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**Mosquitoes and the urban environment: Towards establishing a more
sustainable planning framework for the control of mosquitoes and the
health threats they may pose**

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**Mosquitoes and the urban environment: Towards establishing a more
sustainable planning framework for the control of mosquitoes and the
health threats they may pose**

by

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Report

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Dedication

This final product is dedicated to my beloved Mari Jose Diaz Diaz who has for too long suffered the fate that is dating a graduate student.

Acknowledgements

I would like to recognize the professionals who gave their time to contribute their insight and understanding of the practice of mosquito control and public health for the purposes of this work. Special thanks must be given to Sarah Dooling and John Abbott for their patience in this process.

Abstract

Mosquitoes and the urban environment: Towards establishing a more sustainable planning framework for the control of mosquitoes and the health threats they may pose

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The University of Texas at Austin, 2014

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This paper delves into the issue of mosquito control strategies through an examination of present day issues and evaluates literature on administrative, technical, regulatory and professional practices involved in reducing exposure to mosquito borne diseases and how are their strategies tailored to specific contexts. The main issue that this paper will attempt to address is the development of a more sustainable framework for the control of mosquitoes and their respective health threats. In order to accomplish this, an examination is conducted with stakeholders involved in public health and mosquito control at local, state and national levels who can comment on their activities with authority. A list of interview questions tailored to different groups of stakeholders is utilized with the intent of eliciting data that answer to my research questions. Through this process, I am able to examine the current processes that are in use within such organizations and determine whether they are efficient, forward thinking and effective in addressing the myriad issues involved in proper mosquito control when compared to

current literature on the subject. It is expected that through this paper, a better understanding of the current mosquito control processes within L.A. and Houston will be developed resulting in the creation of better practices as a direct result of the investigation.

Table of Contents

List of Tables	x
List of Figures	xi
Chapter 1 Introduction.....	1
Background of Study	3
Objectives.....	5
Scope and Limitations	5
Report outline	7
Chapter 2 Literature Review	8
Introduction to Literature.....	8
Encounters with Disease	9
Current Practices Dealing with Mosquito Populations.....	12
Urban Development Practices that Contribute to Mosquito Ecology	16
Chapter 3 Methodology	18
Introduction to methodology	18
What is Qualitative Research?.....	18
What Will be Examined?	19
Research Design.....	19
Participants.....	20
Study Concerns	21
What Qualitative Methodologies will be used and Why	22
Structured Interviews.....	20
Theoretical Framework	21
Chapter 4 Research Results	29
Roles Played by Government Agencies.....	29
Best Management Practices for Reducing Exposure to Disease	31
Agencies and Budget Constraints	33
How Public Agencies Plan for Change.....	34

Comparison between Harris and L.A. countie in terms of practices ..	37
Proposed Framework for Cooperation	39
Chapter 5 Conclusion	43
Bibliography	44

List of Tables

Table 1:	Governmental Framework Responsive to Threat of Mosquito Born Disease	28
Table 2:	Population, California & Texas	34
Table 3:	Potential Impact of Crowd Sourced data gathering	38

List of Figures

Figure 1:	California Human WNV Cases, 2004- 2007	9
Figure 2:	California WNV positive Dead Birds	10
Figure 3:	Conceptualization of optimal ecological arrangement for transmission of pathogen	11
Figure 4:	Graphic Abstract of the Mo-Buzz Crowd Sourcing System	39

Chapter 1: Introduction

The 1999 discovery of West Nile Virus (WNV) in New York City presented a an ominous new mosquito-borne threat to public health (Herrington 2003). A particularly deadly outbreak of WNV in the Dallas, Texas area in 2012 and occurrences of Dengue fever in Florida and Hawaii have demonstrated the necessity of developing planning frameworks for government agencies including the federal Centers for Disease Control (CDC) and state and local authorities in order to mitigate and control the outbreak of mosquitoes in and around populated urban environments. This outbreak of WNV ran contemporaneously with a worldwide trend that saw a renewed threat of mosquito-borne disease, following decades during which such illnesses were relatively under control through the use of habitat modification and modern pesticides, most notably DDT (Institute of Medicine (US) Forum on Microbial Threats 2008). On the one hand, a consequence of international travel and trade provide a bridge between distant ecosystems that permit the emergence of foreign disease as well as disease vectors such as mosquitoes. Further, persistent and wanton use of pesticides in the past has not only produced increasingly resistant mosquito populations but has become controversial for imposed secondary effects on non-target species, the environment at large and possibly human health (Flexner 1986). Until the establishment of WNV in the U.S., the ephemeral success of driving out malaria and yellow fever brought about a quiescence of public concern and a dearth of expertise regarding mosquito control in public health (Institute of Medicine (US) Forum on Microbial Threats 2008; Patterson 2009).

The pace and extent of international trade and travel offer a heightened risk of introducing non-native disease and disease vectors to regions where they may thrive (Herrington 2003). The overall ecological consequences of such events are generally regarded as detrimental though very difficult to anticipate (Institute of Medicine (US) Forum on Microbial Threats 2008). One particular consideration for public health regarding invasive competent disease vectors is a heightened disease threat when the habitat in question coincides with humans and their agricultural assets (Reisen 2010).

High human density is of particular concern when humans themselves act as a reservoir of disease for which mosquitoes are the vector such malaria, dengue and yellow fever: infected mosquitoes do not need to fly as far in order to extract blood from multiple hosts thereby facilitating the spread of diseases within a relatively short amount of time (Vezzani 2007). Although health officials are ever mindful of the potential future *threat* of the aforementioned diseases that are of greater concern outside the United States, the transmission cycle of WNV complicates the relationship between human infection rate and urbanization (Reisen 2010). Although humans can become infected with WNV via a mosquito bite, humans themselves are not reservoirs of the disease (ie. a mosquito cannot acquire the virus through biting an infected person) (Adams & Kapan 2009). A number of vertebrates have varying levels of reservoir competency for WNV but only some bird species have been identified as the primary reservoir hosts (Reisen 2010). Similarly, only some mosquito species are recognized as highly competent vectors (Reisen 2010). Nonetheless, urbanized areas where these birds, humans and mosquitoes intersect present a WNV health concern (Gleiser & Zalazar 2010; Reisen 2010).

Coupled with the proximity of modern day cities to large bodies of water and the ubiquitous nature of stagnant pools of water within many urban locations (i.e. rooftops, alleyways, backyard containers etc.) this has created a “perfect storm” for the proliferation of mosquitoes resulting in the need to address such concerns with a planning framework that can be utilized by government agencies to minimize such a threat to public safety (Lydy 2013).

While concern for WNV has prompted action at national, state and local levels of government to mitigate its impact and that of other mosquito-borne diseases, a review of policy actions by separate jurisdictions and how they play out can provide lessons on what practices are most effective in achieving public health goals (Herrington 2003; Hodge 2002). There are many opportunities in the lifecycle of biting mosquitoes as well as the disease organisms they may transmit that may be neglected by public agencies (Institute of Medicine (US) Forum on Microbial Threats 2008). The most obvious image of mosquito control is the reaction to an identified threat by spraying pesticide, which may indeed halt further disease transmission but can be expensive, bears secondary impacts on the environment and the disease may have already inflicted a toll before the intervention (Cumberland 2009). While surveillance and monitoring provide actionable intelligence as to the threat posed by mosquito borne disease, what proactive public action measures are available that incorporate mosquito control objectives in designing our urban landscapes? And given the countless variations of possible administrative and legal relationships between various agencies at different levels of government, what replicable arrangements optimally provide cost effective public safety with mosquito borne disease in mind? Similarly, what funding mechanisms prove resilient in providing service in the

face of a local economic recession that limits available public resources. Finally, as well as awareness of how local ecological and public health contexts can easily be altered by the introduction of a foreign vector or disease organism, how are authorities addressing long term consequences as a result of the climate change trend. An exhaustive national survey of local mosquito control agencies in their elemental jurisdictions would yield a substantial understanding as to what regulatory, administrative and technical practices offer the most promise. Short of such an extensive effort, this investigation focuses on two comparable but distinct case study regions to identify examples of systematic variations in planning and performance of government agencies charged with a role in the control of mosquitoes and mosquito born disease. The resulting discussion of differing approaches to the local impact on the mosquito threat is informed by authoritative literature on the subject and yields lessons for consideration by the planning and policy community for enhancing public health and quality of life

OBJECTIVES

This report will attempt to answer the following questions regarding mosquito control in Los Angeles County, California and Harris County, Texas:

1. What are the administrative, technical, regulatory and professional practices involved in reducing exposure to mosquito borne diseases and how are these strategies tailored to specific contexts as Best Management Practices (BMPs)?
2. How do different levels of government respond to controlling and regulating exposure to mosquito borne disease?
3. How has the recent economic recession affected allocation of funding for mosquito control?

