Perceptions of measures to control *Aedes* mosquitoes and mosquito-borne diseases in Costa Rica

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Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Master of Science
in the
Department of Geography

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May 3, 2016
Blacksburg, Virginia

Keywords: Costa Rica, mosquito control, mosquito-borne diseases, public health

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Abstract

Aedes mosquitoes are responsible for the transmission of several arboviruses throughout tropical and subtropical regions of the world. In the Americas, *Aedes aegypti* is the most competent vector of dengue, chikungunya, Zika, and yellow fever. With up to 400 million cases globally each year, dengue fever is the fastest growing vector-borne disease in the world, and it has become an increasingly significant risk to global health. In the Western Hemisphere, dengue, and more recently chikungunya and Zika, exists throughout much of Latin America and the Caribbean. Both diseases are spread via *Aedes* mosquitoes and both constitute major health risks in Costa Rica. A dengue outbreak in Costa Rica in 2013 was the largest epidemic in the country since the return of the disease in 1993. Moreover, between 2014 and 2015 there was a 54.9% increase in dengue cases in Costa Rica, further demonstrating the relevancy of research on mosquito-borne diseases. Given this context, this study employs qualitative methods to critically investigate measures to combat *Aedes* mosquito-borne diseases in Costa Rica. Data were collected using household interviews (n = 80); semi-structured key informant interviews with public health officials, researchers, nonprofit organizations, and community leaders (n = 22); and a focus group discussion in each of two study areas. The results provide broad and place-specific information about mosquito control efforts and other actions deployed in Costa Rica to mitigate mosquito-borne diseases. The data reveal differences in perceptions and disease incidence among household interviewees as well as where households source information about mosquitoes and mosquito-borne diseases. Varying degrees of knowledge on mosquitoes and mosquito-borne diseases were uncovered across the study sites, as were differing attitudes among the general population regarding mosquito control techniques (e.g., fumigation, education campaigns, and household visits by public health officials). Additionally, data indicated a gap in knowledge regarding the ability of the public to report mosquito-related problems to health authorities. Households also exhibited discrepancies in knowledge pertaining to chikungunya transmission and details about the vector.

Acknowledgements

First, I would like to thank the Virginia Tech Department of Geography for the incredible opportunity that has been awarded to me, specifically, Luke Juran and Korine Kolivras for their roles as advisors and mentors. Second, I appreciate and recognize the work of Anne Wallis as a committee member on this project.

Special gratitude to the people of Costa Rica, for the immense hospitality and cooperation. To Gail Nystrom and the Costa Rica Humanitarian Foundation—thank you for doing what you do. Particular thanks to the Bogarín family—Mary, Carlos Sr., Thais, and Carlos, your friendship and love was appreciated and cherished. Carlos and Sophia, this work would be incomplete without you. Lastly, I need to thank my family for the unconditional support through all my endeavors.

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1. Introduction

1. Introduction

Vector-borne diseases have become an increasingly important health issue around the world. The literature demonstrates a rapid increase in both vector-human interactions and vector-borne disease cases. Vectors (e.g., mosquitoes, ticks, flies, fleas, and other disease spreading agents) can transmit diseases that often involve a human-vector cycle, with humans potentially serving as a host. Public health officials study and monitor vector populations in order to prevent disease, and efforts to control vectors have become a primary focus of public health officials. While vector-borne diseases are of great concern, mosquito-borne diseases in particular have become the most important vector-borne diseases in terms of morbidity and mortality. Dengue, chikungunya, Zika, and yellow fever are all transmitted by the *Aedes* mosquito. Disease transmitted by the *Aedes* mosquito have been highlighted by public health officials around the world because several billion people are at risk for *Aedes*-transmitted diseases.

Dengue fever has been a health hazard in many parts of the world for hundreds of years (Gubler and Clark 1995), with roughly one-third of the world's population potentially at risk for infection and nearly 400 million infections each year (Bhatt et al. 2013). The dengue virus, which is an arbovirus, is the most significant vector-borne virus in the world due to its rapid emergence in tropical and subtropical areas with a 30-fold increase in the past 50 years (WHO 2016). As humans continue to migrate to urban areas, specifically in the tropics, risk of dengue infections will only increase given that dengue epidemics are typically found in poor, urban areas (Troyo et al. 2008). Risk of other *Aedes* mosquito-borne diseases--including chikungunya, yellow fever, and more recently Zika--exists in similar locations where the genus is present.

Chikungunya and Zika are not yet as common as dengue in Latin America and the Caribbean. With concern over increased risk of dengue and other mosquito-borne diseases, an improved understanding of policies related to combat mosquitoes will support efforts to prevent and control epidemics in the region and around the world.

Many tropical and subtropical regions with dengue endemicity have deployed mosquito control methods to reduce *Aedes* populations and prevent mosquito-borne diseases. It is widely believed that mosquito control is the most effective approach to prevent mosquito-borne diseases, especially in cases where no vaccine has been developed. Efforts to control mosquito-borne diseases in Latin America and the Caribbean have harnessed a variety of tools to combat mosquitoes and the diseases they transmit, primarily through prevention (i.e., education) and source reduction (i.e., removal of standing water and insecticide use). Awareness campaigns are a common tactic globally, while more deliberate efforts vary according to particular geographic contexts.

Costa Rica is an interesting context in which to investigate mosquito control and mosquito-borne diseases. Mosquito populations, and thus the diseases they spread, have undergone a process of emergence and reemergence, and have recently risen to become a serious health concern for the country. Dengue was present in Costa Rica (and much of Latin America and the Caribbean) until 1960, when successful eradication efforts ridded the country and much of the region of the *Aedes* mosquito (Troyo et al. 2006). Disease eradication campaigns were successful in combatting vectors that spread tropical diseases and nearly eradicated some. For over 30 years, there were no domestic cases of dengue in Costa Rica. However, in 1993 the disease reemerged and has been endemic ever since (Diaz-Quijano and Waldman 2012; Troyo et al. 2006).

Outbreaks in Costa Rica and Latin America over the past few decades have sparked various responses from governments, nonprofits, and community-based organizations to address the growing concerns of dengue and other mosquito-borne diseases. In 2013, the western hemisphere had its first case of chikungunya in the Caribbean (CDC 2016). Since then, the virus has spread to dozens of countries in the region. The first case of chikungunya through autochthonous transmission in Costa Rica occurred in 2014, which has made chikungunya a major public health concern. More recently, Zika has surfaced as a threat to the western hemisphere from its African origin. Zika has spread rapidly through South America and the region, most notably in Brazil, due to dense populations of *Aedes* mosquitoes. Rapid urbanization and the ability to be transmitted sexually continues to worry health officials.

2. Medical geography

Geography invites a variety of research investigations of the physical, human, and built environments, which has led to the discipline's constant expansion (Clifford et al. 2012). As a result, the methods employed by geographers vary greatly according to sub-discipline and the respective study. Within the subfield of health and medical geography, research ranges from vector ecology, disease diffusion, access to healthcare, and health policy (among others). This research draws on disease ecology, which explicates the relationships among population, habitat, and behavior as factors that influence health as illustrated in Figure 1 (Meade and Emch 2010). This framework allows for an understanding of the complex dynamics at play when studying mosquito-borne disease. The habitat in Costa Rica, both built and natural, greatly influences the mosquito population and its behavior. Largely a tropical climate with two distinct seasons, Costa Rica possesses a natural environment rich in biodiversity that also supports robust mosquito populations. Further, the built environment does not sufficiently mitigate the spread of mosquito-borne diseases. *Aedes aegypti* mosquitoes primarily rely on humans for blood meals and thus tend to live among the built environment where humans spend time (e.g., homes, schools, churches, etc.). Humans also behave in ways that are shaped by the natural and built environments. Thus, vulnerability to mosquito-borne diseases varies across communities as a function of behavior. In Costa Rica, for example, the use of insecticides and window coverings (i.e., screens) varies according to place, with such behaviors influenced by a set of factors, most importantly socioeconomics. Population characteristics such as socioeconomic status and education attainment are key factors of mosquito-borne disease vulnerability and transmission (Bhatt et al. 2013). Barriers exist throughout Costa Rica that restrict people from taking necessary precautions to prevent mosquito-borne diseases, including irregular trash collection, standing water near homes, and infrastructure that often facilitates larval habitats. Furthermore, lack of a sufficient knowledge base on mosquitoes and mosquito-borne diseases can situate a community or family unit as more susceptible or vulnerable. The triangle of human ecology is therefore a useful framework to address mosquito-borne diseases within medical geography and will be used to frame this study.

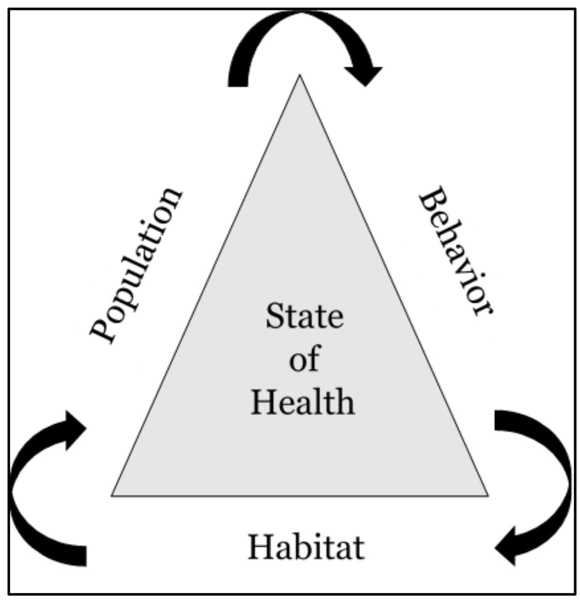

Figure 1: Disease ecology triangle adapted from Mead and Emch (2010). The figure demonstrates the relationships between the environment, humans, and their behavior.

3. Problem statement and research objectives

No other study has specifically examined levels of knowledge and attitudes of mosquito-borne diseases using qualitative methods in Costa Rica. Therefore, the overall objective is to add to the body of literature on policies and programs employed to combat mosquito-borne disease in

Costa Rica and similar geographies, particularly in the area of public perceptions. The efficacy of such measures will be investigated in terms of their awareness and recognition among the general population, and the accuracy of this knowledge will be triangulated by speaking with key informants and experts on the measures. The literature demonstrates that efforts to control mosquitoes and dengue have been activated in Latin America and the Caribbean with a paucity of research conducted in Costa Rica. Furthermore, the limited research that does exist in Costa Rica was primarily conducted in the greater Puntarenas area. This study supplements the existing literature in Puntarenas and investigates unstudied areas around the capital city of San Jose.

