Sectoral Collaboration	Establishment of National Rabies Committee and legal framework to	Trainings for policymakers encouraging legal action on animal	Establish Regional Alliance and National Committees for	Inter-Sectoral collaboration achieved, legal frameworks with

	enhance multi-sectoral collaboration	control and dog ownership,	Rabies Elimination, all countries implement National Elimination Programs	defined roles and responsibilities established
Monitoring and Evaluation	Operational research on all core components to evaluate and assess impact	Surveillance outcomes measures used to monitor and evaluate pilot project	Indicators to monitor and evaluate program components	KAP surveys estimated dog vaccination coverage and dog-human relationships
Sustainability and Elimination	Resource mobilization through government, international, and NGO partners	Upgrade National Vet Institute to produce in-country vaccines, scale-up to other regions, external partnerships	Sustained political commitment achieved by designation of government agency roles within a collaborative framework	Dog registration fees funded program, establishment of island laboratory, community engagement
Status	Ongoing	Ongoing	Ongoing	Complete

All four examples contain core elements such as mass animal vaccination campaigns, the promotion of responsible pet ownership and/or animal welfare, the construction or upgrading of a local laboratory facility, community education and engagement, and the education of policymakers and/or healthcare professionals. Each strategy includes provisions for sustainability, whether through in-country efforts to fund program components or political will to generate funding from donors. All strategies also have components of monitoring and evaluation, whether through key performance indicators or KAP surveys to evaluate the changes in behaviors or knowledge after the intervention. Context and culture largely account for the variation in activities, such as Ethiopia's education of local healers on treating bite wounds and Kenya's need to establish cross-border surveillance to account for migrating dogs. South-East Asia's strategy is particularly interesting because it seeks to unite and coordinate the efforts of countries within the entire region. Regional issues informed the activity plans, such as the establishment of National Elimination Committees in all countries, phasing-out the use of nerve-

tissue PEP vaccines, and PreP to help protect schoolchildren against rabies due to a high incidence of dog bites among schoolchildren.

While the Kenya, Ethiopia, and South-East Asian strategies are still under implementation, the Bohol, Philippines, strategy finished in 2010. The Bohol setting most closely resembles Haiti in terms of geography. This strategy emphasized a legal framework with clear roles and responsibilities for each sector of government. Community contributions via the recruitment of volunteers and dog registration fees helped ensure program funding and sustainability. The community education campaign resulted in an increase in the number of residents who registered dogs and took ownership responsibility for animals [37]. Reporting of suspect rabid animals increased due to the construction of additional treatment centers, and the intervention was successful at reducing human rabies deaths and animal rabies cases on the island [37]. The key lessons from this campaign are to generate support for the program at all levels of society and ensure ownership for the program through legal governmental responsibilities and community education about its importance.

2.4 Research Areas

In order to develop context-specific recommendations for Haiti, it is important to expand upon the literature and understand the characteristics of the dog population, animal vaccination, and animal welfare in Haiti. Specifically, data from the KAP survey will explore vaccination behaviors of pet owners, evaluate general community care for owned and stray animals, and estimate the frequency of dog bites and the nature of dog deaths. This analysis will help inform the development of objectives and activities within the strategy components of community education, animal vaccination, and animal welfare. The goal of the data analysis is to explore

animal population characteristics and human practices in order to develop effective and efficient program recommendations for rabies prevention and control in Haiti.

III: Methodology

Knowledge, Attitudes and Practices Among Dog-Owning Households Who Attended a Government Sponsored Vaccination Campaign, Sep 2014 – Dec 2014

3.1 Introduction

The objectives of this study were to characterize the size of the owned dog population in Haiti, identify the vaccination habits of dog owners, evaluate animal welfare by assessing care provided to owned and community dogs, and assess the nature and frequency of animal bites as well as human deaths from rabies in order to inform recommendations for a Rabies Prevention and Control Strategy for CDC in Haiti. Recommendations for this program strategy are ideally intended for collaborative program use among CDC, the Ministry of Public Health and Population of Haiti, and the Ministry of Agriculture and Natural Resources of Haiti.

Survey results will help inform program recommendations in the areas of animal vaccination, animal welfare, and communications. Results will ensure that recommended program activities are tailored to the specific situation in Haiti, based on the size of the owned dog population, availability of veterinary services, and the existing need for education or veterinary services among animal owners. Data were collected from dog owners who vaccinated their animals at specific sites varying from rural to urban areas during specified times in 2014.

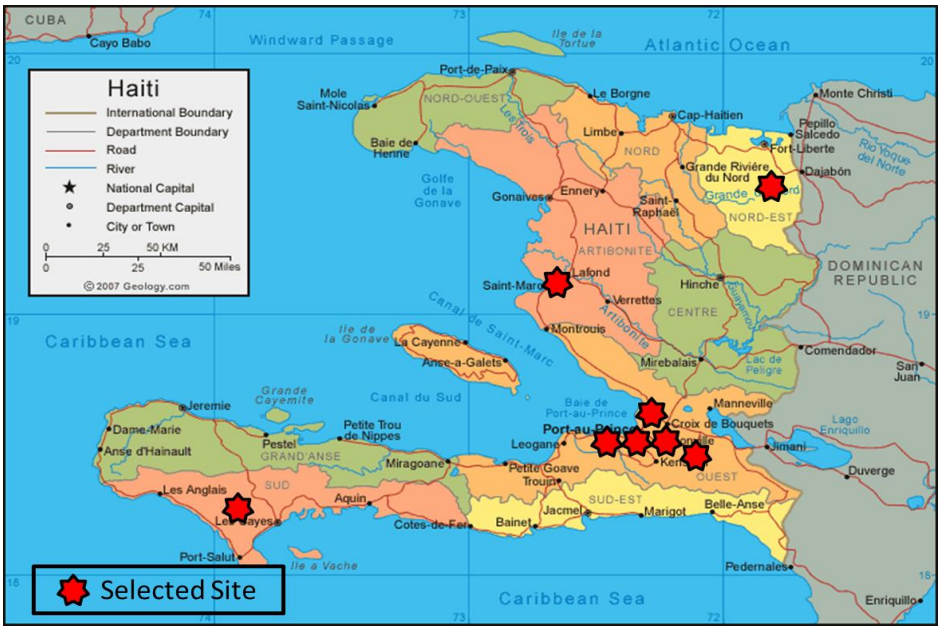
This study does not include data collected on stray or 'street' dogs, but data on owned dogs informs program activities that will also benefit stray animals in turn.

3.2 Population, Sample, and Research Design

Four out of ten total geographical departments were included in this study, *Ouest* (west), *Sud* (south), *Nord-Est* (north-east), and *Artibonite* (geographically, north). The *Ouest* department includes the capital Port-au-Prince, and had a population of around 3.6 million individuals in 2009 [41]. Catchment areas were randomly selected using a random number generation method in rural, semi-urban, and urban areas within the country. Because only 8 sites were selected, some departments are not represented in this sample. GPS coordinates were used to tag specific sites selected for data collection.

Eight sites were selected for data collection. The first data collection period occurred in the two semi-urban catchment areas of Delmas and Sannet as well as the rural area of Croix-des-Bouquets within the *Ouest* Department. It lasted from June 4 to July 18 of 2014 and was conducted in conjunction with Christian Veterinary Mission (CVM). Additional data was collected during October 2014 at 2 other urban sites in the *Ouest* Department, Carrefour and Port-au-Prince, and 1 rural site in the *Sud* Department, Torbeck. Data collection also occurred in December 2014 at 2 additional sites, semi-urban Ouanaminte and urban St. Marc, in the Departments of *Nord-Est* (north-east) and *Artibonite* (geographically, north), respectively. A total of 1448 surveys were collected.

Figure 3: Map of Sites Selected for Data Collection [42]



Our sampling frame consisted of all dog owners within randomly selected catchment areas in Haiti. We selected dog owners as the sampling unit in order to best capture the needs, beliefs and practices of the primary caregivers for owned animals. It was also important to understand dog ownership characteristics in Haiti, such as the number of dogs per household and care that owners provide to community animals. Additionally, this population was logistically ideal because sampling could occur simultaneously with animal vaccination, thus facilitating participation from animal owners while promoting responsible animal ownership habits. This population is particularly useful to study because future program activities such as mass vaccination and education will likely be most successful with individuals who engaged in our vaccination campaign. Understanding their beliefs and practices will facilitate the development of successful program strategies.

3.3 Procedures and Instruments

A veterinarian working with Christian Veterinary Mission (CVM), Port-au-Prince, trained survey enumerators. Survey enumerators travelled to 8 different randomly selected districts over the course of several months. The Ministry of Agriculture announced the vaccination clinics over loudspeakers one week prior to the day of vaccination, and once more on the day of vaccination. Vaccination sites were established in geographic centers of sites, with up to eight satellite sites spread across the community, depending on the population size of the site. Vaccination sites were considered centralized, in that community members came to a central location for vaccination, rather than door-to-door efforts. Enumerators were given dog collars, counting devices, a GPS unit, and survey forms in French and English. Surveys were administered orally in Creole to dog owners presenting for free rabies vaccination of their animals at district sites on various sponsored vaccination days during summer, fall, and winter of 2014. Vaccinated animals were given unique collars and temporary wax ID markers to identify them as already vaccinated and thereby prevent duplication of sampling. The survey methodology employed convenience sampling in that every owner who presented animals for rabies vaccination received the survey and could elect to participate or not. Using these methods, the entire catchment area at the specified GPS coordinates was canvassed for dog owners. The sample is therefore representative of the geographic area in which it was collected.

Our data collection instrument was a Knowledge, Attitudes, and Practices (KAP) survey. The survey consisted of 16 questions focusing on the number of animals under care, the level of care provided to animals, rabies vaccination habits, symptoms of rabies in previously owned animals, the nature of deaths of previously owned animals, and any occurrences of dog bites or symptoms of rabies deaths in any known individuals. 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 preliminary valid characterization of dog ownership practices and animal welfare in Haiti. To our knowledge, only one published study on animal ownership habits in Haiti exists. This study was limited to Port-au-Prince and was conducted after the 2010 earthquake. Our study encompasses a broader geographic area and provides results that characterize the beliefs, practices, and population estimates in Haiti today.

3.4 Data Analysis

Survey data was entered into the Microsoft Access database. Data was exported to SAS, where the data were cleaned. Data are solely quantitative; no qualitative data was collected as part of this study. A descriptive trend analysis was conducted. The analysis focused on the following themes: dogs per household and per person, dog care by owner and community, dog health and the nature of dog deaths, and frequency of dog bites and human deaths from rabies. Results were stratified and analyzed according to geographic type (i.e. rural vs. urban).

3.5 Ethical Considerations

The purpose of the KAP survey was to characterize the dog population in Haiti and assess knowledge, attitudes and practices of dog owners. As a project designed to provide feedback to inform improvements to rabies vaccination campaigns and other related activities in Haiti, this project did not meet the definition of research under 45 CFR 46.102(d). IRB review was not required.

3.6 Limitations

A delimitation of this study is that only 'owned' dogs are accounted for, except in the case of animal welfare relating to community dogs. Our KAP study obtained data from survey respondents rather than from researcher observations; therefore, it is impossible to acquire information on the health status and needs of animals who receive minimal or no care from community members.

