The Asian Tiger Mosquito (*Aedes albopictus*):
Spatial, Ecological, and Human Implications in Southeast Virginia

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(ABSTRACT)

The overall theme that drove my research was the concern for public health and its possible compromise due to the colonization of large areas of the United States by the disease-vectoring *Aedes albopictus*. The main objective is to determine the elements that make an environment conducive to *Aedes albopictus* populations. Specifically, the objective of this research is to identify the socio-economic impact of *Aedes albopictus* on residents in the Hampton Roads area in southeast Virginia and determine if there is an identifiable environment in which *A. albopictus* could be found. Data were collected at the Census block group level (demographic variables) and at the single household level (survey and physical-cultural variables). The variables were then correlated (Pearson) and the results were analyzed. Only variables that were less than (.1) significance were examined. The following physical-cultural variables were found to be associated with the reduction of *A. albopictus* activity: having a sea breeze, being near an oceanfront, cutting the grass frequently, and keeping the overall neatness of a property high. Secondary variables that are related to the decrease in *A. albopictus* populations are sunny yards, yards with no containers that can hold water, and yards that contain coniferous trees versus deciduous trees. The primary socio-economic variables that can signify an environment with high *A. albopictus* activity are: lower house value and median rent value, lower levels of education, and a lower median income level. Other demographic variables that help determine the size of an *A. albopictus* population are (in order of significance): ethnicity (white or black), poverty/unemployed, owner/renter occupied, and the year a house was built. These secondary variables increase *A. albopictus* numbers if the following trends exist: high percent of persons in poverty and unemployed, higher percent of renter occupied homes, and older houses.

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PREFACE

The purpose of this research is to better understand the spatial characteristics of *Aedes albopictus* (the Asian Tiger Mosquito, or ATM), with particular reference to the socio-economic and physical-cultural environmental variables that are present where ATM populations exist. The principal elements that encouraged me to study the ATM includes its role as a severe biting pest and its potential threat to public health. I chose to investigate the environment of the ATM in an attempt to determine whether or not certain variables could be identified and linked to either friendly or non-friendly ATM habitats. If successful, a better understanding of the ATM and its needs would be achieved. *Aedes albopictus* is a public health concern due to its ability to transmit approximately 22 arboviruses to humans and heartworms to dogs. The ATM has been marked by local mosquito control agencies as "public enemy number one." Following its arrival in the continental U.S. in 1985 near Houston, TX, *Aedes albopictus* has diffused widely and rapidly through the Gulf States, the Mid-Atlantic States, and into parts of the Ohio Valley, Pennsylvania, and New Jersey. Furthermore, the limits of the ATM's ability to expand are only roughly known because it is a new resident of the U.S. and is still adapting to conditions in its new home. The present pattern of global warming appears to exacerbate the diffusion of the ATM. Its maximum diffusion range will not be known for years. With global diffusion the ATM has increased its range to include Europe, Africa, Oceania, and the Americas. It has become well established outside Asia where it originated. For these reasons, the ATM is considered a problematic mosquito species to manage and control. Therefore, it is imperative to increase our knowledge and understanding of the ATM so that its potential impacts on humans can be further understood and dealt with.

This thesis will provide a foundation about the ATM, including its history in the U.S., its basic biology and behavior, and its ecological needs. It contains descriptive data concerning the ATM in southeast Virginia based on a number of variables including: survey, demographic, physical and cultural.

Figure 1. ***Aedes albopictus***

PROLOGUE

An article by Steven Wrage, "Watering to Endanger," in *The Atlantic Monthly*, June 1996, discusses the proactive and serious approach that the government of Singapore takes regarding the ATM and other container-breeding mosquito species.

> Though I have not yet been convicted of any caning-worthy offense, I did have my first brush with the law one evening not long ago…I was startled to find two officers, standing shoulder to shoulder in the door frame…The moment had the makings of a minor confrontation. I had jerked the door open, and I hadn't moved back at once…To my relief they stepped back two feet and pointed off to my left…
>
> The senior guy broke the silence. "You do live here?" He asked. He spoke in an intelligent voice with an educated British accent. No introductions or preliminaries, though… "And this is your plant?" " It is."
>
> What could be the problem? Plant abuse? Obstruction of traffic?
>
> But every one had plants outside the door, without exception…
>
> "You are subjecting the neighborhood to the danger of dengue hemorrhagic fever", the officer announced matter-of-factly…
>
> "I am?"
>
> "That saucer is a magnet for lethal disease," the officer said without a trace of humor. "Standing water is precisely what pregnant female mosquitoes are searching for…"
>
> "I understand…"
>
> …I emptied the dish into the bathtub…
>
> I brought the dish back outside and put it in place, and prepared to lift the fern into it. By now there were five others (neighbors) on the balcony…"
>
> "I don't recommend that you do that," the officer said. I stopped and looked up at him. "Plants do very well here without saucers, and the problem will recur. You will notice that none of your neighbors use saucers under their plants."

Though the cleaning up of one saucer may not seem significant, it does indeed add up. For example, while I was passing out questionnaires for my research, in August 1998 and April 1999, I walked door to door, house to house, and each house was different from the next in the number of containers that were visible on the property. The more containers that I saw with water in them (saucers, canoes, plastic buckets, garbage cans, children's play toys, etc.), the more mosquitoes and breeding I saw. The amount of mosquitoes and suitable breeding conditions frequently changed drastically from one residence to the next. Unfortunately, it only takes one "unsanitized" property to infest an entire neighborhood with biting mosquitoes.

The U.S. government, state and local health agencies can learn from the disease outbreaks associated with *A. albopictus* in Asia. Additionally, since the arrival of the ATM in South America (Brazil) and the Caribbean (Cuba), it is suspected of causing two serious viral outbreaks. The outbreak in Cuba was dengue. *A. albopictus* has also established itself in Europe. Italy's Mediterranean climate would suggest that the ATM could establish itself in parts of California, though to date it has not happened. Also, recent evidence has detected enclaves of ATM populations in Mexico. From such history, it would be prudent for U.S. health agencies to study and heed actions that the Asian, Brazilian, and Cuban governments and agencies have taken against the ATM and disease outbreaks.

U.S. health agencies should ask and act upon the following questions concerning ATM related disease outbreaks in the Americas:

- How did the outbreaks start?
- How were the outbreaks contained?
- How did the respective health systems handle the outbreak crises?
- How was the infrastructure of the public health system set-up prior to outbreaks and how was it adjusted to handle future outbreaks?
- What is the landscape epidemiology and cultural landscape where the outbreaks occurred?
- What are the demographics of the populace affected by the outbreak?
- What are the spatial and temporal patterns of the outbreak?

A few important questions that should be considered with regard to the U.S.A. public health system include:

- Are U.S.A. health agencies and governments studying the circumstances of these outbreaks?
- Are they asking some of the questions posed above?
- Is the U.S.A. public health care system prepared (infrastructure, supplies and materials and planning) for a disease outbreak such as:
    - ability to identify and quarantine an area where an outbreak has occurred
    - ability of doctors and public health officials to identify and diagnose uncommon or emerging diseases
    - have sufficient quantities of vaccines available
    - prepared public service announcements ready in the case of an outbreak
    - prepared logistical coordination (political, economic, and human resources) between various health agencies (local-federal) to address disease outbreaks

It is unlikely that the U.S. has heeded such history and properly prepared for potential disease outbreaks. This is evident in news reports aired on major networks concerning the woeful preparedness of public health agencies for chemical, biological, or nuclear disasters. Rather, U.S. health agencies and governments will probably not restructure and properly prepare until it is too late. Such questions are important and relevant to this thesis because the arrival of the ATM has increased the likelihood that new diseases (Potosi) will be introduced and that disease outbreaks will increase. Thus, the identification of variables conducive to ATM populations and activity would be an important element in combating potential disease outbreaks.

INTRODUCTION: Every Beginning Has A Past

Relevance

The introduction of an exotic mosquito species into a new environment has great potential significance. First, the importation of *A. albopictus* into the continental U.S.A. is important in that it represents only one specific example of GEI. Second, the ATM does affect humans socio-economically, causing a decrease in the Quality of Life (QoL). Third, the ATM is a major biting pest. Lastly, *A. albopictus* is potentially a significant vector of 22 arboviruses that could affect public health. The ATM is also upsetting the ecological balance of domestic mosquitoes (established for centuries) by out-competing and -reproducing them in the short time that it has been here (13 years) (Virginia Beach Mosquito Control, McCreary, 1998; O'Meara, 1995).

Research Questions

This thesis will address the following questions: What have been the socio-economic impacts of *Aedes albopictus* as indicated by survey interviews in Virginia Beach, Virginia? Do correlations exist between the survey responses, census data for each neighborhood, and physical-cultural elements around the houses of surveyed residents that might account for variations in ATM populations and activity in certain areas relative to others?

What do scrap tires, globalization, and mosquitoes have in common? The answer to this question depends on the temporal and spatial considerations of a household. This section addresses Global Economic Integration (GEI) and the diffusion of a particular species of mosquito (ATM).

Genesis: GEI & Diffusion

The intent of this section is to address the importation of the ATM from Japan into the continental U.S.A. The connection that the ATM has with GEI is that the ATM was probably transported into the U.S.A. via scrap tire shipments from Japan (Garrett, 1994, p.257; Hawley et al., 1987).

Two questions arise, "Why does Japan ship scrap tires to the U.S.A., and "why were there no safeguards to protect against species introduction from its source(s) to a non-indigenous area?" To answer the first question, the used tire trade involves many more nations than Japan and the U.S., making it truly global. Scrap tires can be used in the following ways: recapping/repair, fuel, artificial reefs, crash barriers, soil erosion control, asphalt, sandals, gaskets, outdoor playground surfaces, and running tracks. Obviously, the diversity of uses and products made from scrap tires can lead to profitable business. The ability to process and sell used tires varies greatly from one country and market to another. The U.S. is most able to process used tires, giving them new life as a commodity. Also, the U.S. market is ideal for reselling the new used tire products because it is large and relatively affluent. Additionally, not all tires that are imported into the U.S. are for domestic consumption, but rather, the U.S. exports new tire products back to Asia, Europe, Africa, and Central and South America. Lastly, most U.S. tires are steel-belted and therefore cannot be readily broken down; nor can differing components be separated and used as raw/recycled material in products that require pure rubber. A high percentage of Japanese tires are made solely of rubber; thus, they can be readily broken down and used as material to build other products (Craig, 1993). The obvious meaning of this is cost efficiency and expediency, which may translate into increased competitiveness in a volatile world market that can mean profits and survival for the respective businesses.

Consequences of the introduction of new species into an area have been well documented. In the U.S., it turns out, safeguards did exist but they were only enforced within the U.S. military as it left and returned to the country during wartime, normal tours of duty, and in support of U.S. overseas military bases. However, the introduction of the ATM and its establishment among sections of the U.S. general populations is not linked to the U.S. military. Rather, it is linked to unregulated civilian importers/exporters of used tires.

How did this happen? There was a time when U.S.A. civilian importers of scrap tires went mainly through military channels to obtain them. But, during the period of 1966-75 (Vietnam War), all shipments were routinely quarantined, treated with larvicide and inspected. Consequently, this took time, and in a global capitalist economy, time is money. Thus, U.S. importers turned to foreign exporters of scrap tires who were not regulated like the U.S. military (Reiter & Sprenger, 1987). One result of the reorganization of the U.S. scrap tire trade was that the military no longer served as a shield against the importation of the ATM into the U.S., and it

ceased to be the major conduit of used tires within the global economy. This allowed the ATM to become established within the U.S.A. (Houston-Harris County, TX) in 1985. Of note, on January 1, 1988, the U.S. Public Health Service required that all used tires arriving at U.S. ports from areas known to be infested with *A. albopictus* be dry, clean, and fumigated or otherwise disinsected (shredding of tires). However, by the time the disinsection requirement was put in place, the ATM had established itself in 15 states (Moore & Mitchell, 1997). Reports of disinsected tires state that ATM eggs have a survival rate of 5-20%. This is due to the fact that even disinsected tires can hold water because they still retain their curved shape. The implication here is that the ATM eggs have survived and can still hatch.

Role of Technology

Specifically, there are two aspects of time-space compression involving technological advancement that have allowed the ATM to diffuse from Japan to the U.S.A. The first element is due to advancements in the transportation field. Increased transportation speeds (ships and/or aircraft) means that it takes less time to transport goods from one place to another than was previously possible. If it takes less time to reach a sustainable environment, the ATM is more likely to survive the journey. Second, the mammoth size of transport ships and planes allow for the movement of mass volumes of goods across the globe. Thus, it is much more likely that an exotic insect species will be transported to another location. Third, advances in communications have made it possible to coordinate the transport of goods worldwide in a much more efficient manner (decreasing delays and increasing the chances of ATM survival). Advances in communications and equipment have increased the efficiency with which cargo ships and aircraft are unloaded. This results in decreased storage times and faster distribution. Thus, the chances for the ATM to survive are increased because it is introduced to possible suitable environments more rapidly. Fourth, the advent of containerized shipping provides the ATM, while it is in water-filled scrap tires, with a safe, protected and sealed environment as it is moved from one location to another (Craig, 1993; Reiter & Sprenger, 1987).

One anecdotal example of "containerization" and the ATM comes from personal experience. In August 1998, I placed oviposition traps in Williamsburg, VA. An employee of the Williamsburg Mosquito Control, upon my request, sent the ovitrap samples back to me through the U.S. mail. I did not open the box for 2-3 weeks because I thought I had received dry samples. The samples were in ziplock bags inside of a box, but the ziplock bags were full of

water thus exposing the seed germination paper (a rough paper which the ATM lays her eggs on) and ATM eggs to water for three weeks. To my surprise, when I examined the bags of water, mosquito pupae were swimming around and about 7 adult ATMs were alive, well and ready to fly out if I had opened the bags that they were in. Imagine the results if this very small example is applied to the many thousands of massive containerized boxes that ships and planes carry from one destination in the world to another every day.

The Origin of the Asian-(American) Tiger Mosquito

The last connection that will be drawn between the diffusion of the ATM and GEI is that of global cities-states. A global city or state can be considered, in its simplest terms, a centre of economic, political, technologic, financial, military, or cultural importance and influence across the globe. Much of the literature that addresses the origins of the diffusion of the ATM to the U.S. points to Japan as the probable source. Japan is one of the premier global states that is integral in the nodal economic network that criss-crosses the world. Additionally, Japan is only one of a dozen nations that the ATM calls home, though this is rapidly changing. Japan, as a global state, is a major epicenter of economic activity for the world.

Keeping the above elements in mind, consider that the first recorded permanent presence of the ATM was in Houston, TX. Houston is considered a global city and serves as a focus point of international trade and commerce (Dicken, 1992; Allen & Hamnett, 1995). It is surmised that the scrap tire shipment carrying the ATMs arrived on the U.S. West Coast, in either the cities of Los Angeles or Seattle (global cities), before being shipped to Houston. The cities of Los Angeles and Seattle are higher hierarchically in global city rank than Houston. Houston provided a suitable environment for the ATM to establish itself in the U.S. and diffuse from there. It is important to keep in mind that it is very likely that there has been multiple introduction and dispersal sites of the ATM in the U.S. To be discussed later in more detail, supporting evidence suggests that the ATM that arrived and established itself in temperate areas of the U.S. was indeed from Japan because Japan has a mid-latitude climate unlike many other nation-states in Asia to which the ATM is indigenous. Although it is true that China and Korea do have mid-latitude climates that harbor the ATM, it is still much more likely that the ATM came from Japan. Japan is a major trading partner of the U.S., an economic superpower, is involved extensively in the world tire trade, and has a handful of important global trading cities.

China and Korea, in 1985, were not the economic powers, nor connected to the world to the extent that Japan was when the ATM was introduced to the U.S.

Revelations

GEI connects the world in a multiplicity of ways at various degrees and levels. The dendritic network that reflects GEI across the globe is not homogeneous and has many idiosyncrasies. Due to the unequal development and growth of this global network, each place and person is affected and impacted differently by GEI. Subsequently, all are at varying stages of engagement with the global capitalist economy and thus their experience with *A. albopictus* will vary greatly.

In this section only a few examples of how GEI (concerning the ATM) was at work were presented. GEI and the ATM involved the concepts of technological change (communications and transportation), time-space compression, and global cities-states. All of these forces contributed to the relocation to and the establishment of an exotic mosquito species (*A. albopictus*) from Japan to the U.S. *A. albopictus* is impacting the quality of life and lives of those living in the U.S. because of its ability to transmit disease and because it is a severe biting pest and nuisance. Very importantly, it is also impacting the political, economic, and social environments in areas that it is established and affecting change at the local, state, and national scales. ATM influence is variable, and transcends gender, ethnic, and socio-economic divisions. The ATMs introduction into the U.S. is only one example of unintended specie introduction (diffusion) via globalization. There are a plethora of other examples of specie introduction that have and are causing wide spread environmental, ecological, political, and economic troubles. A few examples include the following: Killer African Bees to South America to North America, South American Fire Ants to North America, and the European Rabbit to Australia.

The Diffusion of *Aedes albopictus* in the U.S.A.

Aedes albopictus can be identified by its black and white markings (tiger-like) on its legs and body, including a single and very distinctive white stripe down its thorax. Since 1985, a massive wave of these black and white mosquitoes has made its way from Houston, TX, saturating the Gulf and Mid-Atlantic states as far north as Virginia and establishing enclaves in

Maryland, Pennsylvania, southern New Jersey, Ohio, and Illinois. The spatial and temporal diffusion of the ATM is evident in Figure 8 (page 20). An important fact about the ATM is that it is a non-migratory species with a flight range of less than .6 km. The rapidity of its spread to so many locations in the U.S. is therefore remarkable, and implies an efficient man-made dispersal mechanism (Reiter & Sprenger, 1993). The early diffusion pattern of the ATM in the U.S. is related to the proximity of a county to an interstate (high volume traffic movement) Figures 2-7. Many counties infested with the ATM have interstates that run through them. Once the ATM became established in a county, local transport and short migrations over time completed the dispersion. The dispersion of the ATM also followed human commercial activity especially as it related to the movement of scrap tires for retreading, recycling, legal junk yards, illegal dumping, or other purposes conducive to the transport of ATM eggs (Moore & Mitchell, 1997).