In an applied sense, this research is valuable to public health officials because it investigates local knowledge and perceptions of mosquito-borne diseases in Costa Rica in order to understand their relationships with control measures and disease prevention. A better understanding of such measures is important for mitigating mosquito-borne diseases in Costa Rica, especially in cases where there is a lack of vaccines, prophylaxes, and treatment. The research addresses two overall questions:

1. What policies and programs exist to combat *Aedes* mosquitoes and mosquito-borne diseases in Costa Rica?
2. What are perceptions and levels of knowledge of such measures among the general population?

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2. Literature Review

1. *Aedes* mosquitoes

The two main vectors of dengue, chikungunya, Zika, and yellow fever are *Aedes aegypti* and *Aedes albopictus*, which are present in much of the world (Figure 2). Vector eradication programs in the Americas during the 1950s-1960s successfully decreased mosquito populations until the campaign ended in the United States in 1970 and elsewhere in the region around the same time (Gubler and Clark 1995; Ibanez-Bernal 1997). Twenty-five years after the campaign, *Aedes aegypti* populations returned to pre-eradication campaign levels, as shown in Figure 3 (Gubler and Clark 1995).

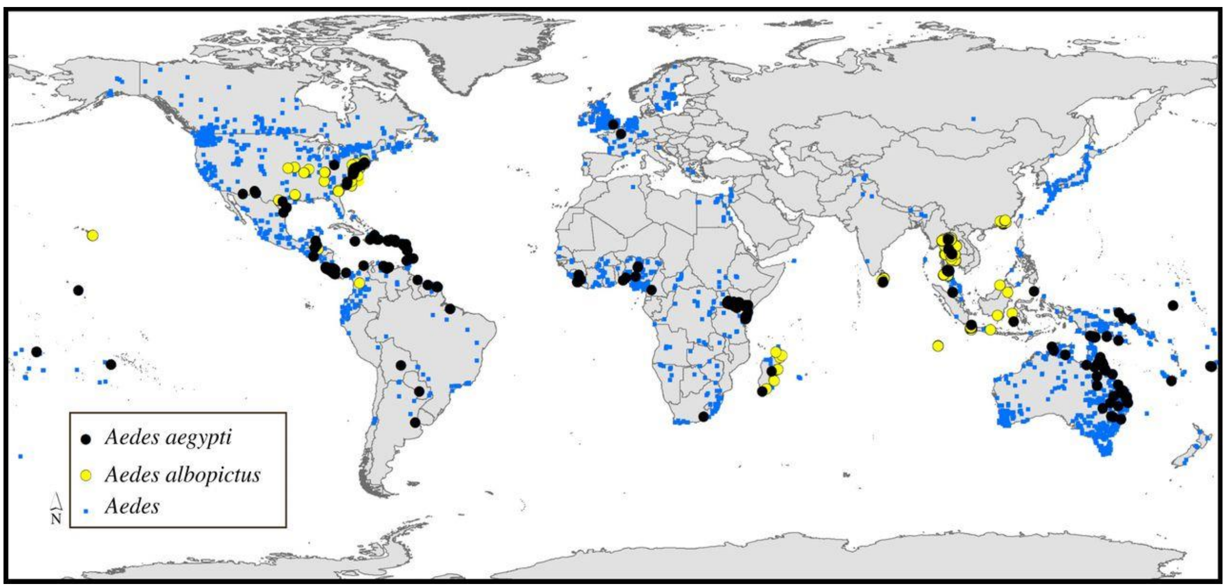

Figure 2: Global range of *Aedes* mosquitoes (Campbell et al. 2015).

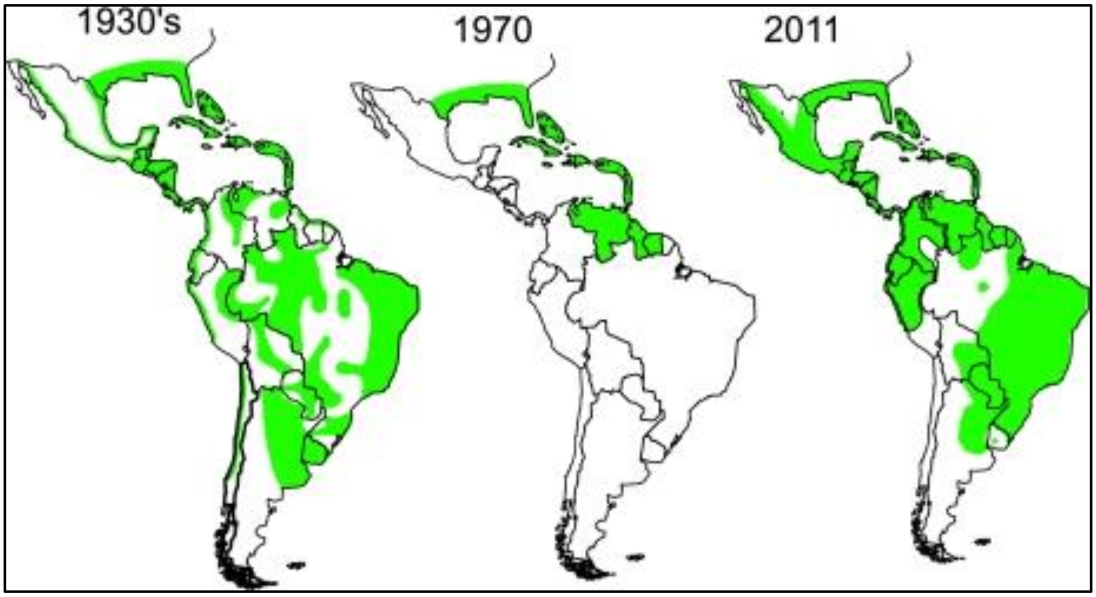

Figure 3: Range of *Aedes aegypti* before and after insecticide use campaigns (Gubler 2011).

Climate change is thought to have expanded the range of *Aedes* mosquitoes making endemic regions more vulnerable to an increase in cases (Field et al. 2014). An increase in temperature positively affects mosquito populations as well as dengue transmission. Specifically, a mosquito becomes infectious in a shorter period of time when temperatures are warmer, and increases in temperature enable mosquito ranges to expand in both latitude and altitude. The literature suggests that environmental factors may be increasingly used as predictors of dengue occurrence (Fuller et al. 2009), particularly in urban areas that can sustain increasing populations of *Aedes* mosquitoes. As temperatures rise, the range of mosquito habitats will likely continue to expand. This expansion will increase the likelihood of mosquito-borne diseases appearing in new areas. With population centers at relatively high elevations in Costa Rica, including the capital city of San Jose at 1,172 meters above sea level, areas that were previously too cold for dengue transmission have become increasingly vulnerable under warmer temperatures.

While climate variability has aided in the range expansion of *Aedes* mosquitoes, it remains only one factor. Land use and land cover change (LULCC) has led to the alteration and encroachment of natural landscapes. Thus, practices such as deforestation and agriculture necessarily perturb natural landscapes, thereby leading to new and different interactions between humans and mosquitoes. Most recently, rapid urbanization has been a leading human-induced factor in range expansion and mosquito-borne disease transmission (Guzman and Kouri 2003). Poorly established, informal, and overstressed infrastructure (and related human behavior) create an environment suitable for *Aedes* habitats.

Aedes aegypti is the primary and most competent vector for dengue globally (Diaz-Quijano and Waldman 2012; Ibanez-Bernal et al. 1997; Troyo et al. 2006), while *Aedes albopictus* is a secondary vector responsible for outbreaks mainly in Asia and Oceania (WHO 2016). It is believed that *Aedes aegypti* was introduced to the Americas during the trans-Atlantic slave trade. The *Aedes aegypti* mosquito also serves as the primary vector for chikungunya, Zika, and yellow fever with *Aedes albopictus* as a secondary vector. *Aedes aegypti* is the more peridomesticated species and is most likely to be found in urban areas. They primarily rely on humans for habitat and blood meals and have become problematic to the public as they breed in man-made structures and containers such as tires and waste containers. These breeding habits have been targeted by cleanup campaigns and other organizations as a control measure (Perich et al. 2003). *Aedes albopictus* can also be found in urban habitats along with *Aedes aegypti* but is typically found in sylvatic habitats in tropical and subtropical regions (Ibanez-Bernal et al. 1997). In some areas, primarily more humid regions, *Aedes albopictus* has been found to outcompete *Aedes aegypti* mosquitoes. *Aedes albopictus* were first reported in the Americas from a shipment arriving to Houston, Texas from Asia. It is believed that *Aedes albopictus* mosquitoes also arrived in similar ways through Brazil and Columbia (Rai 1991). In Costa Rica, *Aedes albopictus* most likely arrived through range expansion from sources of introduction in the region (Calderon-Arguedas et al. 2010).

2. *Aedes* mosquito-borne diseases

Every year there are over one billion cases and an estimated one million deaths globally from vector-borne diseases, mostly from mosquitoes (WHO 2016). Human behavior has led to an increased risk of vector-borne diseases, which account for 17% of all infectious diseases annually (WHO 2016). Dengue ranks number one in morbidity and mortality among all arboviruses, and it is also the most widespread arbovirus, currently present in over 100 countries (Troyo et al. 2006). Other arboviral diseases, such as chikungunya and Zika, have many similarities to dengue fever (e.g., vector and symptoms) and are also endemic in the western hemisphere. Researchers have identified education campaigns, conducted leadership summits, intensified research, and increased vector surveillance as methods to combat dengue fever and other mosquito-borne diseases (Gubler and Clark 1995; Hotez et al. 2014).

Dengue

Dengue, or "break bone fever," is caused by a flavivirus and is an infection with one of four strains of the dengue virus (DEN-1, DEN-2, DEN-3, and DEN-4), which is endemic to tropical and subtropical regions of the world. When a new strain, or serotype, is introduced to an area, a local epidemic can be initiated. Exposure to individual strains confers immunity to that strain, but when multiple serotypes are present, referred to as "hyperendemicity" (Orozco 2007), individuals are at greater risk of contracting dengue hemorrhagic fever (DHF) when infected with a new serotype. DHF results in a higher rate of mortality and requires a more complex treatment approach than dengue itself.

Humans and mosquitoes are responsible for the transmission of dengue fever. The transmission cycle of dengue requires a mosquito (i.e., vector) to orally receive the dengue virus when biting an infected human (i.e., reservoir), which it then spreads to other individuals in subsequent bites, thus propagating the disease (Figure 4). Symptoms of dengue include flu-like symptoms, muscle and joint pain, headaches, and rash (among others). The case fatality rate of dengue is less than 1% with proper treatment and access to care (WHO 2016). While nearly 400 million cases of dengue cases are seen each year (Bhatt et al. 2013), there are approximately 500,000 cases of DHF annually, mostly among children, which results in a higher case fatality rate of 2.5% (WHO 2016).