The exclusion of stray animals decreases the generalizability of the sample to the welfare of all dogs in Haiti, but data on community and owned dogs will help to structure program recommendations from which stray or feral dogs may indirectly benefit. Even if data were available, it is difficult to make program recommendations for stray animals because community members who either own dogs or care for community dogs are the primary data sources and program activity targets. Moreover, estimates from Africa are that truly feral animals that receive no community care constitute quite a low percentage of the total dog population, between 1 and 5 percent [43]. It is likely that these estimates are similar for Haiti and that the vast majority of dogs are either owned or community dogs.

Another limiting factor is the length of the survey. The survey was limited to the most important questions to ensure that campaign vaccination efforts would not be negatively affected by the administration of the survey. We used a short survey that assessed animal welfare, population size, barriers to vaccination, and incidence of rabies like illness (RLI) and excluded questions relating to rabies knowledge or respondent characteristics such as socioeconomic status and education level.

A final limiting factor is the sampling method. Convenience sampling of only those presenting for animal vaccination affects the internal validity of the study. Pro-active and concerned owners are more likely to participate in the study than owners who are less concerned for the welfare of their animals, so results may overestimate care provided to animals or underestimate the health problems that dogs face in Haiti. However, vaccinations were subsidized, campaigns were advertised in advance, and satellite sites were constructed to offset the effect of convenience sampling and limit barriers to vaccination among dog owners. Results will be generalizable to owned dogs in Haiti, but not to any populations external to Haiti.

IV: Results

Characteristics of Dog Ownership among Dog-Owning Households who Attended a Government Sponsored Vaccination Campaign, Sep 2014 – Dec 2014

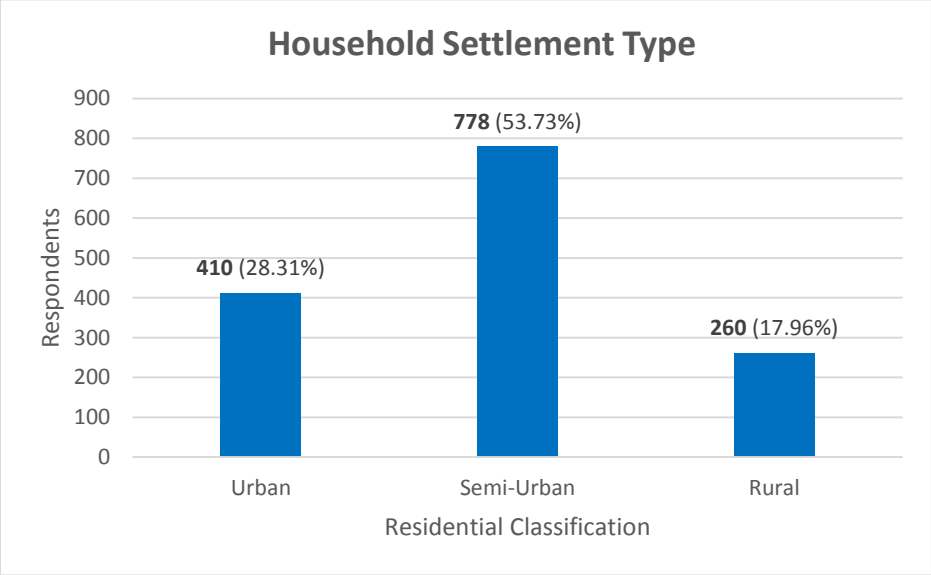
4.1: Introduction

A total of 1448 surveys were collected from 8 data collection sites for this analysis. Surveys were collected from dog owners who presented animals for vaccination during scheduled vaccination clinics occurring once at each site. There are 1448 households, 8872 individuals, and an estimated 3,808 total (1,313 deceased and 2,495 living) dogs represented in this sample. The following descriptive analysis presents the findings from this study in four sections that will inform different components of the program strategy: dog and household population characteristics, animal welfare, animal vaccination, and exposures and need for post-exposure prophylactic (PEP) treatment.

4.2: Dog and Household Population Overview

The median respondent age was 28. Average household size was 6.13 persons per household. Urban areas had a mean household size of 5.83, Semi-Urban areas had a mean household size of 6.21, and rural areas had a mean household size of 6.36. Household size was missing for 103 of 1448 (7.12%) observations. In these cases, household size for an urban, semi-urban, or rural respondent was reassigned to the value of the mean household size for urban, semi-urban, and rural areas, respectively. Roughly 28 % (n=410) of respondents were from urban sites, 54 % (n=778) were from semi-urban sites, and 18 % (n=260) were from rural sites.

Figure 4: Household Settlement Type (N=1448)



There are 2495 reported currently owned dogs. Households with no reported household dog size were cleaned to have the household dog size match that of the household dogs presented for vaccination at the time of the survey. There were 92 such observations, accounting for 6.35% of total respondents. Eleven observations (0.76%) had no calculable household dog size because

both the number of dogs presented for vaccination and the household dog size were missing. Household dog size was set to missing for these 11 observations. Among the total survey population, the mean household dog size was 1.72 dogs per household, with an average of 1 dog per 3.57 persons in the household. Urban areas had a smaller average household dog size of 1.60 dogs per household, but a similar ratio of dogs to household persons (1 per 3.57 persons). Semi-urban areas had a slightly larger mean household dog size of 1.64 dogs per household but a smaller proportion of dogs to persons, at 1 dog per 3.85 persons in the household. Rural areas had the largest mean household dog size at 2.15 dogs per household as well as the highest proportion of dogs to persons at 1 dog per 2.94 persons in the household.

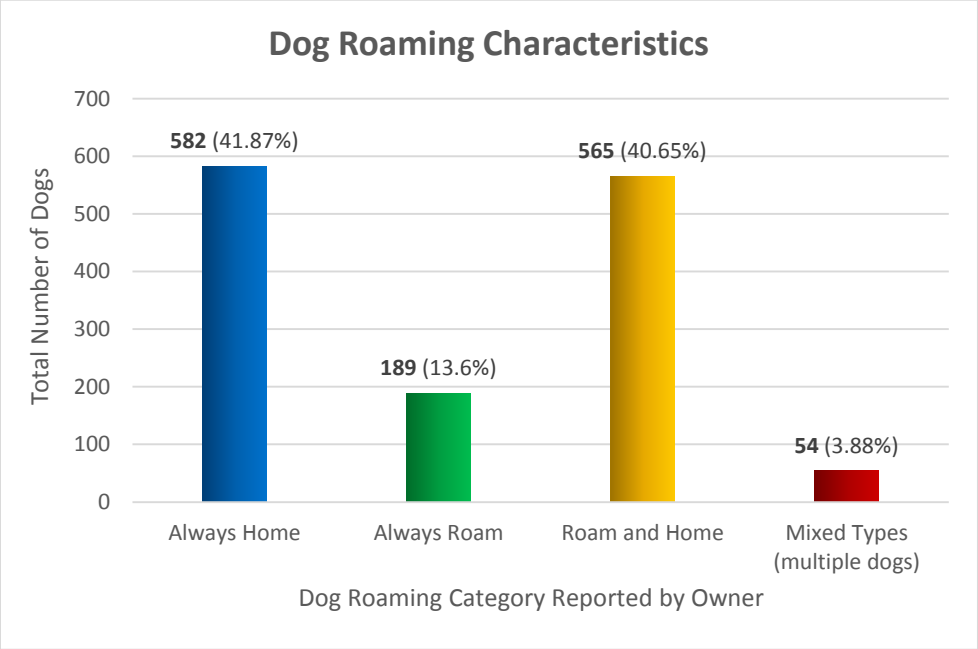
Three selections were available for respondents to describe the roaming characteristics of the dogs within their households: those that always stay at home, those that always roam the street unsupervised, and those that both roam unsupervised part of the time and stay at home part of the time. Since these categories are mutually exclusive, respondents that indicated a positive response for more than one of these categories (usually indicated by a check mark or 'X') but failed to provide a numerical value for the categories were assigned a value according to the following calculation:

(Household dog size / number of dog categories reported) = Value for each reported dog roaming category

For example, if a respondent reported 4 dogs in the household and indicated that of the household dogs, some 'Always stay at home' and some 'Roam unsupervised sometimes,' but neglected to provide individual counts for these responses, a value of '2' dogs was assigned to

the category ‘Always stay at home’ and a value of ‘2’ dogs was assigned to the category ‘Roam unsupervised sometimes.’ A total of 52 respondents (3.59%) were reassigned values to their reported dog roaming categories according to the above formula. A further 47 respondents (3.25%) reported a household dog size but did not provide a response for any of the three dog roaming categories. Household dog size and roaming status were set to missing for these observations.

Figure 5: Dog Roaming Characteristics by Household (N=1390)[a]

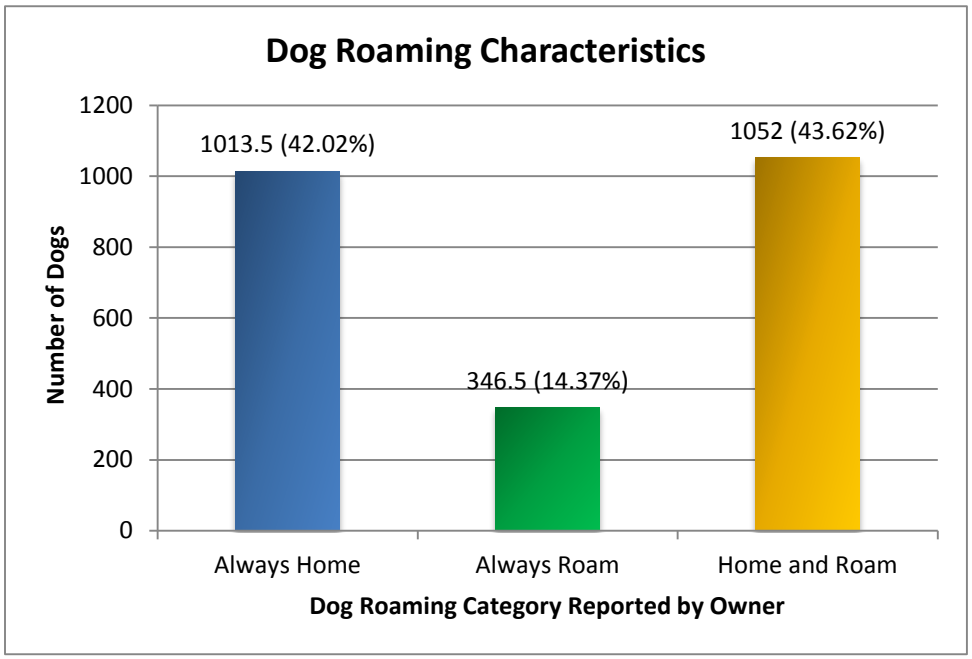


[a] 58 missing observations because no dog roaming categories were reported and/or no dog size was calculable

The majority of owners (41.87%) reported that their dogs always stay at home. An almost equal percentage (40.65%) reported that their dogs both stay at home and roam the streets unsupervised sometimes. Only 13.6 percent of owners reported that their dogs are always on the

street. Almost 4 percent of respondents reported owning dogs that fall into more than one of these roaming categories.

