EVALUATION OF THE DEPARTMENT OF DEFENSE INSTALLATION MOSQUITO SURVEILLANCE PROGRAM, UNITED STATES 2012-2015

By

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Abstract

West Nile virus (WNV) is the primary arbovirus acquired within the United States and is transmitted by the bite of a mosquito. Mosquito surveillance programs are key components of overall WNV disease surveillance programs at the local, state, and federal levels. The valuable information collected from mosquito surveillance is used to direct methods to protect public health. To consolidate human and nonhuman (including mosquito surveillance) WNV surveillance data from all states, the Centers for Disease Control and Prevention (CDC) partnered with state public health departments and created ArboNET, the national arboviral surveillance system. Mosquito surveillance programs on Department of Defense (DoD) installations provide valuable information on WNV surveillance within their state. This study was the first to evaluate ArboNET WNV mosquito surveillance data to determine if DoD installations reported to state health departments. Mosquito surveillance data was received from the Army Public Health Center (Provisional) and the Air Force School of Aerospace Medicine. Data was reviewed from 2012-2015 for Army and Air Force installations and cross-referenced with an ArboNET dataset from the CDC. From 2012-2015, Army installations did not report 46.6% (range of 0-86% annually) and Air Force installations did not report 47.4% (range of 16-81% annually) of WNV positive mosquito pools to state public health departments for inclusion into ArboNET. Improved communication, standardization of data fields collected during surveillance, and a standardized database to collect mosquito surveillance data from DoD installations could aid in the improvement of mosquito surveillance data to state health departments.

Introduction

Field Experience Overview

I conducted my field experience at the Kansas Department of Health and Environment (KDHE) in Topeka, Kansas in the spring and summer semesters of 2016. The internship was coordinated through Dr. Ingrid Garrison, the State Public Health Veterinarian. As the State Public Health Veterinarian, Dr. Garrison oversees Kansas' mosquito surveillance program for West Nile virus (WNV). The collected WNV data from surveillance programs within Kansas was entered into ArboNET, a national arboviral surveillance system managed by the Centers for Disease Control and Prevention (CDC) and state public health departments. Dr. Garrison noticed the absence of WNV surveillance data in counties where large military installations were located. This led her to question if military mosquito surveillance data from Department of Defense (DoD) installations was reported and captured by the ArboNET system. This main question led to the basis of my project.

While at KDHE, contacting the different organizations (Army, Air Force, Navy and the CDC) to request the mosquito surveillance data and analyzing the data took the majority of my time. However, I was able to observe the many roles taken on by the State Public Health Veterinarian. I was able to observe the implementation of the recommendations from the new Compendium of Animal Rabies Prevention and Control, published by the National Association of Public Health Veterinarians, in the state of Kansas. I was able to observe and participate in the CDC's Zika virus summit webinar for the preparation of state public health departments to assess and respond to the Zika virus. I was also able to observe the medical investigators and epidemiologists within the Bureau of Epidemiology and Public Health Informatics. The opportunity to observe the Kansas State Public Health Veterinarian, medical investigators and epidemiologists at KDHE enabled me to receive a broad overview of the workings of a state public health department and broaden my experience in public health.

Project Objectives

The main objective of this project was to compare and evaluate the DoD WNV mosquito surveillance data to the ArboNET data to determine if the DoD installations had reported surveillance data to ArboNET.

Learning Objectives

The learning objectives for this field experience were to:

- Describe the national arboviral disease surveillance system ArboNET.
- Describe how arboviral disease surveillance was conducted by the State of Kansas and how case investigation was performed.
- Describe the Department of Defense arboviral disease surveillance system(s).

Background

Since the introduction of West Nile virus (WNV) into North America in 1999, mosquito surveillance programs have been one important tool used by public health officials and researchers in an effort to track the virus and predict potential human cases. These programs have been incorporated into (overarching) disease surveillance programs at the local, state, and federal level. Mosquito surveillance programs differ based on the managing organization, but all share the common goal to identify the presence of vectors of arboviral diseases. Once vectors and diseases are identified, steps can be taken to protect the health of the public.

West Nile Virus

West Nile virus was first identified in the United States in the summer of 1999 during investigations into an epizootic of avian deaths and a group of human encephalitis cases in New York City.[1] After the initial identification in 1999, West Nile virus progressively spread throughout the United States. By the end of the mosquito season in 2001, WNV had spread to 10 states and by the end of 2002 it had spread to the West coast. As of 2016, the Centers for Disease Control and Prevention (CDC) reported that infections in people, animals (including birds), or mosquitos had occurred in 48 states and the District of Columbia.[2] From 1999-2014, 41,762 human cases of WNV and 1,765 deaths had been reported to the CDC.[3] West Nile virus is now considered endemic in the United States and human and animal infections have been reported every year since its introduction.

West Nile virus is a RNA virus within the family Flaviviridae. Other flaviviruses include Saint Louis encephalitis virus, Japanese encephalitis virus, Dengue Fever, and Zika virus. Most people infected with WNV, an estimated 70-80%, do not develop any symptoms.[4] An estimated 20% of people will develop symptoms of infection. The clinical symptoms are usually self-limiting with fever as the most common symptom. Various other symptoms such as headache, body or joint aches, rash, vomiting, diarrhea, or fatigue may also develop. Less than 1% of those infected will develop severe neurological clinical symptoms, such as meningitis or

encephalitis. WNV is fatal in about 10% of those that develop severe neurological disease, and for those that recover some neurological impairment may be permanent.[4]

West Nile virus was first isolated from a female patient that exhibited a mild febrile illness in 1937 in the West Nile district of Uganda. The isolation was an incidental finding during an epidemiological study of Yellow Fever virus.[1] The discovery of this new virus spurred multiple studies on the ecology of West Nile virus and the epidemiology of human WNV infections. A comprehensive three-year study conducted by researchers with the U.S. Naval Medical Research Unit Number 3 (NAMRU 3) in Egypt sought to "elucidate the epidemiology of human infection and the natural history and life cycle of the virus" in Egypt.[4] The researchers captured multiple species of bloodsucking arthropods (ticks, lice, fleas, mites, lice, and mosquitos), but were only successful isolating WNV from mosquitos. The researchers also experimentally demonstrated mosquitos could be infected by feeding on a viremic host and transmit the virus by a bite.[5] Therefore, evidence was established that the vector for WNV was the mosquito.