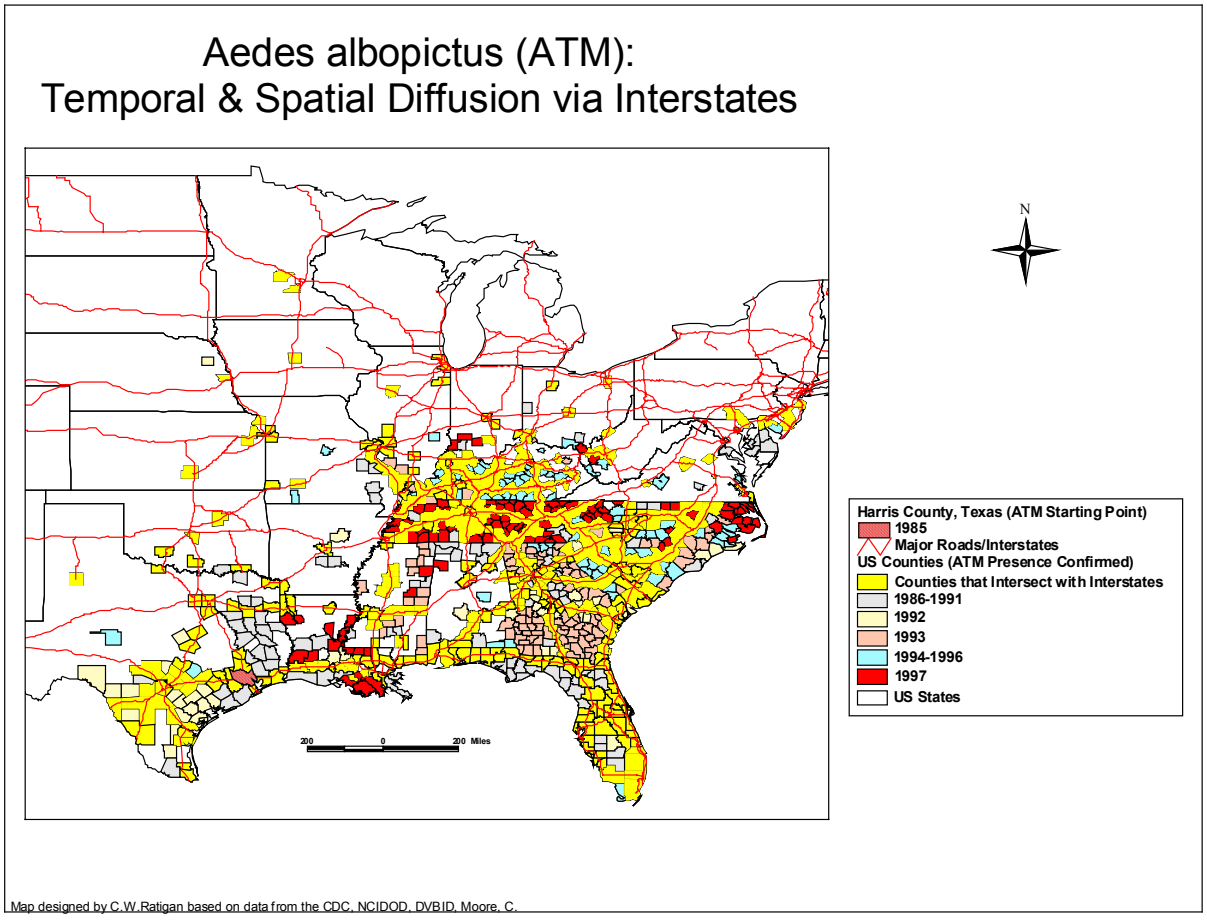


Figure 2. ***Aedes albopictus*** **Interstate Diffusion**

Additionally, the ATM's diffusion is related to cemeteries. ATM eggs readily survive in the multiple flowerpots and saucers that can be found at a cemetery. These vessels are routinely collected and moved outside a cemetery to another location and the ATM moves right along with it (O'Meara, 1992).

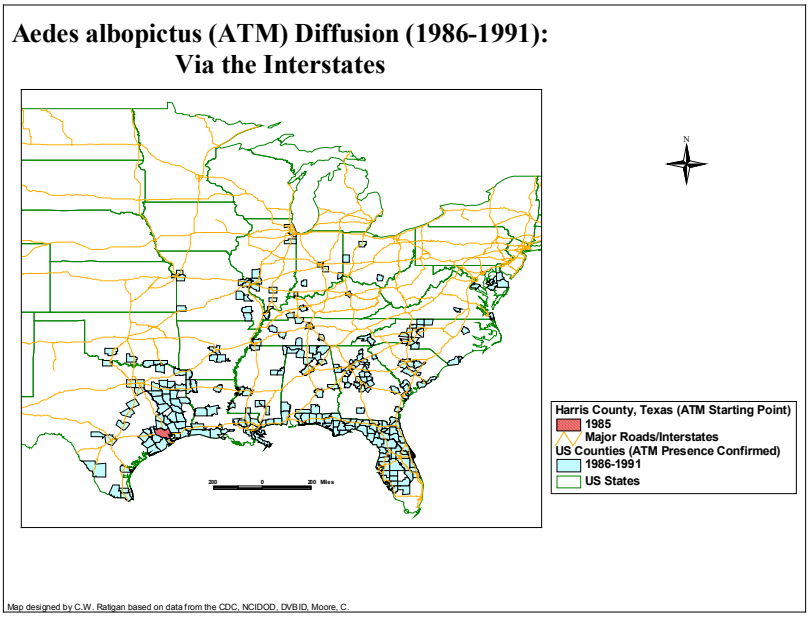


Figure 3. *A. albopictus* Interstate Diffusion (1986-91)

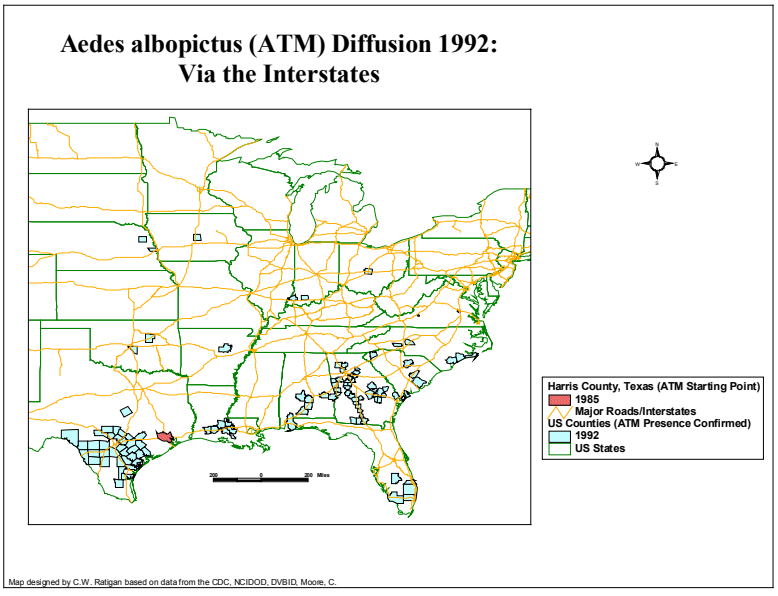


Figure 4. *A. albopictus* Interstate Diffusion (1992)

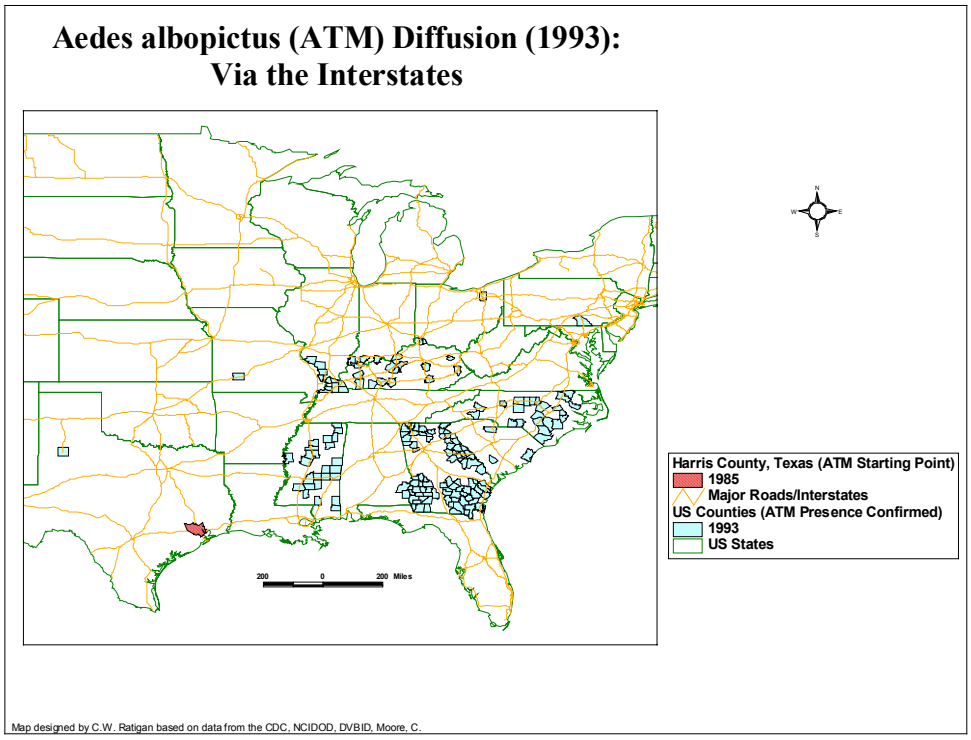


Figure 5. *A. albopictus* Interstate Diffusion (1993).

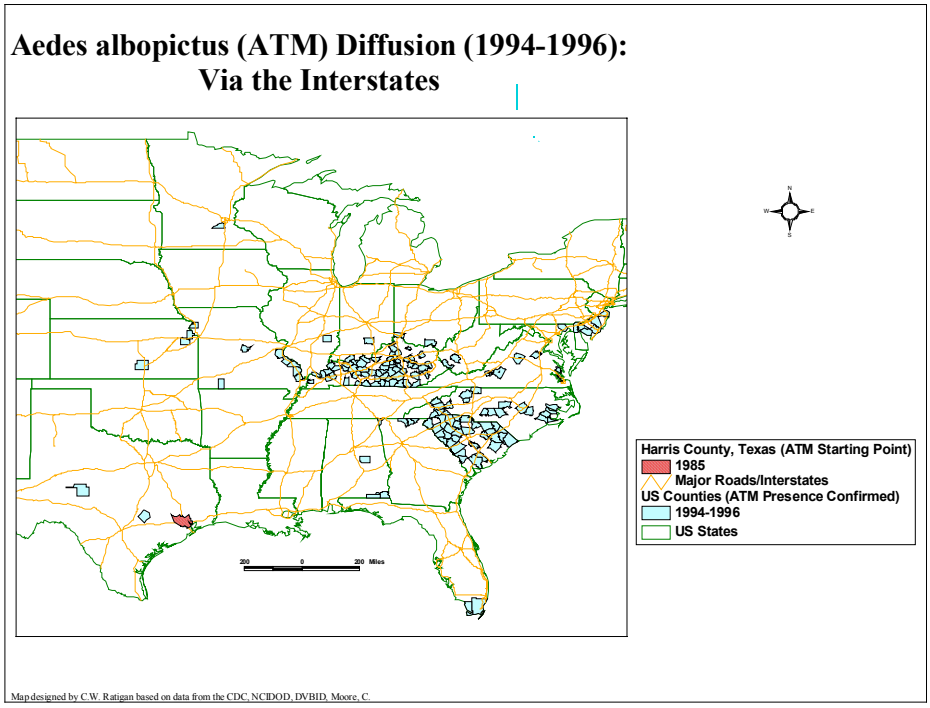


Figure 6. A. albopictus Interstate Diffusion (1994-1996)

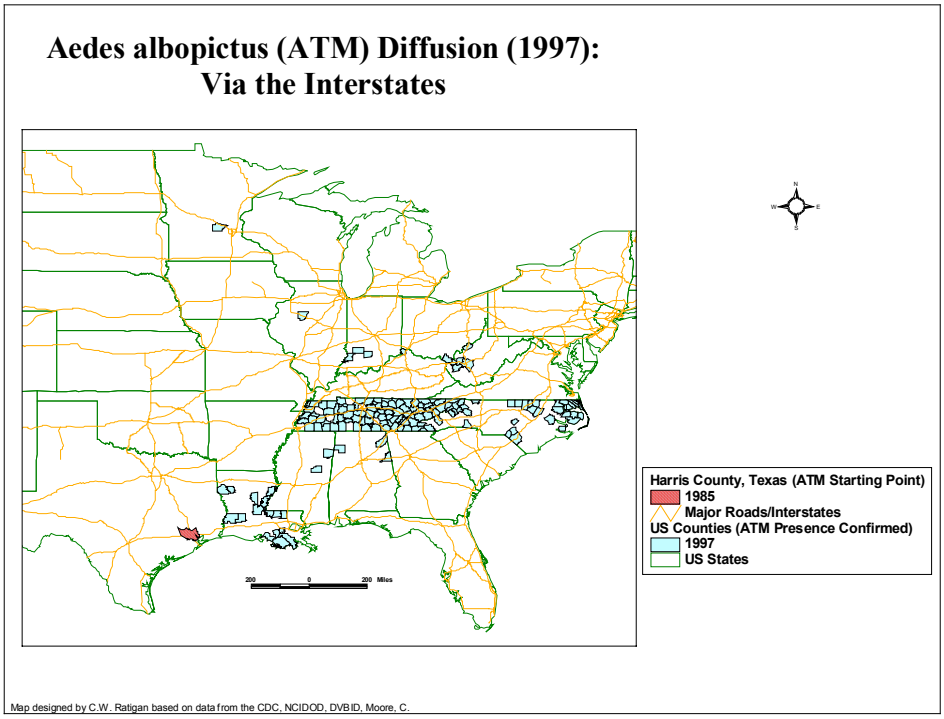


Figure 7. A. albopictus Interstate Diffusion (1997).

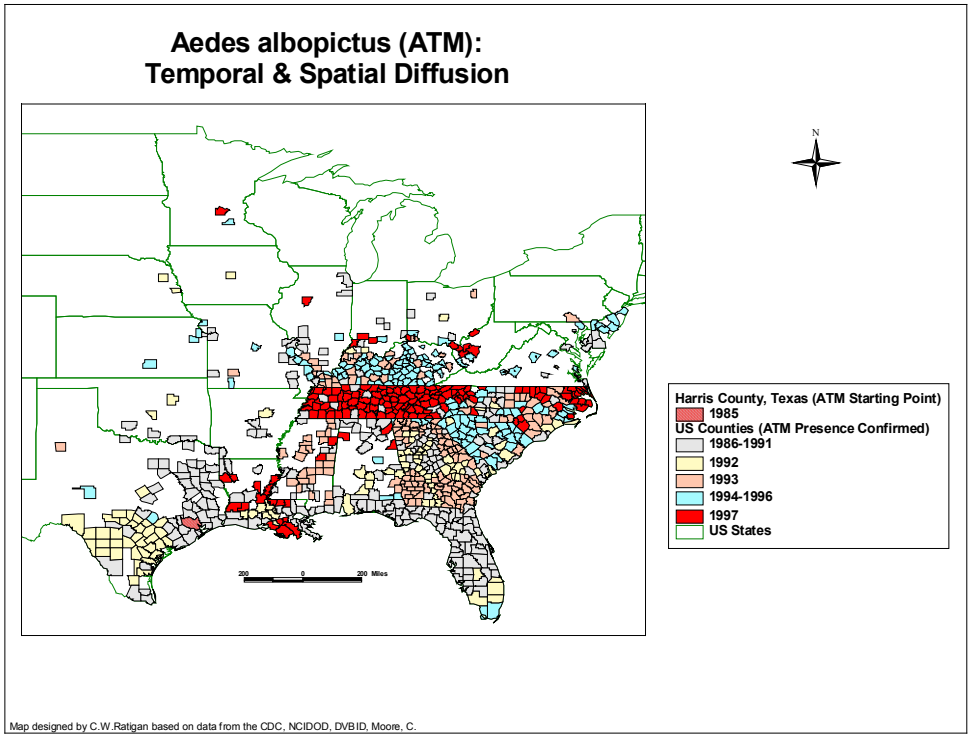


Figure 8. Aedes albopictus Aggregated Temporal & Spatial Diffusion

A. albopictus: Basic Biology, Ecology & Behavior

The ATM is unavoidably a concern to those with whom it shares the same living space. This mosquito will feed on virtually any creature that has blood (avian, mammal, human, and reptile). Introduction of new diseases to the U.S. population is thus enhanced because the ATM is a "cross-species feeder" increasing the likelihood that new arboviruses will be transmitted to humans along with known transmittable arboviruses. Exacerbating the situation is the fact that the ATM is out-competing and out-producing domestic mosquitoes and prospering for reasons that are currently hotly debated.

A few theories about why the ATM is doing better than other "like" mosquito species (i.e. species that share the same habitat/traits/behaviors) are that the ATM, in general, has a faster life cycle. The ATM can reproduce more months out of the year than other mosquito species. *A. albopictus* is hardier (able to withstand colder and drier conditions) than many other species and can feed off of a multiplicity of creatures, warm- or cold-blooded. The ATM has adapted quite nicely to living with humans in rural, suburban, and urban environments. Also, when obtaining blood meals, the ATM will only continue to suck blood if it feels safe. By being a skittish feeder, the ATM increases its chances of not being killed by the creature it is feeding on because it is willing to fly away. Thus, the ATM is willing to attain a partial blood meal, fly away to stay alive, and find another blood source later in order to attain a full blood meal so that it can lay its eggs.

Lastly, in the case of *Aedes aegypti*, the two species exchange certain parasites due to the fact that they live in the "same" environment and have contact and mate cross-species. The ATM is unharmed by the *A. aegypti* parasite while *A. aegypti* is harmed (females are unable to reproduce) by the ATM's parasite (gregarine). A few other potential variables as to why the ATM is out-competing *A. aegypti* are: competition among larvae and larva-induced egg hatch inhibition (O'Meara et al., 1995). Added to the equation for potential disease outbreaks is the fact that the ATM is a particularly aggressive feeder and always hungry (Moore & Mitchell, 1997; Niebylski et al., 1994; O'Meara et al., 1995; Savage et al., 1993). Lastly, the ATM is active when humans are increasing the odds of contact between the two forms of life. Increased contact between the ATM and humans could translate into an increase of the ATM being a

nuisance to humans, the increased possibility of disease transmission to humans, and a decrease in the Quality of Life (QoL) for humans.

Examination of the ATM as a disease vector has revealed that it is a competent laboratory vector of at least 22 arboviruses. Cache Valley, Keystone, Potosi, and Eastern Equine Encephalomyelitis are four arboviruses that have been isolated from U.S.A. populations. *A. albopictus* is also a competent carrier under experimental conditions of the following flaviviruses: Dengue and Yellow Fever. Additionally, vector competence tests show that the ATM can also transmit LaCrosse and Rift Valley fever. Lastly, *A. albopictus* has been found to be naturally (vertical and horizontal transmission) infected with Dengue, Japanese Encephalitis, Potosi, Keystone, Tensaw, Cache Valley, and Eastern Equine Encephalomyelitis (Moore & Mitchell, 1997; Francy et al., 1990).

Another important reason underlying the ATM's diffusion in the U.S. is the presence of favorable habitats. It reproduces rapidly in a wide variety of artificial and natural containers, and readily inhabits and adapts to a rural, suburban, and urban environment. When such conditions combine with the other reasons, the potential for disease outbreaks is very real. As such, the ATM is currently considered the nation's most dangerous mosquito species (Crans, 1996, Niebylski et al., 1994; Moore & Mitchell, 1997).