4. How may climate change effect exposure to mosquito borne disease and how can communities aptly respond to changing ecological contexts?

BACKGROUND OF THE STUDY

Mosquitoes and their irritating bite represent a public nuisance in and of itself but of greater concern is their role as a disease vector. Diseases such as West Nile Virus, Dengue Fever, Eastern Equine Encephalitis, St. Louis encephalitis and Dog Heartworm are transmitted by a variety of mosquito species in North America (Herrington 2003). The nuisance and threat of disease posed by mosquitoes inhibit full enjoyment of outdoor recreation and public spaces.

Aggressive use of DDT and other synthetic pesticides were until recently viewed as a silver bullet in combating mosquito-borne disease. Massive and comprehensive spraying efforts following WWII all but eradicated malaria in Western Europe and North America (Becker 2010; Patterson 2009). Despite the effectiveness of DDT, what became clear in the aftermath was that such policies also carried severe secondary effects upon non-target species, water quality and public health (Patterson 2009).

Since the 1970s, efforts have instead focused on limiting mosquito contact with humans to levels that can be considered tolerable (Flexner & Croft 1986; Patterson 2009). This strategy of Integrated Mosquito Management (IMM) focuses first on source prevention by inhibiting the growth of aquatic larvae by physical, biological or chemical remediation (Patterson 2009). Sophisticated mosquito control programs maintain regular monitoring programs to estimate changes in populations of certain species and incidence

of any carrying disease (Institute of Medicine (US) Forum on Microbial Threats 2008). Many communities simply rely on clinical cases of human infection as an impetus to investigate further or escalate intervention in a largely reactive manner (Hodge 2002). Because mosquitoes can exploit features of the urban landscape and urban ecosystem, and because this landscape and its ecosystem are largely shaped by the way we plan our cities, planners have an opportunity to physically preclude the presence of a significant fraction of those mosquitoes. With globalization and the ease by which people may travel long distances, infectious diseases now spread much faster than they have in the past (Patterson 2008). The arrival of West Nile Virus in the U.S. and recent outbreaks of Dengue in Florida and Hawaii only elevate the need for attention (Institute of Medicine (U.S.) Forum on Microbial Threats 2008). Similarly, as witnessed with the recent introduction of the Asian Tiger mosquito, non-native disease vectors alter the dynamic of our ecosystem only to present new challenges (Della Torre 2007; Gleiser 2010). While exotic diseases such as Malaria, Yellow Fever and Chikungunya are endemic in countries outside the U.S., there is a very real threat that an infected host traveler can inadvertently pass disease to viable mosquito vectors in the U.S. and propagate an epidemic cycle (Kitron 2010).

Finally, as a better understanding of climate change takes shape in the scientific community, much has been published about the role that climate change trends may play in altering the geographic range and habitat opportunity for mosquito species of particular concern (Ezzano 2012; Institute of Medicine (U.S.) Forum on Microbial Threats 2008; Lin 2012; Reisen 2010). While it would be beyond the scope of this research to predict how mosquitoes will respond to an altered ecology congruent with climate change, it is

nonetheless important to gage how public health and mosquito control authorities are prepared for such contingencies.

REPORT OUTLINE

The report will consist of the following parts:

Chapter 1 contains the introduction, background of the study, the study limitations as well as its aims and objectives.

Chapter 2 consists of a literature review detailing the impact mosquitoes have on public health, the current processes that have been implemented to combat them as well as their general level of effectiveness

Chapter 3 describes the methodology utilized in the study as well as the means by which data is collected.

Chapter 4 reveals the results of the study and discusses their implications.

Chapter 5 consists of the conclusion and recommendations section of the report.

Chapter 2: Literature Review

INTRODUCTION TO LITERATURE

This section reviews and evaluates literature on administrative, technical, regulatory and professional practices involved in reducing exposure to mosquito borne diseases and how their strategies are tailored to local and regional contexts within the U.S. Through this section, readers will be able to better understand how different levels of government respond to controlling and regulating exposure to mosquito borne disease, the impact of the recent economic recession on mosquito control, how climate change may affect exposure to mosquito borne disease and how communities can aptly respond to an altered threat context.

MOSQUITO SPECIES AND DISEASES

Based on an examination of relevant literature regarding mosquito populations, it was noted by this study that the *Culex* mosquitoes, the *Aedes* mosquitoes as well as mosquito-borne encephalitis diseases, West Nile disease, St. Louis encephalitis (SLE), eastern and western equine encephalitides and California encephalitis are the topics the cause the most concern for mosquito control agencies given their historic relevance in affecting the U.S. population (Wimberly 2012). It is worth mentioning that it is only the adult female mosquito that ever bites for a blood meal. The purpose of the blood meal is to render protein rich nutrient for the purpose of egg development (Adams & Kepan 2009).

ENCOUNTERS WITH DISEASE

The West Nile virus arrived in the U.S. around 1998 - 1998 through either an infected bird (which is the most likely scenario given the distance involved in introducing the virus to North America) or an infected mosquito (which had taken blood from an infected bird) (Hodge 2002; Herrington 2003; Kitron 2010). The result was that by 2002 nearly 884 cases were reported in Illinois alone with 67 of those cases resulting in the death of the infected individual (Rasgon 2009). The following are graphical illustration of the number of cases of the West Nile virus that were seen in California between 2004 and 2007:

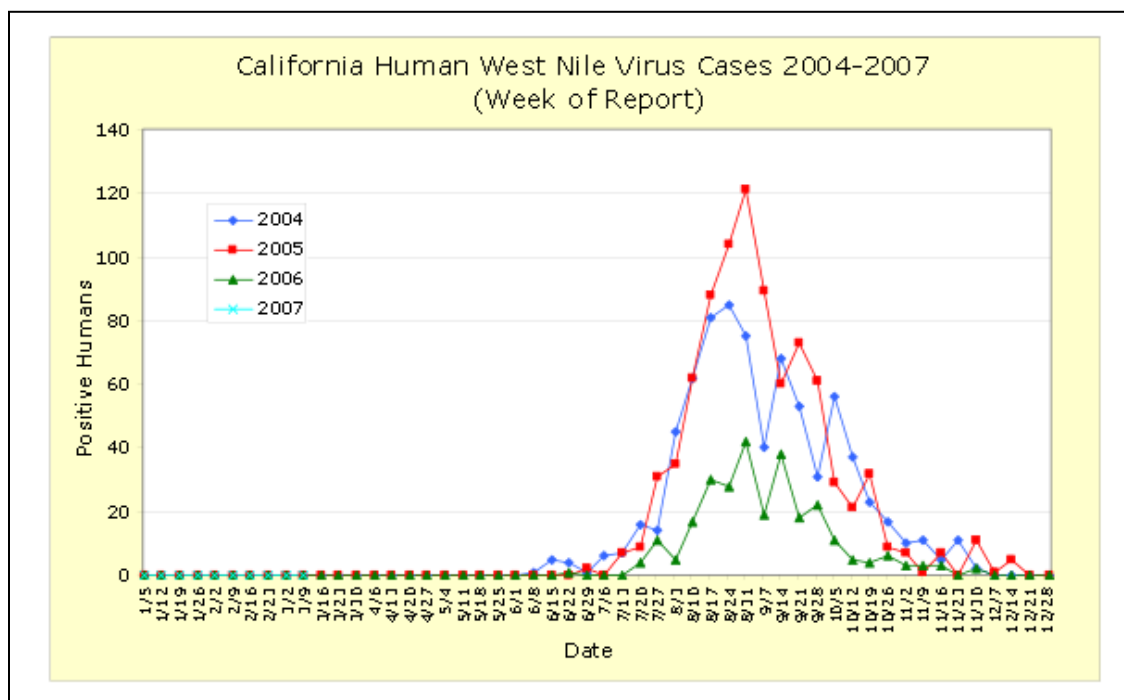


Figure 1: Graph shows clinical human cases of WNV infection

Source: California Department of Public Health

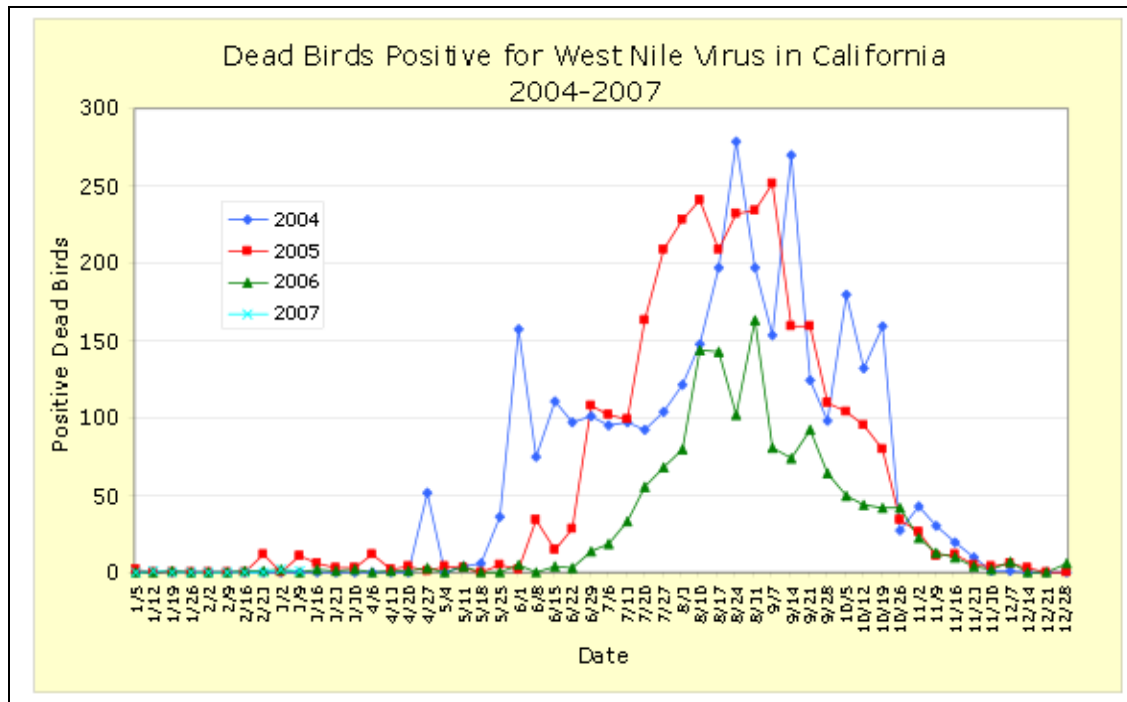


Figure 2: Graph shows incidence of dead birds positive for WNV

Source: California Department of Public Health

As it can be seen, there appears to be a correlation between the increase in the number of human victims of the virus and the number of dead birds within the region that have died as a direct result of the virus. Further, incidence of dead birds lead human WNV cases by several weeks, thus demonstrating their epidemiological value in preparing for public health threats (Resien 2010). What is also shown in the tables is the seasonality of the disease. As Reisen (2010) points out, "For transmission to occur, climate must attain seasonal ranges within the tolerances of host and vector species and be suitable for pathogen replication within the poikilothermic arthropod vector". Reisen describes this ecological intersection as a "nidas" of disease transmission (see Figure 4) Even though data suggests that elevated temperatures and bouts of dry conditions hamper

vector survival, warmth accelerates pathogen replication thus shortening incubation time and overall amplifies the transmission cycle (Reisen 2010).

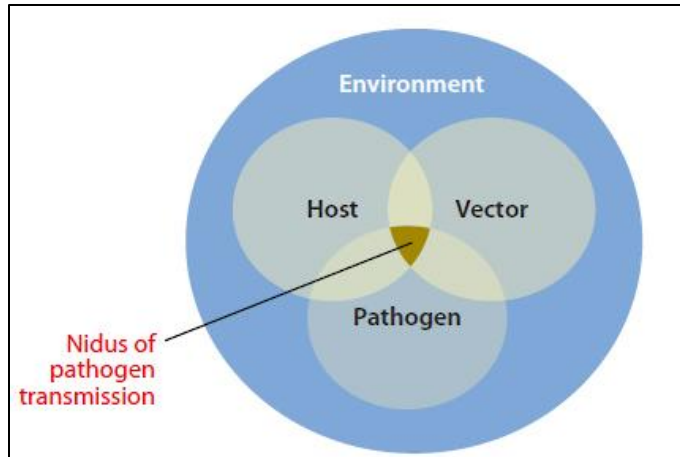


Figure 3: Conceptualization of optimal ecological arrangement for transmission of pathogen

Source: Reisen 2010

According to the CDC (2013), of the 5,764 diagnosed cases of human infection in 2012 in the U.S., 75% of cases required hospitalization for neuroinvasive disease and 5% resulted in death. For the same year and based on previous studies, the CDC (2013) estimates that as many as 86,000 to 200,000 people may have contracted WNV that resulted mild to no symptoms. Those most vulnerable to developing disease via WNV include those with suppressed immune systems and older age (CDC 2013; Tesh et al. 2004). Another endemic mosquito-borne disease is St. Louis encephalitis virus (SLEV) which normally occurs in and around the Mississippi Valley (Geier 2010). During the 1970s nearly 2,000 cases were reported in Missouri alone as a direct result of mosquitoes acting as vectors for the disease which originated from infected birds (Adams & Kapan 2009). The La Crosse encephalitis virus (LACV) is also transmitted by mosquito vectors

using small mammals as amplifying hosts. (Anderson et al. 2013). LACV is primarily seen in and around the state of California and is normally not fatal; however, children below the age of 16 are particularly vulnerable to infection which may result in severe complications to a child's nervous system for several years (Anderson et al. 2013).

CURRENT PRACTICES IN CONTROLLING MOSQUITO POPULATIONS

When it comes to handling mosquito populations, the following are the main practices utilized by government agencies:

a.) Use of pesticides for control of larvae and adult mosquitoes

In this particular action, agencies utilize narrow or broad spectrum conventional pesticides that are either applied through a spray container or (and this is the method often utilized) through aerial distribution over a large scale area (Beier 2007). The end result usually kills off larva and various adult mosquitoes which help to control the population of mosquitoes within a certain area (Beir 2007).

The successful use of a given pesticide (aerially applied or otherwise) in the control of mosquito populations has proved to be ephemeral over time (Patterson 2009). This is simply the result of mosquito populations developing resistance to the effects of a pesticide. (Patterson 2009). Especially when using broad spectrum agents, non-target species, many of which prey upon mosquito larvae, are affected by the pesticides and cannot adapt as quickly resulting, in fewer natural predators which could inevitably boost the local mosquito population in the long term (Lydy 2006). This technique has the potential to create significant ecological damage to local flora and fauna depending on

the strength of the pesticide in question and how much of it is utilized within a given time period (Oduola et al. 2012). Nonetheless, appropriate & responsible use of pesticides are still considered to be the most cost effective means of controlling a mosquito population in a short period of time (Flexner, Lighthart & Croft 1986; Institute of Medicine (US) Forum on Microbial Threats 2008). Analysis of efficacy through monitoring and rotation of pesticide type can minimize the effects of resistance development (Institute of Medicine (US) Forum on Microbial Threats 2008). Many anti-mosquito pesticides used today are touted as being effectively benign to non-target species when used properly, although this remains the source of much controversy within the environmental movement (California Department of Health Services 2005; Flexner, Lighthart & Croft 1986; Lydy 2006).