The study by the NAMRU 3 researchers demonstrated that multiple species of *Culex* mosquitos could transmit WNV in Egypt. In the United States, WNV has been identified in over 65 species of mosquitos, but transmission to humans is primarily from *Culex* mosquitos.[6] There are a variety of *Culex* mosquito species in the U.S. and the specific species varies according to the geographical region (Figure 1). According to the CDC, the most important species for WNV transmission are *Culex pipiens* (throughout the northern United States), *Culex tarsalis* (western United States), and *Culex quinquefasciatus* (southern United States).[6] The degree to which

other *Culex* species contribute to WNV transmission to humans is not well understood.

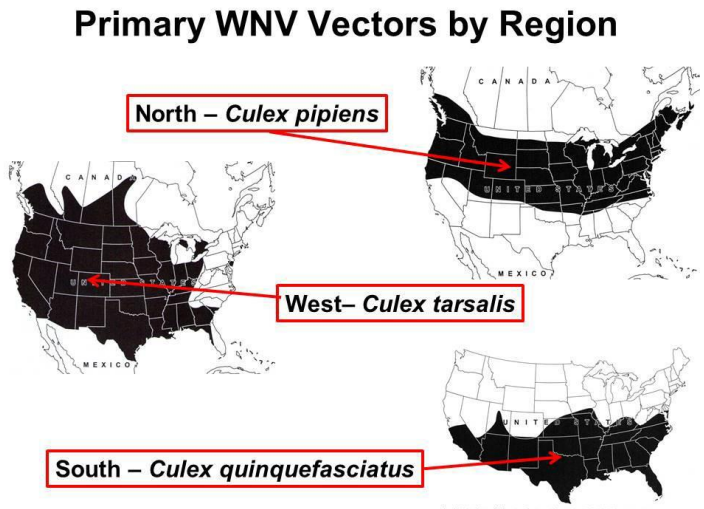


Figure 1: Approximation of Habitat of the Primary Vectors of WNV[6]

http://www.cdc.gov/westnile/resources/pdfs/wnvguidelines.pdf

Culex mosquitos are considered a permanent water mosquito. They prefer quiet bodies of freshwater with sunlight, surface vegetation, and little to no water movement. Examples of preferred habitats are the shallow edges of ponds or slow moving streams. *Culex* mosquito populations peak during the summer months into early fall (July through October).[7] Due to the extensive range of *Culex* mosquitos within the United States, WNV spread across the United States in a matter of 3 years. Currently, the CDC reports that WNV is present in all 48 states within the continental United States and within at least two-thirds of U.S. counties.

The *Culex* species of mosquito prefers to feed on birds and mammals. Therefore, the WNV cycle is maintained in the environment between the mosquitos and avian hosts. Some birds are considered an amplifying host of the virus; they can produce a high concentration of virus in their blood and transmit the virus to the mosquito through a bite. In the United States, the American Robin is considered an amplifying host.[6] The infected mosquito then transmits the virus to other birds and the cycle continues. Infected mosquitos can also bite humans and other mammals, however, humans and mammals are considered "dead-end" hosts (Figure 2). "Dead-end" hosts do not develop high enough concentrations of the virus to infect mosquitos during a mosquito bite. Of the mammal species, humans and horses are especially susceptible to the virus.

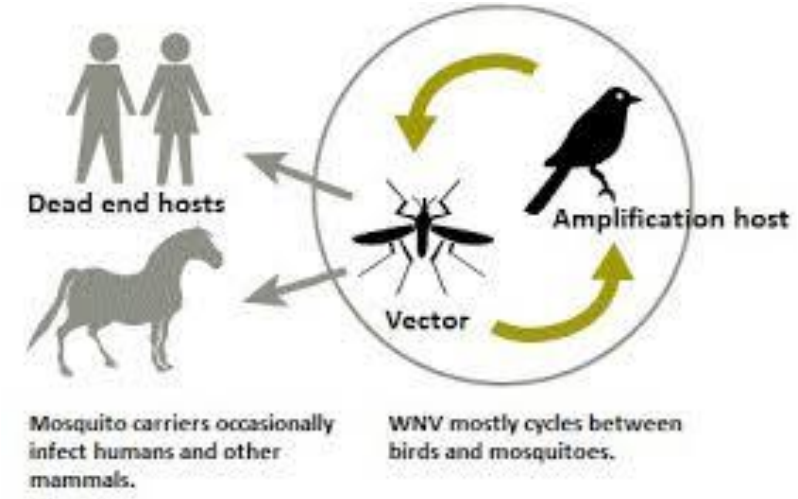


Figure 2: WNV Transmission Cycle

https://www.elpasotexas.gov/~/media/files/coep/public%20health/epidemiology/new%20epi%20documents/wnv_2014.a

In 2013, the CDC published an update to their West Nile virus Guidelines for Surveillance, Prevention, and Control.[6] In the guidelines, mosquito-based surveillance programs were described. Surveillance for these vectors consisted of the collection and testing of mosquito samples for arboviruses. The mosquito-based surveillance program is described as an integral part of the environmental surveillance performed for the detection of WNV. The objective of environmental surveillance of WNV is to identify the virus in vectors and other vertebrate hosts prior to the occurrence of any human cases. The mosquito-based surveillance system focuses on the primary vectors of WNV (*Culex pipiens, Culex tarsalis,* and *Culex quinquefasciatus)* but may also target other *Culex* species if they are identified as important to local spread.[6]

Mosquito surveillance programs provide important information to public health officials because the information gathered is used to determine mosquito control measures. Mosquito control measures vary from decreasing available breeding habitats to employing larvicides to control the population. Mosquito surveillance data also directs communication with the public. As mosquito populations increase, state and local public health departments warn the public about mosquitos, the possible health threats, and how to protect themselves. Finally, mosquito surveillance provides information on the types of mosquito species that are present to better defend against emerging and re-emerging diseases. Mosquito surveillance identifies the mosquito species present in the local area, which is valuable information because it helps

determine which diseases may pose a threat for that area. For example, Chikungunya, Dengue, and Zika virus are all viral diseases that have mosquito vectors and have emerged recently within the United States.