Adding to the ATM's adapta-flexibility is the fact that it can be differentiated into two basic strains—tropical and temperate. The tropical ATM strain is non-diapausing in that the eggs are not photosensitive to a shortened or lengthened day with the changing of seasons. Thus they do not go into hibernation or diapause (where the eggs are in a protected state, hardier and can survive harsh climatic conditions more readily). This means that in sub-tropical environments such as Florida and other Gulf states, ATM populations and eggs are non-diapausing and breed year round. Thus, the eggs continue hatching as normal regardless of the weather or time of day, and they are not protected against weather extremes (freezing temperatures). What this translates to is that in a state such as Florida, if a freeze should hit, the mosquito population would be greatly reduced because a high percentage of adults and eggs would be killed off due to the fact that they are not adapted to such low temperatures. The opposite of the above is true for diapausing and photosensitive eggs (temperate ATM strains), which go into hibernation when days grow shorter. This, in effect, makes the eggs more durable and much more likely to survive freezing temperatures and water deprivation. When the days

grow longer, the eggs come out of hibernation and continue their cycle of life. This latter case would be true for ATM populations in Virginia, Pennsylvania, and West Virginia.

Lastly, the ATM can be considered a survivor because it is a container-breeding generalist. What this means is that *A. albopictus* can breed and live in rural settings, forested or bushy areas, dumps, suburban and urban environments. The ATM will reproduce in anything that can serve as a container that can hold water (tree holes, tires, Pepsi cans, upright canoes, stopped up rain gutters, trash cans, children's toys left outside, etc.).

The ATM is considered to be a highly problematic mosquito species to control for the following reasons: continued diffusion, evolution, aggressive attitude and voracious appetite, potential vector of disease, active from dawn to dusk, opportunistic container-breeding generalist, ability to live in rural-urban environments, quick and numerous reproduction, specie variation, and photosensitivity and diapause. All of the above factors that make the ATM problematic, I have labeled as "Adapta-flexibility and Non-habitat requirements". When considering adapta-flexibility and non-habitat requirements, the physical, cultural, and epidemiological landscape of the ATM is exceptionally broad and wide-ranging, adding to the problematics of this mosquito species.

Examples of Socio-Economic & Potential Medical Geographic Impacts of Aedes albopictus

Concerning the impact of the ATM on U.S.A. populations, I have three anecdotal accounts. Of these three accounts, I have personally talked with individuals involved in two of them.

Social & Quality of Life Impact of A. albopictus

The first account concerning the impact of *A. albopictus* on U.S.A. populations takes place in New Jersey.

> "Some of the local residents in areas where the mosquito has been established complained of severe mosquito annoyance this summer and were able to accurately describe the characteristic markings of *A. albopictus* with considerable detail. A private citizen that read an article about the Asian Tiger Mosquito in the local newspaper decided that the mosquitoes that had been pestering her all summer were most certainly this exotic species. When she heard we were conducting a survey in the area she went into her backyard and captured

a perfect adult female *A. albopictus* for us to identify. The mosquito is a pest that New Jersey mosquito control workers will have to deal with in the future" (Crans, 1996).

Potential Medical Geographic Impact of Aedes albopictus *in Wise County, Virginia*

The second example was provided by Dr. Sally Paulson of the Department of Entomology at Virginia Tech. In her research with a graduate student, she uncovered a possible link in the transmission of a disease known as LaCrosse Encephalitis in Wise County, Virginia. Five individuals in Wise County were diagnosed and treated for the LaCrosse virus in the summer of 1997. Wise County is now considered to be a "hot spot" of Lacrosse virus because it was not confirmed there prior to 1997. Of added interest is the fact that the ATM has only recently established itself in Virginia. Additionally, the ATM has been positively identified as having established a permanent residence in Wise County. These factors have lent support to the theory that the ATM was responsible for some of the LaCrosse infections.

Socio-economic & Quality of Life Impact of *A. albopictus*

The third account was related by Phil Meekins, of the Virginia Beach, VA, Public Works. Meekins relayed the following story.

> 'There is a private campground located next to a junkyard that has a high number of tires. As is well known, tires serve as excellent breeding grounds for the Asian Tiger Mosquito and as such, the ATM population at this junkyard was quite populous and active. The private campground had asked the manager/owner of the junkyard to clean it up because its condition created a nuisance that disrupted their business. Within twenty minutes of arrival and unpacking, the campers were besieged by very aggressive mosquitoes. This prompted them to pack-up their belongings, demand their money back and leave the campground. The Asian Tiger Mosquito was responsible for the attacks on the campers. Economic losses incurred at the campground led its owner to sue the owner of the junkyard for damages and clean up. The suit was litigated in court during the summer of 1998. The campground won its case with the help of Virginia Beach

Mosquito Control. The owner of the junkyard was forced to comply with the courts decision and clean up his property.

During my research in Virginia Beach in the August 1997, an official from Virginia Beach Mosquito Control brought me to the campground. We went to property line between the campground and junkyard where hundreds of containers could be seen and the area was overgrown and thick with vegetation. After spending a minute or two in the brush, the ATM's attacked and the Mosquito Control Official proceeded with a landing rate count of ATMs on me. The official counted 15-20 ATMs that landed on me in 30 seconds and by then I had had enough so we quickly left.

Virginia Beach Mosquito Control Annual Mosquito Reports to the City of Virginia Beach

The City of Virginia Beach has living within its borders approximately 9 different mosquito species with approximately 18 different mosquito sub-species. Virginia Beach Mosquito Control is responsible for the control and surveillance of these 18 mosquito sub-species. During the course of a mosquito season that lasts approximately from mid-late April to early November in Virginia Beach, a high percentage of Public Works-Mosquito Control Division work hours and budgetary monies are expended in control of the ATM. The Mosquito Control Division as a whole has a "fleet" of workers that is tasked with control of the 18 mosquito sub-species. The Biologist at Virginia Beach Mosquito Control is assigned an extra person (Inspector) whose sole job during mosquito season is to handle ATM related work (public education, personal house calls, research, and abatement). No other mosquito type receives this kind of personal attention from Mosquito Control. The Virginia Beach Mosquito Biologist and the ATM Inspector spend approximately 1370 work hours during the course of a single mosquito season. These hours translate into 100% of the Inspector's time spent combating the ATM, while the Biologist spends 33% of her time solely addressing this problem. Lastly, the work hours and materials spent just on the ATM by the Biologist and Inspector alone amounts to approximately $20,000 per season (City of Virginia Beach, Public Works, Mosquito Control, McCreary, April 22, 1999). In a budget issues letter dated November 14, 1997, the Virginia Beach Mosquito Control, sums up the city's main mosquito problem and concern. It states:

The Asian Tiger Mosquito continues to be the largest identifiable mosquito problem in the City of Virginia Beach. Some of our public educational efforts have been very successful in its control and some require modification…Of great concern is this vector's potential for spreading certain endemic diseases, and its prevalence in our city. Human and animal cases of vector-borne disease in other communities in Virginia and our own problems with salvage operations and tire storage facilities make a stronger case for enforcement of the city's nuisance ordinance.

Below are three tables that represent annual data reports from Virginia Beach Mosquito Control to the City of Virginia Beach (City of Virginia Beach, Public Works, Mosquito Control, 1993-1998).

Table 1. Service Requests

Service Requests by Species Type	% of Total 1998	% of Total 1997	% of Total 1996	% of Total 1995	% of Total 1994
A. albopictus	32	33.1	42	78	47
Unknown/Other	47	56.4	14	13	28
Marsh	3.9	3	5	9	25
Culex	5.3	6.1	*	*	*
Temp. pool/Woodland	11.8	1.4	39	*	*

Table 2. Adult Samples

Adult Samples by Species Type	% of Total 1998	% of Total 1997	% of Total 1996	% of Total 1995
A. albopictus	24	60.5	57.3	65.5
A. albopictus & Others	8	5.3	35.9	10.9
Saltmarsh	12	10.5	1.9	20
Other	56	23.7	4.9	3.6

Table 3. Larval Samples

Larval Samples by Species Type	% of Total 1998	%of Total 1997	% of Total 1996	% of Total 1995	% of Total 1994	% of Total 1993
A. albopictus	42.9	43.2	67.6	66.8	78	51
Culex	43.5	33.2	18.9	17.4	16	33
Both	7.5	14.1	11.7	12.7	*	*
Other	6.2	9.5	1.8	3.2	6	16

The above data clearly indicate that *A. albopictus* is certainly the greatest mosquito pest and is either leading or among the top population leaders for mosquitoes (adult/larval). Unlike many mosquito species in Virginia Beach that present problems only during certain times of the summer, the ATM is a constant problem throughout mosquito season. What is truly surprising is the fact that the ATM was able to out-compete long-established U.S. domestic mosquitoes in a 2-4 year timeframe after its arrival. Though it may appear that ATM numbers are decreasing since the early 1990's, this is not the case for a variety of reasons. First, the reporting methods of Virginia Beach Mosquito Control (VABMC) have changed in that if a mosquito nuisance can not be identified at a complaint site, it is not assumed to be the ATM (early 1990's), rather, the species is listed as unknown. VABMC maintains that of the unknowns, the ATM makes up the highest percentage by far. Second, the decreased amount of rain received in the Virginia Beach area during the mid-late 1990's has reduced ATM numbers. Lastly, residents in Virginia Beach have probably become more tolerant and used to the ATM since its arrival, and are not reporting problems as often.

The natural environment of Virginia Beach (ecology, climate & weather-temperature-humidity-precipitation, varied habitats-rural-urban, and food sources-human-reptile) is exceptionally friendly to the ATM in its ability to permanently establish itself and flourish. It is not surprising that the environment of Virginia Beach is a good fit for the ATM when it is compared and contrasted to the ATM's biology, ecology, and behavior. Exacerbating the beneficial fit of Virginia Beach to the needs of the ATM is urban-suburban sprawl. Essentially, once marshy-swampy-wetland areas that were home to other mosquito species (other than the ATM) have been and are being destroyed in-order to build housing tracts, malls, and shopping centers. One result is that domestic mosquito species have been all but eliminated from these changed landscapes because the habitat can no longer support their ecological needs. The livable

habitat for the ATM has been increased through the re-creation of the landscape. Two main impacts can be attributed to urban sprawl with regards to domestic mosquitoes and the ATM. One, mosquito ecology is disturbed in favor of the ATM thus affecting balance. This means that the ATM grows in numbers and area in which it can impact the lives of people. Two, humans are now brought into these new landscapes where they once did not live. A result is that humans are now brought into an environment conducive to ATM life. Additionally, once humans have established themselves, they help the ATM to prosper by introducing another food source (themselves and pets), places to rest and breed, and places to reproduce (containers). Thus, as humans shape the landscape in their own image for their own benefit, how much does this reshaping actually hurt humans and what about the delicate ecological balance? Virginia Beach has historically been an area where mosquitoes have been a threat to public health. A threat serious enough that a result is that the City of Virginia Beach has ordinances that allow for legal action to be taken against persons who create environments overly supportive of mosquito life. The landscape epidemiology of the area is changing as humans continue to alter the landscape of Virginia Beach making it more livable for the ATM. In this case, change is not good, because by increasing the range and number of ATMs in Virginia Beach, the likelihood of disease occurrence and transmission increases (common, uncommon, and exotic).

LITERATURE REVIEW

There is a vast amount of literature across a variety of academic disciplines that is pertinent to this research. My thesis topic is centered in medical geography. General concerns of this field include the ecology of disease and health (interrelationships of population, environment, and behavior), and patterns of change in pace and place. A cartographic approach maps rates of disease and is linked to epidemiology and the geography of health care (study of disease incidence and causes, where it started and how, distance of disease, and where it spread to elucidate the social and environmental causes of illness and health). Examples of such work include Meade (1988), Oppong (1998), Curtis and Taket (1996), and Lears (1995) In order for me to conduct my research, I had to become more knowledge in the following interrelated fields: entomology, epidemiology, biology, history, economics, and geography. All of the literature to be discussed is interrelated with medical geography with the following sub-topics: geography of technology & travel, geography of tracking technology, physical geography, cultural-ecological-demographic geography, and the geography of *A. albopictus*.

The overall theme that drove my research was the concern for public health and its possible compromise due to the colonization of large areas of the United States by the disease-vectoring ATM. The main objective is to determine the elements that make an environment conducive to ATM populations. This literature review will examine materials that address the proliferation of disease at the global, regional, and local scales.

Advances in technology and its subsequent impact on the transportation of goods was discussed earlier (pp. 14-16) along with the geography of the ATM as related to its arrival in the U.S.A. (pp. 12-19). Closely related to technology's impact on the transportation of goods is the transportation of people, which often means the transportation of disease and vectors of disease (Johnston et al., 1995, p. 206-223; Bouvier et al., 1990). Such disease outbreaks can occur in two ways. First, a mosquito (anopheles) carrying malaria was transported to Geneva-Cointrin International Airport, Switzerland, from the tropics, where it escaped and caused several local malaria cases (Johnston et al., 1995). A second example would be an infected passenger in the infectious stage of a disease before overt and recognizable symptoms appear. Fellow passengers are all potentially exposed, but may disperse without being aware of the exposure. Thus, the speed and range of aircraft mean that people who may be infectious will be arriving in airports

long before clinical symptoms for many diseases have had time to develop (Johnston et al., 1995 and Hagget, 1994).

There are two growing tracking technologies that are used in the field of epidemiology known as remote sensing (RS) and geographic information systems (GIS). Acronyms to represent the use of these technologies with epidemiology that are used in this paper are RSEPI and GISEPI. These technologies are much more than tracking technologies since they allow for the recording, storage, and analysis of data. Also, RSEPI and GISEPI allow for the surveillance and mapping of elements and the creation of historical and probability models. The use of RSEPI and GISEPI allows researchers to monitor and predict when or where a disease outbreak might occur. Such predictions are based, for example, on the analysis of the habitat of arthropods and the diseases they can transmit to humans (arboviruses).

There have been several studies that have used RS and GIS to study disease. A study by D. Roberts (Roberts et al., 1991) used RS technology in a predictive model of vector population dynamics and malaria transmission potential in Tapachula (Chiapas), Mexico. Another study by Byron Wood (Wood et al., 1991) used RS and GIS to analyze rice field dynamics in northern California as they relate to *Anopheles freeborni* (malaria mosquito) populations. This allowed researchers to predict which rice fields would have lower or higher yields. The fields with higher yields supported many more *Anopheles freeborni* and were located close to pastures (bloodmeal sources). Based on rice field maturation, the peak of larval populations of *Anopheles freeborni,* could be predicted with 90% accuracy two months in advance. The implications of such a study are immense and could benefit public health greatly through control and prevention methods. Similar studies (Daniel et al., 1990) have attempted to predict tick presence and populations because of their potential to transmit arboviruses. Lastly, researchers such as Fred Knapp and Paul Grimstad are using RS to detect illegal tire dumps. The detection of tire dumps is important because they are exceptional breeding sites for the ATM and other mosquitoes that can transmit such diseases as La Crosse Encephalitis, St. Louis Encephalitis, Eastern Equine Encephalitis, and Dengue and Yellow Fever.

Studies in physical geography that are related to this research address the recent and controversial trend of global warming as it relates to the spread of disease. Biological diversity of viruses and bacteria is partly temperature-dependent, and is much greater in low than in high

latitudes (Johnston et al., 1995; Haggett, 1994). Also, the warming of the earth would result in the expansion of warmer climates to higher latitudes, which could result in an increase in the habitat range of vectors such as the ATM, past 42 degrees latitude in the U.S.A. Historical analysis seems to confirm such a hypothesis, as malaria has shifted geographically over the millennia in accordance with major climate changes (Garrett, 1994).

The interaction of human culture and demographics with the physical environment gives us cultural ecology. Cultural ecology is studied by medical geographers to determine the interactions of factors that can lead to disease (landscape epidemiology). Human interactions with the environment, such as travel, migration, urbanization, war, dam building, and forest clear-cutting to increase agricultural lands (agriculture colonization and environmental disruption), have brought humans into contact with disease cycles (Haggett, 1994; Morse, 1990; Gesler, 1991).

A study by Meade, "Landscape and Disease in the Carolinas" (1996), focuses on how the four different ecological zones (tidewater, coastal plain, piedmont, and mountain) have different "landscapes" of health. Depending on the zone that a person is in, that person will be more or less likely to become infected with a disease. Based on Meade's model, it appears, in general, ceteris paribus, that the lower the elevation, the more likely disease transmission will occur. This makes sense because elevation simulates latitude in terms of climate zones. Thus, when one increases in elevation/latitude, the climate will become cooler and disease transmission less likely, with the opposite being true when one moves to lower elevations/latitude. The article concentrates on the interaction of the physical environment with the modified and built-up environments as the result of human cultural manipulation (Meade, 1996).

In another article, Meade elaborates on the four types of regions when studying the landscape epidemiology anywhere. The four regions are biotic, biotic realms of evolution, culture realm, and the natural nidus. This article discusses the interaction between the four zones and humans, and based on this, disease transmission is partially determined. The concept of landscape epidemiology and the interaction of humans with the environment will impact the relationship that residents in Virginia Beach, VA have with the ATM. For example, marshland in Virginia Beach is being destroyed (urbanization), and thus, marsh mosquito habitat is being destroyed along with the mosquito. But, in place of the marshland, houses are being built (i.e. the building of habitats for the ATM).

There are several topics concerning the ATM's presence in the U.S.A. that researchers have studied. These topics can be generalized into three main sub-topics to include how and where the ATM arrived into the U.S.A., how and where the ATM diffused in the US.A., and its potential threat to the public health of Americans as a vector of arboviruses. These topics about the ATM were discussed in the Introduction. Researchers such as Chester Moore, George Craig Jr., William Hawley, Paul Reiter and Craven, Stefan Nawrocki, George O'Meara, Savage and Niebylski, and Sprenger have been responsible for amassing a great deal of knowledge concerning the ATM in the U.S.A. Moore has studied the health implications of the ATM in the U.S.A. (Moore et al., 1997). Craig and Hawley investigated the diaspora of the ATM in the U.S.A. and its arrival into the U.S.A. (Craig, 1993; Hawley et al., 1987). Reiter and Craven have examined the world tire trade as a mechanism of the worldwide dispersal of container breeding mosquitoes (Reiter et al., 1987; Craven et al., 1988). Nawrocki and Hawley have studied the northern limits of the ATM and overwintering survival of ATM eggs (Nawrocki et al., 1987; Hawley et al., 1989). O'Meara has studied the spread of the ATM and decline of *Aedes aegypti* (O'Meara et al., 1995) and has examined the spread of the ATM in Florida via scrap tire piles and cemeteries (O'Meara et al., 1992). Savage and Niebylski have researched the blood host feeding patterns of the ATM, which makes possible the introduction of new arboviruses into the U.S.A. populace (Savage et al., 1993; Niebylski et al., 1994). Sprenger was responsible for one of the first studies on the ATM in the U.S.A. as he reported on the discovery and distribution of *A. albopictus* in Harris County, TX (Sprenger et al., 1986). Lastly, a study by William Robinson addressed the attitudes of homeowners towards mosquitoes in Virginia Beach, VA in 1983. Research I conducted in August 1998 and April 1999 is similar to the Robinson study. One result of this is that between the three survey years (1983, 1998, and 1999) there are a few variables that have common characteristics in all three surveys. The data between the three surveys and from other studies (Gerhardt et al., 1973 and Headlee, 1932) are similar, thus lending credibility to the data I collected (Table 4).