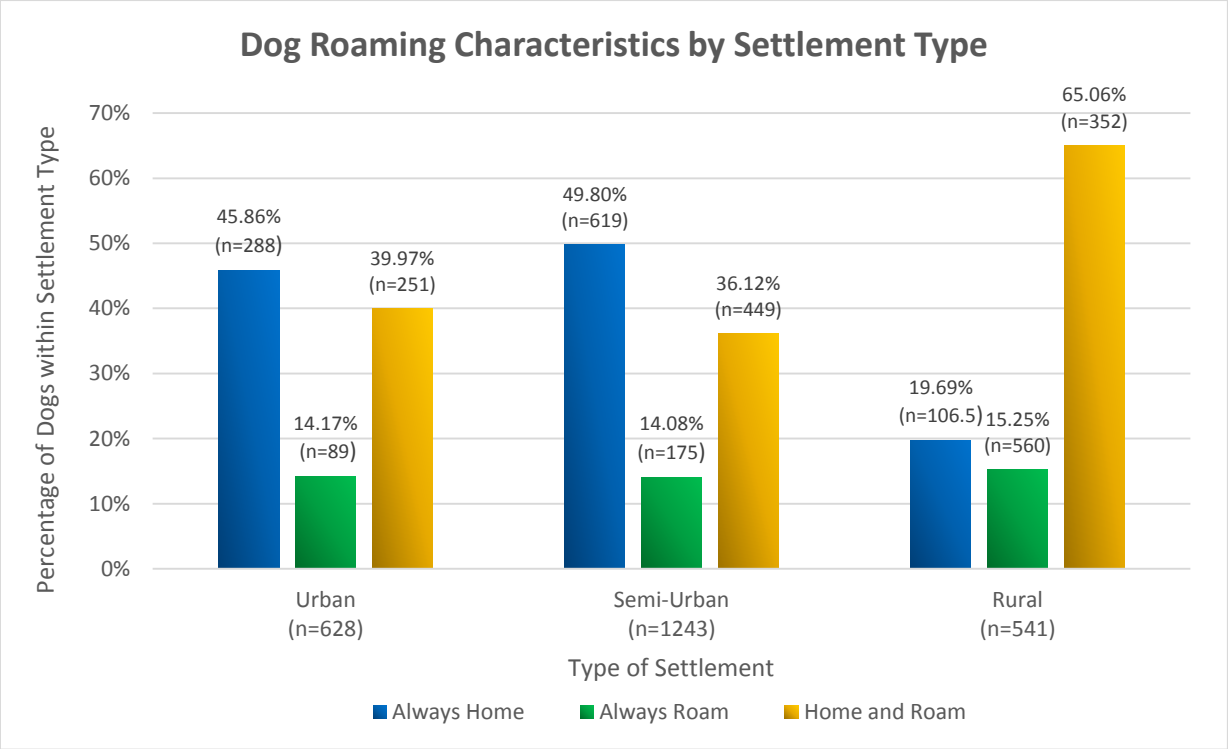
Figure 6: Dog Roaming Characteristics by Total Number of Dogs (N = 2412)[a]



[a] 47 missing observations because no dog roaming categories were reported, excluding 83 out of 2495 total dogs

The breakdown of the total number of dogs by roaming category is similar. Around 42 % of dogs are reported to always stay at home, but a slightly higher percentage of dogs (43.62%) both stay at home and roam the streets. A little over 14 percent of owned dogs stay on the street all of the time. These results indicate that the majority of dogs (around 85 %) spend at least part of the time under supervision and care at home, while around 58 percent of dogs are routinely exposed to conditions and animals outside of the home.

Figure 7: Dog Roaming Characteristics by Settlement Type (N=2412)[a]



[a] 47 missing observations because no dog roaming categories were reported, excluding 83 out of 2495 total dogs

Figure 7 illustrates the same distribution of dog roaming characteristics, stratified by settlement type. Urban and semi-urban areas share similar characteristics, with just under half of dogs always staying at home and almost 40 percent of dogs roaming between home and the street. Across all areas, the proportion of dogs that roam the streets full-time is close to 15 percent. However, rural areas show a much higher proportion of dogs who both roam and stay at home, as well as a much lower proportion of dogs that are always at home, as compared to urban and semi-urban areas. These data indicate that there is a greater likelihood of communal animal interaction in rural areas than in urban or semi-urban areas.

4.3 Animal Welfare

While understanding the demographics of owned dogs is foundational to developing rabies control strategies for dog populations, understanding the care that owners and the community provide to dogs is equally important to assessing the health of dogs and ultimately developing lasting long-term strategies for ensuring the well-being of dogs. Table 2 illustrates owner-reported care for owned and community animals. Food is the most frequently provided form of care, with around 95 percent of owners reporting that they provide food for their dogs. However, twenty-five percent provide shelter and only 13 percent provide veterinary care to their dogs. Full care is measured by providing food, water, shelter, and veterinary care to owned animals. Only 4 percent of respondents reported that they provide all four of those forms of care to their animals.

Table 2: Care Provided to Owned and Community Animals (N=1447)

Type of Care	**Owned Animals**		**Community Animals**	
	Frequency	**% of total respondents**	**Frequency**	**% of total respondents**
Food	1371	94.94	923	63.79
Water	1233	85.39	668	47.55
Shelter	359	24.86	76	5.25
Veterinary Care	189	13.09	70	4.84
Other (unspecified)	0	0.00	5	0.35
Total Respondents [a]	**1444**		**1447**	
Care Combinations	**n**	**%**	**n**	**%**
No Care Provided	54	3.74	473	32.69
1 Source Provided	149	10.32	288	19.92
2 Sources Provided	781	54.1	592	40.92
3 Sources Provided	399	27.63	86	5.95

4 Sources Provided (Full Care)	61	4.22	8	0.55
Total Respondents [a]	**1444**	100.00	**1447**	100.00

[a] 1 observation excluded from 'Owned Animals' and 4 observations excluded from 'Community Animals' because of missing data due to contradictory answers to questions 9 and 13

The data on community animals suggests that community care for stray or communal dogs is quite substantial, with around 64 percent of respondents reporting that they provide food and nearly half reporting that they provide water to community animals. Around 67 percent of individuals reported providing some sort of care to community animals, which is promising for the health of 'un-owned' animals and the development of community-based rabies prevention strategies. However, only 5 percent of respondents provide veterinary care to these dogs and a total of eight individuals (0.55 %) reported that they provide full care to community animals. Veterinary care is the least frequently provided form of care. The low figure could be related to cultural norms about providing this type of care to dogs, a lack of access to veterinary care, or insufficient funds or time for providing veterinary care. The section on animal vaccination will further explore the reasons for low veterinary care based on reported reasons for not vaccinating dogs.

Table 3 displays the frequency of dog deaths in the past year, as reported by owners. Results are stratified based on urban, semi-urban, and rural areas. Urban and semi-urban areas were the most likely to experience dog mortality due to car accidents (21 % and 28 % of deaths, respectively). Rural areas experienced a substantially higher proportion of dog deaths (around 35 %) due to human intent, such as unspecified killings or poisonings, than did urban or semi-urban areas. Disease or illness as a cause of death was markedly higher in semi-urban areas than in urban or rural areas (27 % vs. 11-13 %). Urban areas were the most likely to experience an

unknown cause of death (around 37 percent). This factor could be related to dogs disappearing or otherwise dying in densely populated areas, thus contributing to difficulty recovering a body or relocating an animal. It is important to note that 58 percent of owners reported some sort of owned dog death in the past year.

Table 3: Reported Dog Deaths in the Past Year by Settlement Type (N=840) [a]

Cause of Death	**Urban**		**Semi-Urban**		**Rural**		**Total**		**P Value[c]**
	Freq.	**Col %**	**Freq.**	**Col %**	**Freq.**	**Col %**	**Freq.**	**Col %**	
Hit By Car	59	21.00	185	27.86	15	8.29	259	23.00	< 0.001
Killed [b] or Poisoned	62	22.06	173	26.05	65	35.91	300	26.64	< 0.001
Disease/Illness	31	11.03	181	27.26	23	12.70	235	20.87	< 0.001
Natural Causes	1	0.36	6	0.90	0	0.00	7	0.62	0.32
Exposure [c]	1	0.36	4	0.60	4	220	9	0.80	0.06
Other	22	7.82	11	1.66	18	9.94	51	4.53	< 0.001
Unknown Cause	105	37.37	104	15.66	56	30.94	265	23.53	< 0.001
Total Dog Deaths [b]	**281**	**100.0**	**664**	**100.0**	**181**	**100.0**	**1126**	**100.0**	

[a] 608 (41.99% of total) observations excluded from this table because no deaths were reported

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

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

[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] P-values compare row cause of death versus all other causes of deaths among settlement types

Table 4 shows the distribution and frequently of owner-reported dog deaths due to a canine rabies like illness (RLI) during the past year. This illness was defined based on owner-reported clinical canine symptoms. Without diagnostic testing, it is impossible to confirm that an animal died of rabies.

Table 4: Reported Number of Dogs that Died of Canine Rabies-Like-Illness [a] in Past Year (N=1448)

	Urban		Semi-Urban		Rural		All Settlements		P value
	Dogs	**Col %**	**Dogs**	**Col %**	**Dogs**	**Col %**	**Dogs**	**Col %**	
Canine RLI Deaths	37	3.79	71	3.52	79	9.63	187	4.91	<0.001
Other Canine Deaths	281	28.82	664	32.99	181	22.07	1126	29.57	<0.001
Living Dog Population	657	67.38	1278	63.49	560	68.29	2495	65.52	0.019
Total Est. Dog Population	**975**	**100.00**	**2013**	**100.00**	**820**	**100.00**	**3808**	**100.00**	

[a] Rabies Like Illness (RLI) measured as responding positively to at least 2 of the following symptoms: *Hypersalivation, Aggressiveness, Biting people or animals, Difficulty Walking, or Change in the Dog's Voice*

[b] Rates: 49 per 1,000 dogs have RLI ; 142 per 1,000 dog deaths attributable to RLI

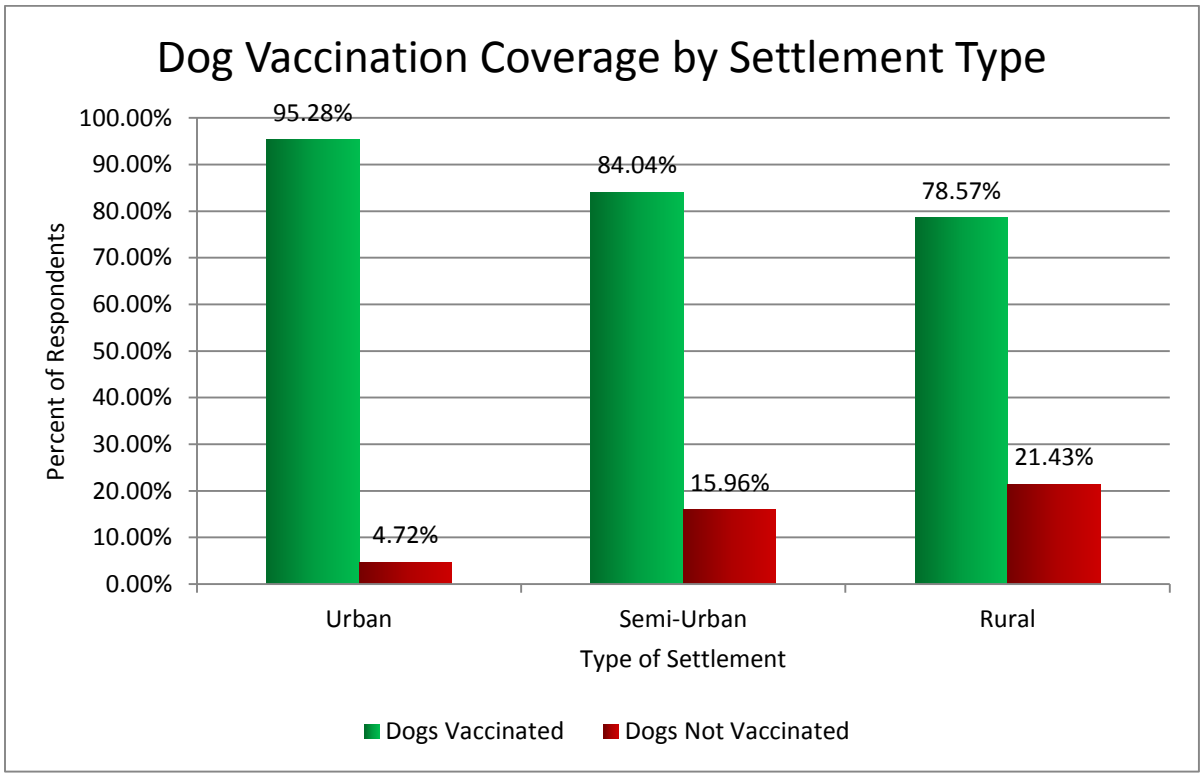
Among all populations, a canine RLI is estimated to have caused canine mortality among nearly 5 percent of the total estimated dog population. Rural areas experienced the highest rate of canine RLI, at 9.63 percent of the total estimated dog population during the past year. Urban and semi-urban areas experienced a little over 3.5 percent canine mortality due to a canine RLISemi-urban areas experienced the highest proportion of other causes of dog deaths, at around 33 percent of the total estimated dog population. These causes were displayed in Table 3. The rate

of canine RLI among the total dog population captured in this survey was 49 per 1,000 dogs and 142 of 1,000 dog deaths are estimated to be attributable to a canine RLI.