Kansas WNV Surveillance

Within the United States, WNV surveillance is de-centralized and is the responsibility of each individual state. In Kansas, the Kansas Department of Health and Environment (KDHE) oversees the West Nile virus surveillance program which is comprised of three main components: vector surveillance, human surveillance, and the sharing of results with key public health partners. KDHE has performed WNV vector surveillance since 2001. The design of the current WNV mosquito surveillance program has been in place since 2013 and has consolidated mosquito surveillance into Sedgwick County, Kansas.

According to the 2014 Arboviral Disease Surveillance report published by KDHE, KDHE has contracted out mosquito surveillance to the Kansas Biological Survey (KBS).[8] KBS conducted surveillance weekly during the mosquito season (May to September) in Sedgwick County. KBS set 9 Encephalitis Vector Survey (EVS) traps in sites that were most likely to have mosquito arbovirus transmission. For example, traps were placed where mosquitos were most likely to come into contact with people. KBS collected, counted, and identified the different mosquito species. *Culex* species of mosquitos were then submitted to the state laboratory, the Kansas Health and Environmental laboratory, for WNV testing. Mosquitos were tested for WNV using polymerase chain reaction, PCR. Results of WNV testing was reported to KDHE.[8]

WNV is a required to be reported to public health officials, when diagnosed in humans, in Kansas. Cases are captured by a passive surveillance system. Local health care providers reported suspected cases of WNV to local health departments. Local health departments investigated the reported cases and classified it as a case according to the CDC case definition. Once epidemiological cases were completed results were entered into the state disease surveillance system, EpiTrax. The final Kansas case count included both confirmed and probable cases.[8]

Department of Defense WNV Surveillance

In response to the appearance of WNV in the United States, the Department of Defense (DoD) became engaged in WNV surveillance in 1999. In July 2002, the Assistant Secretary of Defense issued a health affairs policy on the subject of West Nile virus surveillance at military installations. This policy directed the Army, Navy and Air Force to "develop WNV surveillance and prevention plans appropriate for the region and installation in conjunction with local public health programs already in place."[9] This policy spurred activities such as mosquito, bird, and nonhuman mammal surveillance on military installations, human surveillance within Military Treatment Facilities, and expanded the ability of DoD laboratories to perform diagnostic testing.[10] Military installations were directed to conduct active mosquito surveillance in order to determine the presence of WNV vectors (mainly *Culex* species of mosquito), the abundance of the vectors, and the presence of WNV infected mosquitos.[10] According to the DoD Health Affairs policy, DoD installations were required to report WNV positive mosquito populations to state health departments. It was then the responsibility of the state health departments to include the data in their reports to the CDC.

As WNV has become endemic within the United States, individual branches of the military have established their own guidelines and the individual military installations have adapted the guidelines to fit their local environment. Many of the guidelines used to customize an individual military installation's mosquito surveillance programs have been provided by the Armed Forces Pest Management Board. The Armed Forces Pest Management Board "recommends policy, provides guidance, and coordinates the exchange of information on all matters related to pest management throughout the Department of Defense (DoD)."[11]

Army Installation WNV Surveillance

According to the United States Army website, www.goarmy.com/about/post-locations.com, there were 69 active duty Army installations in the continental United States. Each individual Army installation has standard operating procedures for conducting vector surveillance on their installation. The vector surveillance, at a minimum, was to identify the presence of medically important pests.[12] Mosquito surveillance has been an important part of

the vector surveillance program on Army installations, and results have been used to determine mosquito control measures. Each Army installation has tailored their mosquito surveillance program for their environment and to meet their objectives. Once mosquito surveillance starts for the mosquito season, mosquitos are captured and collected. The collected mosquitos may have been identified down to species by a member of the installation Public Health or Environmental Health staff depending upon expertise. After capture, the mosquitos were pooled and shipped to one of three regional Army laboratories for WNV testing. The laboratory identified the mosquito down to species and tested the pools of mosquitos for WNV. Results were consolidated and a report was returned to the submitting Army installation. Reports were also forwarded to the Army Public Health Center (Provisional) to be included in the Vector-Borne Disease reports published monthly during the summer.

Air Force Installation WNV Surveillance

There were 68 active Air Force Bases within the continental United States according to the Air Force website, www.airforce.com. Individual Air Force installations utilized the Air Force's Guide to Operational Surveillance of Medically Important Vectors and Pests to develop local standard operating procedures for conducting arbovirus surveillance on their installations.[13] Mosquito surveillance has been a major part of the Air Force vector surveillance program, and the resulting information has been used to determine control measures. During the mosquito season, Air Force installations collected adult mosquitos and shipped them to the Air Force Entomologist at the United States Air Force School of Aerospace Medicine at Wright-Patterson Air Force Base. The Entomologist identified the mosquito(s) down to the species and performed tests for arboviruses, including West Nile virus. A report was generated for each individual installation which identified the species of mosquito(s) collected, shared some basic ecology information on the mosquito species, and provided the results of the arboviral testing.