Table 4. Data Comparison for Credibility

Question	Gerhardt-1973	Robinson-1983	Ratigan-1998	Ratigan-1999
1.) Age, Mean	*	47	45	*
2.) Gender, Female	*	68%	59%	*
3.) Do You Have Mosquito Problem	69% Yes	55% Yes	*	62% Yes
4.) Has the Mosquito Problem Gotten Worse in the Last 5 Years	*	30% Yes	52% Yes (See More Mosquitoes)	61% Yes
	*	*	44% Yes (Bitten More by Mosquitoes)	*
5.) Do Mosquitoes Limit Your Time Outside	*	58% Yes	47% Yes (Affect My Activity)	33% Yes (Affect My Activity)
	*	*	67% Yes (Think About Going Outside)	47.4% Yes (Think About Going Outside)
	*	*	77% Yes (Forced Inside by Mosquitoes)	57.1% Yes (Forced Inside by Mosquitoes)
6.) Does Mosquito Control Need to do More	*	49% Yes	59% Yes	58.2% Yes
7.) Would You Pay More Taxes for More Mosquito Control	43% Yes	49% Yes	48% Yes	42.9% Yes
8.) Mosquito Bites/Night	*	3 median	*	*
9.) Mosquitoes Bites/Day	*	*	4.75 median	2.6 mean
10.) 4 <= Mosquitoes Bites/Hour (not a problem, Headlee, 1932)	*	*	37.5%=Sm.Prob 19.5%=Lg.Prob	45% A Problem 55% No Problem
11.) 4 > Mosquitoes Bites/Hour (a problem, Headlee, 1932)	*	*	25.2%=Sm.Prob 45.9%=Lg.Prob	100% A Problem

A great deal is known about the ATM, including its behavior, biology, general habitat needs, origins, arrival in the U.S.A., diffusion in the U.S.A., feeding habits, and its threat to public health as a disease vector. Study of the ATM is deficient in at least the following two major areas. First, there have been no probability studies using GIS and RS that could help to determine the likelihood of where the ATM will diffuse in the U.S.A. Second, more research is needed concerning the specific characteristics of ATM environments and populations in areas that it has colonized. My study examines and correlates the physical, cultural, and demographic variables based on a survey of residents to determine an environment friendly to the ATM at a micro level (block group and/or residence).

PILOT STUDY

Introduction

I conducted a pilot study to test the feasibility of my ideas and methodology. Subsequently, I made a number of improvements to develop the main study. My main methodology includes personal interviews, removal of redundant survey questions, and acquisition of addresses for discrete point data for geocoding purposes. Additionally, the study was concentrated in one city district, pictures were taken of each surveyed residence to record the physical and cultural landscape, and a random number generator was used to select census block groups for the study. Lastly, an employee of the Virginia Beach Mosquito Control Office (VABMC) accompanied me during the field research to help with public relations and to decrease delays in finding targeted neighborhoods.

The pilot surveys provided information on the following:

- where the mosquitoes were encountered
- what mosquito species are most known by the populace
- perceived number of mosquitoes encountered by residents per day
- perceived mosquito problem
- probable identification of the main mosquito specie nuisance
- desire of citizens to have mosquito control offices to do more
- willingness of citizens to pay more in taxes for more mosquito control
- basic socio-economic impact of mosquitoes

I want to emphasize that the data and information that the Pilot Study generated are small components of the Research Methodology and were used to support the main body of the Research Methodology. Several aspects of the Research Methodology were included in the Pilot Study as introductory material before the main study. Lastly, the Pilot Study is important in that it helps to define the physical, cultural, demographic and ATM environment in southwest Virginia and it provides a context from which the Research Methodology can be better understood.

Why Southeast Virginia was Chosen as the Study Area

Familiar Area & A. albopictus *Presence Confirmed*

Southeast Virginia was chosen as the study area because the ATM is the number one mosquito nuisance based on information from mosquito control offices. Based on 1997 data from the CDC regarding Virginia, the ATM was reportedly confirmed only in Virginia Beach and Hampton. This encouraged me to look at many other districts for the ATM and its socio-economic impact. Additionally, I lived in southeast Virginia for four years and was familiar with it. It was also accessible to Blacksburg.

Impact of A. albopictus *Confirmed and Allies Are Found*

The ATM's arrival in southeast Virginia led the City of Virginia Beach Mosquito Control Office (a division of the Department of Public Works) to carry out a public awareness and education campaign. This campaign was designed to signify the ATM as a major biting pest and disease carrier. It was disruptive to everyday life for the populace, and its control required site-source reduction. The public education campaign directed at the ATM began in 1992, less than a year after its confirmed arrival in the area (City of Virginia Beach, Public Works, Mosquito Control, 1991). The Virginia Mosquito Control Association (VMCA) stepped up its public awareness and education campaign against the ATM in 1996 as it began to air public service announcements throughout the region of Hampton Roads (Chesapeake, Virginia Beach, Norfolk, Hampton, Williamsburg, and York).

The VMCA was a valuable asset as I conducted my research in its respective jurisdictions as it was well-networked in southeast Virginia. This helped my research efforts because all of the county/city districts in which I wished to conduct my research had VMCA offices. Securing cooperation was relatively easy because the VMCA was receptive to my study. The VMCA/local mosquito control offices have people familiar with the ATM and with the areas in which I wanted to conduct my research. Additionally, local mosquito control offices have established a relationship with the city's residents. Local mosquito control offices supplied me with data concerning mosquitoes in the area (including the ATM), and they knew where the ATM could be found. These local mosquito control offices are linked together via the VMCA, which allows the sharing of data and information.

Southeast Virginia: A Hub for A. albopictus Contact and Diffusion?

Southeast Virginia is potentially very important to the further diffusion of the ATM. It is a highly transient area (military and Department of Defense hub and federal job employing hub), it has international shipping ports, and it has an international airport. Between Colonial Williamsburg and Virginia Beach, 4-5 million visitors/vacationers visit the area annually. The potential implications include further diffusion of the ATM domestically and internationally, and increased contact between people and the ATM. Although not likely, the ATM can, under the correct conditions, transmit up to 22 arboviruses to humans. The consequences of this transmission potential are not known, and would vary based on the virus, the number of people and mosquitoes infected with the virus, and the response of public health organizations. Confirmed arboviruses isolated from the ATM are shown in Figure 9.

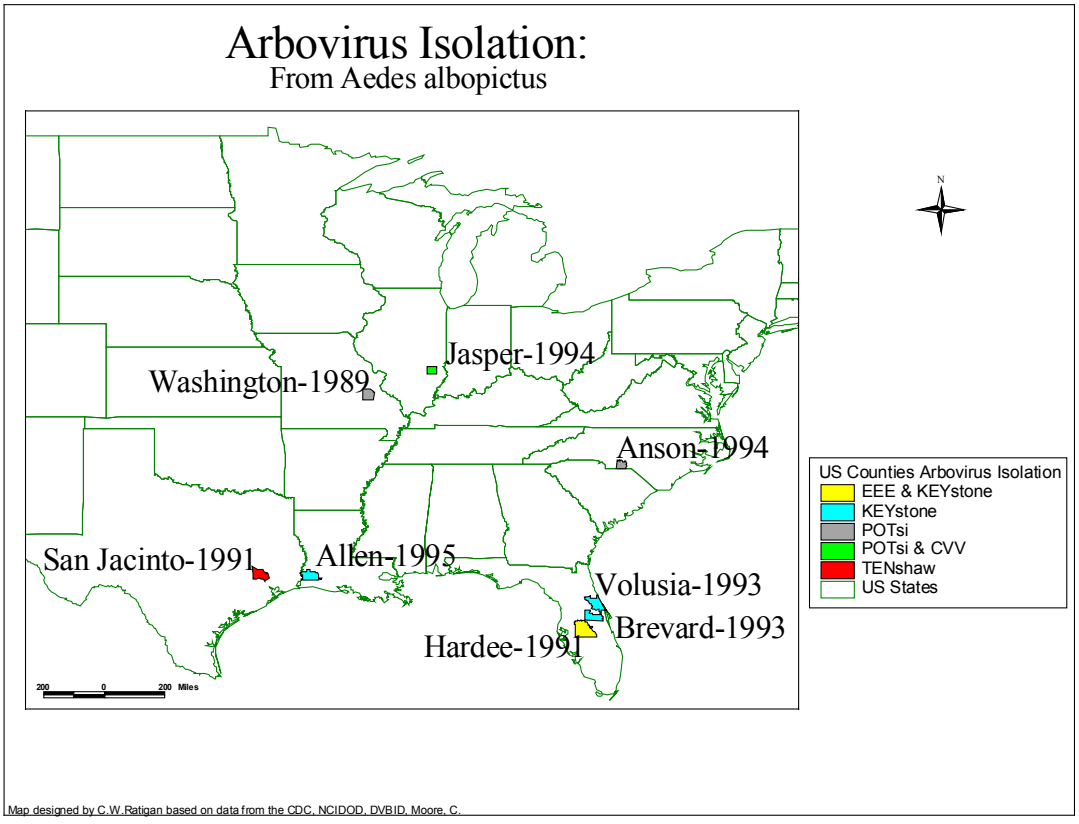


Figure 9. Arbovirus Isolation: Asian Tiger Mosquito

Pilot Survey Specifics, Diffusion, and the VMCA:

I distributed numerous surveys throughout southeast Virginia in August 1998 (Figure 10).

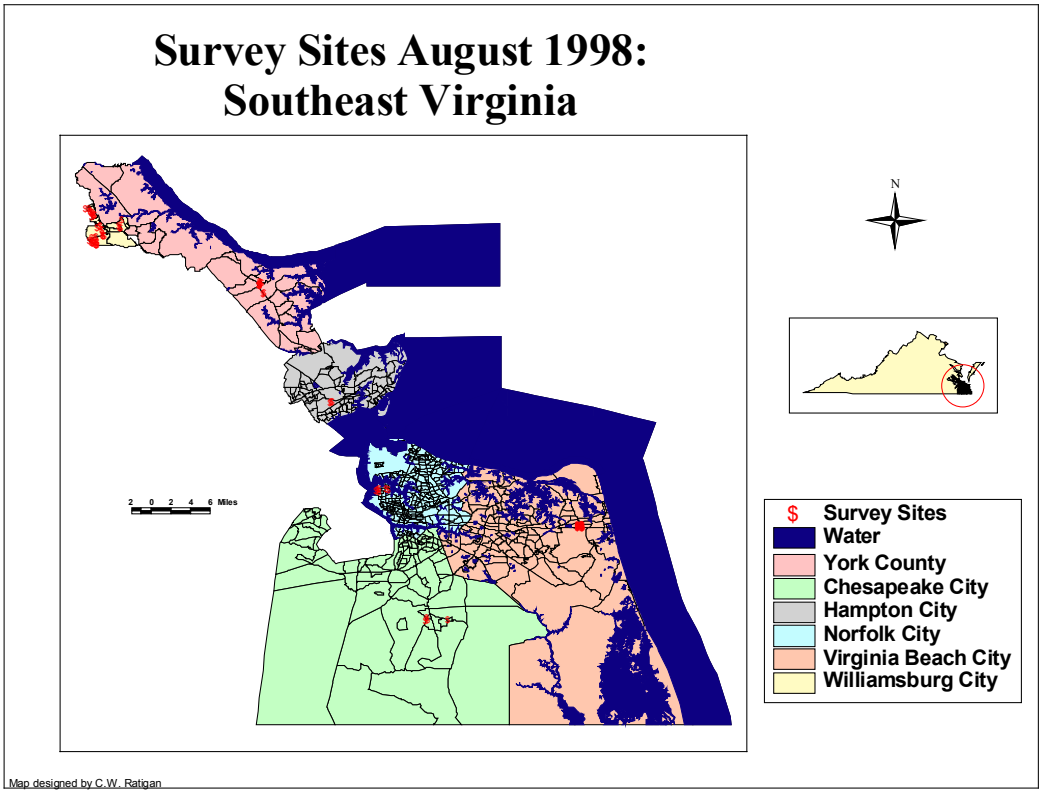


Figure 10. Southeast Virginia Survey Sites, August 1998

Table 5. Survey Localities, August 1998.

Name of County/City	Surveys Distributed	Surveys Returned
Chesapeake	141	9
Virginia Beach	150	16
Hampton	89	8
Norfolk	145	27
York	105	14
Williamsburg	149	22
TOTALS	**779**	**96**

The survey was made up of 56 questions and was attached to a flier explaining the purpose of the survey and who created it (Appendix A). The purpose of the survey was to gain a

sense of the socio-economic impact of the ATM and to possibly determine the species of mosquito most responsible for decreasing the quality of life (QoL) in the surveyed areas. The surveyed residents had the task of returning the surveys in a self-addressed envelope. They had to provide the stamp and mail it. This partially explains why the response rate was low.

Two objectives of this survey were to determine ATM presence and its socio-economic impact on residents surveyed. Thus, it was important to find out where the ATM could be found. To find neighborhoods where the ATM had an established presence, I asked local mosquito control offices to take me to neighborhoods where the ATM was established based on complaint calls, specimen collection, or their experience in the field.

Pilot Study: Streets, Landscape, and Base Demographics:

This section gives the location of the surveyed neighborhoods, provides imagery of the neighborhood's landscape, and provides base demographic information for each neighborhood. The demographics of the individual neighborhoods will become more important as this data will be correlated to survey data in the main methodology conducted in April 1999. Maps and imagery of these neighborhoods can be found in Appendix B.

Table 6. Demographics-1, August, 1998.

City/County	No HS Diploma %	College Graduates %	House Value	Household Income
Chesapeake	12	7	80,000	28,000
Hampton	19	9	87,000	39,000
Norfolk	2	25	117,700	48,000
Virginia Beach	15	4	68,900	22,200
Williamsburg	8	11.7	110,600	27,000
York	10	8	100,300	39,000

Table 7. Demographics-2, August, 1998.

City/County	Year House Built	Unemployment Rate %	Gender Responding % F/M	Time in Area	Age
Chesapeake	1973	5	55 F	27	47
Hampton	1965	2	62.5 F	28	54
Norfolk	1944	4	59.3 F	16	42
Virginia Beach	1960	15	68.7 F	24	45
Williamsburg	1966	2.8	50 F	12	48
York	1985	1	64.3 F	8	37

It should be noted that the surveyed neighborhoods (approximately 100 household units) are smaller geographic units than the census block groups (400 households). The importance of this is that the demographics of the census block groups represent a larger population than the population surveyed. Thus, the demographics of the surveyed individuals/households are not necessarily the same as the census block group demographics.

Survey Results

According to 1997 CDC data, ATM populations were first detected in southeast Virginia in 1991 in the City of Virginia Beach and in 1993 in Hampton City (Moore, CDC, NCIDoD, 1997) (Figures 2, 3, & 8). The CDC data is supported by Virginia Beach Mosquito Control's (VABMC) data on the arrival of the ATM to Virginia Beach (City of Virginia Beach, 1991-1998). When CDC, VMCA and VABMC data (ATM arrival in SE VA) are compared to the survey data that was collected for this research, the data and mosquito control officers support the answers that the survey respondents gave (i.e. intensification of the mosquito problem was mostly due to the arrival of the ATM) (City of Virginia Beach, Public Works, Mosquito Control, 1999).

Mosquito control offices in the Tidewater region have identified the ATM as the number one mosquito nuisance due to its activity and numbers.

Table 8 is based on data gathered from the August 1998 survey distributed in Tidewater. The columns of the table represent 15 different census block groups where the surveys were passed out. Each cell in the top row has a number over a three-letter code. The number represents the number of residents that the data for the column are based on. The data in each column is the average response of residents to questions in the survey. The three letter codes stand for, in order, the following districts: York-YOR, Virginia Beach-VAB, Hampton City-HAM, Chesapeake-CHE, Norfolk-NOR, and Williamsburg-WIL. Finally, the variables from the pilot study will be listed by their abbreviated form and then defined. This list will help clarify the variables presented in Tables of data that are to follow.

Survey Variables, August 1998

TIA-- Time in Area (years and months)
Which One %- ATM-- Percentage of respondents identifying the ATM as the mosquito that they have heard about in different media
Skeet Dscrp (**SD**) %-- Percentage of individuals that described the color of the mosquitoes that they saw in their yard as either **Brown, Black,** and/or **Striped**.
Garden or Grass %-- Percentage of respondents that encountered mosquitoes in their **Garden** or while **Cutting the Grass**.
Yes When Worse-- The year that residents, with a mosquito problem, identified as **THE** year that their mosquito problem became worse.
When Buy-- The number of years ago that residents started to buy mosquito control products (counting back from 1998).
You Out (**YO**) %-- Compared to five years ago, do you spend **More** or **Less** time outside.
Bites Self (**BS**) %-- Compared to five years ago, do you notice **More** or **Less** mosquito bites on yourself.
Discuss (**D**) %-- Compared to five years ago, do you discuss mosquitoes **More** or **Less** with others.
Hearing (**H**) %-- Compared to five years ago, do you hear **More** or **Less** about mosquitoes from the media.
Skeet Prob (**SP**) %-- Rate your mosquito problem, **Small** or **Large**.
Actv Affect %-- Percent of respondents that said that mosquito activity affects their daily activity.
Out But No %-- Percent of persons that are deterred from going outside by the possibility of biting mosquitoes.
Out-Come In %-- Percent of respondents that are forced inside by biting mosquitoes.
$/Year-- Amount of money respondents spent per year on mosquito control products.
Pay More (PM) %-- Percent of persons willing to pay more in taxes for more mosquito control.
Do More (DM) %-- Percent of respondents that think mosquito control offices need to do more to combat mosquitoes.
Bites/Day-- Number of bites received by the respondent each day.

Table 8. *A. albopictus* Presence, August 1998.