4.4 Animal Vaccination

Routine dog vaccination is a critical component of rabies prevention among dogs and humans. Figure 8 illustrates the dog vaccination coverage achieved during the vaccination campaign conducted in conjunction with this survey. Vaccinated dog numbers are based on the number of dogs brought by owners for vaccination, and unvaccinated numbers are based upon the remaining reporting household dog size.

Figure 8: Campaign Dog Vaccination Coverage (N=1434) [a]



[a] 13 missing observations and 1 observation that vaccinated more dogs than those owned not included in figure X

[b] Vaccinated dog numbers based on those vaccinated at the time of survey

[c] Non vaccinated numbers determined by reported household dog size

Campaign coverage was most successful in urban areas, with around 95 percent of dogs owned by clinic participants vaccinated as a result of this campaign. Semi-urban areas had a high but lower coverage of 84 percent. Rural areas experienced the lowest coverage; around 78 percent of owned household dogs were vaccinated because of this campaign. While all rates exceed the established minimum coverage of 70 percent for achieving herd immunity, the proportion of household dog owners who never presented for campaign vaccination is unknown, as is the proportion of community owned and stray dogs. Therefore, the true coverage rate for these communities cannot be determined without additional studies.

Table 5: Reported Reasons for Not Vaccinating Dog(s) among Eligible Dog Population [a] (N=731) [b]

Reason for Not Vaccinating Dog(s)	**Urban**	**Semi-Urban**	**Rural**	**Total**
	Freq (%)	**Freq (%)**	**Freq (%)**	**Freq (%)**
No Money to Vaccinate	86 (37.72)	32 (9.82)	14 (7.90)	132 (18.06)
No Vaccine Available from Vet	105 (46.05)	200 (61.35)	108 (61.02)	413 (56.50)
No Vaccine Available from Government	32 (14.04)	119 (36.50)	53 (29.94)	204 (27.91)
Lack of Knowledge	3 (1.32)	24 (7.36)	2 (1.13)	29 (3.97)
Other Reason	4 (1.75)	39 (11.96)	0 (0.00)	43 (5.88)
Total Respondents [c]	**228**	**326**	**177**	**731**

[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] 717 (49.52% 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

Reasons for not previously vaccinating dogs are further explored in Table 5. Only 50 percent of respondents reported a reason for not vaccinating their dogs. The most frequently reported reason was no access to the vaccine at the veterinarian. This reason was most frequently cited among all three settlement types (46 to 61 percent of respondents). No access to a vaccine from the government was less frequently cited (around 30 percent of respondents), suggesting that individuals may regard animal vaccination as a service that should be provided by a veterinarian rather than a governmental responsibility. Around 37 percent of urban respondents reported insufficient funds as a reason for not vaccinating their dogs, while this reason was less of a concern in semi-urban and rural areas (less than 10 percent). Lack of knowledge about the need for rabies vaccination was infrequently cited (around 4 percent of respondents).

4.5 Exposures and Need for Post Exposure Prophylaxis

The final section of these results focuses on potential exposures to rabies via animal bites. Table 6 summarizes reported household bites among adults and children in the past year, stratified by settlement type. Children are traditionally at the highest risk of dog bites worldwide. Consistently across all settlement areas, between 64 to 76 percent of household bites were among adults, while 24 to 36 percent of household bites were among children. In rural areas, household child bites accounted for the lowest proportion of total household bites (24 percent). Among the total estimated surveyed household population, 3.6 percent of persons were exposed to a dog bite in the past year. This rate varied between 1.8 percent in urban areas and 4.7 percent in semi-

urban areas. The overall dog bite rate was 36 per 1,000 persons. Our rate may underestimate the true rate because survey participants were asked to report bites for all household members. It is likely that household members may not have reported bites to survey respondents, or that participants forgot about bites experienced by other individuals.

Table 6: Reported Incidence of Household Dog Bites in Past Year and Ever Known Human Deaths Due to Rabies (N=1448)

Type of Bite	**Urban (%)**	**Semi-Urban (%)**	**Rural (%)**	**All (%)**
Total Household Bites	**42 (1.76)**	**227 (4.70)**	**54 (3.27)**	**323 (3.64)**
Adult Bites	27 (64.29)	153 (67.40)	41 (75.93)	221 (68.42)
Child Bites [b]	15 (35.71)	74 (32.60)	13 (24.07)	102 (31.58)
No Reported Bites	**2347 (98.24)**	**4603 (95.30)**	**1599 (96.73)**	**8549 (96.36)**
Total Population	2389 (100.00)	4830 (100.00)	1653 (100.00)	8872 (100.0)
Type of Human Death	**Urban**	**Semi-Urban**	**Rural**	**Total (% of respondents)**
Known Deaths from Dog Bites	2	4	0	6 (0.41)
Known Deaths from 'Rabies'	1	5	2	8 (0.55)
Total Known Human Deaths	**3**	**9**	**2**	**14 (0.97)**

[a] Bite Rate: 36 per 1,000 population

[b] 'Child' is defined as anyone under the age of 18

The second section of Table 6 includes known community human deaths due to rabies or a dog bite. Nearly 1 percent of respondents indicated that they had known someone in the community who died after being bitten by a dog or from a disease called 'rabies.' Household dog bites do occur among this population, which indicates that an opportunity for transmission of rabies from a dog to a human exists. With an average of 5 percent of the dog population dying from a canine RLI annually, there are numerous opportunities for a human to be potentially

exposed to rabies. Moreover, these results indicated that human rabies cases have occurred in the surveyed areas. Timely post-exposure prophylactic (PEP) vaccinations are critical to preventing human exposures to rabies from developing into human cases of rabies, which ultimately become fatal once symptoms appear.

V Discussion

5.1 Introduction

The KAP survey administered in 2014 provides a foundation for understanding the characteristics of the dog population in Haiti. Understanding the dog population is critical to developing strategies to prevent and control cases of rabies. Ownership before the 2010 earthquake was estimated at 1.83 dogs per household and 1.40 dogs per household in 2012 after the earthquake [46]. The earthquake displaced both humans and animals, resulting in a decrease in owned dogs and an increase in street or stray dogs. Our finding of 1.73 dogs per household is therefore consistent with these estimates and may indicate a rise in 'owned' dogs since the last estimate of 1.40 from 2012. Attitudes of ownership were not explored in our survey, but there is evidence that dog ownership in Haiti can refer to both community and traditionally 'owned' animals [46], so community dogs may be a separate population from stray or feral dogs.

While the majority of dogs spend at least some time at home, over half of dogs spend part or all of their time of their time roaming outside of the home. The owned dog population is sizable, with almost two dogs per surveyed dog owner and household. Rural dogs were more likely to spend at least part of their time roaming away from home than urban or semi-urban dogs. Although no formal estimates of the stray or community dog populations exist, community dogs are estimated to be almost twice that of the owned dog population in Haiti and stray or feral

animals likely constitute a small percentage of the total dog population, between 1 and 5 percent [44, 46]. Using this guideline, our owned dog population can serve as a proxy population to form recommendations for community and stray dog populations as well. The following discussion will explore the research areas of animal welfare and population management, animal vaccination, human exposures to rabies, canine morbidity and mortality, and canine rabies like illness (RLI). Finally, the importance of community-based solutions and civic participation will be discussed in relation to our findings.

5.2 Animal Welfare and Population Management

While the vast majority of owners provided food and water to their own animals, shelter and veterinary care provision were quite low. Although our study was limited to dog owners, these respondents also reported on the care that they provide to the community dog population, which helps characterize the welfare of community dogs in Haiti. Two-thirds of owners reported providing food and half reported providing water, indicating that basic community dogs' needs are often met. There is also evidence that dogs in Haiti may feed from multiple sources, so community animals may be well fed even though the data suggest that there is a gap in provision of basic needs to these animals [46]. As might be expected, shelter and veterinary care were lower for community animals than owned animals.

Shelter and measures to control animal migration are critical to limiting the risk of environmental exposures and improving the overall health of the dog population. Improperly disposed trash attracts roaming dogs to areas inhabited by humans, while behaviors such as open canine defecation can promote the spread of disease in these populated areas [46]. Nearly half of our owned dog population was free-roaming and at home part of the time, which indicates that

there is a platform for the transmission and spread of a multitude of diseases from the community to homes or vice-versa. Moreover, the One Health theory supports the inextricable connection between the health of animals, humans, and the environment. Environmental hazards and inadequate veterinary care have a direct effect on the health of the human community.

Veterinary care remains low among both owned and community animals. Low veterinary care could result in part from a dearth of qualified veterinarians in Haiti. CDC estimates that there are around 40 veterinarians in all of Haiti. According to estimates from different studies, between 42 to 57 percent of all urban households in Haiti own dogs [46]. By contrast, there were an estimated 59,230 veterinarians in the United States in May of 2013 [47] and an estimated 69.9 million owned dogs in the U.S. in 2012 [48]. The ratio of veterinarians to owned dogs in the U.S. is therefore 8.5 veterinarians per 10,000 dogs. By contrast, the ratio of veterinarians to owned dogs in Haiti is 0.35 per 10,000 dogs. The AVMA's method was used to calculate the estimated owned dog population in Haiti of 1,143,750 [48]. The calculation is outlined in Table 7.