ArboNET

Nationally notifiable diseases are diseases that occur in the United States and that through state legislation and regulations are mandated to be reported to state health departments. The list of notifiable diseases is compiled through a cooperative effort between

state health departments and the CDC.[14] West Nile virus is listed as a nationally notifiable disease and human cases must be reported to the CDC.[15] Therefore, the DoD is required to report human cases of WNV to state health departments, and these cases are included in state and national disease case counts.

Nonhuman cases of WNV are not required be reported to the CDC. In order to consolidate all WNV surveillance data (human and nonhuman) from across the United States, the CDC and state health departments created ArboNET in 2000. In 2003, ArboNET was expanded to report all arboviral diseases with public health significance present within the United States. Currently, the important arboviral diseases that are reported to the CDC for inclusion in ArboNET are West Nile, Chikungunya, Saint Louis encephalitis, Eastern Equine encephalitis, Western Equine encephalitis, La Crosse encephalitis, Powassan encephalitis, and Dengue Fever. In regards to West Nile virus, the ArboNET system maintains data reported from state health departments on cases of human disease, to include viremic blood donors, animal disease (infected animals, sentinel animals, or birds), and mosquito surveillance data (positive mosquitos are reported). The CDC's Division of Vector-Borne Diseases consolidates the data and reports cases (whether it be a person, mosquito, sentinel animal, bird, or animal) according to the county of residence. The ArboNET data is displayed as a map on the US Geological Survey's website, and can be easily accessed by the CDC, health departments, government agencies, or the public. (http://diseasemaps.usgs.gov/)

The objective of this study was to evaluate the DoD WNV mosquito surveillance data to determine if it was reported to the ArboNET surveillance system. ArboNET, as an arboviral surveillance system, is only as effective as the data that is entered into it. If the data entered into it is not complete, if county level data where military installations are located is missing, then it is not as useful as it could be. The evaluation of the DoD WNV mosquito data and the ArboNET data could provide insight into the effectiveness of ArboNET as it relates to communication between DoD departments of public health and the state public health departments. The DoD and the state health departments have the common goal of protecting the health of their population, and it is important to identify what is effective, what could be improved, and what knowledge gaps are present.

Methods

The DoD does not have a centralized repository for the West Nile virus mosquito surveillance data collected at the individual DoD installation level. To obtain the WNV mosquito surveillance data, each DoD service was contacted individually. To obtain the United States Army mosquito surveillance data the Army Public Health Center (Provisional) was contacted. A Data Use Agreement (DUA) was established and approved by the Public Health Review Board. Consolidated WNV mosquito surveillance data from the continental United States from 2011-2015 was requested from the Disease Epidemiology section of Army Public Health Center (Provisional).

To obtain WNV mosquito surveillance data from the United States Air Force, a Freedom of Information Act (FOIA) request was submitted to the Wright Patterson Air Force Base FOIA office by electronic mail. In the FOIA the following data from 2011-2015 was requested: date mosquitos were collected, date mosquitos were received, installation from where the mosquitos were collected, location of the installation performing the mosquito trapping (county and state), the collection method used, the number of trap nights, the species of mosquitos captured, the number of males captured, the number of females captured, and the WNV or other arboviral test results.

To obtain data from the United States Navy, the Navy Marine Public Health Center was contacted. They recommended contacting the Navy Entomology Center of Excellence. Numerous attempts were made to contact the Navy Entomology Center of Excellence without success.

ArboNET data was obtained from the Arboviral Diseases Branch of the Division of Vector-Borne Infectious Diseases within the Centers for Disease Control and Prevention. A non-human arboviral surveillance data request form was completed and submitted by electronic mail. All mosquito-borne virus surveillance data for the United States for 2011-2015 was requested. ArboNET data is entered into the database by state public health officials. If local public health or individual counties are conducting mosquito surveillance the information

should be communicated to the state public health official for inclusion into ArboNET. The state public health official enters the following ArboNET data into the database: a CDC-assigned state identification number, species of mosquito(s) captured, the county in which the mosquito(s) were trapped, arbovirus the mosquito(s) were positive for, and the date the mosquito(s) were collected.

Excel © spreadsheets of all active duty Army and Air Force installations, and their corresponding counties, were created. Army and Air Force records were reviewed and positive mosquito pools were entered into the spreadsheets by year of capture. The data in these spreadsheets was cross-referenced with the ArboNET dataset to determine if WNV positive pools from DoD facilities were reported to ArboNET. If the ArboNET dataset did not include the WNV positive mosquito pool from a county with the DoD facility, it was concluded that the DoD facility did not report the WNV positive mosquito pool to the local or state health department for inclusion into ArboNET. If the ArboNET dataset did include the WNV positive mosquito pool from a county with the DoD facility, the exact date (month, day, year) was matched to determine if it was the DoD facility that reported the positive pool instead of another surveillance source.

The proportion of WNV positive mosquito pool(s) that had a corresponding county and date within ArboNET were calculated by year for both Army and Air Force installations. For the Army data, if the installation's corresponding county was listed with a positive mosquito pool(s) for that year, then it was considered reported to the state health department. If the installation's corresponding county was not listed at all in the ArboNET data, the positive WNV mosquito pool was considered as not reported. For the Air Force data, there were three categories. If the corresponding county and matching mosquito collection date was listed as having positive mosquito pool(s) in the ArboNET data, it was considered as reported. If the corresponding county was listed, but had a different date of mosquito capture, it was considered as most likely not reported. If the corresponding county was not listed at all within the ArboNET data, it was considered as not reported. The aggregated results were reported; individual installations were not named.

The mosquito pools that tested negative for WNV and were reported to the CDC from state health departments were excluded from this study. The negative data was not evaluated because of inconsistent reporting of the data to ArboNET.