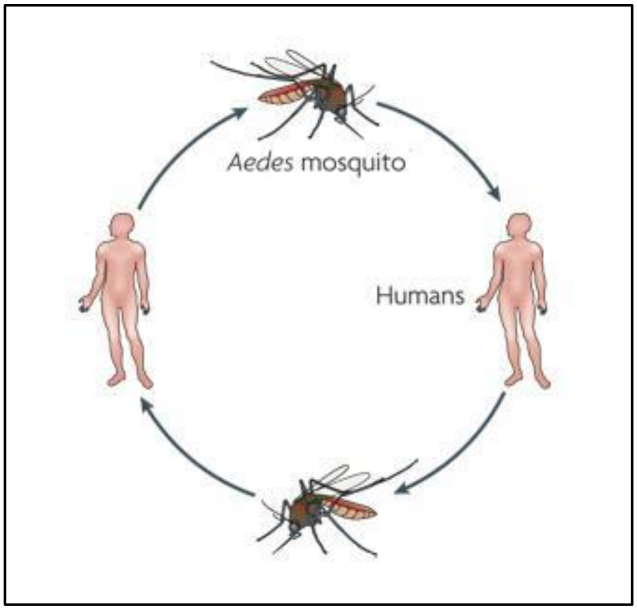

Figure 4: Transmission cycle of dengue (CDC 2016).

Dengue's natural place of origin is in Africa. Through processes of trade and increased global travel, the disease spread to Asia and the Americas (Gubler and Clark 1995). While dengue has existed for hundreds of years, the more severe hemorrhagic form of the disease, DHF, is thought to have originated in the Philippines (Meade and Emch 2010). DHF spread to Thailand in the 1950s and was originally more prevalent among children (Meade and Emch 2010; WHO 2014), but it can in fact affect the entire population. Mosquito avoidance (e.g., insecticide use, source reduction) is currently the most effective method of preventing mosquito-borne diseases, especially for dengue and other diseases for which no vaccines exist. There is, however, a prophylactic vaccine that has undergone clinical trials and is in production as a potential measure to combat dengue in the future. Sanofi, a French pharmaceutical company, expects to produce 60-80 million doses of a dengue vaccine each year beginning in 2016 (Sagonowsky 2016). Until the vaccine is widely available and affordable, the prevention and control of epidemics is the first line of defense. Measures previously mentioned, such as mosquito avoidance, can be communicated to the public through education and awareness campaigns, which can also help health officials to combat mosquitoes through the individual use of insecticides and the reduction of potential breeding sites (i.e., trash, open containers, standing water).

Recent studies suggest that dengue incidence rates in the Americas are rising as are dengue-related deaths (Diaz-Quijano and Waldman 2012). While population density, precipitation, and the United Nations Human Development Index are all thought to be predictive of the impacts of dengue, the chief predictor of dengue incidence and deaths is the age of endemicity (Diaz-Quijano and Waldman 2012). The disease becomes more severe over time once it is established in a country or region. Data from the Pan American Health Organization (PAHO) suggest that endemicity in the Caribbean was established in 1969, making it the region with the longest endemicity in the western hemisphere. These data are supported by the fact that the Caribbean and Brazil have exhibited the largest increase in incidence rates and dengue-related deaths. In fact, Costa Rica experienced a dengue outbreak in 1993 for the first time after eradication campaigns had ended decades earlier. Puntarenas, an urban center in Costa Rica, was one of the first cities in which the virus reemerged (Calderon-Arguedas et al. 2009). As a result, the greater Puntarenas area was one of the first regions in the country to begin prevention and control measures.

In the Americas, humans may not be the only reservoir for dengue and chikungunya. A recent study has cited bats as potential non-human, non-primate reservoirs (Platt et al. 2000), while monkeys have been confirmed as a host and reservoir in Africa and Asia. Several bat species in

Costa Rica and Ecuador can serve as actors in the transmission chain of dengue (Platt et al. 2000). If a new reservoir enters the transmission chain in addition to humans and mosquitoes, current measures would no longer suffice and efforts to combat dengue would need to expand. The inclusion of bats in the dengue transmission cycle could allow the disease to spread more freely during dry seasons while *Aedes aegypti* survive as eggs. Currently, dengue epidemics arise in tropical regions of the Americas immediately following the rainy season, which is typically May to October in Costa Rica (Platt et al. 2000). At this time, *Aedes aegypti* use the increased precipitation to lay eggs, often in containers around human dwellings. The inclusion of bats or other mammals would complicate the existing control and prevention measures already in place in Costa Rica and the region that currently only target mosquitoes. If bats were to become a reservoir for the virus, a new approach to dengue prevention would need to be developed--which would be further complicated since many bat species are protected by the government.

Chikungunya

Chikungunya is an alphavirus transmitted by *Aedes* mosquitoes. Chikungunya literally means "that which bends up," referring to its symptoms of joint and muscle pain as well as fever and nausea, which typically manifest 4-8 days after a bite from an infected mosquito (Charrel et al. 2007; Hamer and Chen 2014; WHO 2016). As with dengue, areas vulnerable to outbreaks of chikungunya are located in tropical and subtropical regions, largely mirroring the range of *Aedes* mosquitoes.

Once a disease of regional importance near its place of origin in Tanzania, chikungunya has now emerged as a global threat to public health. Both *Aedes aegypti* and *Aedes albopictus* are competent vectors for transmission and, in some circumstances, non-humans are involved in the transmission cycle. Monkeys are believed to act as a reservoir/host for chikungunya in Africa and

Asia (Enserink 2007), while human-mosquito transmission remains the only cycle in Asia and the Americas. A 2006 outbreak in the island state of La Réunion was traced to a 2004 outbreak in Kenya. A mutation of the virus occurred, which affected vector specificity, and thus *Aedes albopictus* become responsible for an epidemic in the region (Parola et al. 2006; Tsetsarkin et al. 2007). Before the outbreak in La Réunion, many scientists underestimated the capability and intensity of chikungunya, with some even calling it "benign" (Enserink 2007). Approximately 40% of the nearly 790,000 people of La Réunion became infected with chikungunya. In January 2006, 47,000 new cases were reported in a single week (Enserink 2007). It was during this 2006 outbreak that mother-to-child transmission of chikungunya was first documented (Hamer and Chen 2014), as well as the first fatal infections of the disease (Tsetsarkin et al. 2007). The epidemic had a mortality rate of only 0.1%, leaving an estimated 40% of the population of La Réunion immune to the disease. The chikungunya epidemic caused great concern as the disease quickly spread to new regions and populations. Scientists followed chikungunya as outbreaks moved from Asia to Africa to Europe and eventually the Americas in 2013. St. Martin in the Caribbean was the first country in the western hemisphere to report chikungunya in October 2013 (Hamer and Chen 2014), and by the end of 2014, chikungunya had diffused throughout much of Latin America with sporadic cases in the United States. Just as is the case with dengue and other related diseases, there is no vaccine or cure for chikungunya. Patients are often given acetaminophen to manage their symptoms (Hamer and Chen 2014).

Zika

Zika is a flavivirus first discovered in 1947 in the Zika Forest of Uganda during yellow fever research with rhesus monkeys. In 1952, the first known human cases of Zika were identified in Uganda and Tanzania (CDC 2016; WHO 2016). Zika is transmitted by *Aedes* mosquitoes with symptoms similar to dengue and chikungunya. It has emerged as a recent global health risk due to a sweeping, ongoing outbreak that began in Brazil in 2015. Before the 2015 epidemic in the Americas, Zika outbreaks had occurred in Yap and French Polynesia in 2007 and 2013, respectively. It is estimated that 80% of all Zika cases are asymptomatic, which hampers detection and treatment. Likely underestimated, Zika cases present additional challenges beyond the typical symptoms of rash, fever, or muscle aches. Scientific consensus exists citing Zika as a cause of microcephaly, a birth defect causing underdevelopment in a fetus' head (CDC 2016), as well as Guillain-Barre Syndrome (GBS) (WHO 2016).

Yellow Fever

Yellow fever is a flavivirus endemic in Africa and South America. The disease has three transmission cycles that vary according to habitat (CDC 2016; WHO 2016). The first transmission cycle occurs in urban settings and usually results in large outbreaks due to high population density. A second cycle involving nonhuman primates occurs in jungle habitats and is usually referred to as sylvatic transmission. Finally, an Africa-specific cycle of yellow fever, known as savannah, occurs where monkeys and humans carry the disease; this transmission cycle has resulted in only small outbreaks up to this point (CDC 2016; WHO 2016). *Aedes aegypti* is the main vector of yellow fever outbreaks in urban settings due to the prevalence of clean, standing water preferred by the species. Yellow fever differs from other *Aedes* mosquito-borne diseases as a vaccine exists, however, despite the vaccine, outbreaks still occur in endemic areas (e.g., Africa and South America). Immunity is conferred once someone is infected with yellow fever. Therefore, both vector control and vaccines exist as methods to fight yellow fever.

3. Costa Rica health infrastructure and administration

In 1941, a national healthcare system was established in Costa Rica. *Caja Costarricense de Seguro Social*, known as the *Caja*, serves the health needs of most of the country's 4.5 million people. Vastly improving the standard of living in Costa Rica, the *Caja* has contributed to the extension of the country's life expectancy and helped raise their health indicators on par with the developed world (Marmot 2006). While the Ministry of Health (MOH) remains in control of national health policy, planning, and other administrative duties, it commissions the *Caja* to deliver the actions of "prevention, recovery, and rehabilitation of health" (del Rocio Saenz et al. 2010).

The Ministry of Health (MOH) and *Caja* are the most significant actors in mosquito control and disease prevention in Costa Rica. The MOH forms and directs health policy while the *Caja* is responsible for the operative aspect of health. Ministry officials are tasked with the oversight and surveillance of mosquitoes and vector-borne diseases in Costa Rica. The MOH, in conjunction with the *Caja*, international organizations (e.g., Red Cross, World Health Organization, Pan American Health Organization), and other entities, develops methods to prevent, control, and manage mosquito-borne diseases. While the MOH is responsible for surveillance and vector control, the *Caja* delivers health care services and assists with communication. Joint campaigns by the MOH and *Caja* disseminate information on mosquitoes, mosquito-borne diseases and their symptoms, and prevention measures. These campaigns include television advertisements and literature that detail preventative measures such as how to eliminate potential mosquito breeding habitats. Local clinics of the *Caja* are known as EBAIS, an acronym for *Equipos Básicos de Atención Integral en Salud,* which often execute preventive and primary health measures at the community level. These efforts often include household visits and the dissemination of print and television literature on mosquitoes, dengue, chikungunya, and their mitigation.