Table 7: Owned Dog Population Extrapolation for Haiti

Settlement Type	Population Size	Persons per household[b]	Households	Proportion[c]	Dog-owning Households	Dogs per household[d]	Owned Dog Population
Urban[a]	6,000,000	6	1,000,000	.50	500,000	1.6	800,000
Rural	4,000,000	6.4	625,000	.25	156,250	2.2	343,750
Total	10,000,000	6.13	1,625,000	N/A	656,250	N/A	**1,143,750**

[a] 'Urban' includes both urban and semi-urban areas
[b] Persons per household calculated based on KAP results
[c] Proportion of urban households obtained from middle estimate of Fielding et al.[46] and Natael [49] estimates; proportion of rural households is an estimate
[d] Dogs per household proportions based on KAP results

In part to compensate for an inadequate number of veterinarians in Haiti, over 30 field veterinary and health agents were trained in the past 3 years as part of the CDC Rabies Program in-country activities. Only 5 of these agents and 2 technicians were employed and currently conduct animal surveillance, diagnostic testing, and animal euthanasia in 5 communes spread over 2 departments (the *Petionville*, *Carrefour*, and *Croix- des- Bouquets* communes in the *Ouest* Department, and *Saint Marc* and *Gonaives* in *Artibonite* Department) [50]. There is still a critical need for access to veterinary care, particularly in remote rural regions of the country [15]. Other reasons for low provision of veterinary care could be related to a lack of education about the importance of veterinary care, the absence of historical precedence for veterinary care, or insufficient funds or time for providing veterinary care.

In August of 2013, CDC staff interviewed healthcare workers about various topics relating to rabies knowledge. Knowledge about how to handle suspect rabid dogs was low, varying from instructions to killing the animal (i.e. by burning to death) to quarantining it. Street dogs were often cited as causative vectors in the rabies problem and suggestions for tackling the issue largely focused on vaccinating these animals. There appeared to be less awareness of the potential for household dogs as vectors of disease, but some interviewees reported keeping their own dogs separate from roaming street dogs in order to reduce the risk of transmission of rabies.

These findings are consistent with those of a KAP survey conducted as thesis research by Master of Epidemiology student Natael Fenelon in 2013 in the urban area of Petion Ville, Haiti. Nearly half of respondents indicated that they would kill an animal that bit them but only 10 percent reported that they would quarantine the animal to observe whether it developed rabies [49]. Eight-five of these respondents knew that dogs could transmit rabies, but 20 percent did not

know how rabies was transmitted from an animal to a human. Forty-six percent of respondents believed that removing street dogs would result in a reduction in the incidence of rabies.

5.3 Animal Vaccination

The prevalence of canine rabies and the low provision of veterinary care among owned dogs indicate that there is a significant gap in animal rabies vaccinations. The Haitian Ministry of Agriculture conducted several sporadic mass dog vaccination campaigns in the past. Most recently in 2012, a total of 400,000 dogs were vaccinated [2]. By our estimate of an owned dog population of 1,143,750, the proportion of dogs vaccinated in 2012 was around 35%. As previously established, a vaccination threshold of 70 % is critical to achieving herd immunity. Significantly under-vaccinating a population does not successfully control the spread of rabies, particularly when there is a high population turnover and campaigns are not conducted regularly.

The relatively high vaccination coverage achieved among dog-owning households within a vaccination site in our study demonstrates that motivated dog owners will vaccinate their animals when the opportunity arises and that sustained mass vaccination campaigns in Haiti are likely to achieve herd immunity among dog populations. Although the proportion of dog owners who never presented their animals for vaccination is unknown, participation in this vaccination clinic is promising. Unvaccinated dog numbers among participants could represent dogs previously vaccinated or dogs too young to vaccinate, so it is not possible to estimate true vaccination coverage among the total surveyed dog population. However, the high vaccination coverage among dog-owning households shows that most household dogs were unvaccinated prior to this campaign, suggesting that access to vaccines may be a crucial component of achieving dog vaccination among this population. Lower vaccination coverage in rural areas, as

compared to urban areas, could be a result of a greater proportion of dogs that roam unsupervised and were not able to be located for vaccination.

Knowledge of the campaign was also critical to owner turnout. Our campaign was announced over loudspeakers twice before the vaccination clinic was established in a central location. Similar campaigns conducted in the Philippines and Chad were also advertised either door-to-door, via pamphlets or posters, by word of mouth from community leaders, or over loudspeakers before implementation and achieved anywhere from 70 to 88 percent vaccination coverage of owned dogs and 64 to 87 percent of total dogs [51, 52]. This consistency with our results indicates that necessary vaccination thresholds for herd immunity can be met during well-advertised mass vaccination campaigns.

The standard cost of rabies vaccines in Haiti is 2 USD per dog, and previous vaccination campaigns have been fully subsidized by the Ministry of Agriculture [50]. Although respondents were not asked how much money they would be willing to pay for a vaccine, lack of money for a rabies vaccine was reported as a reason for not vaccinating owned dogs 18 percent of the time, suggesting that most owners either feel confident that they can afford the vaccine or expect that the vaccine be fully or partially subsidized by the government. The Ministry of Agriculture fully subsidized the vaccines supplied as part of our study, so there was no cost of vaccination to the owners. It is possible that participation might have been lower if owners were asked to pay for the vaccine. However, as demonstrated in Bohol (Philippines), asking owners to pay a modest amount for a service such as dog registration or rabies vaccine contributes to local buy-in and can be used to generate communal funds for prevention and control activities [37].

Reported reasons for not previously vaccinating dogs substantiate the hypothesis that lack of access to a vaccine is the most important barrier to dog vaccination. Whether the vaccine was expected to come from a veterinarian or from the government, no access was reported over 80 percent of the time. Rural areas were much more likely to report no access to a vaccine (90 percent of respondents) than urban or semi-urban areas (60 and 73 percent, respectively). Underlying these results is the reality that vaccines are almost only available during infrequent government-sponsored campaigns. According to our population estimates, these campaigns do not provide enough vaccines to reach the required thresholds for herd immunity [50]. Combined with low lack of knowledge about the importance of vaccination, these results indicate that a sustained supply of subsidized rabies vaccines could successfully reach a majority of owned dogs, particularly if owners are aware of vaccine availability. KAP results from a study conducted in 2013 were consistent with these findings; ninety-one percent of respondents reported that the vaccine was unavailable in their location [49]. Moreover, in-depth interviews conducted by CDC revealed that healthcare workers desire greater participation of the government in implementing prevention and control measures, one of which is mass vaccination campaigns. Consistent access to free or affordably subsidized animal vaccines in all areas of Haiti has the potential to reduce the spread of rabies and thereby improve the health of both animals and humans alike.

5.4 Exposures for Need for Post Exposure Prophylaxis

Human exposures to rabies via canine bites account for the vast majority of human rabies cases worldwide. Reducing the prevalence of rabies limits the risk associated with dog bites, and reducing dog bites also limits the risk of the spread of rabies. Inextricably linked to dog bites as a potential rabies exposure is the need for access to safe post-exposure-prophylactic treatment

(PEP) and education about the importance of obtaining treatment after a dog bite. Without timely access to life-saving treatment, individuals exposed to rabies will become ill and eventually die.

The incidence of household dog bites among our study population was 3.6 percent and varied slightly among settlement areas. Semi-urban and rural households were more likely to report a bite among household members than urban areas. Children accounted for 32 percent of dog bite cases, which is similar to but slightly lower than worldwide estimates of 40 percent [2]. There were no estimates of bites occurring among persons living outside of the household unit, and household bites could have resulted from household dogs or other street dogs. However, this figure does provide a baseline estimate of the incidence of dog bites among the Haitian population. Knowing the frequency of bites substantiates the need for PEP and provides an estimate of the quantity of supply needed for life-saving treatment.

There is evidence that knowledge about rabies is low among the public and even within the healthcare field. Healthcare workers interviewed by CDC staff in 2013 demonstrated knowledge that individuals exposed to rabies should go to a hospital for treatment, but some interviewees reported that bite victims who report to healthcare centers are often given an anti-tetanus shot, but are not always given PEP vaccination treatment. These findings are consistent with a KAP study conducted in Petion-Ville, Haiti in 2013, where only 14 percent of survey respondents reported that they would request a rabies vaccine after being bitten by an animal [49]. This gap in knowledge of rabies treatment represents a critical linkage to care that is often absent in this country. Preventing exposures to rabies from becoming human cases of rabies is impossible without knowledge of when, how, and where to get PEP treatment, particularly if the healthcare community itself is misinformed about treatment protocol.

Lastly, nearly 1 percent of respondents reported having known someone who died of rabies or after being bitten by a dog. In another study, 5.2 percent of respondents reported knowing someone who had died of rabies [46]. While there is no opportunity to confirm whether these reported mortalities were in fact due to rabies or to estimate rates from these responses, it is important to note that the public is aware of the condition and it is likely that rabies cases are occurring without any official record of them. Clinical diagnosis remains the only form of diagnosis in Haiti until laboratory capacity is scaled up to test for rabies in humans and human rabies cases are rarely reported through surveillance channels, largely because surveillance is still scarce in most of Haiti. Education across all sectors of Haitian society and access to life-saving vaccines remain the most critical components of preventing human rabies cases in Haiti.

5.5 Canine Morbidity and Mortality

Morbidity and mortality estimates are extremely critical components of assessing animal health. Less than 1 percent of dogs that died in the past year reportedly died of natural causes, while over half died of preventable or man-made causes such as accidents, killings, or disease. Thirty percent of the total estimated owned dog population in Haiti died in the past year, compared to an estimated turnover rate of 7.9 percent of household dogs in 2004 in the U.S. [53]. Particularly concerning is the high proportion of dog deaths due to human killings such as poisonings, shootings, and electrocution (27 %). This figure was significantly higher in rural areas (35%) than in urban and semi-urban areas and suggests that animal welfare may not be highly valued among segments of Haitian society, presenting a challenge to prevention and control efforts and substantiating the need for vast public awareness and education about the importance of animal health. However, while owners may be persuaded to provide better shelter

and veterinary care for their animals, the individuals responsible for these canine deaths will not be as easily persuaded to contribute to animal welfare.

Studies indicate that the majority of dogs in Haiti are two years old or less [46], supporting our finding that mortality and morbidity rates are high among Haitian dogs. Constant repopulation by unsterilized dogs compensates for canine mortality, thereby maintaining a relatively stable dog population. Because of low veterinary care and environmental hazards such as heat, minimal shelter, and disease, puppies and pregnant or nursing females are particularly vulnerable to morbidity and mortality in Haiti [46]. Part of this problem is inextricably linked to poor infrastructure throughout the country, which is impossible to address in the context of rabies alone. The need for access to veterinary care and improvements in dog health resulting in greater canine longevity is critical to controlling rabies. Mass vaccination campaigns and other prevention and control efforts will not be successful with such a high population turnover, which will result in greater costs and fewer gains to program efforts.

5.6 Canine Rabies-Like-Illness (RLI)

The most concerning results relate to the estimated incidence of canine rabies-like-illness (RLI) in Haiti. Although Haiti is widely recognized as enzootic for rabies, prior studies have not attempted to estimate the prevalence or incidence of rabies in Haiti. Among our study population, death due to a RLI occurred 187 times in the past year, encompassing nearly 5 percent of the total estimated dog population in the past year. This figure is remarkably high when compared to pre-2012 national estimates of 2 - 5 canine rabies cases annually, further underscoring the need for prevention and control efforts in Haiti. Because this question was measured based on reporting at least 2 rabies symptoms, it may overestimate the true incidence

of rabies among this dog population. Some of these reported deaths may not be attributable to the rabies virus. A full list of differential diagnoses can be found in Appendix C. However, animal welfare is certainly implicated as a causative factor in these deaths and an area that could be improved to reduce overall canine morbidity and mortality. Regardless of the true incidence of rabies, crowded living conditions, low access to canine rabies vaccines, frequent migration of dogs between the community and the household, and the occurrence of household bites indicate that rabies has the potential to spread widely and rapidly among both canine and human populations in Haiti.