State Arboviral Disease Report Review

Since the Army data did not contain a date of mosquito capture to cross-reference with the ArboNET data, differentiation between Army installation WNV mosquito surveillance results and the local city, county, or state public health department's surveillance results was attempted by reviewing individual state arbovirus surveillance reports for 2012-2015. A subset of state reports were selected for review based on the results of the Army data and ArboNET data evaluation. The state arbovirus reports were obtained from the individual state's websites.

Results

Army

The Disease Epidemiology section of Army Public Health Center (Provisional) provided consolidated Excel spreadsheets containing data only for positive WNV mosquito pools for years 2012-2015. These spreadsheets were created from data received from three different Army Public Health Command regional (PHCR) laboratories: PHCR-South, PHCR-North, and PHCR-West. Each laboratory was responsible for the military installations within their specific section of the country, and conducted the arboviral testing of mosquitos from those installations. The consolidated data spreadsheets from the Disease Epidemiology section only listed the regional lab submitting the report, the installation name/trap site, number of WNV positive pools, and the WNV test results. The spreadsheet did not contain the date mosquitos were trapped or collected, therefore, if the county was listed in the ArboNET data it could not be determined if the installation reported the positive WNV mosquito pool or if surveillance was performed by the local or state public health department. If the county was not reported as positive in the ArboNET data, it was assumed the installation did not report the positive mosquito pool to the local or state health department.

The consolidated data spreadsheets from the Disease Epidemiology section of Army Public Health Center (Provisional) also contained information for installations other than Army. The regional labs identified and tested mosquitos for other military installations within their area of responsibility. If WNV positive mosquito pools were found for installations other than Army, the information was excluded from the analysis.

There are 69 active duty army installations in the continental United States.[16] The number of active duty Army installations that conducted WNV mosquito surveillance each year was not able to be determined because the reports that were received listed only positive WNV results. Overall, for the four years (2012-2015) there were 191 WNV positive mosquito pools identified on Army installations. Of these 191 positive pools, 89 (46.6%) were not reported to state health departments for inclusion into ArboNET.

In 2012, 12 Army installations/counties conducted surveillance and had positive WNV mosquito pools. A total number of 87 WNV positive mosquito pools were identified from the 12 installations/counties. Seven of the 12 counties did not have positive WNV mosquito pools in ArboNET, which accounted for 75 WNV positive mosquito pools. Therefore, 86% (75/87) of WNV positive mosquito pools were not reported to ArboNET.

In 2013, there were a total of 35 WNV positive mosquito pools across five Army installations. All five counties in which the Army installations were located had positive WNV mosquito pools reported in ArboNET, therefore, it was assumed that all of the WNV positive mosquito pools were reported. One of the counties had exactly the same number of WNV positive mosquito pools as reported from the Army installation and the other four counties had several more positive pools than were reported by the Army installation.

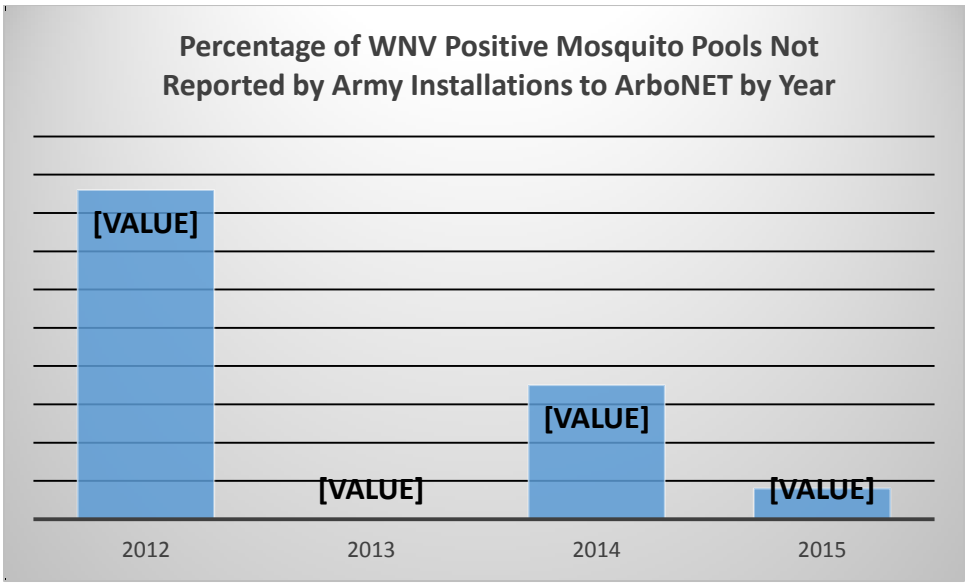
In 2014, there were a total of 31 WNV positive mosquito pools across seven Army installations. Of these seven counties, one county (with one WNV positive mosquito pool) was not listed in ArboNET. A second county only had four WNV positive pools included in ArboNET whereas the Army data reported 12 WNV positive pools, therefore, eight of the 12 were not reported. The total number of WNV positive mosquito pools not reported to ArboNET was nine. Therefore, 35% (9/31) of WNV positive mosquito pools were not reported to ArboNET.

In 2015, there were a total of 38 WNV positive mosquito pools spanning nine Army installations. Of the nine counties, three of the counties were not listed in ArboNET. The three counties that did not have their positive mosquito pools in ArboNET had three total WNV positive mosquito pools. Therefore, 8% (3/38) of the WNV positive mosquito pools were not reported.

Table 1: The Proportion of WNV Positive Mosquito Pools Not Reported by Army Installations to ArboNET by Year

ARMY	2012	2013	2014	2015	TOTAL
X	75	0	11	3	89
Y	87	35	31	38	191
PERCENTAGE	86%	0	35%	8%	46.6%

Key: X is the number of WNV positive mosquito pools not found listed by county within the ArboNET data. Y is the total number of WNV positive mosquito pools identified on Army installations for the corresponding year.