4. Mosquito control and disease prevention policy

Without vaccines, the best way to prevent dengue, chikungunya, and Zika is through mosquito control efforts. Mosquito control usually attempts to combat (and not permanently eliminate) local mosquito populations. Keeping mosquito populations in check by eliminating larval habitats helps curb the risk of disease outbreaks. When an epidemic occurs, it is important for health officials to fumigate in order to eliminate infected mosquitoes that can quickly transmit the disease to neighbors or beyond when considering travel and trade.

Community-based programs designed to eliminate standing water around homes helps reduce mosquito populations, especially in urban areas where *Aedes aegypti* is most common. Recent methods for curbing mosquito populations include genetically modified mosquitoes as an increasingly viable option in various geographic contexts to combat tropical diseases. GMO mosquitoes were considered to be the optimal strategy against malaria transmitting mosquitoes in Brazil (Rafikov et al. 2009), and initial data reveal that the approach has successfully decreased populations. The use of GMO mosquitoes through the British company, Oxitec, involves the release of altered male mosquitoes that then mate, which leads to offspring that never reach adulthood once hatched. Officials in Florida have recently considered using GMO mosquitoes to prevent dengue, as south Florida is considered a gateway for the disease to the United States from Latin America and the Caribbean (Allen 2015).

Disease prevention exists in other forms beyond mosquito control (i.e., mosquito avoidance, education). While vaccines are absent in treating dengue, chikungunya, and Zika, other prevention techniques exist. Education campaigns and information dissemination on mosquitoes and mosquito-borne diseases are critical for raising awareness and decreasing the susceptibility of at-risk populations. Such campaigns and information include but are not limited to literature, posters, media broadcasts via radio and television, household visits from health authorities, and informal community talks.

Some governments have chosen to control mosquito populations through a top-down approach, such as the broad-scale use of insecticides applied via backpack sprayers (Perich et al. 2003). In Costa Rica, chemicals and insecticides are currently used to control outbreaks once cases have been reported. Mosquitoes generally do not travel far between blood meals, and thus the use of insecticides at the neighborhood level has proven effective. According to Perich et al. (2003), the effectiveness of backpack spraying (using ultra low volume and fog spraying) in Puntarenas was 100% after 24 hours had passed, meaning that all mosquitoes had been killed. Spraying around households (e.g., doorways) by handheld methods is more effective in killing *Aedes aegypti* than aerial or vehicle spraying during dengue outbreaks (Perich et al. 2003).

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3. Perceptions of measures to control *Aedes* mosquitoes and mosquito-borne diseases in Costa Rica

1. Abstract

Dengue fever has become an increasingly significant risk to global health. With up to 400 million cases annually, dengue constitutes the fastest growing vector-borne disease in the world. In the western hemisphere, dengue, and more recently chikungunya and Zika, exists throughout much of Latin America and the Caribbean. These diseases, in addition to yellow fever, are spread by *Aedes* mosquitoes, which have been present in Costa Rica for centuries. Therefore, this study uses qualitative methods to critically investigate the prevention of *Aedes* mosquito-borne diseases in Costa Rica. Specifically, this study examines the policies and programs in place to combat *Aedes* mosquito populations and the diseases they transmit. Original data were collected via household interviews (n = 80); semi-structured interviews with public health officials, researchers, nonprofit organizations, and community leaders (n = 22); and a focus group discussion in each of two study areas (Puntarenas and San Jose). The results provide broad and place-specific knowledge on mosquito and disease control efforts in Costa Rica. Varying degrees of public knowledge on mosquitoes and mosquito-borne diseases exist both within and across the study sites. These differences include conflicting perceptions of mosquito control techniques (e.g., fumigation, education campaigns) as well as disease source, habitat, and risk.

Keywords: Costa Rica, mosquito control, mosquito-borne diseases, public health

2. Introduction

Aedes mosquitoes--the vector that transmits dengue, chikungunya, Zika, and yellow fever--have experienced increases in range and have established endemicity in new areas over the past few decades. Thus, it is imperative to understand the role of vector control and disease prevention, and public perceptions of both, in order to formulate and operationalize effective measures to combat mosquitoes and the diseases they transmit. A clearer understanding of public perceptions is even more important given that dengue, chikungunya, and Zika can only be prevented by mosquito control since no vaccines currently exist. Therefore, this research gauges local knowledge of mosquitoes and mosquito-borne diseases in order to critique methods of vector-borne disease prevention in Costa Rica. Commonly deployed strategies, such as education campaigns, media blasts, and insecticide use, can then be adapted or recalibrated to address knowledge gaps and improve efficacy.

In Latin America and the Caribbean, *Aedes aegypti* is the main vector in mosquito-borne disease transmission, although *Aedes albopictus*, generally a less competent vector, is also present to a lesser extent. Strategies to combat mosquitoes and their diseases vary across Latin America, the Caribbean, and globally. In the western hemisphere, for example, strategies often include fumigation and public health messaging through media and education campaigns. These actions are understudied in Costa Rica and the region, and even more so are public perceptions of such vector and disease prevention measures. A clearer understanding of public knowledge and perceptions on mosquitoes, the diseases they transmit, and mosquito control techniques are imperative for improving public health.

Using a variety of qualitative methods, this study explores mosquito and vector-borne disease control efforts in Costa Rica. Moreover, the knowledge, perceptions, and attitudes of both the general public and health authorities will be examined. The research is informed by data from eight study sites in the study areas of Puntarenas and San Jose. Research findings unpack the actions of health officials in Costa Rica and are supplemented by local knowledge and perceptions of such measures in locations where mosquito control and mosquito-borne diseases are present. The objective is to address an evident research gap on mosquito control and mosquito-borne disease prevention in Costa Rica and to establish an overall narrative that may support modifications to current efforts to control mosquitoes and mosquito-borne diseases.

3. Background

The range expansion of *Aedes* mosquitoes around the world has led to epidemics and an increased burden on global health. The *Aedes aegypti* mosquito can be traced to Africa and was imported to the western hemisphere by way of the trans-Atlantic slave trade. *Aedes albopictus* is of Asian origin and is commonly known as the Asian tiger mosquito. Through human behavior, both species eventually found their way to the New World, bringing with them the ability to transmit foreign mosquito-borne diseases. Mosquito control programs swept across the hemisphere in an effort to combat yellow fever, a disease transmitted by *Aedes aegypti*. The Pan American Health Organization (PAHO) organized control efforts from the 1950s into the 1970s, with the chief aim to reduce mosquito populations (Gubler and Clark 1995). During this period, *Aedes aegypti* populations and range decreased significantly. However, once programs were suspended, the mosquito population reestablished its presence and now exists throughout almost the entire hemisphere. While a vaccination for yellow fever was developed in the 1970s--which is still used to combat epidemics around the globe--new diseases have emerged in the region (i.e., dengue, chikungunya, and Zika) for which there are no vaccines. For such diseases, mosquito control and information dissemination are the best defense.

Dengue, or "break bone fever," first appeared in the western hemisphere around the same time as its vector in the late 1600s (Dick et al. 2012). Those with dengue suffer from flu-like symptoms, body aches, fever, and rash, typically for 2-7 days (CDC 2016). While disease eradication programs of the PAHO were temporarily effective, the post-eradication effort era (1970s and beyond) coincided with the restoration of mosquito habitats throughout the western hemisphere. As a result, dengue began to reemerge and, in 1993, the first case was recorded in Costa Rica after a hiatus of several decades (Troyo et al. 2006).

The number of dengue cases in Costa Rica has fluctuated since its return in 1993. Its cyclical pattern underscores the complexity of the disease and therefore the challenges it presents to public health officials and the general population. In 2013, a large dengue outbreak occurred that alone accounts for nearly 15% of all cases from 1993 to 2015. The outbreak triggered a shift in strategies for combatting dengue and signified a turning point in mosquito-borne disease prevention. In place of the top-down approach of the mid-20th century (i.e., broad-scale insecticide use) came localized, bottom-up approaches involving solid waste collection, elimination of small-scale larval habitats, and information dissemination among the public.

While mosquito control efforts regrouped, in 2013 chikungunya emerged in the western hemisphere for the first time, further complicating the scenario. One year later, autochthonous transmission of chikungunya occurred in Costa Rica, joining dengue as an endemic mosquito-borne disease. Since, health officials have again increased efforts to reduce the burden of mosquito-borne diseases. Meanwhile, in 2016, Zika virus emerged in the region and in Costa Rica to join dengue and chikungunya as locally transmitted *Aedes*-borne diseases. Zika presents similar symptoms as dengue and chikungunya, and attention to its mitigation has surged due to association with microcephaly and Guillain-Barré Syndrome (GBS) as well as the ability of Zika to be sexually transmitted. In fact, the regional impact of Zika was the focus of Eric Carter's (2016) recent *Journal of Latin American Geography* piece entitled "JLAG Perspectives: Zika Anxieties and a Role for Geography."

Strategies to combat mosquitoes and mosquito-borne diseases shifted from the expansive eradication campaigns of the 1950s through the 1970s to more community-based, bottom-up approaches. Community engagement has proven successful in the region in terms of improved public knowledge on dengue and related health information (Perez-Guerra et al. 2005, Winch et al. 2002). Bottom-up approaches such as education campaigns and household visits are now widely used, as narrated by Alex Nading in *Mosquito Trails*, which is set in nearby Nicaragua. Interestingly, despite the recognized importance of bottom-up approaches, the literature on mosquito control in Costa Rica predominantly investigates insecticide use and pest management, resulting in a scarcity of research on community-based efforts. It is this paucity of research on bottom-up approaches in Costa Rica, as well as critiques of these approaches, that this research seeks to address. While similar studies investigating knowledge, attitudes, and perceptions related to mosquito-borne disease have been conducted elsewhere, this research will be the first of its kind in Costa Rica.

Most research on knowledge, attitudes, and perceptions of mosquito-borne diseases seeks to gather participants' knowledge of vectors, habitat potential, and disease transmission. Through this exercise, attitudes and perceptions emerge, which generates themes and often place-specific narratives. As with other research in the region (Perez-Guerra et al. 2005, Winch et al. 2002), this study gathers participants' knowledge of mosquitoes and mosquito-borne diseases (i.e., symptoms, transmission, prevention measures). Just as Perez-Guerra et al. (2005) asked a series of open-ended questions to participants in Puerto Rico, this study also follows similar structure by using semi-structured household surveys. Literature supplemented by original data of knowledge, attitudes, and perceptions is critical in identifying gaps in knowledge and misconceptions among the populace regarding mosquitoes and control measures. Data gathered by this study aid and inform public health officials in Costa Rica, which serves as an applied characteristic of this research.