5.7 Community-Based Solutions

Healthcare workers interviewed by CDC staff indicated that there is a great need for community involvement in rabies awareness and prevention efforts. Virtually all interviewees claimed that community awareness of the dangers of rabies is low, if present at all. Community solutions to animal bites often center around killing a biting animal, but little to no action may be taken on post-bite treatment for bite victims. Some individuals may use traditional home treatment methods such as placing burnt dog hair the wound, which is believed to protect against the development of rabies. Thirteen percent of respondents to the KAP survey in Petion-Ville in 2013 reported placing the ashes of dog hair in their wound after a dog bite, while only 34 percent went to the hospital and 36 percent reporting doing nothing at all to treat the bite [49]. Even healthcare workers are often misinformed about proper treatment, highlighting the necessity of an educational campaign that targets all segments of Haitian society.

As part of an effort to educate and engage the community in rabies prevention and control, healthcare workers suggested a collaborative community approach. Community leaders

such as priests, voodoo healers, teachers, and local governmental leaders were mentioned as critical to raising awareness and lending credence to educational efforts. Participatory learning opportunities such as community meetings and small group exercises were cited as influential and necessary to reach the public in a meaningful and effective manner. The government should legally and financially support these efforts in order to ensure that access to vaccines and healthcare post-bite treatment is available and affordable to Haitians irrespective of their geographic location.

5.8 Summary

These findings demonstrate that the lack of knowledge, current attitudes and practices, and overall infrastructure 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 canine mortality is high, when compared to the developed world. An estimated 5 percent of the total dog population dies from a canine RLI every year. Although the human burden of disease remains unquantifiable, 1 percent of our study population knew someone who died of rabies. Veterinary care provision is remarkably low, but understandably so in a country where there are only 0.35 veterinarians per 10,000 dogs. Numerous barriers may exist to explain the low access to canine rabies vaccines. Methods for reliable and sustainable access to canine rabies vaccines should be developed in order to inoculate the current dog population at a proportion of 70 percent and continue to compensate for a high canine population turnover. The presence of community animal welfare is promising for rabies prevention and control efforts, and community-based solutions are needed to create and sustain awareness and knowledge about the risks of rabies and key methods of prevention. Education about correct rabies treatment protocols is needed both among the general public and healthcare providers. Without proper education and

the implementation of vast countrywide measures to curb the spread of rabies, rabies will continue to persist and impact the health of dogs and humans alike. The following section draws conclusions and offers program recommendations for a National Prevention and Control Strategy for Haiti over the next 5 years. It is critical that action is taken immediately and that efforts continue into the future in order to prevent the re-emergence of disease.

VI: Conclusions and Recommendations

The below conclusions and recommendations are equally important and crucial components of a rabies prevention and control strategy. To fail to include any component will directly affect the success of the other component areas. These recommendations for program activities must be implemented jointly in order for program efforts to be successful.

Surveillance and Laboratory Diagnostic Capacity

As demonstrated previously, surveillance is the foundational core component of a rabies prevention and control strategy. Without surveillance, necessary data on potential cases are absent and efforts to prevent future cases will be impossible. Since the introduction of surveillance in Haiti in 2012, reported suspect and confirmed cases are steadily growing. It is crucial to expand the surveillance network to encompass all areas of the country and maintain this network into the future.

Laboratory confirmation of infection is a complementary component of a surveillance system. Without laboratory confirmation of disease, all cases will rely on clinical diagnosis.

There is currently only one laboratory for the country of Haiti that is equipped to test and diagnose rabies.

All human surveillance is currently reliant upon clinical diagnosis, which is contingent upon the presence of symptoms. The case fatality rate for symptomatic individuals is over 99 percent. While the existing laboratory could be expanded to include human samples, it is critical that a human surveillance system be established in order to quantify and monitor the burden of disease among humans. This monitoring will help target interventions to the most at-risk populations and prevent future human cases of rabies.

Recommendations:

1. The Ministry of Health should enhance the national veterinary diagnostic laboratory to accommodate additional testing capacity, including human samples, and meet international bio-safety recommendations within the next 2 years
2. The Ministry of Agriculture should establish sample processing stations in all 10 departments within the next 2 years
3. The Ministry of Agriculture should conduct on-going training and employment of additional veterinary agents, veterinary technicians, and surveillance officers to be active in all 10 departments within the next 2 years
4. The Ministry of Health should employ and train a rabies epidemiologist within the next year to oversee rabies prevention and control activities and act as a point of contact for program efforts on the Rabies Taskforce (see section “Legal Frameworks and Inter-Sectoral Collaboration” below)

Animal Vaccination

Mass animal vaccination is the most cost-effective component of rabies prevention and control. It is absolutely critical to reach the primary reservoir population of dogs in order to reduce the prevalence of canine rabies, which is responsible for the vast majority of human deaths due to rabies. Annual vaccination campaigns that reach 70 percent of the total dog population or higher are sufficient to achieve herd immunity among the dog population, particularly when combined with reactive vaccination of local dog populations during an outbreak.

The high coverage achieved among the vaccination campaigns conducted as part of the KAP study indicates that it is possible to achieve herd immunity with sustained comprehensive mass vaccination efforts in all areas of Haiti. The greatest barrier to animal vaccination is access to a vaccine, and this factor was even more pronounced in rural areas. Well-organized and geographically comprehensive sustained vaccination campaigns have the potential to achieve herd immunity among owned and community dog populations, which are estimated to comprise the vast majority of the total dog population in Haiti. Because of the high turnover in the dog population, we recommend twice annual mass vaccination campaigns.

Recommendations:

1. The Ministry of Agriculture should conduct twice annual canine rabies vaccination programs for the next 5 years, with a total of 800,000 canine rabies vaccination doses distributed each year.
2. The Ministry of Health should work with local NGO partners to develop educational curricula and identify community leaders for community-level educational campaigns in

all departments to improve awareness of animal health and promote animal vaccination within the next year

3. Within the next 3 years, the Ministry of Agriculture should build veterinary stations that can provide low-cost vaccination and veterinary services for animals of community members in each department

Animal Welfare and Population Control

The One Health prevention strategy recognizes that the health of animals, humans, and the environment are intricately and inextricably interrelated. Zoonotic diseases such as rabies link infections in animals to those in humans. Improving the health of the dog population improves the health of the human population in turn. Improper sanitation and pockets of waste in urban and rural areas facilitates the attraction of animals to these areas and creates epicenters for the spread of disease.

Our findings indicate that dogs roam frequently between the home and outdoor areas in Haiti. This movement is a vector for the transmission and spread of disease. It is critical to manage the dog populations by reducing waste and improving outdoor sanitation. Haiti has a high animal population turnover, which means that vaccination and other prevention efforts will be unsuccessful without proper population management. Animals in Haiti are dying at a high rate from illness, human killings, and other accidents. Animal population management via sterilization and waste removal will reduce the high population turnover and improve the overall health of dogs.

Recommendations:

1. The Ministries of Health and Agriculture should work with sanitation services to reduce waste piles that sustain street dog populations over the next 5 years.
2. The Government of Haiti should introduce legislation to reduce the number of dogs allowed to roam freely via humane methods such as surgical or chemical sterilization within the next 6 months and partner with international donors for funding and expertise training for these efforts within the next year.
3. The Ministry of Agriculture and Ministry of Health should immediately introduce and enforce legislation focused on defining animal welfare in Haiti and minimum standards expected of animal owners, including requirements for rabies vaccination and limitations on free-roaming dogs.

Pre and Post-Exposure Prophylactic Treatment

Post-exposure prophylactic (PEP) treatment is the only method for preventing a human rabies exposure from becoming a deadly case of disease. Pre-exposure prophylaxis (PrEP) can be administered prior to exposure in order to reduce the needed post-exposure doses, but PrEP alone does not prevent the onset of disease after a rabies exposure. Haiti suffers from a shortage of human rabies vaccines and relies on vaccines from outside donors. Therefore, the consistent availability and access to safe PEP vaccines is of the utmost importance for the treatment of human rabies exposures.

Recommendations:

1. The Ministry of Health should establish sustainable and reliable methods for acquiring and maintaining a steady supply of the human rabies vaccine within the next year

2. The Ministry of Health should immediately incorporate the human rabies vaccine into the National Immunization Program so that it can be efficiently distributed to health centers and communities without establishing a new mechanism for delivery
3. The Ministry of Health should prioritize availability of PEP near schools and in other communities with demonstrated high bite rates

Education and Communications

Education is the most important strategy for preventing human exposures to rabies, ensuring that treatment is received for exposures, and promoting responsible animal ownership. The Health Belief Model and Social Cognitive Theory support the development of activities that initiate and sustain prevention efforts among humans by emphasizing that action is driven by perceived risk of disease and influenced by our social networks and role models. Qualitative data from in-depth interviews conducted in Haiti illustrated that misconceptions about rabies relating to the treatment of disease exist, and that the perceived severity of disease, risk of disease, and knowledge of disease reservoirs may not be uniformly present among all sectors of society. Education directly impacts all of the other core component strategies and facilitates their uptake and success among the population. A multi-tiered educational campaign with uniform messaging is the key to reaching the public and creating a sustained dialogue among the population. Participatory community-level approaches supported by the government and private partners offer the greatest opportunity for engaging the population and creating bottom-up movement that can be managed and sustained by local communities into the future.

Recommendations:

1. The Rabies Taskforce should develop and implement a three-tiered educational campaign over the next 3 years (1 year of formative research and curricula development and 2 years of implementation) : mass awareness among the public, training of veterinary and medical professionals, and education modules in schools
2. The Ministry of Health should work with partners to conduct KAP studies to assess the rabies knowledge amongst the public before and after the educational campaigns in order to both target educational efforts and assess the effectiveness of the campaigns in 3 years after implementation
3. The Rabies Taskforce should, within the next year, make available translated international guidelines and protocols for treatment of rabies cases in humans and animals in every healthcare or veterinary clinic in Haiti

Legal Frameworks and Inter-Sectoral Collaboration

Because of the interdisciplinary nature of rabies prevention and control, human, animal and environmental sectors must work collaboratively on program activities to achieve success. The establishment of a legal framework is critical to encoding laws and assigning the burden of responsibility upon an authoritative force. Authorities should take responsibility for rabies prevention and control, but programmatic activities should be collaborative and involve public and private partners to maximize cost-effectiveness and practical effectiveness.

Recommendations:

1. The Government of Haiti should immediately establish a legal framework for rabies prevention and control

2. The Government of Haiti should immediately develop a Rabies Taskforce with representatives from the Ministries of Health and Agriculture, Centers for Disease Control and Prevention Haiti, Christian Veterinary Mission, and other international or local NGO partners that meets monthly to coordinate and monitor program activities

Monitoring and Evaluation

Program efforts should consistently be monitored to ensure that activities are reaching their targets. Evaluation should also occur after a specified period to determine the effectiveness of different program components, and inform their continued development into future years. Surveillance data, KAP surveys, and medical center records are examples of data sources that are foundational to monitoring and evaluation.

Recommendations:

1. The Ministry of Health should evaluate the human rabies surveillance program to establish improved methods for case detection after 3 years
2. The Ministry of Agriculture should evaluate the animal rabies surveillance program to establish improved methods for case detection after 3 years

Sustainability and Elimination

In order to achieve regional elimination of canine-transmitted rabies, all of the aforementioned activities must be sustained until rabies reaches Stage 5 of the Canine Rabies Blueprint [10]. At Stage 5 there are no human rabies cases and no dog-to-dog cases for a

consecutive 12 months. Consistent efforts to prevent and control cases of rabies in wildlife through oral wildlife vaccination and ongoing surveillance are equally important to domestic animal vaccination in order to prevent the introduction of rabies variants into canine populations. In the case of Haiti, particular attention must be paid to the border with the Dominican Republic and other sources of importation of disease via cargo or airports. Collaboration with the neighboring Dominican Republic is ideal for eliminating rabies from the island of Hispaniola.