Graph 1: Percentage of WNV Positive Mosquito Pools Not Reported by Army Installations to ArboNET

State Arboviral Disease Report Results

Maryland's annual arbovirus surveillance reports for WNV positive mosquito pools were reviewed because four different Army installations within Maryland consistently identified positive mosquito pools from 2012-2015. In 2012, eight of the 87 positive pools were located on these four installations.[17] Maryland's annual arbovirus surveillance report for 2012

confirmed that all eight of these positive pools were reported to the state public health department because the report specifically cited that the results were from a DoD installation.

Next, the state of Arizona's 2012 annual arbovirus surveillance report was reviewed to determine if La Paz County had reported one positive mosquito pool to compare to the Army data.[18] Arizona's annual report had 40 positive mosquito pools reported in La Paz County in 2012. The report did not differentiate if the information came from a DoD installation.

Finally, the District of Columbia's 2012 West Nile mosquito surveillance report was reviewed, and it specifically listed the DoD installation's positive mosquito pools.[19] When cross referenced with the Army and the ArboNET data, the Army installations were reporting positive pools to the District of Columbia Department of Health.

For 2012, it was determined that the Army installations within Maryland and the District of Columbia (DC) reported to the state and that the information was being captured by ArboNET. It could not be determined if the Arizona Army installation had reported; however, the analysis showed that 86% (75/87) of WNV positive pools were not reported to ArboNET.

To help differentiate Army installation reporting and individual county reporting for 2013 the annual arbovirus surveillance reports for the District of Columbia, Oklahoma, Maryland, and Texas were reviewed. Unfortunately, the Oklahoma 2013 arbovirus surveillance report was not reviewed because the 2015 report was the only one available for review on the Oklahoma State Department of Health website. The District of Columbia Department of Health published a district map broken into eight wards with stars indicating positive mosquito pools, instead of a spreadsheet listing specific locations of traps as in 2012.[20] There was no indication if any of the stars represented DoD installations. Similar to 2012, the Maryland Department of Health and Mental Hygiene published their annual report and specifically listed the positive pools found on DoD installations.[21] These numbers coincided with the Army data. The state of Texas had a robust arbovirus surveillance program in 2013. Their annual reports were available on the Texas Department of State Health Services website. In 2013, 16 positive mosquito pools were identified on one Army installation in Texas according to the Army data.[22] The 2013 report from the Texas Department of State Health Services reports 35 positive pools in the

same county in Texas. There was most likely additional arboviral surveillance being performed by the local or state health departments in that county.

In 2013, the analysis showed there was 100% reporting of positive mosquito pools identified on Army installations to ArboNET. To determine if the positive pools were reported to ArboNET from the Army installations, individual state arbovirus surveillance reports were reviewed. The positive pools in Maryland were confirmed, but the positive pools in the District of Columbia, Oklahoma, and Texas could not be confirmed. Therefore, the 100% reporting of Army installations to ArboNET in 2013 may be falsely elevated due to the possibility that the positive pools were reported because of local or state public health surveillance.

In 2014, differentiation between surveillance results from Army installations and those from local/state public health surveillance programs was attempted by reviewing state arbovirus reports in Maryland, DC, and Texas. As in previous years, the Maryland Department of Health and Mental Hygiene published a spreadsheet specifically listing DoD installations with the number of positive mosquito pools.[23] The number corresponded with the number listed in the Army data. Unfortunately, the 2014 WNV surveillance report for the District of Columbia was a map of eight wards with stars representing trap locations, but no results.[24] The Texas Department of State Health Services 2014 report listed that one county had four positive mosquito pools whereas the Army data had reported 12 positive mosquito pools for the installation within that county.[22] This means that all of the positive mosquito pools were not reported to ArboNET, however, without confirmation on dates it was assumed four of the 12 were reported to ArboNET and the remaining eight were not reported, contributing to the 35% of WNV positive mosquito pools that were not reported to ArboNET in 2014. If the four positive mosquito pools had been considered as not reported, then the number of WNV positive mosquito pools not reported to ArboNET would have increased to 15 and the percentage would have increased to 48% (15/31).

For 2015, an annual arbovirus surveillance report review for the states of Maryland, Texas, and Georgia was attempted. Unfortunately, the 2015 annual reports had not been published on their state health department websites. The 2014 Georgia Department of Public

Health (GDPH) end of year summary stated that due to funding cuts, the GDPH was no longer conducting WNV mosquito surveillance.[25] Individual counties with contracts were still conducting surveillance; however, the submitted data results for positive mosquito pools were often incomplete. Without the individual state annual reports, the determining how many WNV positive mosquito pools could not be determined with confidence. However, using the given data it could be determined how many WNV positive mosquito pools were definitely not reported to ArboNET.

Air Force

The FOIA request was submitted electronically to the Air Force and the request was approved. The information received consisted of a CD that contained over 1200 files. The files were individual Air Force Base (AFB) mosquito surveillance reports from 2011-2016. The memorandums were from the Air Force entomologist to the public health officials on the submitting AFB. The information within the reports included the AFB that collected the mosquito(s), the date the mosquito(s) were captured, the species of the mosquito(s) with a short description on the ecology of the species, whether the mosquito(s) were tested for arboviruses, and if the mosquito(s) were positive or negative for the arboviruses.

For the years 2012-2015, 1227 files were reviewed (see Table 1). Overall, for the four year period (2012-2015), 59 WNV positive mosquito surveillance pools were identified on Air Force installations. There were 28/59 (47.4%) WNV positive pools not reported to ArboNET.