One unique category of larvacide is *Bacillus thuringiensis v israelensis* (Bti), a bacterium that is stored and applied like a chemical to still bodies of water in which mosquito larvae are present (California Department of Health Services 2005). The bacterium produces a toxin that then kills the larvae. Advocates of Integrated Mosquito Management (IMM) favor this method of larvacide to the use of conventional chemicals because it affects few other non-target species (Patterson 2009).

b.) Physical Control Source Reduction

Source reduction is the remediation of water bodies so as to minimize or eliminate their viability as breeding grounds for mosquito populations (Paskewitz 2008; Ritchie 2009). This can entail locations as small as birdbath or a swimming pool to areas as large as a local wetland. Draining and ditching of the water body may be required (Ritchie

2009). Identification of breeding sites often relies upon citizen complaints (Vezzani 2007). Public health agencies may collaborate with public works departments and storm water managers to identify potential breeding grounds and advise on remediation strategies (Metzger 2005). Because public land and infrastructure fall under the purview of various agencies whose policies and budgets do not address mosquito source control, an opportunity exists for local policy makers to bridge this public interest gap through concurrent agency collaboration. CalTrans, the California transportation authority, for example actively incorporates designs into their storm water Best Management Practices (BMPs) that inhibit mosquitoes' access to underground tunnels (Metzger 2005).

c.) Public Education and Community Outreach

Public education comes in the form of the various road shows, school presentation, public awareness campaigns, pamphlets and other paraphernalia that are meant to draw attention to the inherent dangers surrounding mosquitoes and the necessity of taking precautions to ensure that an individual is not bitten (Killeen 2008; Patterson 2009). The main purpose of this practice is to educate the general public and create awareness. Citizens are empowered to take responsibility for potential mosquito sources on their property for their own safety and that of their community at large. Gleiser and Zalazar describes this process as a proactive measure that is meant as an important line of defense, due to the inherent limitations of agencies to respond to all possible threats involving mosquitoes before an outbreak occurs (Gleiser & Zalazar 2010). Greenway, Patrick, and Chapman (2009) explain this situation by stating that aside from environmental factors, one of the main reasons why this particular method is focused on by numerous agencies is that it helps to reduce the number of cases of infections due to

shared knowledge. Many public outreach efforts in the U.S. tout a simple reminder of the four 'D's: **Drain** all unnecessary free standing water; **Dress** in long sleeves and long pants; **Dusk and Dawn** are the prime active time for many outdoor mosquito species; and apply **DEET** insect repellent when outdoors (Alameda County Mosquito Abatement District Control Program 1999; Patterson 2009).

d.) Surveillance and monitoring of mosquito populations and reservoir hosts

This practice entails taking detailed samples of active mosquito populations ((Raveton 2011). This normally involves having to test local water sources for the amount of mosquito larvae present or capturing adult mosquitoes using various traps (Raveton 2011). Many jurisdictions regularly collect dead birds to be tested for the presence of WNV and public health data on human clinical cases are also incorporated for analysis (Institute of Medicine (US) Forum on Microbial Threats 2008). Geographic Information Systems (GIS) are often employed to integrate this data, often enriched with remote sensing technology, to establish an understanding of where potential vector-borne disease threats may emerge (Geir 2010). Surveillance, testing and data interpretation come at a premium cost for mosquito control agencies but provide indispensable intelligence for forecasting threats and employing responsive targeted intervention efforts (Patterson 2009).

There are other strategies that are not quite as common. One is biological control. The most common example of this is the use of *Gambusia affinis* also known as 'mosquito fish', a hearty freshwater family of fish that has been demonstrated to

effectively control mosquito larvae (Patterson 2009). Multiple mosquito control districts in California offer mosquito fish to residents, free of charge, to citizens for use in isolated and controlled bodies of water (Alameda County Mosquito Abatement District Report 1999). While use of *Gambusia* may initially bear merit as an ecologically sound means of mosquito control when compared to the use of pesticide, much care must be taken to prevent introduction of biocontrol measures where they may disturb natural ecological functions (Courtenay & Meffe 1989; Cote et al 2010)

Yet another set of strategies involve manipulation of the mosquito itself. Sterile Insect Technique (SIT) has been used successfully for decades with other pest insects such as *Drosophilidae* (eg. fruitflies) (Cumberland 2009). SIT involves the sterilization via irradiation of the male of the species. If sufficient numbers of sterile males are introduced to a population repeatedly, that population shall decrease over time (Becker 2010). Applying this technique to disease vector mosquitoes such as *Aedes* and *Culex* has been difficult but recent research, still in the trial stage, offers promise to produce genetically modified mosquitoes which die in the pupal stage (Cumberland 2009).

URBAN DEVELOPMENT PRACTICES THAT CONTRIBUTE TO MOSQUITO ECOLOGY

William Reisen (2012) argues that humans have modified landscapes for urban dwelling and agriculture that “simplify ecosystem complexity”, thus enhancing the environment for a select number of opportunist species which may include mosquito vectors, secondary hosts and pathogens. By contrast, a pre-urban landscape would have higher biodiversity thereby enhancing the *dilution effect* that restrains the efficiency of pathogen transmission to humans. (Reisen 2012; Swaddle 2008) As it happens, urban

environments including Los Angeles and Houston happen to offer accommodating habitat for the *Corvidae* family of birds, which have been found to be highly competent reservoirs of WNV (Reisen 2012). Based on the study of Trawinski and Mackay (2009) which examined urban environments and their contribution towards the development of mosquito populations, it was noted that present day waste management systems in the form of sewers, water reservoirs and other artificial methods of trapping and collecting water within urban environments, significantly contribute towards the population booms of mosquitoes within various cities. While Killeen (2009) does state that the fast moving currents of various pipes and sewers does prevent the problem from getting out of hand, the fact remains that a certain level of stagnation does occur in some of these sewers, resulting in the creation of an ideal area for breeding. These pools of water have several favorable factors for mosquito breeding such as:

- a.) stagnation
- b.) lack of predators within the water
- c.) they are normally in dark areas that have a considerable level of precipitation (

Based on these factors alone, it can be seen that the methods by which waste is removed from cities contributes elevated mosquito populations (Killeen 2009).

Another area of concern comes in the form of the various rooftops of buildings that often go neglected by the building owner. Such areas, especially during the rainy season, accumulate considerable levels of stagnant water which allows mosquitoes to breed almost unabated.

Chapter 3 Methodology

INTRODUCTION TO METHODOLOGY

This section aims to provide information on how the study is conducted and the rationale behind employing the discussed methodologies and techniques. In addition to describing the research design, this section will also elaborate on instrumentation and data collection techniques, validity, data analysis, and pertinent ethical issues that may emerge in the course of undertaking this study.

WHAT IS QUALITATIVE RESEARCH?

Qualitative research is a type of exploratory research than in that it tries to examine and explain particular aspects of a scenario through an in-depth method of examination (Creswell 2003; Merriam 2009). While it is applicable to numerous disciplines, it is normally applied to instances which attempt to explain human behavior and the varying factors that influence and govern such behavior, to informing what they are at the present state (Merriam 2009). Thus, it can be stated that qualitative research focuses more on exploring various aspects of an issue, developing an understanding of phenomena within an appropriate context, and answering questions inherent to the issue being examined.

WHAT WILL BE EXAMINED?

In my research, I examine the cases of Greater Houston (Harris County), Texas and Los Angeles County, California. Both jurisdictions have detailed mosquito control plans as well as systems for regularly monitoring mosquito populations on a geographically discrete basis. Both cities also maintain records of citizen complaints, clinical data, and records of animals infected by mosquito borne disease (Although the Harris County mosquito authority only tracks West Nile Virus at present). Both Houston and Los Angeles are major port cities and as such may act as loci for convergence of disease, host and humans from distant regions. In terms of climate, both regions have remarkably mild winters. A point of departure is the relatively low precipitation in the Los Angeles area.

Following a review of mosquito abatement plans of both cities based on available literature, stakeholders involved in public health and mosquito control at local, state and national levels are identified that can comment on their activities with authority. Lists of interview questions are prepared, each tailored to different groups of stakeholders with the intent of eliciting data that answer to my research questions. The data collected is analyzed to identify key themes and triangulated by examining secondary documents available in local media. This analysis renders findings and a subsequent discussion of those findings as they relate to my research questions.