Recommendations:

1. Once Stage 5 is reached, the Rabies Taskforce and Ministries of Health and Agriculture should conduct reactive vaccination in the case of an outbreak of rabies and continue to conduct surveillance among wildlife reservoirs
2. The Rabies Taskforce should incorporate representatives from the Dominican Republic and share surveillance data within the next 5 years
3. The Rabies Taskforce should consider partnering with the Dominican Republic within the next 5 years to maximize resources and coordinate prevention and control efforts

References:

1. Rabies. (2013). World Health Organization. Retrieved July 1, 2014, from http://www.who.int/mediacentre/factsheets/fs099/en/.

2. Fooks, A. R., et al. (2014). Current Status of Rabies and Prospects for Elimination. *The Lancet 384*(9951). doi: 10.1016/S0140-6736(13)62707-5

3. Wallace, Ryan. (2014). Canine Rabies Control: Haiti. Atlanta, Georgia, USA, Centers for Disease Control and Prevention.

4. Rabies. (2013). Centers for Disease Control and Prevention. Retrieved 26 January 2014 from www.cdc.gov/rabies.

5. Rabies and Rabies-Related Lyssaviruses. (2012). The Center for Food Security & Public Health, Iowa State University. Retrieved 26 November 2014 from http://www.cfsph.iastate.edu/Factsheets/pdfs/rabies.pdf.

6. One Health. (2013). Centers for Disease Control and Prevention. Retreived 25 June 2014 from http://www.cdc.gov/onehealth.

7. Pan American Health Organization. (2013).“Elimination of dog-transmitted human rabies in the Americas by 2015 is within reach, experts say.” Retrieved 16 October 2014 from http://www.paho.org/hq/index.php?option=com_content&view=article&id=9047&Itemid=1926&lang=en.

8. Pan American Health Organization. (2012).“Rabies Cases Have Declined 95 Percent in the Americas Since 1980.” Retrieved 16 October 2014 from http://www.paho.org/hq/index.php?option=com_content&view=article&id=7248%3Arabies-cases-have-declined-95-percent-americas-since-1980&catid=740%3Anews-press-releases&Itemid=1926&lang=en.

9. Rabia. (2014). Pan American Health Organization. Retrieved 16 October 2014 from http://www.paho.org/panaftosa/index.php?option=com_content&view=article&id=509&Itemid=233.

10. Overview of the Stages. (2010). Canine Rabies Blueprint. Accessed 16 December 2014 from http://caninerabiesblueprint.org/6-4-Overview-of-the-stages.

11. Haiti. (2012). Pan American Health Organization. Health in the Americas, 2012 Edition: Country Volume. Retrieved 16 October 2014 from

http://www.paho.org/saludenlasamericas/index.php?option=com_docman&task=doc_view&gid=134&Itemid=.

12. Haiti: Health Profile. (2012). World Health Organization. Retrieved 16 October 2014 from http://www.who.int/gho/countries/hti.pdf?ua=1.

13. At a Glance: Haiti. (2015). UNICEF. Retrieved 27 February 2015 from http://www.unicef.org/infobycountry/haiti_statistics.html#117.

14. Rabies Surveillance Expansion and Activities: 7/2014 – 7/2015. (2014). Unpublished Internal Document, Centers for Disease Control and Prevention.

15. Rabies in Haiti. (2014). The Crudem Foundation. Retrieved 16 October 2014 from http://crudem.org/rabies-in-haiti/.

16. Centers for Disease Control and Prevention. Unpublished surveillance data.

17. Rupprecht CE, R. Willoughby, & D. Slate (2006). Current and future trends in the prevention, treatment and control of rabies. *Expert Rev Anti Infect Ther 4*(6):1021-38. doi:10.1371/journal.pone.0083654

18. Cooperacao Tripartite. (2013). "Twenty thousand doses of rabies vaccines are donated to Haiti." Retrieved 31 October 2014 from http://www.cooptripartite.icict.fiocruz.br/en/content/twenty-thousand-doses-rabies-vaccines-are-donated-haiti.

19. National Plan to Combat Rabies in Haiti. (2007). Ministry of Health and Population of Haiti & Ministry of Agriculture, Natural Resources and Rural Development of Haiti. Unpublished Internal Document. [translated from French]

20. Haiti Earthquake Fast Facts. (2015). CNN. Retrieved 27 February 2015 from http://www.cnn.com/2013/12/12/world/haiti-earthquake-fast-facts/.

21. OIE. (2014). Glossary. Accessed 4 November 2014 from http://www.oie.int/index.php?id=169&L=0&htmfile=glossaire.htm#terme_surveillance.

22. Franka, R. et al. (2013). Current and Future Tools for Global Canine Rabies Elimination. *Antiviral Research 100*(1): 220-5. doi: 10.1016/j.antiviral.2013.07.004

23. Banyard, A.C., et al. (2013). Control and prevention of canine rabies: The need for building laboratory-based surveillance capacity. *Antiviral Research 98*(3): 357-364. doi: 10.1016/j.antiviral.2013.04.004

24. Townsend, S.E. et al. (2013). Surveillance Guidelines for Disease Elimination: A Case Study of Canine Rabies. *Comp Immunol Microbiol Infect Dis 36*(3): 249-61. doi: 10.1016/j.cimid.2012.10.008

25. Overview of Surveillance and Zoning. (2014) Food and Agriculture Organization. Accessed 6 November 2014 from http://www.fao.org/docrep/007/y5325e/y5325e0b.htm.

26. Cleaveland, S. et al. (2014). Rabies Control and Elimination: A Test Case for One Health. *Veterinary Record 175*(8): 188-93. doi: 10.1136/vr.g4996

27. Fitzpatrick, M.C. et al. (2014). Cost-effectiveness of Canine Vaccination to Prevent Human Rabies in Rural Tanzania. *Annals of Internal Medicine 160*(2): 91-100.

28. Hampson, K. et al. (2009). Transmission Dynamics and Prospects for the Elimination of Canine Rabies. *PloS Biol 7*(3): 462-471. doi:10.1371/journal.pntd.0000982

29. Rupprecht, C.E. et al. (2008). Can Rabies Be Eradicated? *Dev Biol (Basel) 131*: pp. 95-121.

30. Ceballos, N.R, D. Karunaratna & A.A. Setien. (2014). Control of Canine Rabies in Developing Countries: Key Features and Animal Welfare Implications. *Rev Sci Tech 33*(1): 311-21.

31. Wera E, Velthuis AGJ, Geong M, Hogeveen H. (2013). Costs of Rabies Control: An Economic Calculation Method Applied to Flores Island. *PLoS ONE 8*(12): e83654. doi:10.1371/journal.pone.0083654

32. Dalla Villa, P. et al. (2010). Free-roaming dog control among OIE-member countries. *Preventive Veterinary Medicine 97*(1): 58-63.

33. Totton, S.C. et al. (2010). Stray Dog Population Demographics in Jodhpur, India Following a Population Control/Rabies Vaccination Program. *Preventive Veterinary Medicine 97*(1): 51-7. doi:10.1016/j.prevetmed.2010.07.009

34. Jana, K. & P.K. Samanta. (2007). Sterilization of Male Stray Dogs with a Single Intratesticular Injection of Calcium Chloride: A Does-Dependent Study. *Contraception 75*(5): 390-400. doi: 10.1016/j.contraception.2007.01.022

35. Glanz, K. a. B. K. R. (1997). Theory at a Glance : A Guide for Health Promotion Practice, U.S. Dept. of Health and Human Services, Public Health Service, National Institutes of Health, National Cancer Institute.

36. Butler, T. J. (2001). Principles of Health Education & Health Promotion. Belmont, CA, Wadsworth/Thomson Learning.

37. Lapiz, S.M.D. et al. (2012). Implementation of an Intersectoral Program to Eliminate Human and Canine Rabies: The Bohol Rabies Prevention and Elimination Project. *PLoS Neglected Tropical Diseases 6*(12): e1891. doi:10.1371/journal.pntd.0001891

38. Clavijo, A. et al. (2013). Gains and Future Road Map for the Elimination of Dog-Transmitted Rabies in the Americas. *Am. J. Trop. Med. Hyg. 89*(6): 1040-1042. doi: 10.4269/ajtmh.13-0229

39. Aikimbayev, A., et al. (2014). Fighting rabies in Eastern Europe, the Middle East and Central Asia--experts call for a regional initiative for rabies elimination. *Zoonoses Public Health 61*(3): 219-226. doi: 10.1111/zph.12060

40. Zoonotic Disease Unit. (2014). Strategic Plan for the Elimination of Human Rabies in Kenya 2014 - 2030. Nairobi: Ministry of Health and Ministry of Agriculture, Livestock and Fisheries.

41. Rabies and Infection of Global Health in the Tropics (RIGHT) Partnership. (2014). Proposed Roadmap for Rabies Prevention and Control in North Gondar Zone, Ethiopia. Unpublished Internal Document, Centers for Disease Control and Prevention.

42. World Health Organization. (2012). Strategic Framework for Elimination of Human Rabies Transmitted by Dogs in the South-East Asia Region. New Delhi: Regional Office for South-East Asia.

43. Total Population, Population 18 Years and Over, Households and Estimated Densities in 2009. (2009). Haitian Institute of Statistics and Informatics. Retrieved 12 January 2015 from http://www.ihsi.ht/pdf/projection/POPTOTAL&MENAGDENS_ESTIM2009.pdf *(translated from French)*

44. Haiti Map- Haiti Satellite Image. (2015). Retrieved 15 January 2015 from http://geology.com/world/haiti-satellite-image.shtml.

45. Bardosh, Kevin, et al. (2014). Eliminating Rabies in Tanzania? Local Understandings and Responses to Mass Dog Vaccination in Kilombero and Ulanga Districts. *PLoS Negl Trp Dis. 8*(6): e2935.

46. Fielding, William, et al. (2012). Care of Dogs and Attitudes of Dog Owners in Port-au-Prince, the Republic of Haiti. *Journal of Applied Animal Welfare Science 15*(3): 236-253. doi: 10.1080/10888705.2012.683760.

47. Occupational Employment Statistics. (2013). United States Department of Labor Bureau of Labor Statistics. Retrieved 10 March 2015 from: http://www.bls.gov/oes/current/oes291131.htm#nat.

48. U.S. Pet Ownership Statistics. (2012). American Veterinary Medical Association. Retrieved 10 March 2015 from: https://www.avma.org/KB/Resources/Statistics/Pages/Market-research-statistics-US-pet-ownership.aspx.

49. Natael, Fenelon. (2013). *Survey of Knowledge, Attitudes, and Practices about Rabies Risk- Petion-Ville, Haiti, 2013.* (Master's Thesis). Unpublished. Translated from Spanish.

50. Update on the Status of Rabies in Animals and Humans in Haiti: 2013 – 2015. (2015). Unpublished Internal Document, Centers for Disease Control and Prevention.

51. Kayali, U. et al. (2003). Coverage of Pilot Parenteral Vaccination Campaign Against Canine Rabies in N'Djamena, Chad. *Bull World Health Organ.81* (10): 739-744.