In Costa Rica, mosquito populations are managed and monitored by the Department of Vector Surveillance of the Ministry of Health (MOH). Officials work throughout the country but are based in a central office in San Jose. MOH officials are responsible for creating policy and responding to health concerns on behalf of the government of Costa Rica. In 1941, the *Caja Costarricense de Seguro Social*, known colloquially as the *Caja*, was created to assist the MOH with the functional implementation of health policies. The *Caja* is essentially the national healthcare system of Costa Rica--the MOH is responsible for creating health policy, while the *Caja* implements policies by delivering actual healthcare services. The two actors also co-sponsor health-based education, media campaigns, and disease prevention activities, rendering their partnership critical in the fight against mosquitoes and mosquito-borne diseases.

4. Study area

Costa Rica, with a total area of 51,100 km^2, is located in Central America (Figure 5). Most of the country's approximately five million people live in the central highland region in and around the capital of San Jose. Costa Rica has a tropical and subtropical climate with coastlines on both the Caribbean Sea and Pacific Ocean. There are two marked seasons, dry and rainy, which run

November-April and May-October respectively. Mosquito-borne diseases peak during the rainy season, which is also when public health campaigns are most active.

Figure 5: Map of Costa Rica with study areas of Puntarenas and San Jose detailed. (Adapted from the World Fact Book – C.I.A.)

Two study areas were selected for this research: the cantons of San Jose and Puntarenas. The cantons provide contextual differences that aid in the investigation of *Aedes* mosquitoes and the diseases they transmit. The greater Puntarenas area has a well-documented history of mosquito control, while the elevation of San Jose had fashioned a physiographic shield against mosquito-borne disease outbreaks until recent warming related to climate change (Epstein 2000). Four districts from each canton were selected as study sites. The four districts in both Puntarenas (Barranca, Chomes, Pithaya, and Puntarenas) and San Jose (Hatillo, Merced, Pavas, and Uruca) had reported cases of both dengue and chikungunya through epidemiological week 19 in 2015 when fieldwork was conducted. The study sites allowed for an array of local knowledge, lived experiences, observations, and ultimately narratives to emerge, which collectively captured the measures being deployed in Costa Rica as well as perceptions of such measures.

Differences exist among study sites, but larger differences are present between the two broader study areas. The San Jose study sites, many of which are densely populated urban communities, are located in the canton of San Jose, which has a population of 288,054 inhabitants.

The level of development varies, but a coexistence of modern and dilapidated infrastructure best describes the area. Window screens, air conditioning, concrete, and asphalt are factors that help prevent mosquito-borne diseases in San Jose by reducing human interaction with mosquitoes. The infrastructure also creates a network that can help eliminate stagnant water by increasing water flow and reducing pooling water. In addition to the built environment, the elevation and geographic location of San Jose inhibit the propagation of large mosquito populations and thus mosquito-borne diseases. Situated at 1,172 meters above sea level in the mountainous region of the central highlands, the capital city of San Jose continues to generally be protected by cooler temperatures relative to population centers closer to sea level. *Aedes* mosquitoes in San Jose are primarily found among the built environment where humans spend much of their time (e.g., houses, schools, and churches) as they rely heavily on humans for blood meals. Human behavior and the urban ecology can thus either facilitate or hinder mosquito-borne disease outbreaks in San Jose or elsewhere. Efforts to combat mosquitoes include both insecticide use and source reduction as explained by Dr. Adriana Troyo of the Department of Parasitology at the University of Costa Rica:

> "Spraying is effective when you need to control outbreaks for stopping transmission. So, if there are cases already being detected then blocking, spraying is a great option because you kill the females, which are the ones that are transmitting . . . but if you do that [spray] without source reduction and then you stop, two weeks later the larvae that are in the water that don't get killed by spraying come back out as adults."

Puntarenas, roughly 60 miles west of San Jose and the second study area in this research, differs greatly from the central highlands region of San Jose. Puntarenas canton occupies the central west coast and a portion of the Nicoya Peninsula with an average elevation at or near sea level. The canton of Puntarenas (which includes sparsely populated villages as well as cities such as Puntarenas) has a total of 126,515 people who interact much more closely with mosquitoes due to climate and physical geography than residents of San Jose. In Puntarenas, most communities no longer share characteristics of the built environment with urban San Jose. Much of the population resides in rural settings that encroach upon the ocean, estuaries, mangrove forests, and sugarcane plantations. This environment attracts tourists to encounter and interact with the natural wildlife. Residents of Puntarenas are exposed to mosquitoes through both agricultural and eco-touristic employment, leaving the population vulnerable to mosquito-borne diseases. This exposure is demonstrated by a history of vector-borne disease outbreaks in the Puntarenas area (Calderón-Arguedas et al. 2009, Troyo et al. 2009). In Puntarenas, mosquito habitats are typically located on patios, in backyards, and within close proximity to sylvatic habitats such as mangroves, estuaries, and beaches. Furthermore, the mosquitoes use organic materials such as coconut husks for larval habitats. While containers that store standing water attract mosquitoes in both study areas, other differences exist between the study areas that generate different risks and therefore call for different control methods.

5. Methods and data collection

Data were collected during May-June 2015 utilizing qualitative field-based methods, specifically household interviews, focus group discussions, and key informant interviews. Four study sites were selected from each of the two study areas of Puntarenas and San Jose. The eight study sites were selected after reviewing official case data of dengue and chikungunya from the

MOH. Districts reporting cases of chikungunya where dengue was also present were selected as study sites. This stratified, purposive site selection enabled the study to target a rich sample set in terms of expected contributions to the research (Babbie 2010; Bernard 1988). A total of 80 households were then randomly selected from the study sites, ten from each site. The overall goal of data collection was to elicit knowledge that is generalizable from the study site level to broader societal constructs (Geertz 1973; Smith 1981). All fieldwork was conducted in Spanish other than a few key informant interviews, and all interviews were taped with a digital recorder unless participants expressed otherwise.

Household interviews

A semi-structured questionnaire was used for household interviews. Ten interviews were conducted in each of the four study sites in Puntarenas and San Jose (n = 80). The goal was to acquire grounded knowledge and gauge awareness of mosquitoes and mosquito-borne diseases among the general population. The interviews gathered basic information about individuals' encounters with mosquito control measures, education campaigns, and tropical diseases (specifically dengue and chikungunya). Interview participants were also asked to share their experiences with mosquito-borne diseases within their household and their community. The interviews helped to triangulate, verify, and sometimes refute data gathered from other sources (i.e., focus group discussions, key informants).

Focus group discussions

A focus group discussion was organized in each of the two study areas. The focus groups allowed for candid, in-depth discussions with people in communities where household and key informant interviews were also conducted (Longhurst 2010). Focus groups generated dialogue among panels of individuals to discuss knowledge, experiences, and perspectives related to mosquito control and mosquito-borne diseases. The aim was to probe community perceptions of actions being taken to prevent mosquito-borne diseases. Prompting was used during the focus groups to engage participants and assess their knowledge and familiarity with relevant topics. For example, literature from the *Caja*, local maps, and images of vectors served as prompts; participants were asked if they were aware of the literature and vectors, and where they could be found (Appendices C and D).

Focus groups supported dialogues with ordinary citizens and corroborated data gathered from household and key informant interviews. Focus groups were comprised of largely homogenous groups in each study area. In the San Jose study site of Uruca, women, often mothers, gather at a local nonprofit to collect fresh produce. Before the women departed the center, they were asked to participate in a focus group, which resulted in seven participants. In Puntarenas, students at a local university (Universidad de Costa Rica, Sede Pacífico) were asked to form a focus group, which resulted in five participants. Participants in the Puntarenas focus group were all students at the university and were asked to frame their responses in the local context and not around their permanent residences potentially elsewhere in Costa Rica.

Key informant interviews

Key informants were interviewed using a semi-structured instrument that varied according to specialization or line of work. A total of 22 key informants were interviewed ranging from public health officials, sanitation workers, nonprofit leaders, tourism managers, community organizers, and other stakeholders involved in preventing mosquitoes and mosquito-borne diseases in Costa Rica. The key informants provided expert knowledge and supplemented the research by contributing beliefs, knowledge, and institutional memory from several specialized perspectives.

The key informant interviews also provided opportunities to acquire observational knowledge. For example, the Vector Surveillance Division of the MOH demonstrated larval studies and permitted a ride-along to witness a fumigation campaign to mitigate the spread of chikungunya in Jaco, Costa Rica. Furthermore, observations and dialogues took place in neighboring Nicaragua and Panama to investigate regional cooperation and integration to combat dengue and chikungunya. There were signage and mosquito-borne disease awareness measures at the border of Nicaragua, and discussions were organized at the Gorgas Memorial Institute in Panama City (where regional health officials are sent for up-to-date knowledge and training on tropical medicine).

Analysis

Responses from household interviews were transcribed, coded, and analyzed using Microsoft Excel and the coding software ATLAS.ti. Results were examined for themes and patterns, which were then stratified according to study site and study area. Data were also organized by shared beliefs and experiences. Key informant interviews and focus groups were also transcribed and analyzed for content.

6. Results and discussion

The household interviews generated interesting and sometimes unexpected findings on the current situation of mosquitoes and mosquito-borne disease prevention in Costa Rica. The coding of data established several dominant narratives, and key informants and focus groups helped corroborate these broader themes while also supplying rich lived experiences. Thus, this section will proceed by presenting the most significant narratives coupled with quotes from interlocutors.

Community health issues

Every community confronts a variety of health issues that are both broad and place-based. The manner in which specific health issues are viewed by society is important for determining how they should be addressed. Households from the eight study sites were asked to articulate the major health issues present in their communities. Open-ended responses uncovered perceptions of health problems generalizable to the study areas and to Costa Rica as a whole. Without any prompting on mosquitoes or vector-borne diseases, results demonstrated the perceived severity and frequency of mosquito-borne diseases across the study sites. In fact, an unexpected result was that mosquito-borne diseases came out as the most cited community health issue--even surpassing issues such as diabetes, hypertension, and cancer, which we had hypothesized would be the most cited issues (Table 1). However, and as anticipated, mosquito-borne diseases were cited more frequently in the Puntarenas study area compared to San Jose. This difference is likely due to geographic and socioeconomic variations that fashion a more suitable environment for mosquito habitats and disease transmission in Puntarenas. Another interesting and unexpected finding is that while mosquito-borne diseases such as dengue and chikungunya were frequently mentioned, Zika, the most recently introduced disease, was mentioned by only one participant, who incidentally learned of it from Facebook.

Dengue and chikungunya were mentioned at the same rate in San Jose, which is intriguing since dengue has been endemic in Costa Rica far longer than chikungunya. We attribute this to an uptick in chikungunya cases that occurred just before fieldwork and thus stimulated a heightened awareness among interviewees. Since the emergence of chikungunya in 2014, health officials have targeted the disease through awareness campaigns, which could explain the parity in mentions of both dengue and chikungunya. Additionally, outbreaks of chikungunya in Costa Rica and abroad have received notable attention from new sources (e.g., newspapers, television, and radio), which we argue has positioned the disease more prominently on the public's radar.