RESEARCH DESIGN

Creswell and Sekran observed most qualitative studies are either descriptive or experimental (Creswell 2003; Sekran 2006). The study utilizes a descriptive correlational

approach because the participant is measured once. Furthermore, it is imperative to note that the study employs an interview technique for the purpose of collecting participant data from the aforementioned areas indicated in the previous paragraph. According to Sekran (2006), an interview technique is used when the researcher is principally interested in descriptive, explanatory or exploratory appraisal, as is the case in this study. The justification for choosing an interview based approach for this particular study is grounded on the fact that the participant will have the ability to respond to the researchers questions more directly and thus provide more information. An analysis of related literature will be used to compare the study findings with research on various strategies utilized by the CDC and other such agencies. Such analysis, according to Sekaran (2006), is important in identifying the actual constructs that determine efficient analysis because “it goes beyond mere description of variables in a situation to an understanding of the relationships among factors of interest”.

PARTICIPANTS

The research subjects used for this paper consist of various government agency officials and were contacted at their respective agency offices. This includes local mosquito control authorities responsible for Los Angeles County and Harris County (ie. Greater Houston) as well as public health officials in other levels of government that have a stake in mosquito control. The proposal for this research was submitted to the University of Texas at Austin Institutional Review Board (IRB) in compliance with academic investigative protocol. The IRB found that the professional and authoritative nature of the subjects in this research effort obviated the need for subjects to submit an IRB consent form prior to participation. Participants were nonetheless offered the full

range of confidentiality and privacy prior to interview. Every participant declined the offer and agreed to have their interviews recorded in digital audio.

STUDY CONCERNS

This research effort is limited by the small number of sample interviewees involved. While the most important agencies directly involved in mosquito control for the two regional case studies are represented, the participation of other valuable stakeholder organizations would certainly afford a more comprehensive opportunity for analysis. Missing from the desired assembly of participants are representatives from FEMA, U.S. Fish and Wildlife, the U.S. Army Corps of Engineers, the Environmental Protection Agency, CalTrans, the L.A. County Dept. of Public Health, the L.A. County Dept. of Public Works, the L.A. County West Vector Control District, the Compton Creek Mosquito Abatement District, the California Emergency Management Agency, the Texas Commission on Environmental Quality, the Texas Department of Agriculture, the American Mosquito Control Association and the Texas Mosquito Control Association. For these organizations, a willing spokesperson couldn't be identified in a timely manner or a representative insisted that their role in impacting mosquito-borne disease was too small to inform my topic. Rick Bayes from the Texas State Health and Human Services did not avail himself for an interview but did agree to respond succinctly to my interview questions in writing. Though valuable, the resulting data should not be given the same weight as the completed interviews.

STRUCTURED INTERVIEWS

One potential avenue of approach when it comes to utilizing an appropriate qualitative method in investigating the research topic is the use of a combination of open ended survey questions and structured interviews. The advantage of utilizing open ended survey questions and semi-structured interviews in a research study is that it allows the research subjects to give a variety of opinions, arguments and generally accepted notions regarding a particular research subject, without having the same restrictions found in structured and close ended survey questions (Meriam 2009). As such, while this at times results in responses that are harder to categorize, it does enable a researcher to better understand issues from the perspective of those who constantly experience them and, as a result, enables the creation of far more accurate conclusions regarding the various problems that are occurring. It is based on this that a structured interview approach is utilized during the data collection process (Meriam 2009).

I forwarded interviewees a questionnaire tailored to the respective role of their organization in the mosquito control framework: mosquito control agencies are asked about their mission, activities and constraints; public health agencies are asked about their role and relationship with other agencies, etc. This allows the participants to prepare and gather specific and important information they may not have available given unanticipated questions during the interview.

A total of six agencies are represented in the interviews: Dr. Vicki Kramer, Director of the California Department of Public Health Vector Borne Disease Section (CAPH-VDB) in Sacramento, CA; Dr. Janet McCallister, Research Entomologist at the

Centers for Disease Control & Prevention – Division of Vector Borne Disease (CDC – DVD) in Fort Collins, CO; Truc Dever, Public Information Officer at the Greater Los Angeles County Vector Control Division (GLACVCD) in Los Angeles, CA; Dr. Daniel Strickland of the U.S. Department of Agriculture – Agricultural Research Service (USDA-ARS); Ken Livingston, Director and Kelly Middleton, Public Information Officer of the San Gabriel Valley Mosquito and Vector Control District (SGVMVCD); and Dr. Rudy Bueno, Director of the Harris County Public Health and Environmental Service – Mosquito Control Division. Only Dr. Bueno was interviewed in person. During the interview, many of the responses to the written questions are followed with follow up inquiry to fully explore the interviewees opinions and insights. Notes are taken on reflections as they come to mind based on the subject's responses.

THEORETICAL FRAMEWORK

This section elaborates on the use of attribution theory and grounded theory as the primary methods of examination utilized by the researcher in order to check the information gathered during the interviews. These theories are chosen to examine the opinions of the interviewees in order to properly interpret the data and create viable solutions and recommendations. For example, through attribution theory, the research will be able to correlate the views of the CDC official with her current experience in mosquito control in order to properly create a sustainable planning framework for the control of mosquitoes and the health threats they may pose. By following grounded theory during the data analysis stage of the study, the researcher will be able to determine the current effectiveness of current programs utilized by various government agencies in charge of mosquito control, whether significant problems exist, what the agencies are

doing to address such issues and if possible, alternatives to current methods have been considered. It is expected that by following the two theoretical frameworks during the examination process of the paper, I shall be able to succinctly address the research objectives of the study.

The main difference between the two theories is that attribution theory concerns itself with the assumptions people have towards a particular product or process while grounded theory focuses more on developing succinct assumptions based on the data that has been presented (Sekran 2006). As such, by combining both methods this enables a researcher to examine the opinions of the officials under an investigative framework while at the same time utilizing another framework to determine the inherent problems within a given scenario and the appropriate method of addressing them. It is based on this that these two theories become an ideal method for addressing the various objectives of the research topic. The main benefit of utilizing both theories in the examination of the research topic is that they enable a better examination of the responses of the interviewees as well as the data from the literature review as compared to merely doing an examination of both aspects utilizing a single theory.

A.) Attribution Theory

Attribution theory centers around the derived assumption of an individual/group of people regarding a particular process, product or service based on their experience with it (Sekran 2006). It is often used as means of investigating consumer opinions regarding a particular product and to determine the level of satisfaction/sustainability derived from its use (Sekran 2006). By utilizing this particular theory as part of

framework for this study, I shall correlate the opinions of the interviewees regarding their assumptions over what practices currently utilized by their respective agencies lead to proper mosquito control. This particular theoretical framework helps to address the research objective of determining current practices within the areas of L.A. and Houston by creating the framework that will be utilized within the interview and examination process. Utilizing attribution theory, the research will delve into the opinions of the government officials in order to better understand what factors influence their planning frameworks for controlling mosquito populations.

The needed information will be extracted through a carefully designed set of questions whose aim is to determine how a particular official's experience with a process affects the way in which mosquito populations are controlled in certain areas and whether, in their opinion, significant improvements need to be implemented or not. However, it should be noted that while attribution theory is an excellent means of examining the opinions of interviewees, it is an inadequate framework when it comes to determining the origin of problems in certain cases. Grounded theory, with its emphasis on utilizing a specific framework to guide a researcher during the examination process can be considered an adequate method of performing the more "in-depth" aspects of the research (Merriam 2009).

B.) Grounded Theory

The advantage of utilizing ground theory over other theoretical concepts is that it does not start with an immediate assumption regarding a particular case. Instead, it

focuses on the development of an assumption while the research is ongoing through the use of the following framework for examination (Sekran 2006):

- a.) What is going on?
- b.) What is the main problem within the organization for those involved?
- c.) What is currently being done to resolve this issue?
- d.) Are there possible alternatives to the current solution?

This particular technique is especially useful in instances where researchers need to follow a specific framework for examining a problem (as seen in the framework above) and, as such, is useful in helping to conceptualize the data in such a way that logical conclusions can be developed from the research data (Sekran 2006).

By utilizing the framework of grounded theory to perform an examination of the responses from the officials and the data from the literature review, I can then examine the processes utilized within subject agencies related to controlling mosquito and whether such processes are effective based on the data collected.

What must be understood is that in qualitative research the concepts or themes are derived from the data. According to Sekran (2006), grounded theory provides systematic, yet flexible guidelines to collect and analyze data. That data then forms the foundation of the theory while the analysis of the data provides the concepts resulting in an effective examination and presentation of the results of the study.