52. Robinson, LE. Miranda ME, Miranda NL, & Childs JE. (1996). Evaluation of a Canine Rabies Vaccinatjon Campaign and Characterization of Owned-dog Populations in the Philippines. *Southeast Asian J Trop Med Public Health 27*(2): 2250-6.

53. New, JC Jr. et al. (2004). Birth and Death Rate Estimates of Cats and Dogs in U.S. Households and Related Factors. *J Appl Anim Welf Sci 7*(4): 229-41.

54. Centers for Disease Control and Prevention. (2015). Unpublished chart.

Appendix A: Data Collection Instrument (English)

Survey ID _____ Date: _____ Vaccination Site: _____

1. What is your age? _____
2. What is your gender? _____
3. Where do you live?
    a. Street _____
    b. Commune _____
    c. Department _____
4. How many people live with you, in your household? _____
5. Are you the primary care taker for your dogs?
    a. Yes
    b. No
    c. Unknown
6. How many dogs are you getting vaccinated today? _____
7. How many dogs belong to your household? _____
8. Of the dogs belonging to your household, how many:
    a. Stay on your property at all times _____
    b. Roam the street unsupervised sometimes _____
    c. Roam the street unsupervised at all times _____
9. What level of care do you provide for your dog(s)? Mark all that apply.
    a. None
    b. Food
    c. Water
    d. Shelter
    e. Veterinary Care
    f. Other: (free response)
    g. Declined to answer
10. If any of your dog(s) have **never** been vaccinated for rabies, what is the reason?
    a. Dog is too young (number _____)
    b. No money to buy vaccine (number _____)
    c. No vaccine available from veterinarians (number _____)
    d. No vaccine available from government (number _____)
    e. No need to vaccinate (number _____)
    f. Other (free response): (number _____)
    g. Declined to answer
    h. Survey ID _____ Date: _____ Vaccination Site: _____

11. For any dogs that died **in the past year**, what was the cause of death? **Indicate frequency of each.**
    a. Hit by Car _____
    b. Poisoned _____
    c. Disease/illness _____
    d. Other: free response _____
    e. I don't know _____
    f. Declined to answer

12. In the past year, have you ever owned a dog that **died** after displaying **at least two** of the following symptoms? **If yes, how many?**

Hypersalivation, Aggressiveness, Biting people or animals, Difficulty walking, Change in the dog's voice

    a. Yes, **number** _____
    b. No
    c. I don't know

13. Do you provide care for any dogs that you do **NOT** own? Mark all that apply.
    a. None
    b. Food
    c. Water
    d. Shelter
    e. Veterinary Care
    f. Other: (free response)
    g. Declined to answer

14. **In the past year**, have you or anyone in your household been bitten by a dog? Mark all that apply.
    a. No
    b. Yes, me
    c. Yes, an adult family member (indicate number if more than one) _____
    d. Yes, my child (indicate number if more than one) _____
    e. Declined to answer

15. Do you know anyone who has **ever** died from a disease caused by the bite of a dog?
    a. No
    b. Yes: Gender: _____ Age: _____ Year of Death: _____
    c. Yes: Gender: _____ Age: _____ Year of Death: _____
    d. Yes: Gender: _____ Age: _____ Year of Death: _____
    e. Yes: Gender: _____ Age: _____ Year of Death: _____
    f. Yes: Gender: _____ Age: _____ Year of Death: _____

16. Do you know anyone who has **ever** died from a disease called 'rabies'?
    a. No
    b. Yes: Gender: _____ Age: _____ Year of Death: _____
    c. Yes: Gender: _____ Age: _____ Year of Death: _____
    d. Yes: Gender: _____ Age: _____ Year of Death: _____
    e. Yes: Gender: _____ Age: _____ Year of Death: _____
    f. Yes: Gender: _____ Age: _____ Year of Death: _____

Appendix B: Data Collection Instrument (French)

Survey ID : _____ Date: _____ Site Vax Localisation GPS: _____

1. Quel est votre âge? _____

2. Quel est votre sexe? _____

3. Quelle est votre adresse?
   a. Rue _____
   b. Commune _____
   c. Département _____

4.Le foyer compte combien de personne? _____

5. Vous êtes le propriétaire ou le gardien des chiens?
   a. oui
   b. aucun
   c. inconnu
   d. Refus

6. Combien de chiens avez-vous pour faire vacciner aujourd'hui? _____

7. Combien de chiens appartenant à votre ménage? _____

8 Sur les chiens appartenant à votre ménage, combien.:
   a. Restez sur votre propriété en tout temps _____
   b. Parcourez la rue sans surveillance parfois _____
   c. Parcourez la rue sans surveillance en tout temps _____

9. Quel type de soins que vous fournissez-vous pour votre chien (s)? Marquez tout ce qui s'applique.
   a. aucun
   b. nourriture
   c. eau
   d. abri
   e. soins vétérinaires
   f. Autres: (réponse libre)
   g. A refusé de répondre

10. Si l'un de votre chien (s) n'ont jamais été vacciné contre la rage, quelle est la raison?
   a. Le chien est trop jeune (nombre _____)
   b. Pas d'argent pour acheter le vaccin (nombre _____)
   c. Aucun vaccin disponible auprès des vétérinaires (nombre _____)
   d. Aucun vaccin disponible auprès du gouvernement (nombre _____)
   e. Pas besoin de vacciner (nombre _____)
   f. Autre (réponse libre): (nombre _____)
   g. A refusé de répondre

Survey ID : _____ Date: _____ Site Vax Localisation GPS: _____

11. Quelle était la cause des différents chiens décédés durant la dernière année? Indiquer la fréquence de chacun.
    a. Par une voiture _____
    b. empoisonné _____
    c. Maladie / maladie _____
    d. Autres: réponse libre _____
    e. Je ne sais pas _____
    f. A refusé de répondre

12. Dans la dernière année, avez-vous déjà possédé un chien qui est mort après l'affichage d'au moins deux des symptômes suivants? Si oui, combien?

Hypersalivation, agressivité, les gens piqueurs ou des animaux,
Difficulté à marcher, les changements dans la voix du chien

    a. Oui, le numéro _____
    b. aucun
    c. Je ne sais pas

13. Avez-vous l'habitude de soigner les chiens errants ? Marquez tout ce qui s'applique.
    a. aucun
    b. nourriture
    c. eau
    d. abri
    e. soins vétérinaires
    f. Autres: (réponse libre)
    g. A refusé de répondre

14. Dans la dernière année, avez-vous quelqu'un de votre ménage qui a été mordu par un chien? Marquez tout ce qui s'applique.
    a. aucun
    b. Oui, je
    c. Oui, un membre adulte de la famille (indiquer le nombre si plus d'un) _____
    d. Oui, mon enfant (indiquer le nombre si plus d'un) _____
    e. A refusé de répondre

15. Connaissez-vous quelqu'un qui a été décédées d'une maladie causée par la morsure d'un chien?
    a. aucun
    b. Oui: Sexe: _____ Age: _____ Année du décès: _____
    c. Oui: Sexe: _____ Age: _____ Année du décès: _____
    d. Oui: Sexe: _____ Age: _____ Année du décès: _____
    e. Oui: Sexe: _____ Age: _____ Année du décès: _____
    f. Oui: Sexe: _____ Age: _____ Année du décès: _____

16. Connaissez-vous quelqu'un qui n'a jamais victime par la «rage»?
    a. aucun
    b. Oui: Sexe: _____ Age: _____ Année du décès: _____
    c. Oui: Sexe: _____ Age: _____ Année du décès: _____
    d. Oui: Sexe: _____ Age: _____ Année du décès: _____
    e. Oui: Sexe: _____ Age: _____ Année du décès: _____
    f. Oui: Sexe: _____ Age: _____ Année du décès: _____

Appendix C : List of 'Canine Rabies Like Illness' Diseases [54]

Canine Rabies-Like-Illness Differential Diagnoses						
	Higher Risk	**Clinical findings/ Neurologic signs**	**Histopathology**	**Diagnostic Testing**	**Zoonotic**	**Prognosis**
Infectious						
Rabies virus	Outdoor **Unvaccinated** History of bite wound	Changes in **behavior** (**aggression**, restlessness), muscle tremors, fever, weakness or incoordination (often period of 1-2 days) CNS disturbance, unexplained progressive paralysis, sudden anorexia, apprehension, nervousness, irritability, hyperexcitability, ataxia, altered phonation, changes in temperament	Mononuclear infiltration, perivascular cuffing of lymphocytes, Negri bodies	IFA on fresh brain tissue	Yes	Fatal
Canine Distemper	**Unvaccinated** Exposure to other dogs	Anorexia, transient fever, lethargy, nasal/ocular discharge, hyperkeratosis of nasal planum/foot pads, enamel hypoplasia, respiratory disease, GI disease Localized muscle twitching, "chewing-gum" fits, convulsions with salivation, circling, head tilt, nystagmus, paralysis	necrosis of lymphatic tissues, cytoplasmic and intranuclear inclusion bodies in respiratory, urinary, and GI epithelium	RT-PCR, CSF evaluation, IFA	No	Poor with neurologic deficits
Fungal meningoencephalitis	**Cryptococcosis** Blastomycosis Histoplasmosis Coccidioidomycosis	Lethargy, dull, fever, upper respiratory disease, optic neuritis, granulomatous chorioretinitis, altered mentation Ataxia, seizures	encapsulated organisms within a connective tissue reticulum	Cytologic examination of tissue	Yes, laboratory workers	Fair

Protozoal Meningoencephalitis	*Toxoplasma gondii* *Neospora caninum* **Young animals**	fever, diarrhea, cough, dyspnea, icterus, myocarditis, depression Ascending paralysis, ataxia, cranial nerve deficits, weakness	Protozoa within tissue (unlikely)	Paired titers	No	Guarded
Rickettsial Meningioencephalitis	**Tick exposure** *Ehrlichia canis* Rocky Mountain Spotted fever	**Fever**, anorexia, lethargy, weight loss, changes in behavior Vestibular dysfunction, hyperesthesia, ataxia	mononuclear cell infiltration in perivascular regions	Paired titers	Yes, indirect	Good, unless severe neurological deficits
Metabolic/toxic						
Acute Lead poisoning	**Puppy, juvenile** Home renovations Access to old buildings	Anorexia, vomiting, diarrhea, constipation, anxiety, hysterical barking, salivation Blindness, ataxia, muscle spasms, opisthotonos, convulsions	Depends on source of poisoning	Lead source in stomach, lead concentration is tissues	No	Good, unless severe neurological deficits
Hepatic encephalopathy	Portosystemic shunt Acute liver failure	Depressed, behavior change (aggression), salivation Circling, head pressing, aimless wandering, weakness, ataxia, collapse, seizures, and coma	astrocyte swelling, hepatocyte changes	Chemistry, ammonia levels	No	Guarded based on underline cause
Neoplasia						
Neoplasia	Primary or metastatic brain tumor **Middle-aged or older**	Signs depend on location of lesion. Often slow onset of signs with progressive deterioration	Mitotic figures	Fine needle aspirate, biopsy	No	Depends on type of neoplasia
Trauma						
Trauma	History of **head trauma** (HBC, etc) Outdoor	Acute onset – signs of intracranial problems. Alternations to consciousness, paresis, cranial nerve abnormalities, laceration around head, skull fractures, blood in ear canals, scleral hemorrhage	N/A	Radiographs, CT, MRI	No	Depends on extent of injuries.