Many households purported that chikungunya and increases in the disease in the region were an etiology of interactions with neighboring Nicaragua. Chikungunya outbreaks have been more widespread in neighboring countries such as Nicaragua, and travel and migration between Costa Rica and Nicaragua is common. This migratory flow is especially common in the La Carpio neighborhood of the Uruca study site in San Jose, which is comprised largely of Nicaraguan migrants. Thus, imported cases or familiarity with chikungunya from familial connections outside of the community could possibly explain why the disease was reported as frequently as dengue in San Jose. Households in half of all study sites mentioned a relationship between Nicaragua and chikungunya, such as Indira of Puntarenas who said: "I heard someone that got chikungunya from around the corner. The person that lives around the corner went to Nicaragua on a trip and she got chikungunya there and carried it all the way to here." In the Puntarenas study area, all but one mention of chikungunya was from Chomes, a rural community on the coast of the Pacific Ocean. All of these responses cited a recent outbreak that took place in the community, which affected one household in a particularly unique way. Gabriel of Chomes said, "There was a case [chikungunya] over here, my older daughter had chikungunya in November of last year…her case was overseen by many specialists as it was almost the first case in all of Chomes."

Questions regarding community health issues went further and asked participants to identify the single most challenging health issue in the community (Table 1). Just as with the previous question, we did not expect mosquito-borne diseases to be the number one response, although we did expect such diseases to be cited more often in Puntarenas compared to San Jose. In Puntarenas, the same number of people who articulated mosquito-borne diseases as present in their community also cited them as the most challenging health issue. When citing mosquito-borne diseases as challenging, perhaps households acknowledged their complexities due to the current status of infrastructure and mosquito control in Costa Rica. Participants may have also cited mosquito-borne diseases as the most significant challenge based on experience or knowledge of disease prevalence, the latter of which may be related to targeted increases in public health messaging. While the number of responses mentioning chikungunya was similar in San Jose and Puntarenas, the number of dengue citations varied markedly--households in Puntarenas more often cited dengue, perhaps due to their greater overall exposure to and thus knowledge of mosquitoes and mosquito-borne diseases.

Ultimately, citizens of Costa Rica perceive mosquito-borne diseases as a major health issue. In fact, mosquito-borne diseases emerged as the most cited community health issue and went on to rank them as the single greatest community health challenge. These data inform us that public health knowledge is reaching communities. Whatever the source and accuracy, information is reaching the general population, and this is an encouraging and necessary first step to combat mosquitoes and mosquito-borne diseases.

Table 1: Results of household interviews - community health issues			
	Puntarenas (n=40)	**San Jose (n=40)**	**Total (n=80)**
Major health issues in the community			
Abuse (drugs or alcohol)	3% (1/40)	0% (0/40)	1% (1/80)
Asthma	18% (7/40)	5% (2/40)	11% (9/80)
Cancer	18% (7/40)	8% (3/40)	13% (10/80)
Pollution/garbage services	0% (0/40)	28% (11/40)	14% (11/80)
Diabetes	28% (11/40)	8% (3/40)	18% (14/80)
Diarrhea	3% (1/40)	20% (8/40)	11% (9/80)
Flu	43% (17/40)	30% (12/40)	36% (29/80)
Hypertension	25% (10/40)	10% (4/40)	18% (14/80)
Mosquito-borne diseases	65% (26/40)	13% (5/40)	39% (31/80)
Single most challenging community health issue			
Abuse (drugs or alcohol)	3% (1/40)	15% (6/40)	9% (7/80)
Asthma	10% (4/40)	3% (1/40)	6% (5/80)
Cancer	18% (7/40)	10% (4/40)	14% (11/80)
Pollution/garbage services	5% (2/40)	23% (9/40)	14% (11/80)
Diabetes	20% (8/40)	5% (2/40)	13% (10/80)
Diarrhea	0% (0/40)	8% (3/40)	4% (3/80)
Flu	10% (4/40)	3% (1/40)	6% (5/80)
Hypertension	13% (5/40)	5% (2/40)	9% (7/80)
Mosquito-borne diseases	33% (13/40)	8% (3/40)	20% (16/80)

Location of mosquito habitats

Knowledge on the location of potential habitats is a critical component of mosquito control. Further, it is not only important to know the location of mosquito habitats for eradication and source reduction efforts, but also so the general population is aware of which habitats foster mosquito populations, where such habitats exist, how the habitats facilitate health hazards, and methods to mitigate those threats. Additionally, it is critical to recognize that potential mosquito habitats exist in both natural and built environments.

The location of mosquito habitats and perceptions of such habitats vary according to local geography. In San Jose, nearly 30% of those interviewed believed that mosquito habitats exist in close proximity to rivers. Interestingly, the behavior of residents living near rivers was cited along with more natural attributes such as humidity. Another 14% cited that mosquitoes use the sides of the streets as habitats. This is contextually accurate, because in much of San Jose the sides of the streets have open drainage/stormwater systems to convey high volumes of water, particularly during the rainy season. However, these open stormwater systems accumulate trash, which often leads to blockage and water stagnation, thus facilitating mosquito larval habitats. Land adjacent to streets is typically littered with trash, which itself provides a suitable environment for mosquitoes. Furthermore, parks and abandoned lots were cited in both study areas. Through a follow-up investigation during fieldwork, it was observed that parks are overwhelmingly under maintained, with the most common sight being tall grass. This environment can in fact facilitate mosquito populations. Due to the geographic setting of Puntarenas, rivers were not mentioned as mosquito habitats. Instead, other natural waterways such as the estuary and coastline were mentioned. Furthermore, in Puntarenas, Ana Maria provided an insightful narrative discussing dengue and the built environment: “Long ago, there was a public swimming pool, actually it is still there, but it was abandoned and it had water sitting for a long time and that produced a big burst in dengue. It was remodeled very recently, but for a long time it was abandoned and had a lot of sitting water."

In Chomes, the rural, coastal study site with a recent chikungunya outbreak, a crew was found cleaning the community. The group was comprised of nearly all women who were sweeping organic materials (e.g., leaves, biomass) and creating small piles that were later burned. One woman, Treicy, who agreed to discuss their work, said that their jobs are commissioned by the Ministry of Work and the municipality of Puntarenas. According to Treicy, only non-biodegradable trash (e.g., bottles, cans, and paper) is collected by the municipality, but in a sylvatic habitat this still leaves risk to mosquito-borne diseases through the existence of leaves, debris, and other organic waste. "We keep the town clean. We collect naturally recyclable [biodegradable] trash to prevent dengue and *Aedes aegypti* and chikungunya," Treicy stated. The women claimed no particular name for their group, however, others in the community recognized them as "*Manos a la Obra*," which literally translates as "let's do it" (Figure 6). Similar work is present in other communities, and the program aims to provide temporary employment for a small salary. However, the work also cleans local communities and eliminates potential breeding habitats for mosquitoes, thus providing ancillary services such as vector source reduction--an important component in mosquito control and disease prevention.

Figure 6: Treicy and other participants of the workgroup, *Manos a la Obra*.

Neighborhood cleanliness varies, but tends to be of greater concern in areas with relatively low socioeconomic status that also happen to be vulnerable to mosquito-borne diseases. Carlos, an employee of the MOH in Barranca, boldly claims that "our culture sadly is a filthy one." The remarks of Carlos came when referring to members of the general population who call upon him to fumigate more often as a way to combat mosquitoes. Carlos qualified his position on the matter from the perspective of a longtime career in mosquito control by stating that fumigation should be used as a last option; the first line of defense is keeping your community clean.

Reporting mosquito-related problems

When households were asked if mosquito-related problems could be reported to an agency or organization, answers were consistent across the study areas. A general finding across both areas was that approximately half of all households did not believe that mosquito-related problems could be reported to government health, sanitation, and public works departments, while the remaining half either said yes or was unsure (Table 2). However, conversations with key informants and households themselves revealed that problems with mosquitoes can in fact be reported to the MOH or local EBAIS. Public knowledge on how and where to report problems is critical for controlling mosquitoes and mosquito-borne diseases, and these data demonstrate a disconnect between public knowledge of the ability to report mosquito-related problems and the government's efforts to inform them of that ability. Television advertisements sanctioned by both the MOH and *Caja* communicate information on mosquito-borne diseases, symptoms, prevention methods, and where to seek assistance or provide ground-level information. Similarly, the *Caja* hangs posters on diseases such as dengue and chikungunya, which also refer the public to their website for additional information.

Next, households were asked if they had ever personally attempted to report a mosquito-related problem, to which approximately 70% responded that they had not (Table 2). While many households have never tried to report a mosquito-related problem, some declared that they never attempted to do so because they thought it was unnecessary. For example, when asked if she has reported problems with mosquitoes, Carmen in Merced, San Jose said, “No, because I don’t see them [mosquitoes]. Not in this house, you cannot see. . . . But of course you should go to the EBAIS if you see a case [of dengue]. You can do it.” Others mentioned that they do not report problems to any health entities because MOH officials and other public health personnel monitor the community through household visits, which they believe is sufficient. The lack of reporting in high risk areas can be a barrier for mosquito control, even when mosquito populations appear to be controlled through the eyes of the public. The opportunity for increased participation from citizens in the form of reporting mosquito habitats and disease incidence exists and should be utilized, because such efforts aid both MOH officials and the communities in which citizens reside. In Puntarenas, more people have attempted to report mosquito-related problems relative to San Jose, which could be due to a higher rate of cases and thus greater familiarity with mosquitoes. However, it is recognized that mosquito-related complaints might not be addressed in a timely manner by public health officials. This is attested to by Olga of Pithaya, who shared her protracted experiences with the MOH: “They sometimes take more than a month [to address complaints] and I get mad and I tell the director of the Ministry of Health and I have actually threatened her. I have to threaten her for her to see things here. I have various suits filed.”