Questions/ Variables	14-- YOR	16-- VAB	8-- HAM	5-- CHE	3-- CHE	1-- CHE	9-- NOR	11-- NOR	7-- NOR	11-- WIL	1-- WIL	1-- WIL	5-- WIL	2-- WIL	2-- WIL
TIA	8	24	28	33.6	12.5	24	11.1	15.7	23.9	13	8	2	18.4	8	2
Which One %-ATM-1	*	100	100	100	100	*	*	100	100	*	*	*	*	100	*
Skeet Dscrp % - Brown	35.7	18.7	12.5	80	33.3	100	55.5	*	14.3	18.2	100	100	20	*	*
SD - Black	28.6	56.2	25	20	*	100	22.2	27.3	57.1	45.4	*	*	40	50	50
SD – Striped	14.3	56.2	25	40	33.3	100	33.3	45.4	71.4	63.6	*	*	*	50	*
Garden - %	42.8	37.5	25	40	*	100	66.6	27.3	85.7	63.6	100	*	40	*	50
Grass - %	28.6	50	25	20	*	100	33.3	18.2	14.3	27.3	*	*	40	*	*
Yes When Worse	1998	1994	1998	*	1996	*	*	*	*	1998	*	*	*	*	*
When Buy	1.17	2.27	2.8	3	5	17.5	1.7	2.5	1.5	4.7	0.1	2	0.1	*	*

There are several important variables included in Table 8 that help establish the presence of the ATM in the respective surveyed neighborhoods. ATM presence and impact can be confirmed through the following:

- High percentages of persons encountered mosquitoes in the garden
- Described their mosquito as black and/or striped
- The mosquito problem got worse around 1996
- Residents started to buy mosquito control around 1995
- Residents lived in Tidewater (which is known to be infested with mosquitoes) 10 years prior to the arrival of the ATM

Table 9, below, is the same format as Table 7 and represents data from the August 1998 survey. Having established that the ATM is, preponderantly, the major mosquito nuisance in Hampton Roads, Table 9 addresses survey questions that attempt to gain insight into the social impact of the ATM on the surveyed populace.

Table 9. *A. albopictus* Social Impact

Variables/ Questions	14-- YOR	16-- VAB	8-- HAM	5-- CHE	3-- CHE	1-- CHE	9-- NOR	11-- NOR	7-- NOR	11-- WIL	1-- WIL	1-- WIL	5-- WIL	2-- WIL	2-- WIL
YO Less	28.6	46.7	50	20	33.3	*	12.5	36.3	28.6	33.3	*	*	25	50	*
Bites Self % More	50	78.6	50	*	33.3	100	62.5	20	42.9	22.2	100	*	50	50	*
Discuss % More	21.4	76.9	12.5	20	33.3	100	75	18.2	14.3	11.1	*	*	*	50	*
Hearing % More	42.8	64.3	25	40	*	*	62.5	45.4	28.6	30	*	*	50	50	*
SP Large	38.5	81	71.3	20	33.3	*	37.5	20	*	27.3	50	*	40	*	*
Actv Affect %-Yes	50	68.7	42.9	0	33.3	100	66.6	36.4	14.3	36.4	100	*	60	*	*
Out But No %-Yes	78.6	87.5	71.4	40	50	100	66.3	60	40	60	*	*	50	*	100
Out-Come In %-Yes	85.7	93.3	83.3	40	33.3	100	88.8	80	57.1	54.5	100	100	80	*	100

Socially, the emergence of the ATM in Hampton Roads has caused a significant percentage of surveyed residents to start buying mosquito control products (alteration in resident behavior) evident from Tables 8 and 9, variable “When Buy.” Table 10 aggregates certain variables from Table 9.

Table 10. 1998 Compared to 1993

QUESTION	% MORE	% LESS
Time Outside	22.8	33.5
Seeing Mosquitoes	52	24
Bitten by Mosquitoes	43.7	9.8
Discussing Mosquitoes	31.8	22.5
Hearing About Mosquitoes	38.6	15.4

Evident from this table is that when southeastern Virginian residents compared 1998 to 1993, they were being bitten more by mosquitoes, were spending less time outside, were discussing mosquitoes more, were seeing more mosquitoes, and were hearing more about mosquitoes from different media. In short, mosquitoes were impacting the lives of these residents more in 1998 than they were in 1993. This data apparently supports the arrival of the ATM in 1991, its establishment in southeast Virginia, and with its establishment, its impact on people's lives and their quality of life. The social impact of the ATM on residents is clear in that the ATM has spurred an increase in public service announcements, increasing the amount of information people are hearing about mosquitoes, and residents are having to consider mosquito activity as they plan their activities throughout the day.

The last data/survey topic that will be discussed mainly concerns the economic impact of the ATM, residents' satisfaction with local mosquito control, and social implications (see Table 11).

Table 11. *A. albopictus* Socio-economic Impact and Satisfaction with Local Mosquito Control

Variables	14--YOR	16--VAB	8--HAM	5—CHE	3--CHE	1--CHE	9--NOR	11--NOR	7--NOR	11--WIL	1--WIL	1--WIL	5--WIL	2--WIL	2--WIL
$/Year	8.64	25.63	13.21	2.5	15	30	9.56	4.2	12.83	6.5	*	20	5.4	0	10
Pay More% Yes	44.4	57.1	60	0	33.3	100	33.3	50	50	50	100	*	40	100	*
PM No	55.5	42.8	40	100	66.6	*	66.6	50	50	50	*	100	60	*	100
Do More %-Yes	44.4	92.3	75	20	33.3	100	75	66.6	25	42.9	100	*	20	50	*
DM No	55.5	7.7	25	80	66.6	*	25	33.3	75	57.1	*	*	80	50	100
Bites/Day	5.43	16.44	4.9	2.5	12.5	*	4.4	6.75	2	3.5	1.5	*	6.25	0	*

Before we examine the basic economic impact of the ATM based on Table 10, please keep in mind the amount of money spent by VABMC annually (pp. 24). VABMC is only one mosquito control office out of the six that I conferred with, and if we estimate that the other offices spend approximately the same, then the yearly expenditure of just six mosquito control offices annually is $100,000. Residents are spending approximately $12/year each on mosquito control products, which would amount to $864/year for all 72 residents that responded to this question. The most telling variable is the response of the public to the question, "Would you be willing to pay more for more mosquito control?" Forty-eight percent of the surveyed residents stated that they would be willing to pay more taxes for increased mosquito control. Politicians find it difficult to convince persons that tax increases for education, law enforcement, and firefighters would be beneficial to the community. Yet 48% of the residents surveyed said that they are willing to pay more for a better quality of life through increased taxes for mosquito control.

The results from my August 1998 Survey (Tables 7, 8, 9, and 10) support the CDC, VMCA, and VABMC data. Additionally, evidence from the literature review, and data from other studies (Robinson, 1983; Gerhardt, 1973; Headlee, 1932) also support the data collected in my pilot study. This Pilot Study has provided data on the arrival of the ATM in the surveyed areas and the tentative identification of the ATM in the yards of those surveyed. Also, this data suggests that the mosquito, as a nuisance and public health concern, has undergone amplification since the early 1990's (ATM arrival), impacting residents socially and economically. When all of the data and facts are compared and contrasted, it is clear that the main mosquito nuisance in the surveyed neighborhoods is indeed the ATM. Lastly, as discussed at the beginning of this chapter, this Pilot Study has also allowed me to make a variety of improvements that were used in my main methodology.

RESEARCH METHODOLOGY for the MAIN STUDY

The pilot study provided a solid foundation from which the research methodology could be built. I was able to discover strengths, weaknesses, and new paths of investigation. My objectives in the larger study were to gather enough data (survey/interview, physical & cultural, and census demographics through empirical observation, photographs and imagery) to correlate the variables, compare and contrast the variables, and determine if there is a specific environment that is conducive to ATM activity/populations.

Research Methods

The research methodologies employed in this study are correlational-predictive and comparative. I will correlate approximately 75 variables and interpret the results. Also, ATM activity can differ from one residence to the next. As such, it will be important to compare these different micro environments and determine and explain their differences and similarities.

Specific Procedures, Research Population Sample & Data Collection

Unlike the pilot study in August 1998, the principal study was conducted in April 1999 solely in the City of Virginia Beach. Besides being personally familiar with Virginia Beach, it is where the ATM was first detected in the state. Time constraint (5 week days) made it necessary to work with one mosquito district instead of six. Advantages of the approach I adopted include:

- The study would be a case study
- Greater control of the different variables and environments
- Compact area (one city)
- Easier access to all neighborhoods to be surveyed
- Allowed the study to be more in-depth

Thus, working in one district offered the best environment for successful completion of my research.

Permission from the City of Virginia Beach

Having decided that the City of Virginia Beach would be the district to conduct my research, the next step was to contact Virginia Beach Mosquito Control, a division within Public Works, to gain their permission and help in the conduct of my study. The pilot study that I had completed in August 1998 gave me the opportunity to establish contacts with Virginia Beach Mosquito Control and its biologist.

Survey Development

Having laid the groundwork, the next step was to develop a survey that would be appropriate for personal interviews. This survey was similar to the one used in the pilot study, with some differences in style, format, and length (Appendix C). I added two major aspects to the new survey. First, the exact address of each surveyed resident was attained for purposes of geo-coding and spatial analysis. Three to five photographs were taken at each surveyed residence. The photographs allowed the collection, recording, and analysis of the physical and cultural elements of the residence. Partially complementing the photographs was a Habitat Evaluation Form that served as a checklist/recorder of physical/cultural elements at a residence (Hope, 1997). Lastly, remotely sensed imagery was collected for each census block group surveyed (15) at one meter per pixel resolution. Also included were 5 overview images of the area at sixteen meters per pixel resolution.

Choosing Census Block Groups & Research Population to Sample

The City of Virginia Beach is made up of 145 block groups which were divided into 3 median income groups (<= $23,000, $23,001 to $49,999, and >= $50,000) (Figure 11). The division of the block groups by median income was chosen because it is my hypothesis that the lower the income, the greater the ATM activity and population, and therefore, greater problems with mosquitoes. One reason for this hypothesis is that I found, in my pilot study, that yards tended to have more containers and were less well kept at the lower income levels. These conditions tend to be prevalent in areas where ATM activity and populations are higher than normal. Because I am looking for variables to correlate and compare that might identify a specific environment conducive to ATM activity, I consciously chose a fairly equal distribution

of block groups that would range from low to medium to high problems with the ATM in the belief that different income divisions would provide the best chance for wide ranging environments. It is acknowledged that there are numerous variables that contribute to high or low levels of ATM activity and that income may not be the best to divide block groups.

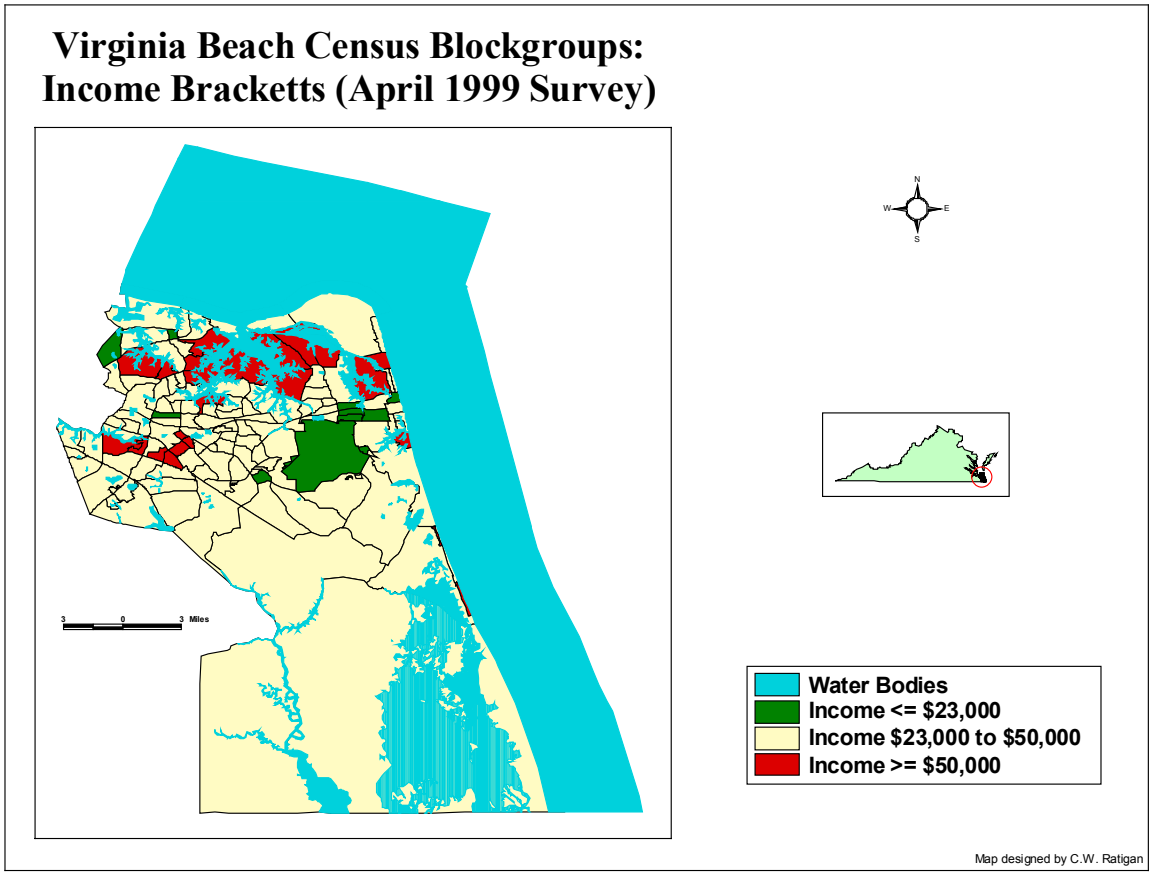


Figure 11. Income Divisions, April 1999

It was necessary to sample at least 10% of the total number of block groups (145) for a viable statistical analysis. A total of 15 block groups were surveyed. The block groups chosen for this research were first divided into their respective income groups, from which I randomly chose which ones to survey. For example, high-income block groups in Virginia Beach totaled 26, and I used a random number generator to generate a number from 1-26 to decide which block groups I would survey. From the random numbers produced, I recorded the first seven block groups, of which I would use the first 5 viable block groups. The reason I needed more than 5

block group options was that some of the block groups either fully or partially fell on a military compound to which I did not have access. Also, one block group was nothing but apartments.

It was important that at least 45 residents be interviewed to attain a minimum sample number for statistical analysis. Three to four residents per block group (15 block groups total) were interviewed and a total of 58 surveys were collected. Also, residents must have lived in their current residence for at least one summer, enabling them to experience at least one mosquito season.

Help from the City of Virginia Beach and the Conduct of Survey Interviews

A VABMC mosquito control representative accompanied me while I conducted my research. The method that I used to chose which houses would be surveyed within a block group was accomplished the following way: drive into a block group, park the vehicle and walk to the nearest residence, begin the surveying, and walk from house to house until 3-4 residents were surveyed. After the first residence, we continued from house to house until we interviewed four residents from that block group. Once the quota for a particular block group was met, we moved on to the next block group and did the same thing. An average of three block groups were surveyed each day. Residents were told the purpose of the survey (graduate research) and that the research was being done in cooperation with the City of Virginia Beach Mosquito Control and was solely a data gathering mission. The results from the research would be used by VABMC to aid them in their mosquito control efforts. Next, residents were asked if they would fill out the survey and permission was requested to take pictures of their yard. We explained to the residents that photographs were necessary to record the landscape of the area in order to determine why some neighborhoods had mosquito problems and others didn't. Out of the 58 residents interviewed, only two did not want pictures taken of their yards. For those two residents, an empirical survey of their yards from a distance was done to record pertinent physical and cultural aspects of the residents' yards. The sample population varied greatly in its demographics, survey responses, and in their physical and cultural landscapes. The block groups that were surveyed are represented in Figure 12.

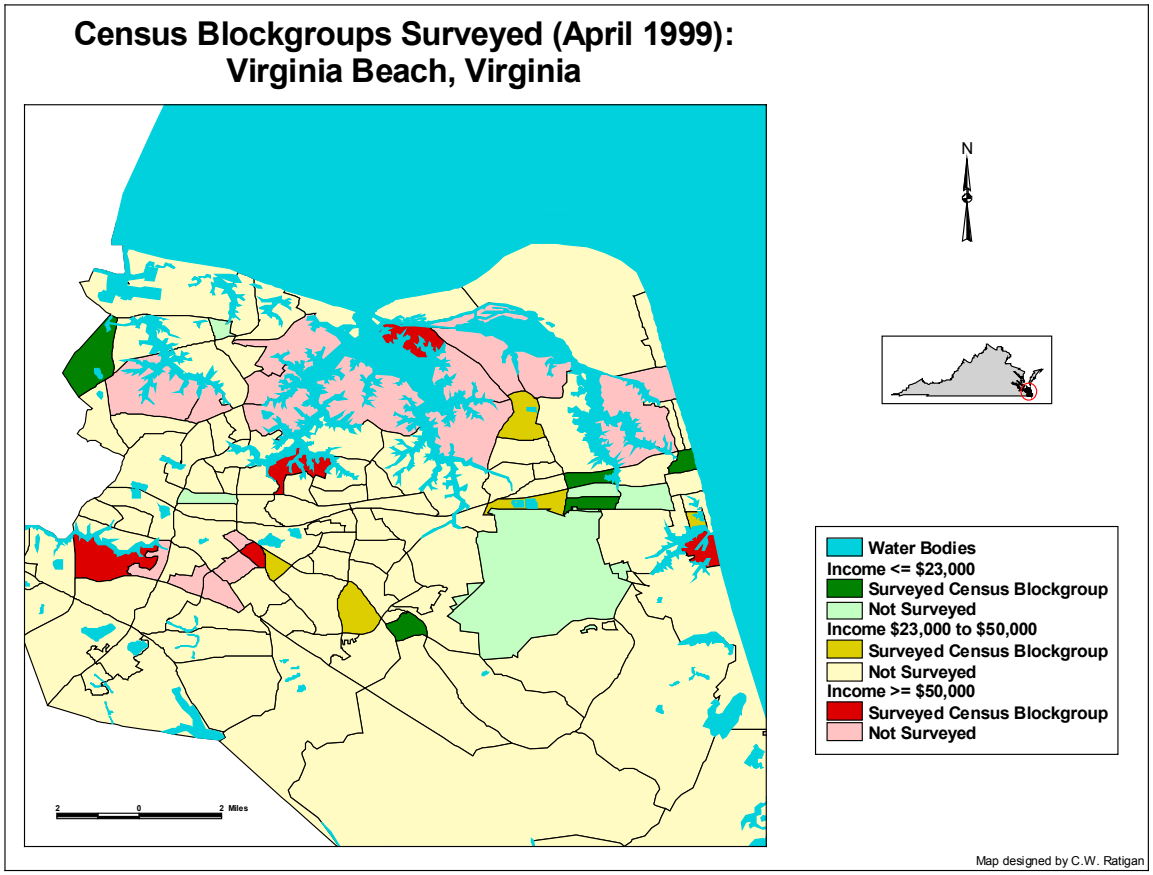


Figure 12. Surveyed Census Block Groups, April 1999.

Treatment of the Data

This section contains a descriptive summation of the surveyed census block groups and individual residents based on data from the survey, the habitat evaluation form and pictures, and demographic data. This data will be presented in tables, and explanations will be provided where necessary. Also, Pearson correlation was used to evaluate the tabular data to detect any significant correlations between the variables. The descriptive evaluation of the data has been divided into sub-sections (ATM presence, ATM socio-economic impact, physical-cultural elements, and demographic variables). Also, the descriptive section of this chapter will summarize the survey area at the following geospatial levels: all 15 census block groups together (58 surveyed residents), and each separate census block group (4 residents per block group).