DATA ANALYSIS

Audio recordings of the interviews are immediately transcribed. The analysis begins with a cursory reading of the transcripts as well as a revisiting of notes taken during the interviews. The transcripts are then read again, but more carefully so as to recognize first glance themes associated with a sample of text, identify key terms and write them into the margins. These themes or codes as their often called in qualitative analysis are recorded in the margin next to the text and as the dialogue continues, some themes are repeated and their relevance becomes more appreciable particularly if they address one of my research questions. At this point I also use attribution theory as a means of developing further themes, notably: “what might compel the subject to state this opinion or make that conclusion?” Reading the transcripts a third time reveals only more insight that wasn’t manifest before, such as an interviewee’s tendency to use linguistic connectors to indicate the presence of a thematic narrative or speak in terms that compare and contrast something she or he thus considers important hence possibly worth coding. Because the texts have been read twice in short order, it becomes easier to anticipate an upcoming theme and how it may relate to the present line being read. Codes that are not as significant to the emergent themes can be mentally discarded and codes that similar can be consolidated or synthesized into a more appropriate code label. A grouping or hierarchical arrangement of themes is explored and refined with a fourth reading of the transcripts. Grounded theory plays out here as organized categories of data emerge from the analysis. Opinions, activities, roles and relationships of the interviewees and the agencies they represent are now made relevant to those of other interviewees because they share a thematic grounding. Finally, because the literature explored in this report is

also packaged in a clear thematic way, it will inform the validity of the opinions, activities, roles and relationships of the interview subjects. This will provide the basis for a discussion of results.

Chapter 4: Research Results

ROLES PLAYED BY GOVERNMENT AGENCIES

Level of Government	Proactive Action	Responsible Agencies
Federal	Support of research that offer solutions for public health and medicine	(CDC; USDA; NIH)
	Development of national standards for safe use of pesticide	(EPA)
	Maintenance of authoritative data clearinghouse and website for community awareness about disease and disease vectors	(CDC)
	Provision of resources and technical assistance in the face of an emergency	(FEMA; CDC)
State	Collection and analysis of mosquito borne disease particular to a state	(California Deptment of Public Health)
	Evaluation of statewide efforts in controlling mosquitos and disease	(UC-Berkley Mosquito Research Program; TAMU Agrilife Extension)
	Establishment of guidelines and standards for state and local agencies to implement mosquito BMPs in their respective activities	(State Legislature)
	Coordination with neighboring states and federal agencies	(California Deptment of Public Health; California Emergency Management Agency)
	Provision of public health laboratory services	(UT-Galveston Medical Branch; California Deptment of Public Health)
	Legislation that facilitates local creation of focused & economically resilient mosquito control districts	(State Legislature)
	Training and certification of pesticide applicators	(TCEQ; California Department of Pesticide Regulators)
	Provision of technical assistance to local jurisdictions	(California Deptment of Public Health)
Local	Designation of a lead agency responsible for mosquito control	(City Council; County Commissioner)
	Development of mosquito control plan suited to local context	(Mosquito Control District)
	Surveillance, monitoring and reporting of disease incidence in humans, vectors, and diseased animals	(Mosquito Control District; County Health Dept)
	Development of public information campaign to create awareness of precautionary health measures and control mosquito breeding habitats	(Mosquito Control District)
	Establishment of responsive mechanism for provision of pesticide flights or declaration of state of emergency	(County Commissioner; County Health Dept; Mosquito Control District)
	Periodic review of mosquito control practices	(Mosquito Control District)
	Establishment of guidelines and standards for local agencies to implement mosquito BMPs in their respective activities	(State Legislature)

Table 1: Governmental Framework Responsive to Threat of Mosquito Born Disease

The table above shows some optimal roles and actions for different levels of government in addressing mosquito threats cooperatively. Through the interviews it was

noted that federal, state and local agencies typically work on what can be aptly described as a "multi-partisan" relationship, wherein there is no clear regulatory framework (aside from assigned individual department responsibilities) when it comes to dealing with mosquito control. Instead, what exists is a type of informal network where departments on a federal, state and local level communicate, cooperate and exchange resources and information in order to deal with mosquito control on either a "per case" basis or as a continuous relationship of collaboration and assistance (Killeen 2013). The basis behind this is elaborated upon by Janet McCallister of the CDC who states that:

no one wants their local districts, areas or states to have a disease outbreaks due to mosquitoes, as such, in the interest of implementing sufficient preventive measures it is necessary for inter-agency/department cooperation in the form of committees and inter-agency organizations to help relay the problem of mosquito control through a per area basis and relegate the necessary assistance in order to immediately deal with the issue at hand. (Interview, 20 June 2012).

While there is no specific mandate that states that the department of fisheries, for instance, should help a local agency that deals with mosquito control, officials' participation in inter-agency collegial organizations such as the Mosquito and Vector Control Association of California (MVCAC) help to encourage communication and collaboration in order to provide the necessary assistance.

Horizontal cooperation between local agencies was ubiquitous when it came to sharing information. Although Rudy Bueno of Harris County Public Health Mosquito Control Division (HCPH-MCD) discussed assisting smaller mosquito control authorities

with equipment calibration and sponsoring pesticide application workshops, this stood in contrast to the level of enthusiastic collective action between L.A. county districts and sister districts throughout the state: “We’re constantly collaborating and communicating with each other...Last year when we first identified *Aedes albopictus* in our jurisdiction, everybody lent personnel and we coordinated a region-wide door to door campaign with 10 agencies and 100 personnel” (Truc Dever, interview 12 Jun. 2012). Both L.A. districts expressed a sense of shared mission and shared fate which is sensible when considering that their boundaries abut one another. Both districts are sufficiently endowed to perform surveillance and keep full time staff. The mosquito control program in Harris county is also robust, but as Rudy Bueno lamented when discussing his agency being the only one in Texas that still tests for dead birds: “I don’t know if we’re the only one but certainly one of the few” (Interview, 11 Sep. 2012). When asked about her opinion about the mosquito control program of Texas, Janet McCallister identified Houston as an excellent program but then expressed surprised that the rest of the state has such a low profile in the mosquito control community (Interview, 20 Jun.2012).

BEST MANAGEMENT PRACTICES FOR REDUCING EXPOSURE TO DISEASE

All interviewees stressed the absolute importance of timely and thorough surveillance of mosquitoes and monitoring of host avian populations. Rudy Bueno of Harris County described with great emphasis, his agency’s rigorous system for collecting mosquito samples from 280 sites in the county for testing; capturing, bleeding and re-releasing live birds for more testing; maintaining a program for collecting dead birds for testing (Interview, 11 Sep. 2012). With such a comprehensive approach to surveillance, I was surprised to hear him respond somewhat dismissively to my question about source

control and larvacide: “Again, because we are disease control, you are going to find disease in the adults so that’s what we focus on” (Rudy Bueno, Interview 11 Sept. 2012). Similarly, in terms of direct control, Harris County only targets adults of the *Culex quinquefasciatus* even though other common species for the are considered competent vectors for WNV ((Rudy Bueno, Interview 11 Sept. 2012)). This stood in stark contrast to literature focused on the practice of Integrate Mosquito Management (IMM) and the inexpensive, ecologically sound value of preventing mosquitoes from developing to adults in the first place when the option is available (Becker 2007; Cumberland 2009; Herrington 2003). Vicki Kramer from CDPH took a different trajectory stating explicitly that “the definition of vector is broad enough to include biting, aggressive mosquitoes even if they are not important in disease transmission” (Interview 14 Mar. 2013). Under conditions such those that may occur days after a hurricane that causes flooding that produce mosquito swarms, and if triggered by an emergency declaration, Houston mosquito control shall switch its efforts to controlling by any means, any nuisance biting mosquitoes (Rudy Bueno interview, 11 Sept. 2012). As Dr. Bueno states, this is to permit the work of recovery and repair experts after the storm (Interview, 11 Sep. 2012). The representatives of the two mosquito control districts in L.A. County recognized the quality of life value of controlling non-vector biting nuisances and take actions to control them in response to citizen complaints, but overall recognized disease prevention as their primary mission (Truc Dever interview, 12 Jun. 2012; Kelly Middleton interview, 30 Mar. 2013).

AGENCIES AND BUDGET CONSTRAINTS

All agencies involved in the study suffered budget constraints as a result of the recent recession. The extent of funding impact varied greatly as a result of different funding mechanisms in place.