Table 2: The Number of Air Force Mosquito Surveillance Reports Reviewed by Year

YEAR	NUMBER OF REPORTS
2012	244
2013	293
2014	341
2015	349
TOTAL	1227

In 2012, 56% (23/68) of Air Force Bases conducted arboviral surveillance within their installation in 2012. The Air Force entomologist's memorandums reported nine mosquito pools positive for WNV spanning six installations/counties. Of these nine WNV positive pools, three counties (with three WNV positive pools) were not found within the ArboNET data set. Therefore, 33% (3/9) of the WNV positive pools were not reported to ArboNET. Six of the WNV positive pools had dates of collection that differed between the Air Force data and the ArboNET data. These were most likely not reported either, but it could not be confirmed.

In 2013, 63% (43/68) of Air Force Bases submitted mosquitos for speciation and arboviral testing. There were 19 WNV positive mosquito pools across 10 different installations/counties. Of the 19 positive mosquito pools, eight of them matched the county and date within the ArboNET data. Eight of the positive mosquito pools had different collection dates in ArboNET. Three of the positive pools did not have their county listed within the ArboNET data; therefore, 16% (3/19) were not reported to ArboNET.

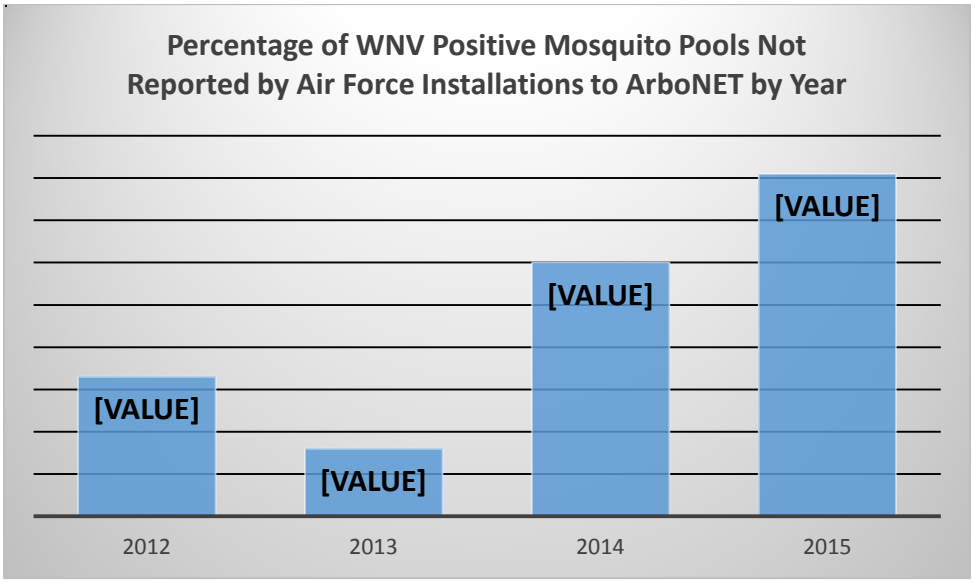
In 2014, 68% (46/68) of AFB submitted mosquitos for speciation and arboviral testing to the Air Force Entomologist. There were 15 WNV positive mosquito pools across seven installations/counties. Of the 15 positive mosquito pools, two matched the county and date in the ArboNET data. Four of the WNV positive mosquito pools identified in the Air Force data had different mosquito collection dates listed in ArboNET. Nine positive pools were not listed in ArboNET (9/15); therefore, 60% were not reported in 2014.

In 2015, 63% (43/68) of AFB submitted mosquitos for identification and arboviral testing to the Air Force Entomologist. There were 16 WNV positive mosquito pools from seven installations/counties. Information from only one WNV positive mosquito pool matched information in ArboNET. Two of the positive pools had different mosquito collection dates listed for that county in ArboNET. 13 of the 16 (81%) positive pools were not listed in ArboNET.

Table 3: The Proportion of WNV Positive Mosquito Pools Not Reported by Air Force Installations to ArboNET by Year

AIR FORCE	2012	2013	2014	2015	TOTAL
X	3	3	9	13	28
Y	9	19	15	16	59
PERCENTAGE	33%	16%	60%	81%	47%

Key: X is the number of WNV positive mosquito pools not found listed by county within the ArboNET data. Y is the total number of WNV positive mosquito pools identified on Army installations for the corresponding year.



Graph 2: Percentage of WNV Positive Mosquito Pools Not Reported to ArboNET by Air Force Installations

ArboNET

The ArboNET arboviral positive mosquito data for 2011-2015 was received in Excel © spreadsheet by email. Each year had its own sheet with the year, state, county (by code) in which the positive mosquito(s) was collected, date the mosquito(s) was collected, the arbovirus with which the mosquito(s) was infected, and the species of the mosquito(s). The final sheet was the county code key.

Discussion

With the introduction of West Nile virus to the United States, the development of mosquito surveillance programs has allowed the scientific community to continue to improve their understanding of the epidemiology, ecology, and transmission of WNV. It has also allowed public health officials to track the spread of disease from the East Coast to the West Coast of the United States. ArboNET is the passive electronic database developed by the CDC and maintained by both the CDC and the state public health departments to collect and display the data obtained from the mosquito surveillance programs. The objective of this study was to describe the WNV positive mosquito pool data from Department of Defense installations, specifically Air Force and Army installations, and determine if it was reported to state health departments from 2012-2015 for inclusion into ArboNET.

Four years (2012-2015) of mosquito surveillance data was reviewed for the Air Force and Army installations. West Nile virus positive mosquito pools identified on the installations were cross referenced using county of origin with ArboNET data obtained from the CDC to determine reporting status. The number of Air Force installations that conducted mosquito surveillance varied each year, however, at least 56% of installations conducted surveillance each of the four years. The raw data obtained from the Air Force was complete and allowed easy cross referencing of the data with the ArboNET data. Over the four year period, 47.4% of WNV positive mosquito pools were not reported. The lack of reporting of WNV positive mosquito pools varied from three out 19 (16%) in 2013 to 13 out of 16 (81%) in 2015.