Analysis of the significant correlations is divided into three sections. The first section compares the mosquito problem to the environment (survey variables versus the physical-cultural and demographic environment). The next set of correlations to be evaluated compares the survey variables against themselves to detect the socio-economic impact of the ATM. Finally, the physical-cultural variables will be compared to demographic variables to detect any relationships between them. Once the descriptive and correlation sections of this chapter have been examined, the spatial analysis of all 58 surveyed residents as their own distinct units will be presented. This analysis will be done in Arcview, a GIS software package. From the spatial analysis of the data, relationships and trends between the various data can be detected and evaluated with the objective of identifying an environment and its elements that are conducive to ATM activity and populations.

Lastly, before we discuss the descriptive and correlated data, it is important to reach an understanding of what comprises a "friendly ATM environment". The ATM prefers lots of containers and shade, deciduous trees to coniferous trees, and bushes and tall grasses to rest in. Yards and house exteriors that are not tidy or kept-up provide many more places for the ATM to breed in and rest. The ATM will bite at any time, but is a notorious daytime biter. Lastly, the ATM arrived in Virginia Beach in 1991. By keeping these basics in mind, the descriptive and correlated data will have more meaning. The list of survey variables below is a list of variables/questions that will be found in the preceding tables of data. Both the abbreviated variable name is given accompanied by its meaning.

SURVEY VARIABLES, April 1999

SEEADAY or SEE/DAY How many mosquitoes do you see a day?

BITEADAY or BITTEN/DAY Please estimate how many times you are bitten by mosquitoes per day?

Please compare **the early 90's (90-92) to the late 90's (96-98)** when you answer the following:

GO908 --Time I grill outside… (Much Less) 1 2 3 4 5 6 7 8 9 10 (Much More)

TO908 --Time I spend outside (working, playing, resting, enjoying)… 1 2 3 4 5 6 7 8 9 10

MAD/MSQT908 --Number of mosquitoes I notice per day…1 2 3 4 5 6 7 8 9 10

TALK908 --Time I talk with my friends and/or neighbors about mosquitoes…1 2 3 4 5 6 7 8 9 10

HEAR908 --Time I hear about mosquitoes from different media…1 2 3 4 5 6 7 8 9 10

Please compare **the mid 90's (93-95) to the late 90's (96-98)** when you answer the following:

GO958 --Time I grill outside… (Much Less) 1 2 3 4 5 6 7 8 9 10 (Much More)

TO958 --Time I spend outside (working, playing, resting, enjoying)… 1 2 3 4 5 6 7 8 9 10

MAD/MSQT958 --Number of mosquitoes I notice per day…1 2 3 4 5 6 7 8 9 10

TALK958 --Time I talk with my friends and/or neighbors about mosquitoes…1 2 3 4 5 6 7 8 9 10

HEAR958 --Time I hear about mosquitoes from different media… 1 2 3 4 5 6 7 8 9 10

MSQTPROB --Do you have a mosquito problem? **YES or NO**

RATE --If you answered YES, please rate your problem

(Very Small) 1 2 3 4 5 6 7 8 9 10 (Very Large)

HAVECONTROL --The percentage of residents that have mosquito control products

CONTROL --What mosquito control devices do you use?

SPEND --Approximately how much do you spend on mosquito control devices per year?

YEARBUY --Approximately what year did you first begin to seriously consider buying mosquito control devices?

ACTAFT --How does mosquito activity affect your daily activity or plans?

DETER --Do you ever wish to do an outdoors activity, like cookout or sit outside, but find yourself deterred by the possibility of mosquitoes biting you? **YES or NO Please Comment.**

FORCEDIN --Do you ever find yourself doing something outside only to move inside due to biting mosquitoes? **YES or NO Please Comment.**

DOMORE --Does the Virginia Beach mosquito control program need to do more to combat or abate mosquitoes? **YES or NO Why?**

PAYMORE --Would you be willing to pay more for more mosquito control? **YES or NO Why?**

YEAR BEGAN TO BUY --The year that residents began to buy mosquito control products.

PINKY/MIDDLE/THUMB --Asks the resident to compare the size of the mosquitoes that they encounter with the size of the pertinent fingernails.

BROWN/BLACK & STRIPED --The color of the mosquitoes that residents encounter in their yards.

Year Into House --Represents how long a resident has been living in their current home at the time of the survey.

No, When Start --The year that residents indicated that they began to have a mosquito problem.

Yes, Gotten Worse --The percent of residents that stated that their mosquito problem has gotten worse.

Worse What Year --The year that residents said their mosquito problem got worse.

BUY IN 90s --Residents who began to buy mosquito control products in the 1990s.

PHYSICAL-CULTURAL

DECID	Number of deciduous trees in the yard.
MATUR	Maturity level of the deciduous trees (young 1-5 old)
CONIF	Number of coniferous trees in the yard
MATUR2	Maturity level of the coniferous trees
SUNSHADE	Amount of sun relative to shade in the yard (sun 1-10 shade)
CONTAIN	Number of containers that can hold water in the yard
BUSHES	Number of bushes in the yard

GRASCOND	Condition of the grass (overgrown 1-5 neat)
SEABREEZ or CBREZ	Presence of a sea breeze (yes 1-2 no)
TIDY	Overall tidiness of the yard/house (poor 1-5 neat)
GRASS/GARDEN/TRIM BUSHES	Places where residents were when they encountered mosquitoes

CENSUS DEMOGRAPHICS (block group)

WATER or H2O	Kilometers of water within the block group
OWNOCC	Percent/Number of owner occupied households
RENTOCC	Percent/Number of renter occupied households
VALMED or HOUSEVAL	Median house value
MEDRENT	Median rent value
NODIP or NODP	Percent/Number of persons with no high school diploma
HS	Percent/Number of persons with just a high school diploma
COLGRAD	Percent/Number of persons who graduated undergraduate college
GRAD	Percent/Number with graduate experience
MEDINCOM or INCOME	Median income
INPOV	Percent/Number of persons in poverty
UNEMPLOY	Percent/Number of persons unemployed
MARKID	Percent of residents that are married with children

April 1999 Descriptive Data Write-Up: ATM Presence, Physical-Cultural & Demographic Elements

The presence of the ATM in southeast Virginia was discussed in the pilot study. Virginia Beach was the first city (including counties) in southeast Virginia to identify the ATM as a new arrival as reported by VABMC and CDC. As such, the first data block that will be discussed from the April 1999 survey conducted in the City of Virginia Beach addresses the presence of the ATM at the residences surveyed. Important variables that relate to the ATM's presence are displayed in Table 12.

Table 12. *A. albopictus* Presence

Year Into House	See/Day	Brown	Black & B/W Striped	Pinky	Middle & Thumb	Garden	Grass	Trim Bushes
1981	16.1	14	33	26	8	11	17	13

MAD908	MAD958	No, When Start	Yes, Gotten Worse	Worse What Year	Year Began to Buy
6.25	6.4	1998	Y=60.7% N=39.3%	1996	1990's = 48% 1950-80's = 52%

Residents have been at their current residences, on average, since 1981-82, a decade before the arrival of the ATM. Over twice as many residents described the mosquitoes in their yards as black and/or black and white striped and the size of one's pinky fingernail. The ATM is very distinct for the area of Virginia Beach and that is why a simple description of the color and size of a mosquito that residents indicated is sufficient to identify the ATM as the probable mosquito when weighed with other data. The brown mosquito described is Culex and is about the same size as the ATM. Residents were asked where they encountered mosquitoes and the overwhelming response was while cutting the grass, in the garden, and trimming the bushes. These activities are accomplished during the day, and the ATM is legendary as a daytime biter. Also, long grass, bushes, and gardens are perfect places to find hungry female ATMs because that is where they rest. When the late-1990s were compared to the early-1990s, and then the mid-1990s to the early-1990s, it was found that residents were noticing more mosquitoes, with 5.5 sightings per day.

The next three questions implicate the ATM as the mosquito menace, with its arrival and impact quite obvious. Residents were asked if they had a mosquito problem, and if so, has it always been this way? If the resident did not always have a mosquito problem, they were asked what year it began. Residents indicated that mosquitoes became a nuisance in 1998. Additionally, residents that indicated that they had had a mosquito problem were asked if it had become worse, and if so, when. Approximately 61% of residents said that their mosquito problem had gotten worse, and on average, they said it got worse in 1996. Lastly, residents were asked when they began to buy mosquito control. Surprisingly, 48% of the residents started to buy mosquito control in the 1990's while the other 52% bought mosquito control products between the 1950's and 1980's. Considering the fact that Virginia Beach has historically been infested with lots of mosquitoes, it is interesting to note that nearly half of those surveyed started

to buy mosquito control in the 1990's. This is certainly an indicator of ATM presence and its impact as a nuisance. When the responses to these last few questions are weighed against the fact that the ATM arrived in Virginia Beach in 1991, it is hard to discount the presence and impact that the ATM has had on those residents who were surveyed. Table 13 addresses the socio-economic impact of the ATM specifically.

Table 13. Socio-economic Impact of *Aedes albopictus*

Bitten/Day	MSQT PROB	Rate	Have Control	Spend	ACTAFT	DETER	Forced In	DOMORE	PAY MORE
2.64	Y=62% N=38%	6.8	Y=67.3% N=32.7%	$10.81	Y=33.3% N=66.6%	Y=47.4% N=52.6	Y=57.1% N=42.9%	Y=58.2% N=41.8%	Y=42.9% N=57.1%

Sixty-two percent of surveyed residents state that they have a mosquito problem. Residents with a mosquito problem rate its seriousness at 6.8/10. Residents are spending an average of $11 a year on mosquito control products and 33.3% state that mosquitoes affect their daily activity. When residents were asked if they were deterred from going outside or forced in due to biting mosquitoes, they responded yes 47.4% and 57.1%, respectively. Of particular note is the fact that almost 43% of the residents surveyed would be willing to pay more taxes for more mosquito control, which is a strong indication that a higher quality of life is desired.

Comments that residents gave with respect to mosquito activity impacting their daily lives are shown below.

- "Plans cut short"
- "I stay inside"
- "Doesn't make me want to do outdoor activities like walking/running"
- "Can't sit outside"
- "Use repellent come in when biting"
- "Sometimes we want to eat outside but go inside if the mosquitoes are bad"
- "We don't cook out much"
- "I get bitten daily & if I see mosquitoes I come inside"

The next section addresses the physical, cultural, and demographic variables for each block group surveyed by briefly comparing the 15 different units.

The 15 block groups were aggregated into three income groups identified before I surveyed the residents. One of my premises is that income level plays a role/is an indicator in determining if the ATM is a problem at a particular residence. The variables that will be presented are the variables that represent most of the significant variables in determining the activity levels of the ATM in a resident's yard. The initial selection of these significant variables is based on Pearson correlations. Below is the summation of the census block group (CBG) data.

Table 14. Block Group Income Divisions, Survey April 1999

CBG Income	See/Day #	Bitten/Day #	MAD908 (1less-10 more)	MAD958 (1less-10 more)	% With A Mosquito Problem	RATE 1-10 low-high	Control %	SPEND $	% BUY IN 90s
Low	17.8	2.7	7.7	7.7	68.2	7.6	75	14.9	65
Mid	17.7	2.7	5.8	8.3	73.2	6.6	66.6	12.9	88.7
High	11.1	2.3	5.2	2.7	45	5.96	53.2	6.4	20

Table 14. (continued)

CBG Income	% ACTAFT	% DETER	% FORCEDIN	% DOMORE	% PAYMORE
Low	28.2	43.2	63.2	53.2	48.2
Mid	56.4	53.2	71.4	73.2	58.2
High	18.2	45	38.2	46.6	26.6

Worthy of note from Table 14 is that there is a distinct difference between low and high income census block groups with respect to mosquito impact while the data for the middle income census block group give mixed responses. This shows a definite correlation between low and high income, but not causation. Regardless of income, there are a plethora of other variables that determine the amount of ATM activity.

Table 15. Block Group Income Divisions, Physical-Cultural, April 1999

CBG Income	Sun-Shade (1-10)	CONTAIN #	SEA BREEZ	TIDY (1-5 neat)	DECID #	GRASCOND (1-5 neat)
Low	5.3	7.3	No	2.43	3.22	3.02
Mid	4.6	8.1	No	2.8	3.2	3.38
High	5.7	4.8	40% Yes	3.85	4.35	4.03

The categories of Containers, Sea Breeze, Tidiness, and Grass Condition show a general trend from low to high census block groups, and this trend basically supports the correlation between ATM activity and income level. More containers generally mean more ATMs. The ATM is a poor flier and if there is a sea breeze, one is less likely to see them. Lastly, the less well-kept a yard is (tidiness and grass condition), the more likely one will have ATMs.

The last descriptive table summarizes the demographics for the census block groups. The findings in Table 16, based on census block groups divided into income groups, are not surprising and are what one would expect to see in the United States. For example, in general, richer areas have more white people with higher levels of education. More expensive houses can be found in richer block groups while poverty and unemployment tend to be lower when compared to poorer block groups.

Table 16. Socio-demographic Block Group Income Divisions, April 1999

CBG Income	% Water	% OWNOCC	HOUSEVAL $	% NODIP	% GRAD	Income $	% INPOV	% UN EMPLOY
Low	0.221	30.8	73680	14.4	2.2	19759	20	10.2
Mid	0.08	49.2	94280	8.8	4.2	31946	5.2	3
High	0.92	85.8	199340	5.4	10	62620	2.6	3.6

Pearson Correlations

This section will explain the different correlations between numerous variables that will help to increase understanding of the block group environments (opinion of residents, physical-cultural, and demographics). The correlated variables that have been investigated should help identify an environment conducive to ATM activity. Correlations investigated are significant less than .05. Remember, as these correlations are explained, their opposite is true (e.g. if the percentage of whites increases, the percentage of blacks decrease, and as the percentage of whites decreases, the percentage of blacks increases). It is recognized that although the variables may be correlated, this does not necessarily mean they are causally related.

Pearson Correlations: Physical-Cultural v. Demographics

The purpose of comparing the significant correlations in the physical and cultural categories to the demographic data at each residence is to help determine if there are any

relationships between the different variables in each category (i.e. Does cultural variable "A" occur each time demographic variable "D" is present?). Having examined this relationship, it is hoped that insight will be gained once the spatial analysis portion of this research is done, and these relationships should be remembered as other correlation blocks are compared. Table 17 displays the relationships between variables with (+,-) symbols representing increases/decreases in the respective variable. Please examine the first row in Table 17. As the number of deciduous (decid) trees at a residence increases (+), the number of owner occupied (ownocc) homes increases and the number of renter occupied (rentocc) homes decreases.

Table 17. Significant Physical-Cultural v. Demographic Variables

Physical-Cultural Variables	Demographic Variables						
+decid	+ownocc	-rentocc					
+dmatur	+ownocc	-rentocc					
+conif	+ownocc/-rentocc	+h2o	+houseval/ rentmed	+colgrad/ grad			
+cmatur2	-yrblt						
+shade	-yrblt	+age>84					
+contain	-rentmed	+nodp/ hs	-colgrad	-income	+inpov	-yrblt	
+bush	+colgrad/ grad	+ownocc/ -rentocc	+houseval/ rentmed	-nodp/ hs	-yrblt	+h2o	+income/-inpov
+grascond	+colgrad/ grad	+ownocc/ -rentocc	+houseval/ rentmed	-nodp	-un employ	+h2o	+income/-inpov
+cbreeze	+colgrad/ grad	+ownocc/ -rentocc	+houseval/ rentmed	-nodp	-un employ	+h2o	+income/-inpov
+ydsize	+markid	-yrblt	+ownocc	-rentocc	+hs	+incom	
+tidy	+colgrd/ grad	+ownocc/ -rentocc	+houseval/ rentmed	-nodp/ hs	+incom	+h2o	-un employ

Pearson Correlations: Survey Social-economic Impacts v. Survey Social-economic Impacts

The reason that survey variables are compared against themselves is to determine any correlations and relationships that might be pertinent to understanding residents' opinions and behavior as they relate to particular mosquito environments. Also, this set of relational variables aids understanding of how the presence of mosquitoes (ATM) can impact residents socially and economically. These variables are questions from the survey (Appendix D).

Table 18a. Survey Socio-economic v. Socio-economic

-go908	+worse what yr						
+mad908	+spend/rate	+talk/ hear908	+msqt prob	+actaft	+deter	+forced in	+domore
+talk908	+msqt prob	+domore					
+hear908	+talk908	+spend					
+go958	+deter	+domore					
+to958	+msqtprob	+forcedin					
+mad958	+see/day	+msqtprob	+forcedin	+paymore			
+talk958	+hear958	+actaft	+rate				
+hear958	+rate	+actaft					

Table 18b. Survey Socio-economic v. Socio-economic

+see/day	+bite/ day	+mad 908/958	+msqt prob	+actaft	+deter	+forced in	+pay more	
+bite/day	+control	+msqt prob	+actaft	+deter	+forced in	+pay more	+do more	+spend
+msqtprob	+control	+actaft	+deter	+forced in	+pay more	+do more		
+rate	+do more							
+control	+spend	+actaft	+forced in	+do more				
+spend	+actaft	+deter	+forced in	+pay more	+do more			
+msqtaftu	+deter	+forced in	+pay more	+do more				

Pearson Correlations: Survey ATM Problem v. Environment

This block of correlations is the most important part of my research thesis. By examining the relationships between environmental variables (physical-cultural and demographic) and survey variables (that address mosquito presence-problems and impacts), the formation of an environment conducive to ATM activity should become evident. The results of these correlations will help in the spatial analysis of the data.

Table 19a. Survey Mosquito Impact v. Physical-Cultural, Significance <.05

ATM Social Impact (survey variables)	Physical and Cultural Variables			
+domore	+decid	+shade	-grascond	-cbreeze
+mad908	+cmatur2	-cbreeze	-tidy	
+hear958	+contain			
+talk958	+contain			
+rate	+contain			
+msqtprob	-grascond	-cbreeze		
+deter	-grascond	-cbreeze		
+actaft	-cbreeze			
+forcedin	-cbreeze			

Table 19b. Survey Mosquito Impact v. Demographics, Significance <.05

ATM Social Impact (survey variables)	Demographic Variables						
+seeaday	-house val	-medrent	+nodip	+hs	-colgrad	-grad	
+mad908	-h2o		-house val	+nodp/ hs	-colgrad/ grad	+inpov/ unemply	
+mad958	-med rent	-income					
+msqt prob	-h2o	-houseval	-grad	-in come			
+rate		-ownocc/ +rentocc	-med rent	+nodp/ hs	-grad	-income	+inpov/ unemply
+msqtaft	-h2o	-houseval	-grad				
+deter	-h2o						
+forcedin	-house val	-h2o	-grad	-in come			
+domore	-h2o						

FINDINGS: ELEMENTS OF AN *A. ALBOPICTUS* ENVIRONMENT

The main focus of this research was to identify an environment conducive (or not) to ATM activity. In order to accomplish this, residents had to be surveyed and the physical-cultural and demographic environment had to be examined. Once all of the data was gathered and placed into a database, the variables were then correlated (Pearson). Lastly, environmental variables (with a Pearson significance of >.05 and <.1, and <=.05,) as they related to survey questions (addressing mosquito problems, numbers, and/or impact) were recognized as elements present at sites where ATM activity was present. The survey questions/variables that were used to delineate areas where ATM activity was disruptive to residents are as follows: SEEADAY, BITEADAY, MAD908, MAD958, MSQT PROB, RATE, MSQTAFT, DETER, FORCEDIN, DOMORE, and PAYMORE. Table 20 represents the environmental elements and the number of times they prove to be significant in each of the survey variables addressing mosquito impacts.