In the state of California, legislation allows for the creation of Benefit Assessment Districts: Special Districts that receive a fixed amount of revenue from each parcel in their jurisdiction, between \$6 to \$20 dependant on the size and the use of the parcel (Kelly Middleton, Interview 30 Mar. 2013). Unlike conventional city and county agencies that rely on an ad valorem property tax, Benefit Assessment District funding is relatively resilient to a recession of the real estate market (Truc Dever interview, 12 Jun. 2012; Kelly Middleton interview, 30 Mar. 2013). Both San Gabriel Valley Mosquito and Vector Control District and the Greater L.A. County Vector Control district are examples although the latter still receives a revenue stream from property taxes. Both same sets of interviewees stated that budget setbacks were imposed on operations and supplies, partly out of real limits to revenue but also out of consideration for their constituents' economic plight (Truc Dever interview, 12 Jun. 2012; Kelly Middleton interview, 30 Mar. 2013). All other interviewees whose agencies' funding was more severely limited stoically accepted the severe cuts in research, operations and some personnel loss.

Although the Benefit Assessment districts are more resilient, officials in L.A. noted that collaborative practices were one of the essential cornerstones in costs reductions for sister mosquito control districts and other agencies faced hardship due to the fact that the problem that some local agencies have to deal with is a lack of sufficient

labor coupled within the size of their respective jurisdictions (Truc Dever interview, 12 Jun. 2012; Kelly Middleton interview, 30 Mar. 2013). For example, in and around L.A. there are areas which can comprise a total population of 6 million or more people. Local agencies dealing with mosquito control on a per district level can range from 50 to 100 personnel on average which have to investigate areas of several thousand acres comprising millions of possible residences. This creates a distinct problem in terms of actually controlling mosquito populations with a constrained budget and a limited amount of personnel (Kitron 2010). As such, through inter-agency collaboration and communication, agencies that specifically deal with mosquitoes can ask help from local agencies of the department of health, department of public works and even the department of waterways in order to help leverage the necessary manpower to investigate all areas and determine the extent of the action needed in order to deal with the mosquito menace (Kitron 2010).

HOW PUBLIC HEALTH AGENCIES PLAN FOR CHANGE

An examination of the interviews reveals that there are several constraints that hamper mosquito control and public health agencies from planning for change as mosquito-borne diseases emerge and climate change alters mosquito habitats in the future. These constraints are composed of the following:

a.) Budgetary Constraints

One of the main problems when it came to planning for possible changes in mosquito populations, as a direct result of climate change, came in the form of the inherent budgetary constraints that many agencies face at the present. The issue lies in the

fact that due to the limited amount of funds each agency is allotted on a yearly basis, there simply is not enough in terms of purchasing the necessary equipment for future operations or hiring more personnel due to the level of uncertainty surrounding climate change at the present.

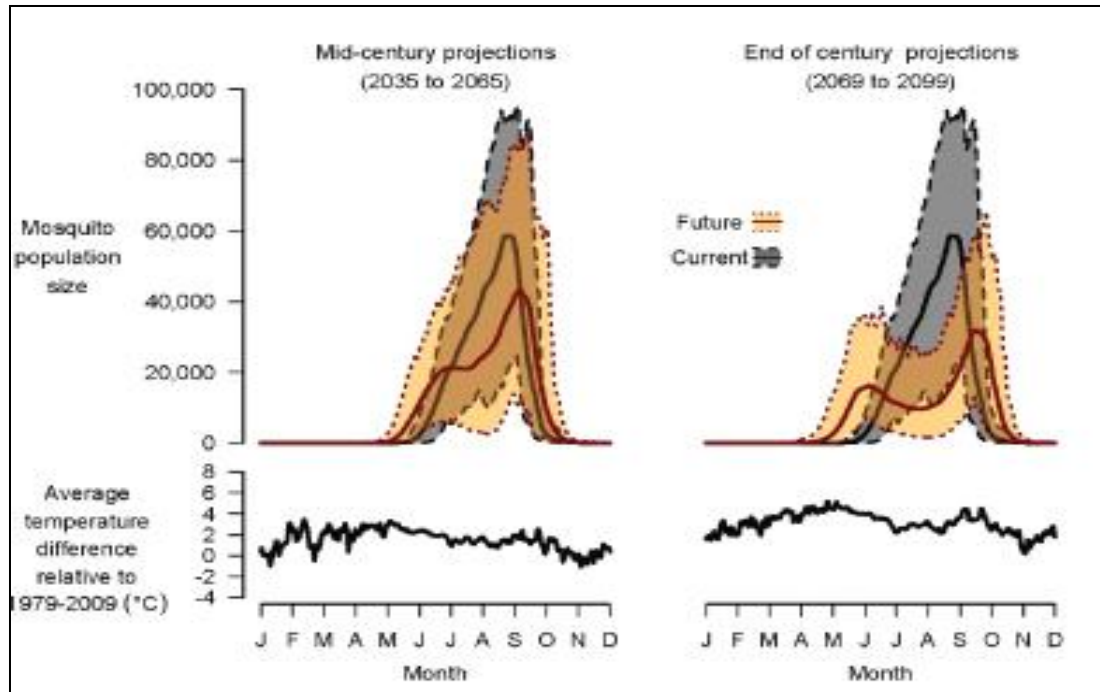


Figure 4

Source: Kitron 2010

The graph above shows one current projected seasonal expansion of the mosquito blooming season as a result of climate change. As temperatures on the Earth increase, it creates a likelihood of greater mosquito population blooms (Kitron 2010).. Under warmer conditions, vector populations tend to reproduce more frequently resulting in more blood feeding thus increasing vector-pathogen interaction; increased pathogen

development within the host shortens incubation time thereby increasing the efficiency of transmission (Reisen 2010). It is uncertain whether the current progression of climate will either result in greater amounts of mosquitoes (Vicki Kramer Interview, 14 Mar. 2013; Reisen 2010). As a result, agencies focus on addressing supply and personnel issues based on past trends in mosquito population blooms rather than speculative planning on events that may or may not occur at all. The present day budgetary constraints faced by such departments, as a result of the financial recession, also hampers their ability to respond to future threats. It is due to this pest control agencies often may need to collaborate with external partners, such as other departments and agencies, in order to supplement their already limited budgets.

B.) Present Year Response Mechanisms

As mentioned earlier, future action on the part of mosquito control and public health agencies comes in the form of an examination of past trends in the increases/decreases of pests and adjusting operations and equipment needs based on the trend lines that were perceived. This is an endemic method of operation based on the literature and interviews that were read which shows how mosquito control agencies function more on a reactive basis of operation wherein they deal with problems as they appear rather than a more proactive method of operation wherein they focus on dealing with problems before they arise. While it may be true that agencies do in fact attempt to reduce mosquito populations by focusing on areas that have shown blooms in mosquito populations in the past before the problems appear, the fact remains that this method of operation still does not take into consideration the possible impact of climate change and

how this could result in population blooms that agencies on a local level will be unable to handle despite considerable support from other agencies and departments.

COMPARISON BETWEEN HARRIS AND L.A. COUNTIES IN TERMS OF MOSQUITO PRACTICES

When comparing both sets of interviews (i.e. officials who were from California and those from Texas) it was noted that there was a considerable disparity in results in terms of developing the necessary inter-agency/inter-department cooperation that was noted in the case of California. For example, while Texas was noted as having several exemplary mosquito control programs in several of its cities, such is not the case when it comes to individual towns and districts which lack the same level of quality and comprehensiveness found in major metropolitan areas (Janet McCallister Interview, 20 Jun. 2012). This is in stark contrast to the case of California wherein a "broad spectrum approach" is utilized which ensures that there is little in the way of significant differences in the quality of program despite an area being rural or urban. The origin of such a problem may be due to the fact that there are insufficient committees, leadership initiatives, and cooperative agreements between agencies and departments in far flung areas resulting in the development different levels of quality in terms of provisioning the necessary amount of mosquito control in certain areas.

The fact is that the individual districts in Texas are far too large and too distant from one another for effective cooperative practices to be implemented and, as a result, individual region have had to develop their own processes based on local trends in mosquito populations. Since California's districts are far closer together, this enables

them to establish inter-agency/inter-department cooperative agreements wherein resources and personnel can be more effectively shared.