Table 2: Results of household interviews - mosquito-borne diseases			
	Puntarenas (n=40)	**San Jose (n=40)**	**Total (n=80)**
Can mosquito-related problems be reported			
Yes	55% (22/40)	50% (20/40)	53% (42/80)
No	33% (13/40)	30% (12/40)	31% (25/80)
Unsure	13% (5/40)	20% (8/40)	16% (13/80)
Reporting mosquito-related complaints			
Yes, attempted to report	23% (9/40)	13% (5/40)	18% (14/80)
No, have not attempted to report	68% (27/40)	73% (29/40)	70% (56/80)
Unsure	10% (4/40)	15% (6/40)	13% (10/80)
Information source on mosquitoes/mosquito-borne diseases			
Media	48% (19/40)	60% (24/40)	54% (43/80)
EBAIS	23% (9/40)	20% (8/40)	21% (17/80)
MOH / *Caja*	38% (15/40)	8% (3/40)	23% (18/80)
Experience with mosquito-borne diseases			
Personally had dengue	65% (26/40)	10% (4/40)	38% (30/80)
Know someone who has/had dengue	33% (13/40)	35% (14/40)	34% (27/80)
Personally had chikungunya	0% (0/40)	0% (0/40)	0% (0/80)
Know someone who has/had chikungunya[1]	28% (11/40)	15% (6/40)	21% (17/80)

[1] Many interviewees independently made a point to state that they know of individuals outside their community who had chikungunya. Cases of chikungunya outside the local community or imported cases were far greater than similar dengue cases.

Information sources on mosquito-borne diseases

Interviewees were asked from where they obtain information on mosquito-borne diseases such as dengue and chikungunya. As shown in Table 2, sources of information were dominated by various forms of mass communication media (e.g., TV, radio, newspaper). While government sources of information were indicated, they demonstrated contrasting levels of impact. The MOH and *Caja* are dominant information sources in Puntarenas but less so in San Jose and EBAIS were mentioned by approximately the same number of households across both study areas. Information from the MOH, *Caja*, and EBAIS comes through a variety of mediums such as literature (Figure 7), advertisements, and household visits. As was found in Thailand by Swaddiwudhipong et al. (1992), household visits from health officials were influential in information reception. Other sources include schools, active community members, and word-of-mouth (among others). Overall, mass media (most notably the televised news) were found to play the largest role in information dissemination, which was also found in a similar study that investigated knowledge, attitudes, and perceptions of dengue in Kuala Kangsar, Malaysia (Hairi et al. 2003). Household interviews revealed that sources of information on chikungunya and dengue mirrored each other, although a consensus was established across both study areas that chikungunya is more serious than dengue. This is most

Figure 7: Dengue literature sponsored by *Caja*.

likely due in part to the recent emergence of chikungunya in Costa Rica and media coverage of large outbreaks in the region.

Interview participants often cited more severe symptoms associated with chikungunya, however, other details about the virus varied. Households from four separate study sites in both Puntarenas and San Jose inaccurately described how chikungunya is transmitted, some even claiming that it is contagious. When asked how chikungunya was transmitted, one participant in Barranca who works for the MOH said, "By the bite during the day. Dengue is during night. I think it's because . . . one of the diseases is transmitted by the male and the other disease is transmitted by the female. I think it's the chikungunya that's the male one and dengue would be the female." Other households across both study areas also referenced the time of day when discussing details about mosquitoes. *Aedes* mosquitoes are typically diurnal feeders, however, no exact times exist that affect risk for disease transmission. While Johnny of Uruca said that *Aedes* mosquitoes do not bite after 7:00 PM, Lidieth of Barranca said that the females feed after 4:00 PM. Inaccurate information did not stop there. Several households across both study areas described chikungunya and dengue to be transmitted by different vectors, with some claiming the vector of chikungunya to be larger than that of dengue. When households were probed further on this, the MOH and EBAIS were cited as sources of the erroneous knowledge. Nana from Puntarenas stated, "The same [vector], by a mosquito but it [chikungunya] is a different mosquito. It is different from dengue." When asked how so, Nana elaborated and claimed, "They [the MOH] say that it's bigger, the mosquito is bigger." In Uruca, Zoraida said, "In the EBAIS, they showed me in a little glass, the bug, the mosquito [that transmits chikungunya]. It looks like a bigger mosquito and it looks even uglier than a cockroach. In the EBAIS, they showed me the bug. I was told that this bug usually lives where there is very old wood." When households reported a difference in size of the vector responsible for transmitting chikungunya, not all respondents claimed it is larger, such as Alex in Barranca who said, "We saw some posters at the Ministry of Health and we saw that the mosquito is black and very, very small but fully black." Thus, while health officials in Costa Rica may have successfully conveyed the severity and increased risk of chikungunya, details on the disease and methods of transmission were misinterpreted by the general populace. The end result is that while dengue and chikungunya are spread by the same vector, many households were under the assumption that a different (and often larger) vector was responsible for chikungunya. Furthermore, even a basic understanding of mosquito-borne diseases--that female mosquitoes spread the diseases, not males--was absent among some respondents.

Experience with mosquito-borne diseases

As found in a similar study in Puerto Rico by Perez-Guerra et al. (2009), an individual's experience with dengue influences their knowledge on the disease. For example, individuals in this study who had or knew someone who had dengue were more likely to know about its vector, symptoms, habitat location, and other essential facts. In Puntarenas, 65% of interviewees personally had dengue at least once, and 98% either had dengue or knew someone who had dengue. In San Jose, only 10% of interviewees had dengue, and only 35% knew someone who had the virus. Of all 80 interviewees, 71% either had or knew someone who had dengue; however, Puntarenas accounted for 87% of all personal cases. These data indicate that virtually every household either had direct or indirect interaction with dengue in Puntarenas, and this finding combined with data from other interview questions reveal that households in Puntarenas were also able to provide more knowledge on dengue relative to those in San Jose. This finding is important because it demonstrates that lived experiences and community interactions can positively affect the diffusion of public health information among the general populace.

Experience with chikungunya was less than that of dengue, and as a result, the demonstration of knowledge on chikungunya was also less. In fact, no members of the 80 interviewed households had experienced a case of chikungunya, which we argue factored into the evident knowledge gap on the virus. While no households experienced a direct case of chikungunya, 20% in Puntarenas knew someone who had chikungunya in their community and an additional 8% knew of someone outside their community; additionally, 3% of San Jose households knew someone in their community who had chikungunya and an additional 13% knew of someone outside their community. The outcome of these data is a knowledge gap on chikungunya relative to dengue, as shared earlier in terms of knowledge on the vector and vector size. Furthermore, according to interview data, over 35% of chikungunya cases were perceived to have come from Nicaragua, while an additional 12% were believed to have been imported from other countries (e.g., Colombia). While it is encouraging that awareness of chikungunya is penetrating local communities, knowledge on the virus was considerably less than that on dengue. We hypothesize that this is in part due to a lack of personal experiences with chikungunya coupled with general unfamiliarity with the disease given that its length of endemicity in Costa Rica is much shorter than that of dengue.

Policies and programs in the community

When households were asked to name a policy or program in their community to control mosquitoes or mosquito-borne diseases, more than 90% could name a visible, tangible measure. The overwhelming majority of households were able to provide government actors (e.g., EBAIS, MOH, and *Caja*) as well as specific techniques (e.g., trash collection, fumigation, and pamphlets) that they had encountered in their community. That being said, those interviewed mentioned varying attitudes toward the efficacy of such measures. For example, some called for additional or more frequent actions to be taken by health officials, as evidenced by the perceived unsatisfactory level of intervention by households in Pithaya. "I think that the Ministry of Health should pay more attention to these [local] places. Time to time they come to fumigate, but they don't alert or say anything. They only appear maybe once every year where there is a case and they fumigate," claimed Lucey, while Alvaro said, "The *Caja* or Ministry of Health don't come here. They will only come here if someone makes a report of something burning or someone burning things." Meanwhile, others were either satisfied with the current extent of mosquito and mosquito-borne disease prevention or, in the case of Carol of Puntarenas, wished that health officials would decrease the use of chemicals to eliminate mosquitoes. "I don't believe in overuse of sprays and chemicals. I refused to let sprayers in because there is no attempt of cleaning this crap up," said Carol while pointing to a pool of standing water on her neighbor's patio.

While over 90% of interviewees were aware of actions to control mosquitoes and mosquito-borne diseases in their community, close to 30% asserted that such measures are not present in their *barrio* (neighborhood). This finding was especially evident in the study area of San Jose, where 43% stated that mosquito-related programs are nonexistent in their neighborhood. However, when pressed further, many of those 43% conceded that mitigating actions do take place in their *barrio,* but the extent is either inadequate or too infrequent.

7. Conclusion

Since eradication efforts were suspended in the 1970s, *Aedes* mosquitoes have reestablished their presence in the western hemisphere. As the range of *Aedes* continues to expand, the significance of mosquito-borne diseases will likely increase and further threaten global health. From 1993 to present, periodic dengue outbreaks have affected the country of Costa Rica. Meanwhile, chikungunya has established endemicity while the lesser understood Zika has raised serious health concerns--and all of these viruses currently have no vaccine. While other studies have investigated attitudes and perceptions of mosquito-borne diseases, no other study has used qualitative research to examine levels of knowledge and perceptions in Costa Rica, which was the aim of this research. Thus, this study serves as a novel measure of how the general population perceives actions to mitigate mosquitoes and mosquito-borne diseases, which is of importance to the fields of epidemiology and public health.

Human behavior can both facilitate and prevent future mosquito-borne disease outbreaks; thus, studying local knowledge and perceptions of mosquito control and disease prevention is critical. Given this context, this study examined the policies and programs in place to control mosquitoes and mosquito-borne diseases in Costa Rica while also considering the knowledge and perceptions of the general population.

Household interviews revealed that mosquito-borne diseases were the most frequently cited community health issue, and such diseases were also perceived to be the single most important health issue. In fact, mosquito-borne diseases outranked chronic illnesses such as diabetes, hypertension, and cancer, which was unexpected and thus valuable to the local public health discourse. However, and as anticipated due to climate and physical geography, mosquito-related issues were more prevalent in Puntarenas compared to San Jose, and households in

Puntarenas also reported more mosquito-related issues to public health authorities. Efforts to inform the public of the dangers of mosquito-borne diseases were found to have been effective, but in some cases households exhibited factually incorrect information on disease transmission, while in other cases households assumed a different vector for dengue and chikungunya. Interestingly enough, study participants implicated health authorities as the source of such inaccurate information. While data from household interviews, key informants, and focus groups varied and sometimes conflicted, valuable knowledge was gathered to help improve the implementation of future mosquito-related measures. Such refinements could include the increased participation of local populations in eliminating mosquito habitats, and revising messages geared to specific diseases (e.g., dengue or chikungunya) to instead target the *Aedes* vector or mosquitoes at large so as to not confuse the population. Furthermore, data suggest that communities may not have been treated equally regarding visible attention from Costa Rican health officials; households in both study areas spoke about the lack of attention their communities receive from health authorities. While this perception cannot be verified, on a positive note it points to the fact that residents appreciate the visible presence of health officials in action.