Table 20. Environmental Variable Appearance / Total Survey Variables (<.05)

houseval/medrent	7/9
cbrez/h2o	6/9
education (grad, colgrad, nodp/ hs)	6/9
medincome	4/9
grascond & contain	3/9
inpov/unemploy	2/9
ownocc/rentocc/conifmat/ conif/tidy/decid/shade	1/9

Certainly of less significance, but having low correlation values nonetheless, environmental variables between .05 and .1 significance were examined because they proved to help define an ATM environment. Table 21 represents environmental variables that could be added to the Significant <.05 (Table 20). Lastly, two new mosquito problem variables from the survey become pertinent (BiteADay and PayMore).

Table 21. Survey Social Impact and Physical, Cultural, and Demographic Variables, Significance .05 to .1

ATM Social Impact (survey variables)	Physical, Cultural, and Demographic Variables				
+seeaday	-cbrez	-h2o			
+mad908	-income				
+mad958	-cbrez				
+msqtprob	+cmatur2	-tidy		-colgrad	+unemploy
+rate	-houseval	-colgrad	-yrhouseblt		
+actaft	-grascond	-income			
+deter	+decid	+cmatur2	-tidy	-houseval	-grad
+forcedin	+shade	-tidy			
+domore	+shade	-tidy	-houseval	-grad	
+biteaday	-cbrez	-h2o			
+paymore	+decid	-grascond	-cbrez/h2o		

Table 22 combines the two additional survey variables with Table 20 with results being <.1.

Table 22. Environmental Variable Appearance / Total Survey Variables (<.1)

cbrez/h2o	10/11
houseval/medrent	9/11
education (grad, colgrad, nodp/hs)	8/11
medincome	6/11
grascond, contain, tidy	5/11
inpov/unemploy, conifmat, decid	3/11
shade	2/11
owner/rentocc, conif, yrhouseblt	1/11

Tables 19 and 21 show the relationships (positive and negative) between the survey variables addressing mosquito impacts and environmental variables at significant levels of <.05 and <.1. Additionally, Tables 20 and 22 represent the number of times an environmental variable is present under a survey variable category. Based on these relationships, elements of a friendly or non-friendly ATM environment can be recognized.

CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

Conclusions and Impacts

It is evident from the research in August 1998 & April 1999 that the ATM does have a significant socio-economic impact on residents. My own experience living with *Aedes albopictus* in St. Louis, MO certainly supports the survey data collected from residents in the Virginia Beach, VA region. I have had to either limit my time outside, or put mosquito repellent on myself when outdoors. Thus, every time I go outside to work or play, I must always consider the ATM's presence. The impact of the ATM was determined from residents' written comments, money spent on mosquito control, willingness to pay more taxes, and alteration of daily activity. The motivating factors that drove my research included the ATM as a severe nuisance and potential threat to public health. I chose to investigate the environment of the ATM in an attempt to determine whether or not certain elements could be identified and linked to either friendly or non-friendly ATM habitats. If successful, a better understanding of the ATM and its needs would be achieved. Mosquito control abatement efforts would be aided, thus decreasing the ATM's role as a nuisance and potential public health threat. The success of public health and mosquito control efforts versus the ATM is heavily dependent on their ability to educate the general public. The CDC has stated that the best approach to the ATM problematic is site-source reduction (i.e. individual households).

The relationships and correlated variables between the mosquito problem/impact versus physical-cultural and demographics are complex. However, there appear to be identifiable elements that are prevalent at sites with high or low ATM activity. There is definitely a general relationship between the socio-economic status of a resident and ATM activity in their yard, but the physical-cultural environment at a resident's house also impacts the ATM population as well. Please note that it is recognized that residences (and their environment [physical, cultural and socio-economic]) around the surveyed households can impact the level of ATM activity that they experience. Thus, I will restate the socio-economic and physical-cultural elements that make an environment friendly or not friendly to the ATM.

The socio-economic profile of generally friendly ATM environments include: lower house and median rent value, lower levels of education, and a lower median income level.

Correspondingly, the opposite values of the aforementioned variables is true, i.e. higher levels of education and income indicate an environment less friendly to ATM populations. The variables just mentioned are the most significant demographic variables that can indicate whether or not the ATM will be present in small or large numbers at a site. Other demographic variables that can help determine the size of an ATM population are, in order of significance, in-poverty/ unemployed, owner/renter occupied, and the year a house was built. These secondary variables increase ATM numbers if the following trends exist: high percent of persons in poverty and unemployed, higher percent of renter occupied homes, and older houses.

Just as important as the socio-economic implications are the physical-cultural characteristics at a resident's home. The most important physical-cultural variables that can help determine ATM activity levels are: sea breeze and water (oceanfront and proximity to the mouth of an inlet), condition of the grass, number of containers, and overall tidiness of the resident's property. Having a sea breeze and/or being very near the oceanfront (within 1-3 streets) will reduce the number of problems a resident will have with the ATM. The more often the grass in a yard is cut and the neater the overall tidiness of a resident's property is, the less likely that resident will have a mosquito problem. Secondary variables, in order of importance, are coniferous maturity and number of deciduous and coniferous trees (shade, breeding and rest areas), sun-shade relationship, and number of containers. The secondary variables impact ATM populations in the following ways: by increasing the maturity of coniferous trees (shade) and number of deciduous trees (shade and rest areas), populations of ATMs will be higher. The more shade there is in a yard, the more likely that the ATM will be present. Lastly, yards with more containers and fewer coniferous trees (the ATM does not like coniferous trees) are more likely to have higher levels of ATM activity.

Since the ATM can only live and breed in an area that can support its ecological needs, the physical-cultural environment is the most important factor in determining ATM activity, although, the adapta-flexibility of the ATM makes this premise somewhat problematic. Thus, the conclusion is that the physical-cultural dynamic is the most important, but the results suggest that depending on the socio-economic profile of a resident, s/he will be likely to follow a general pattern in how they interact with the environment and landscape and alter it. This observation raises the following questions: Does it necessarily follow that the less educated one is, and the lower the income level of a resident, that s/he will for whatever reason have a less tidy yard

(grass, bushes, containers, condition of house, etc.), which is conducive to ATM activity? Does a resident with less education and less income have less of a concern with the upkeep of their yards due to their socio-economic station in life? Or are they less concerned with appearances and superficiality of what a yard's condition represents? Does their lack of education prevent them from understanding the implications of a tidy yard? Have mosquito education campaigns been focused in low income/education areas or areas with high deciduous tree cover?

Based on the findings, it can be concluded that there are indeed environmental elements that can affect ATM populations and activity in an area. That the correct or exact number of variables conducive to ATM activity can be identified is unlikely due to the fluid and dynamic relationships evident in the nexus between humans, the ATM, and their interactions. One person's yard may be very unfriendly to ATMs, but they could have a problem because of a neighbor's yard that is a disaster. Two yards similar in physical-cultural make-up can have residents experiencing two different degrees of ATM activity and this could be due to the fact that one resident's chemicals/oils on skin and lactic acid and CO_2 in breath could be much more attractive to an ATM.

My research is important because it begins to develop a foundation from which probability studies can proceed with this line of inquiry (identifying important elements in an ATM environment and then modeling it in a probability study). I have identified numerous variables (physical, cultural and demographic) that provide a baseline from which probability studies can be conducted at the census block group scale by using remote sensing and GIS systems, software, and analysis. The process would have to be validated through a survey of residents in the modeled areas of the probability study. This approach to the ATM has not been adequately addressed in the literature.

Although the relationship between human, ATM, and environment may be too complicated to identify perfectly, this research has broken the ground for further studies that will provide a better and more focused picture of the elements that impact ATM activity in a certain area. It is my charge that a researcher or mosquito control official with the environmental variables that I have identified in-hand, can perform a walk-through of a neighborhood and, with a fair degree of accuracy, predict what houses will have an ATM problem. Perhaps gaining a better understanding of the ATM's environment and the interaction that humans have with it,

mosquito control and public health officials will be more effective in combating the ATM menace and educating the public.

Lastly, it is important not to lose sight of the larger picture that my research represents which is studying the impact of specie introduction into a foreign environment. The environment that is receiving the exotic resident can be ill-suited at balancing the biological presence to that of domestic life which can cause political, social, economic, environmental and ecological problems. Also, the introduction of a new specie is often an event that can not be reversed. Just as the ATM is impacting the quality of life and the ecological balance in the U.S., so to are African Killer Bees (North America), South American Fire Ants (North America) and the European Hare (Australia). The introduction of such exotic species affects change at a number of levels and scales within their new home that can easily spill into surrounding states, countries, regions and continents. The negative and positive impacts of globalization and specie introduction will be forever felt and during this course, humans will have to adapt and learn to live in a complex and connected world.

Limitations and De-limitations and Recommendations

All studies are limited in many ways. My thesis, as original research, only begins to explore the avenue of investigation that I have pursued concerning the ATM. It combines the technologies of RS, GIS, and GPS with empirical observation and human inquiry (surveys). The limitations of my research are defined as factors that the researcher does not have control over. The willingness of residents to participate in the survey was a limiting factor. Whether a resident was home impacted the study. The ability of residents to remember over a period of 2-8 years back is problematic. The quality of answers and thought given by residents when answering the survey questions is of concern. The number of years spent by a resident in the particular house affects survey answers. Virginia Beach is a highly transient area due to military and Department of Defense presence. By surveying certain population pockets within Virginia Beach during the day (morning-late afternoon), only a certain demographic was interviewed. Time residents spend outside can vary greatly and impact their contact time with the ATM. The housing type in a block group can affect the survey answer; apartments don't have yards, so the time spent outside by residents is less compared to home owners/renters.

Census block group data was the largest scale and best fit available for me to match with the individual residents whom I surveyed. The U.S. Census does not publish certain demographic variable data that I required at the block level (individual streets) for reasons of confidentiality. One way to get a better fit between the individual resident and the demographics of the block group (approximately 400 households) is to sample at least 45 households per block group. Thus, the researcher would attain 10% of the households in the block group which is a minimum sample percent needed for a cross-section of the entire census block group. Some of the block groups that I randomly chose to conduct interviews in were on military bases, which meant that I did not have access and thus had to go to backup block groups.

De-limitations are elements that a researcher has control over. A great deal more could have been learned if I had been able to address a number of de-limitations more appropriately. The research was conducted in only one city. The sample size of those surveyed needed to be much larger (40-50 residents per block group instead of 4). Though the number of block groups surveyed (15) equaled 10% of all block groups. Surveyed residents within a block group need to be systematically dispersed across the block group versus some of the clustering that occurred in my study.

Choosing which block groups to survey is also problematic. Perhaps a five income tier should have been applied to the 145 block groups in Virginia Beach in preparation for a random sampling. Natural breaks may have been a better choice than equal intervals for dividing the block groups into income brackets. On the other hand, should another category be used, such as education levels, tree cover, or house value?

It would be beneficial to increase the detail of the physical-cultural elements of a resident's yard that are collected. The recording of the physical-cultural environment could be better accomplished by recording more categories, reporting more detail, and perhaps using a camcorder to record the environment instead of a camera. The households to be surveyed should have biological samples of mosquitoes collected (oviposition traps, landing rates, and vacpac collection of adults) to determine more accurately which mosquitoes are present, in what numbers, and in what percent relative to other species.

Future studies should also include temperature and precipitation (rainfall or watering of lawns) readings of each resident's yard because ATM activity/population is affected by these two variables. Additionally, the condition of surrounding yards should be considered, as it takes

only one yard that can support ATM activity/populations to impact an entire neighborhood. The flight range of the ATM (approximately 500 meters) should be considered in future studies.

Interviews of residents should probably be done twice, once during the mosquito season and once during February-early April. Surveying the same residents during two different times of the year would be done for two reasons: first, to decrease bias/subjectivity of resident responses and the researcher's study because perception of the residents probably changes from summer to winter. Second, since human memory is not wholly reliable, perhaps biting mosquitoes enhance residents' memories, and by surveying residents when mosquitoes are not biting, a moderated response from residents can be attained.

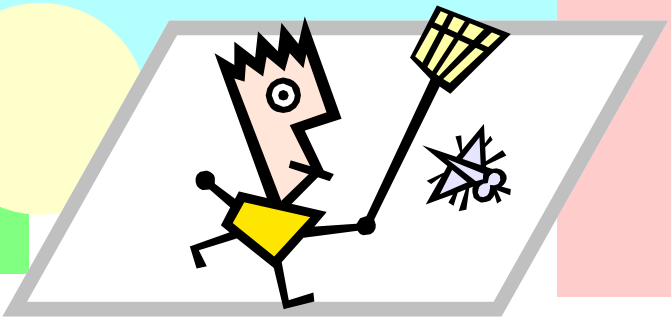
Lastly, based on variables used by this study, it is suggested that future research include the following elements: elevation, humidity, latitude, day length and snowfall. These environmental variables can impact ATM populations and would enhance a probability study (logical regression might be effective) using GIS software. Such an approach would advance understanding of the ATM by further defining friendly/unfriendly habitat environments for ATM populations and allow for probability/predictive models of ATM diffusion to be created. Lastly, predictive studies of ATM enclaves within the U.S. could be performed. An ATM enclave would be defined as the ATM establishing itself in an environment that shouldn't be able to support its ecological needs.

APPENDICES

Appendix A: August 1998 Survey for Southeast Virginia

Help Us Help You Take The Bite Out Of Mosquitoes

J



-WHO AM I? I am Christopher Ratigan, a Geography Graduate Student at Virginia Tech.

-ASSISTING ME are individuals from your local mosquito control office as well as the Departments of Entomology and Geography at Virginia Tech.

-WHY HELP? I can't collect the data I need without you. Thus, your input is highly valued and would not only assist my efforts, but the information I attain would help those of your community and other communities in our control efforts vs. mosquitoes.

-HOW YOU CAN HELP? You can help by filling out the attached survey and returning it to me by placing it in the attached self-addressed envelope. I am sorry that I could not stamp the envelope for you, but as I am a graduate student my nearly non-existent budget can not handle the financial burden of +300 surveys. In this matter, I would immensely appreciate your help.

-I THANK YOU much for your assistance...and your fellow neighbors thank you ...but unfortunately, I doubt that you will find a mosquito that will offer you its thanks.

-Very respectfully,
Christopher Ratigan,
V.P.I.&S.U.Class of 1999 (hopefully)

Survey Mailing Address
Christopher Ratigan
RR1, Box 277
Newport, Virginia 24128-9612
e-mail: cratigan@vt.edu

1. What is your gender? **Female or Male**

2. What is your age?

3. What is your street name, zip and county?

4. How long have you lived in this area?

5. Have you recently screened in your porch? Why?

6. Have you recently installed air conditioning? Why?

7. Compared to five years ago: **(please circle)**

--Do you think you grill out more or less or average now? **MORE or LESS or AVERAGE**
--Do you spend more or less or average time outside now? **MORE or LESS or AVERAGE**
--Do your children spend more or less or average time outside now? **MORE or LESS or AVERAGE**
--Do you notice more or less or average mosquito bites on yourself or children now? **MORE or**
LESS or AVERAGE
--Do you think you notice more or less or average mosquitoes now? **MORE or LESS or AVERAGE**

--Do you use repellents more or less or average now? **MORE or LESS or AVERAGE**
--Do you think that you talk with your friends more or less or average about mosquitoes now? **MORE or LESS or AVERAGE**

--Are you hearing more or less or average about mosquitoes now? **MORE or LESS or AVERAGE** Any one in particular? **YES or NO** If so, which one? How did you hear about the particular specie (radio, TV, news, newspapers, health departments…)?

8. Do you have mosquitoes in this area? **YES or NO**…….If so, do you know what type they are…(Culex, Aedes…)? **YES or NO** If you know the type, please name 1-3…_____ _____ _____ How did you know this?

--Are the mosquitoes in your yard, porch, neighborhood…?

--What color are the mosquitoes (white, brown, black, solid, stripped…)?

9. Are there lots of mosquitoes? **YES or NO**

--Do you notice 5, 10, 20, 30 or more mosquitoes/day (feel free to be more specific)?
--At what time are they most prevalent?

10. What time of day are you bitten the most (morning, afternoon, evening)?

--Where do you spend your time when you get bitten (inside, in the garden, in the pool, cutting the grass…)?
--On a scale of 1-5 (1 = very small…3 = average…5 = very big), how would you rate your mosquito problem?
--If you rated your mosquito problem a 4 or 5, please answer the following,…Have you always had a problem? **YES or NO** If no, when did it start?
If yes, has it gotten worse? **YES or NO**
If yes, When?

--Do you notice a lot of mosquito bites on yourself and/or your children? **YES or NO**
--On average, how many bites do you notice a day?

11. Have you thought about purchasing some mosquito control items for your yard? **YES or NO**

12. Do you have any mosquito control devices like bug zappers, candles, smoggers, repellents, insecticide…?

13. Approximately, how much do you spend on mosquito control devices per year?

14. When did you most seriously consider buying control devices (recently, 1 year ago, 3 years ago, five years ago, …be as specific as you like)?

15. Does mosquito activity affect your daily activity or plans in any way? **YES or NO**……If so, how?

--Do you ever find yourself wanting to do something outdoors, like cookout or sit outside, but find yourself deterred by the possibility of mosquitoes biting you? **YES or NO**

--Do you ever find yourself doing something outside only to move inside due to biting mosquitoes?
YES or NO If so, what time of day does this occur (morning, afternoon, night)?

16. What season are the mosquitoes most bothersome?

--What month during the season are they the most bothersome?