PROPOSED FRAMEWORK FOR COOPERATION BETWEEN GOVERNMENT AGENCIES

The objectives of the framework for cooperation are as follows:

- a. Develop the necessary technology structure utilizing cost effective software so as to enable mosquito control agencies to rapidly respond to public safety concerns presented by the local citizenry.
- b. Determine what management practices should be present that can be utilized to create a rapid response process so as to investigate problematic areas that have been identified.
- c. Create a crowd sourced method of investigation wherein people can report the source of potential threats to an information processing system that then alerts professional mosquito control teams.

Based on the results of the interviewees' concern, one of the main problems of mosquito prevention within most urban areas is the proper identification of potential mosquito hazards before they become actual public safety threats. The interviewees explained that the current level of population density within most urban areas has made investigating every possible area where a mosquito breeding hazard is present is simply not feasible. They point to the fact that most mosquito prevention services have a limited number of personnel present (ex: ranging from 20 to 70 depending on the location) and they are often tasked with determining the cause of mosquito population "blooms" and

creating public service announcements or policies related to proper mosquito hazard prevention (Della Torre 2007). They, in no way, could search an entire city or region and determine the location of every single hotspot before mosquito populations reach a distinct noticeable level even if the amount of personnel was increased by a factor of 10 (Severson 2013). Mosquito control agencies depend on reports from local citizens regarding potential public safety hazards (i.e. dead birds, noticeable increases in the mosquito population, concerns regarding the standards by which a neighbor maintains their pool etc.) in order to properly identify them. Such calls are few and far between which often leads to potential hazards becoming actual dangers for people and property alike (David 2013). It is due to this that I would advocate for the merit of a public crowd sourced information system for mosquito hazard identification to inform agency investigators to follow potential leads and respond as necessary. Work by May O. Lwin has examined the use of a public crowd sourced method of mosquito control investigation in Sri Lanka known as “Mo-Buzz” (Lwin et al 2013)

This service utilizes current mobile phone architecture so that local citizens can identify "hotspots" on a map in combination with Google's map service (Lwin et al 2013).. Process such as these are more efficient than relying on conventional citizen complaints since they are not limited by human biology, rather they can be easily modified or adapted in order to perform ever more complex tasks when integrated with a sophisticated information system (Lwin et al 2013). Such a feat can only enhance the ability of mosquito control technicians' ability to respond to potential threats. Not only that, mobile phones are a ubiquitous aspect of many residents in cities with many of them possessing smart phones that can connect to online applications as in the case with Mo-Buzz. By utilizing a similar application and communicating a message regarding the type

of mosquito hazard present, an average citizen thus becomes an instrument that enables mosquito investigators to instantly know where potential mosquito hazards are present, resulting timely intervention in the identified areas (Lwin et al 2013).

The following table is an approximate extrapolation of Lwin's study of crowd source technology for mosquito surveillance in Sri Lanka applied to Harris and L.A. counties.

		Average Population Set	Distance covered within a day (mi)	Ability to investigate and report cases
Harris County	Mosquito Control organization	55 Investigators	160	5 to 8 cases per day
	Local Citizenry	4,220,000 Smartphone Users	211,000	1000 to 1600 reports per day
L.A. County GLACVCD Jurisdiction only	Mosquito Control organization	65 Investigators	145	6 to 9 cases per day
	Local Citizenry	6,400,000 Smartphone Users	384,000	1800 to 2800 reports per day

Table 2 - Estimated Impact of Crowd sourced method for investigating mosquito sources

Adapted from Lwin et al (2013)

Based on the data from the table above, it can be seen that crowd sourced methods of investigation may offer a wider, cost effective scope of data collection resulting in a greater likelihood to obtain larger amounts of data. This makes the investigation of mosquito blooms that much easier since average people with smart phones can act as investigators and inform the local mosquito control department regarding possible blooms in their area.

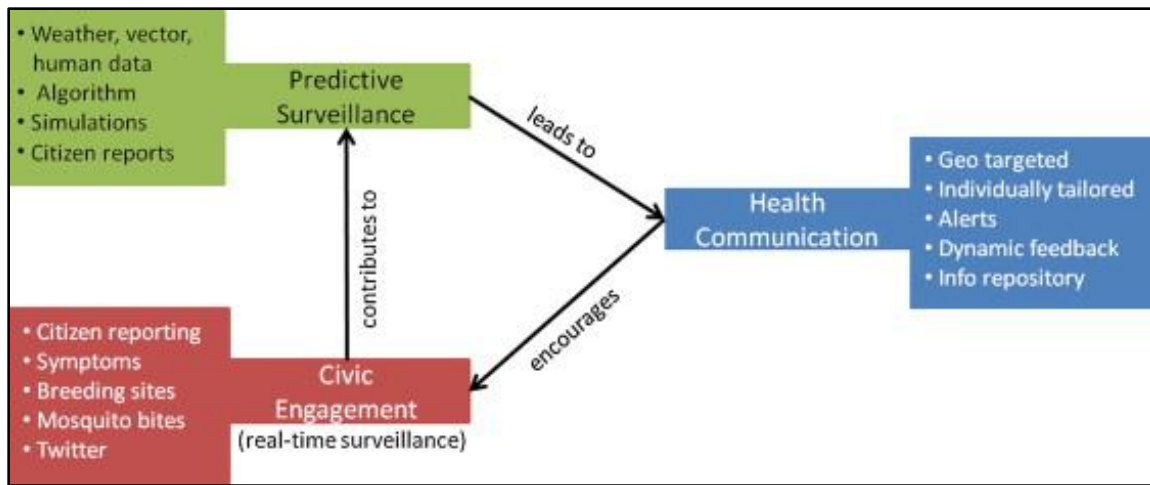


Figure 4 – Graphic Abstract of the Mo-Buzz crowd Sourcing System

Source: Lwin et al. 2013

The graphic above illustrates the The Mo-Buzz system discussed by Lwin, which integrates crowd sourced data into a sophisticated information system that filters the data into actionable information (Lwin et al 2013). This would result in an efficient and effective method of addressing possible mosquito threats thereby reducing their occurrence within a specified mosquito control jurisdiction. It should also be noted that this particular type of system also enables investigators to see patterns and trends in the development of mosquito populations with certain regions. This results in better inter-agency and inter-department cooperation practices since it allows them to map the progression of mosquito populations thereby enabling to determine where responses need to be placed in real time (Lwin et al 2013). This type of mapping and information system can in effect take over from the previous incarnation of communication and information processing which can take a week or more before various agencies are informed regarding potential population explosions of mosquitoes within certain areas.

Another factor that should be taken into consideration is that an earlier and more rapid response time to reports regarding increases in mosquito populations often enables agencies and various departments to apply a method of pest control that is not as environmentally damaging as compared to wide spread use of pesticides that could cause adverse environmental effects after the mosquito population has been dealt with (Naeem-Ullah & Akram, 452-453).

The activities for a proposed framework are as follows:

- 1) Initial project inception wherein the incorporation of the investigators into local mosquito prevention agencies will be done.
- 2) Hiring period of the investigators
- 3) Training period for the prospective investigators
- 4) Development and implementation of the crowd sourced mosquito investigation application
- 5) Promotion of the online application through local council initiatives as well as television and radio announcements that specifically target the public
- 6) Development of the scheduling and management system for the online investigation team
- 7) Separating the investigation and search positions of the team on a revolving basis so as to ensure that all members of the team are familiar with the protocols and areas where reports of mosquitoes are concentrated

Chapter 5: Conclusion

Based on what has been presented in this paper, it can be seen that what is necessary in the case of mosquito control for California and Texas is a crowd sourced method of communication and investigation wherein average citizens can use a smart phone application in order to help local pest control agencies identify hotspots and potential problematic areas. Another factor that has been determined by this paper is that when it comes to mosquito control, a "one size fits all" strategy simply does not work given that different states and regions have a plethora of factors require variations in approach. Further, different geographic and climate contexts create specific threats in terms of which mosquito vector species and diseases pose a local threat. It is based on this that this study recommends that when it comes to developing strategies regarding mosquito control, individual agencies should be given a certain degree of lee-way since what applies in one jurisdiction may not necessarily work in another.

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