This study attempted to be completely objective, but limitations exist that could have affected the results. First, we attempted to construct a national discourse on mosquito control and disease prevention in Costa Rica, but did so by examining only eight sites in a total of two study areas. Furthermore, the population and areal extent of study sites varied, yet the same number of interviews were conducted at each site. Thus, smaller, rural communities were afforded the same weight as larger, urban communities, which does not accurately reflect the demography and distribution of Costa Rica's population. Moreover, potential study sites were stratified to include only municipalities where both dengue and chikungunya cases had been reported. Finally, fieldwork was conducted at the beginning of the rainy season, which is the dawn of the peak season for mosquito-borne disease transmission. Teodoro of Puntarenas said, “I focused on dengue because it’s a thing that appears mostly in winter, in this time of year, so I focused on that because we are already in winter.” At this time (May-June), public health officials had already begun preparing for probable outbreaks and notifying the public of increased risk to mosquito-borne diseases. An increase in flyers, household visits, and television advertisements could have shaped public perceptions of such diseases. We remained reflexive of these limitations during data collection and analysis, and we attempted to triangulate such data by conducting key informant interviews and focus group discussions. Also, the study sites and season were purposely selected in order to efficiently uncover the most rich and insightful data on mosquito-borne diseases in Costa Rica.

Future research should include the collection of socioeconomic and demographic attributes to look for associations among knowledge and perceptions of mosquito-borne diseases. A larger, more representative sampling regime (i.e. one that also includes non-endemic communities) combined with more quantitative data would support statistical analyses, and the incorporation of GIS could help visualize and test for spatial patterns.

8. Acknowledgements

This research was partially supported by the Sidman P. Poole Endowment in the Department of Geography at Virginia Tech, and Dr. Luke Juran. We also extend gratitude to Gail Nystrom and the Costa Rica Humanitarian Foundation for use of their facilities. Lastly, special acknowledgment is reserved for the two research assistants: Carlos Bogarín (Puntarenas) and Sophia Jimenez (San Jose).

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Appendix A: Household interviews

<u>**Semi-structured door-to-door questionnaire**</u>

1. What are health issues in your community?
    a. What are the most challenging?
2. I noticed you did/did not mention mosquito-borne diseases (dengue) why is that so?
3. What do you know about dengue fever?
    a. What have you heard (from what sources)?
    b. Have you or someone you know ever had dengue?
    c. How is dengue fever transmitted?
4. What do you know about chikungunya?
    a. What have you heard (from what sources)?
    b. Have you or someone you know ever had chikungunya?
    c. How is chikungunya transmitted?
5. What policies, programs, and measures are in place in your community to combat mosquito-borne disease and dengue fever?
    a. What are they?
6. Do you encounter mosquito control and dengue fever prevention in your neighborhood?
    a. What do you witness?
    b. Do insecticide sprays occur? If so, how often?
7. Can you tell me where specifically in your neighborhood are you most likely to find mosquitoes?
    a. Why in these specific places? (if not addressed above)
8. What information does the Ministry or Caja give you about the dangers of mosquitoes and the diseases they transmit?
9. Can you report problems with mosquitoes to an organization or agency?
    a. Have you ever reported problems with mosquitoes in your neighborhood?
    b. If yes, what would the response time be for this to be addressed?
10. Does an inspector log information concerning their visit for mosquito control?
11. Who else would you recommend me talking to for more information?
12. Is there anything I did not ask that you would like to comment on or address?

Appendix B: Key informant interviews

<u>**Key informant interview questions:**</u>

Health officials

1. What is your title and line of work/duties?
2. By holding this position, what role do you play in public health in Costa Rica?
3. What are major health concerns in Costa Rica?
4. I noticed you mentioned/did not mention mosquito-borne disease (dengue fever) why?
5. In what ways does your job deal with mosquitoes and mosquito-borne diseases?
6. What are your experiences with dengue fever within your job or otherwise?
7. What guidelines exist to inform the public of the dangers/symptoms of dengue fever?
8. Does susceptibility of a population affect how it is treated by officials?
9. Is the level of funding for health education programs appropriate for meeting your goals?
10. What is being done to prevent dengue outbreaks?
11. How long is the average dengue epidemic and does this vary by neighborhood or community? How does this relate to policy? (if not addressed)
12. Are there any new developments that will be able to change the course of dengue fever?
13. What policies, programs, and measures exist to combat dengue?
14. Do these policies, programs, and measures exist at different levels within society?
    a. If yes, which do you believe are most effective?
15. Do people often wait longer than advised (according to information) in seeking treatment for dengue fever? Why do you believe this is the case?

Doctors/health professionals

1. What is your title and line of work/duties?
2. By holding this position, what role do you play in public health in Costa Rica?
3. In what ways does your job deal with mosquitoes and mosquito-borne diseases?
4. What are your experiences with dengue fever?
5. What are the most common symptoms patients display when arriving for treatment for dengue fever?
6. Due to the symptoms of dengue fever how do most misdiagnoses occur with dengue fever?
7. What are you experiences with chikungunya? Are they similar to that of dengue fever?
8. Are some people more susceptible to mosquito bites than others? If so, are they at a higher risk for getting dengue fever?
9. What does a current treatment plan look like in [*Puntarenas or San Jose*]?
10. Do people often wait longer than advised (according to information) in seeking treatment for dengue fever? Why do you believe this is the case?

NGOs/community activists

1. What is your title and line of work/duties?
2. What, if any, programs have you participated in that dealt with health and wellness?
3. In what ways does your job deal with mosquitoes and mosquito-borne diseases?
4. What are your experiences with mosquito control?
5. What are your experiences with disease prevention such as dengue fever or chikungunya?
6. What guidelines exist to inform the public of the dangers/symptoms of dengue fever?
7. How is dengue and mosquito-borne disease viewed from a Costa Rican cultural perspective?
8. Are there any new developments that will be able to change the course of dengue outbreaks in Costa Rica?
9. What policies, programs, and measures exist to combat dengue?
10. Do these policies, programs, and measures exist at different levels within your organization and community at-large?
    a. If yes, which do you believe are most effective?

Sanitation

1. What is your title and line of work/duties?
2. Does this line of work have a role in public health?
3. Does sanitation influence mosquito-borne disease?
4. In what ways does your job deal with mosquitoes and mosquito-borne diseases?
5. What do you know about dengue fever?
6. What do you know about chikungunya?
7. What policies, programs, and measures exist to combat dengue?
8. Do these policies, programs, and measures exist at different levels within the community?
    a. If yes, do you believe are most effective?

Tourism

1. What is your title and line of work/duties?
2. In what ways does your job deal with mosquitoes and mosquito-borne diseases?
3. What do you know about dengue fever?
4. What do you know about chikungunya?
5. Do dengue outbreaks and other public health concerns have an effect on tourism?
    a. If yes, does this help expedite attention from the Ministry of Caja?
6. What policies, programs, and measures exist to combat dengue?
7. Do these policies, programs, and measures exist at different levels within the community?
    a. If yes, do you believe are most effective?

Appendix C: *Aedes* mosquito

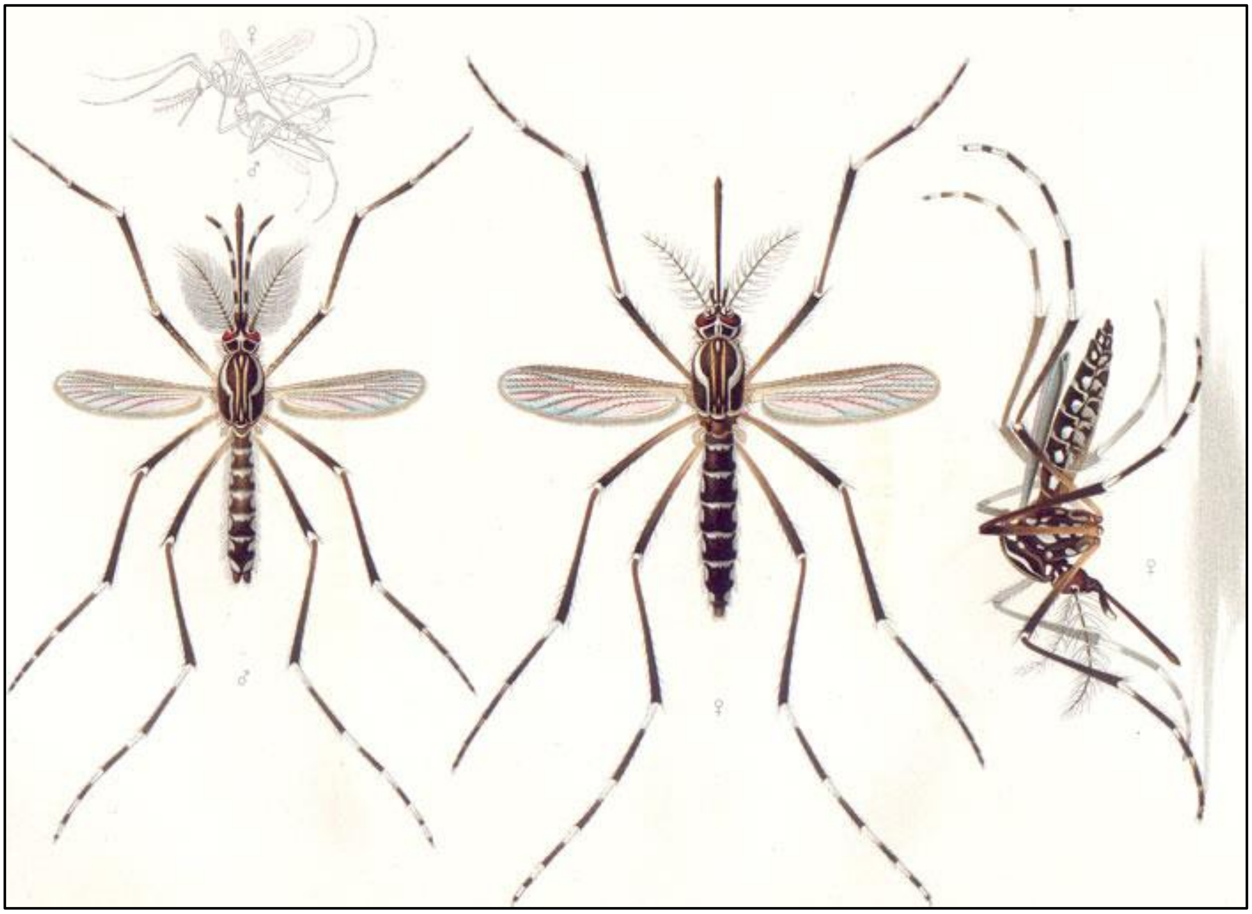

Image of the *Aedes aegypti* mosquito used during focus group discussions.

Appendix D: Map of La Carpio neighborhood *(barrio)*

Map of the La Carpio neighborhood of Uruca district, San Jose, Costa Rica. This map was used during a focus group conducted in La Carpio.