17. Do you notice more mosquitoes during hot/cool, dry/wet days?

--What about hot, humid days vs. cool dry days?
--On windy days, do the mosquitoes bother you as much? **YES or NO**
--Do you think you have gotten more or less or average rain than normal this year? **MORE or LESS**
or AVERAGE

18. Does the county have a mosquito control program? **YES or NO**
--If you have a mosquito control program, how often do you see them or have contact with them?
--If you have a mosquito control program, have you ever called them concerning a problem with mosquitoes? **YES or NO**
--If you have a mosquito control program, does it need to do more vs. mosquitoes? **YES or NO** If yes, how?
--Would you be willing to pay more for more mosquito control? **YES or NO**

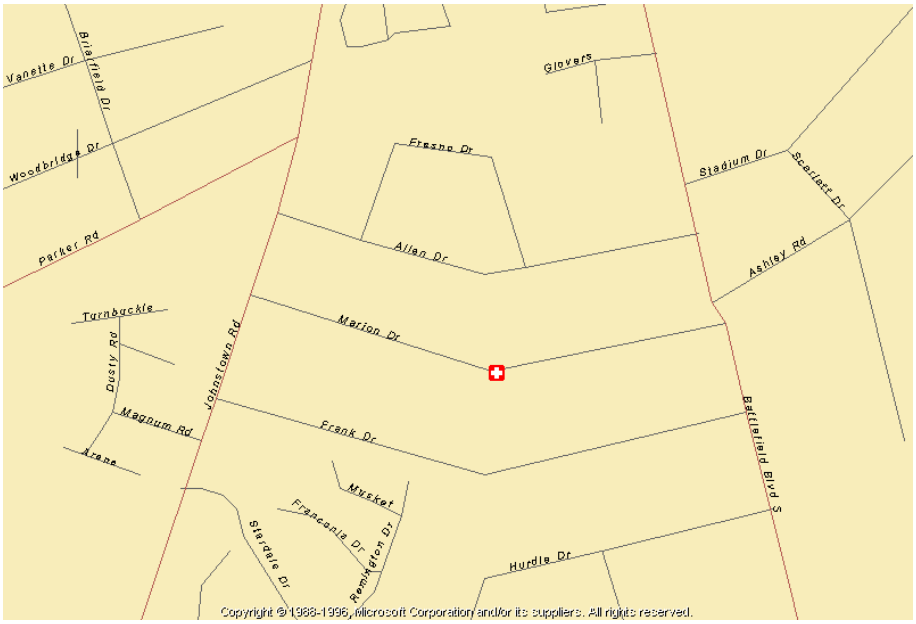
19. Other…Any additional comments that you would like to make?

THANK YOU GREATLY FOR THIS VALUABLE INFORMATION

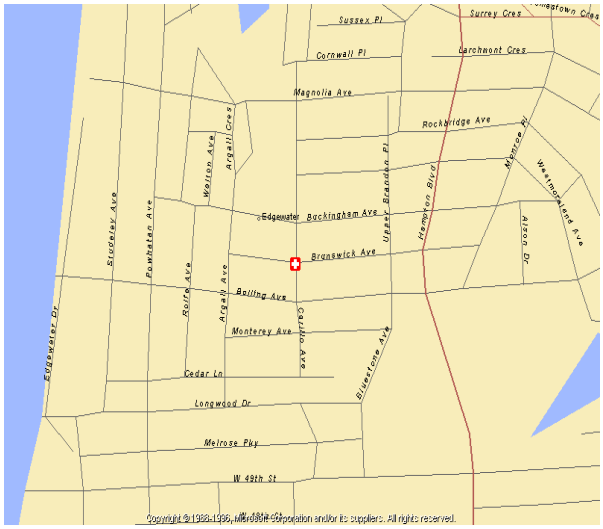
Sincerely,
Christopher Ratigan

Appendix B: Sample Maps & Imagery of Surveyed Block Groups, August 1998

CHESAPEAKE



NORFOLK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Surrey Cres
Cornwall Pl
Larchmont Cres
Magnolia Ave
Rockbridge Ave
Argall Cres
Walton Ave
Brandon Pl
Hampton Blvd
Monroe Pl
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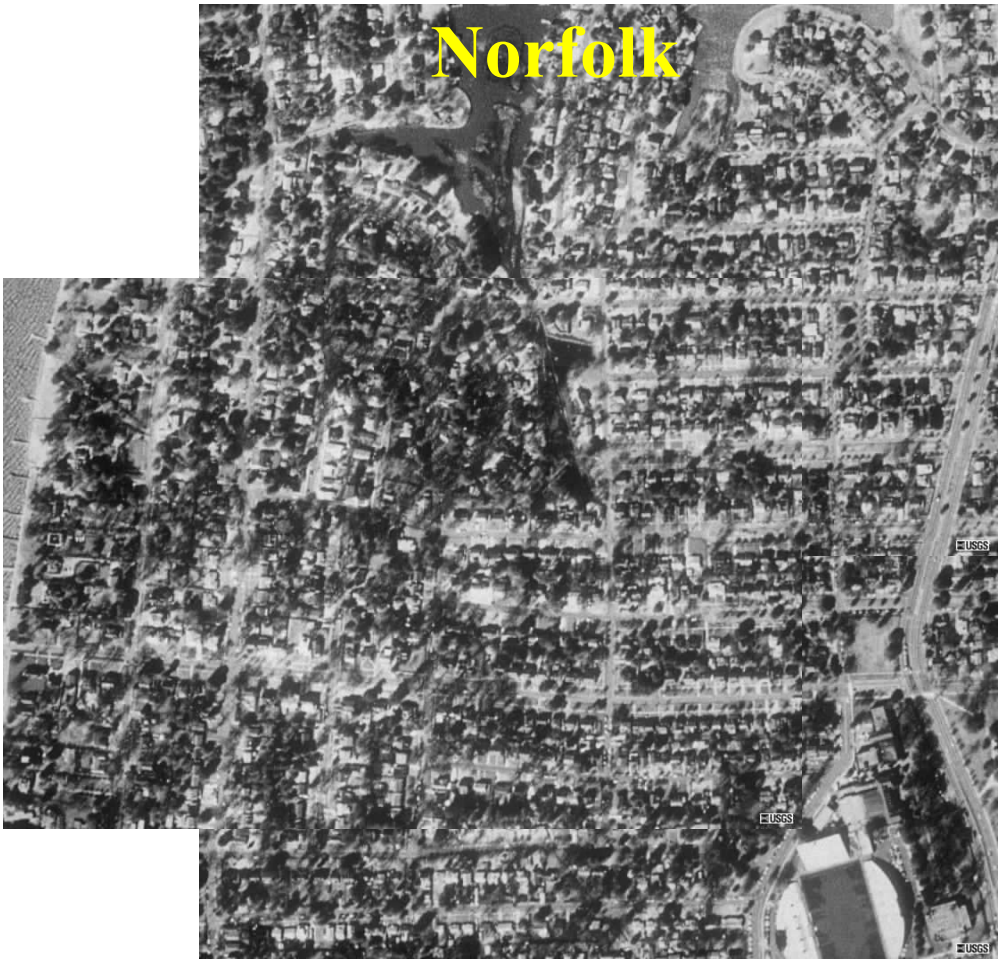
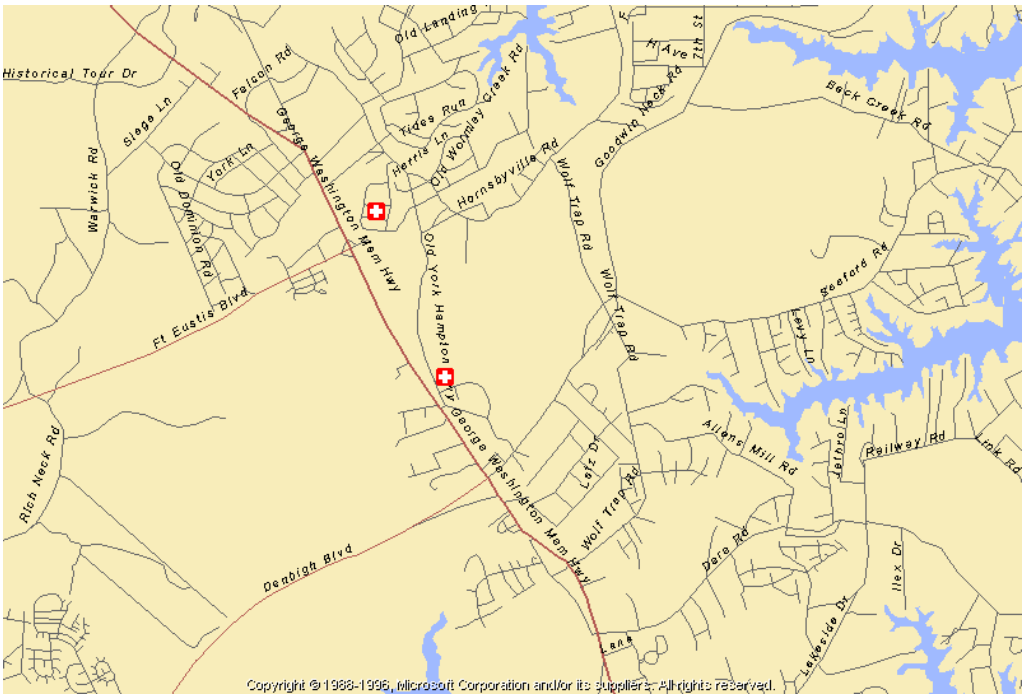
Alison Dr
Edgewater Buckingham Ave
Brunswick Ave
Stuyvesant Ave
Pawnbrake Ave
Rolfe Ave
Argall Ave
Bolling Ave
Monterey Ave
Carillo Ave
Ellsworth Ave
Edgewater Dr
Cedar Ln
Longwood Dr
Melrose Pky
W 49th St


Norfolk
USGS
USGS
USGS

YORK


Historical Tour Dr
Siege Ln
Warwick Rd
Falcon Rd
Old Landing
George Washington Mem Hwy
York Ln
Old Dominion Rd
Ft Eustis Blvd
Rich Neck Rd
Denbigh Blvd
Tides Run
Herris Ln
Old Womley Creek Rd
Hornsbyville Rd
Old York Hampton Hwy
George Washington Mem Hwy
Wolf Trap Rd
Wolf Trap Rd
Goodwin Neck Rd
H Ave
27th St
Back Creek Rd
Seaford Rd
Kevy Ln
Railway Rd
Link Rd
Jethro Ln
Allens Mill Rd
Lois Dr
Wolf Trap Rd
Dare Rd
Ilex Dr
Lakeside Dr
Lane
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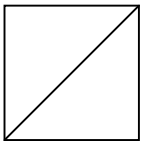
York
USGS

Appendix C: Survey, Virginia Beach, VA, April 1999

SURVEY QUESTIONS: **Date & Time:** **LA/L: N** **W**

1. What is your house number, street name, and zip? Survey # 

2. What year and month/season did you move into this residence?

3P. How many mosquitoes do you see a day? Roll-frame

4P. What time of day do mosquitoes bother you?

5S/P. Please estimate how many times you are bitten by mosquitoes per day?

6P. Please circle the following descriptors that best describe the mosquitoes that bother you.

Color/Pattern: Brown, Black, Black & White Striped OTHER
The size of my: pinky-fingernail, middle-fingernail, thumbnail OTHER

7S/P. During which activities are you more likely to be bitten by mosquitoes (in the garden, cutting the grass, trimming the bushes/shrubbery, in the flowerbed, in the house, swimming in the pool, etc.)?

NOTE: If you have lived at this residence for **6+ years please answer question 8 and then go to question 10.
NOTE: If you have lived at this residence for **5 years or less, please answer question 9 and then go to question 10.

8S/P. Please compare **the early 90's (90-92) to the late 90's (96-98)** when you answer the following:

--Time I grill outside… (Much Less) 1 2 3 4 5 6 7 8 9 10 (Much More)

--Time I spend outside (working, playing, resting, enjoying)… 1 2 3 4 5 6 7 8 9 10

--Number of mosquitoes I notice per day… 1 2 3 4 5 6 7 8 9 10

--Time I talk with my friends and/or neighbors about mosquitoes… 1 2 3 4 5 6 7 8 9 10

--Time I hear about mosquitoes from different media… 1 2 3 4 5 6 7 8 9 10

-What mosquito do you hear the most about?
-Please describe.

9S/P. Please compare **the mid 90's (93-95) to the late 90's (96-98)** when you answer the following:

--Time I grill outside… (Much Less) 1 2 3 4 5 6 7 8 9 10 (Much More)

--Time I spend outside (working, playing, resting, enjoying)… 1 2 3 4 5 6 7 8 9 10

--Number of mosquitoes I notice per day… 1 2 3 4 5 6 7 8 9 10

--Time I talk with my friends and/or neighbors about mosquitoes… 1 2 3 4 5 6 7 8 9 10

--Time I hear about mosquitoes from different media… 1 2 3 4 5 6 7 8 9 10

-What mosquito do you hear the most about?

-Please describe.

10S/P. Do you have a mosquito problem? **YES or NO**

--If you answered YES, please rate your problem…(Very Small) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | (Very Large)

-- Have you always had a problem? **YES or NO**

-If no, what year did it start?

-If yes, has it gotten worse? **YES or NO**

-If yes, What year?

--Have you considered moving away because of mosquitoes? **YES or NO**

-If Yes, Why?

--Do you know of other who have moved out of your neighborhood or Virginia Beach because of mosquitoes?

YES or NO Feel free to explain.

11S. What mosquito control devices do you use?

--When and how often do you use them?

12E. Approximately how much do you spend on mosquito control devices per year?

13S/P. Approximately what year did you first begin to seriously consider buying mosquito control devices?

14S. How does mosquito activity affect your daily activity or plans?

15S. Do you ever wish to do an outdoors activity, like cookout or sit outside, but find yourself deterred by the possibility of mosquitoes biting you? **YES or NO** **Please Comment.**

16S. Do you ever find yourself doing something outside only to move inside due to biting mosquitoes?

YES or NO **Please Comment.**

17S/E/P. Does the Virginia Beach mosquito control program need to do more to combat or abate mosquitoes?

YES or NO **Why?**

18S/E/P. Would you be willing to pay more for more mosquito control? **YES or NO** **Why?**

19. Do you know if mosquitoes are breeding on your property?

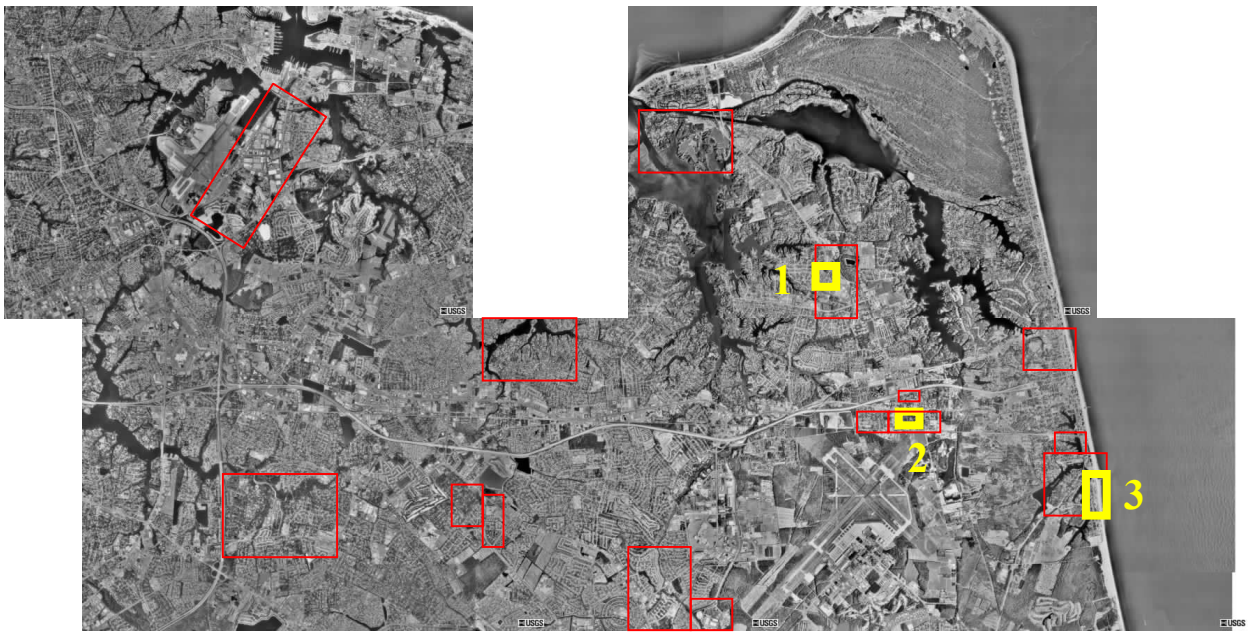
20. Do you know where the mosquitoes are coming from?

Appendix D: Imagery Overview, Survey Census Block Groups, Virginia Beach, VA, April 1999.

Census Block Group

Area within Block Group where surveys were distributed

Survey Overview, Virginia Beach, VA, April 1999



Site 1

Site 2

Site 3

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Mosquito control offices and the individuals that I worked with were: City of Williamsburg Mosquito Control-Bob Debellis, Great Bridge Mosquito Control (Chesapeake)-Leroy Bohn and Kirby Foley, Hampton Mosquito Control-Joe Kertesz, Virginia Beach Mosquito Control-Dreda McCreary, Norfolk Mosquito Control-John Neely and Agnus Flemming, and York County Mosquito Control-Jim Rhineflesh.

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GLOSSARY

Adapta-flexibility. This term combines the words adaptability and flexibility. First, in relation to the ATM, the "adapta-" stands for the ability of the ATM to evolve biologically or behaviorally and adapt to new or changing environments, climates, ecological niches, and circumstances. Second, flexibility refers to the ATM's non-habitat requirements and the fact that it is a container-breeding mosquito, which means, that it can virtually make its home anywhere once in a suitable environment (from urban to rural, sea level to high altitudes and from 0 degrees latitude to approximately 43 degrees).

Arbovirus. A virus that is transmitted from insect, in this case mosquito, to human.

ATM. Asian Tiger Mosquito (*Aedes albopictus*).

Census Demographic Data. Census demographic data is attained from the U.S.A. Census conducted every 10 years. This data is organized into various spatial units. These spatial units of demographic data are basically organized at the State, County, Tract, Block group, and Block levels. The State is the largest unit of analysis while the Block is the smallest. For this research, I am working at the Block group level (approximately 400 households).

Diapause. A period in which growth/development is suspended. Mid-latitude *Aedes albopictus* eggs go into diapause when daylight time grows shorter. Thus, diapausing eggs are essentially hibernating and as a result, are more protected against weather extremes. Once daylight time grows longer, the eggs come out of their diapause state and continue their life cycle.

GISENT. The use of geographic information systems (GIS) in the field of entomology (ENT).

GISEPI. The use of geographic information systems (GIS) in the field of epidemiology (EPI).

Horizontal Transmission. The transmission of a virus from a creature, such as the ATM, to another creature that can act as a viral reservoir.

(Non)-habitat requirements. This term refers to the fact the ATM, unlike many other mosquito species, does not require a specific niche within a climate zone, certain environment, or ecological zone. Once the ATM is in a climate(s) that can support it, it can then spread throughout that climate(s).

Photosensitive. The sensitivity of a creature to day-length with corresponding alterations in its life cycle and behavior (adult or egg).

RSENT. The use of remote sensing (RS) in the field of entomology (ENT).

RSEPI. The use of remote sensing (RS) in the field of epidemiology (EPI).

Vertical Transmission. The transmission of a virus from an adult mosquito, such as the ATM, to its offspring, making the offspring a carrier once it becomes an adult (female). This is also know as transviral transmission.