Over the four year period the Army installations did not report 46.6% of the WNV positive mosquito pools found on their installations. In 2012, 86% (78/87) of WNV positive mosquito pools were not reported, and the highest reporting percentage was 100% of positive pools in 2013. The Army raw data did not include the collection dates of positive mosquito pools. Due to the absence of mosquito collection dates, it could not be determined if the Army installations were truly reporting or if additional surveillance was being performed by the state or city within that specific county. Therefore, the WNV positive pools that were not reported to ArboNET were described in this study.

The reporting of positive mosquito pools to ArboNET needs significant improvement by both services. It is difficult to determine why WNV positive mosquito pools were not reported to state public health departments and subsequently not included in ArboNET. The lack of reporting could have been due to many different variables. For example, mosquito surveillance to identify WNV may not been conducted because WNV is considered endemic and efforts are directed at mosquito control instead. Mosquito surveillance may not have been performed if the installation did not have the public health resources available, or if there was a lack of qualified personnel to oversee the mosquito surveillance program. There was also the possibility that surveillance was not performed because of other mission requirements taking priority. If mosquito surveillance was performed the installation public health personnel may not know it needs to be reported to the state public health department, or they may not know who to report it to at the state level.

Impact of Mosquito Surveillance

The reporting of mosquito surveillance results from military installations to local or state public health departments, as well as ArboNET, is important for a number of reasons. According to an article published in 2012 that assessed the utility and satisfaction of state health departments with ArboNET, state and local health departments found the data contained within ArboNET to be useful.[26] Most of the nonhuman surveillance data (mosquito surveillance, equine disease surveillance, and sentinel animal disease surveillance) was used by state health departments to help determine when public health control measures should be implemented. The article also pointed out that as state funding for arboviral surveillance was cut, many states had to decrease their nonhuman surveillance programs, including mosquito surveillance. This has affected the ability of state public health departments to implement public health control measures, such as the application of larvicide to mosquito breeding grounds, to protect the health of the public and prevent WNV outbreaks among people. With the decrease in funding for state mosquito surveillance programs, the mosquito surveillance performed on military installations becomes very important. The sharing of the results of the surveillance provides the state public health departments with an important resource. If the results indicate the presence of WNV in the mosquito population, the state public health

department can notify the local public health department and can begin to implement controls to protect the population of that county.

Finally, reporting the results of the mosquito surveillance performed on military installations is valuable because it enables public health departments, both military and civilian, to better defend against emerging and re-emerging diseases. Mosquito surveillance provides the identification of the mosquito species present in the local area. Identifying the mosquito species is valuable information because it helps determine what diseases pose a threat for that area. For example, Chikungunya, Dengue, and Zika virus are all diseases that have mosquito vectors and have emerged recently within the United States. Zika virus emerged in the Americas in South America in 2015 and has become an increasing concern in the United States in 2016. To help assess the threat posed by the Zika virus in the United States, the CDC requested data from each state on the Zika virus vector, the *Aedes* species of mosquito. Since states, such as Kansas, were conducting mosquito surveillance they were able to look at historical records of mosquito species collected and determine if the *Aedes* species of mosquito had been identified. In Kansas, some of these historical records that had identified the presence of the *Aedes* species of mosquito had been reported from a military installation to the Kansas Department of Health and Environment.

Study limitations

The findings of this study were subject to several limitations. First, it was a challenge to determine if the WNV positive mosquito pool(s) reported to ArboNET were the results of mosquito surveillance performed by the state, city, county, or Army installation. The Army data received did not have the date of mosquito collection for the WNV positive mosquitos, therefore, when compared to the ArboNET data it could not be differentiated if the data was reported by the Army installations or other surveillance programs. This may have falsely elevated the proportion of Army installations that reported their positive mosquito pools to state public health department for inclusion into ArboNET. The raw data that the Army provided was reviewed to try to identify dates of mosquito collection, but the information from the three regional labs that performed the WNV testing all had different data fields and did not always include date of collection. The number of Army installations that performed

surveillance was also not determined because the data received was already consolidated into only those installations that had WNV positive mosquito pool(s). In 2015, the Army Public Health Command underwent a reorganization and the regional labs that identified and tested mosquitos for WNV had a geographic change to their areas of responsibility. This change may have delayed submission of mosquitos from Army installations who were not sure of where to send their specimens, or it could have delayed the reporting of results from the labs to the installations. This would have affected the reporting of the mosquito test results to state public health departments and ArboNET.

The second limitation was the inability to determine the number of military installations that had public health assets (staff and equipment) to perform mosquito surveillance. A lack of public health assets would explain why not all Army and Air Force installations conducted mosquito surveillance. Negative mosquito data was excluded so there could be some instances where military installations reported data to state public health departments, however, it was not included in data reported to ArboNET. Finally, there may be some instances in which positive mosquito pools were reported to local or state health departments, but state health departments did not report the positive pools to ArboNET.

Recommendations

This study found that there was no centralized database for DoD arboviral surveillance data, which made it a challenge to find and review mosquito surveillance data. The DoD has an Armed Forces Health Surveillance Branch (AFHSB) which may be the appropriate organization to collect and analyze the mosquito surveillance data. The vision of the AFHSB is "to be the central, integrated, customer-focused epidemiologic and global health surveillance proponent for the U.S. Armed Forces." Since DoD installations did not have the ability to directly upload information into ArboNET, the standardization of data fields collected during mosquito surveillance should follow the fields required by ArboNET. This would allow for easy input of the DoD mosquito data into ArboNET by state health departments when reported from DoD installations. The minimum data fields collected should also be standardized across all of the

services. This would improve data quality and allow for rapid and timely analysis. Finally, it is recommended that the laboratories and individuals performing the WNV testing include a statement on their reports to remind the submitting installation to report WNV positive findings to their state health department.

Conclusions

This paper presented results from the first evaluation of WNV positive mosquito data from military installation surveillance programs into ArboNET. This study found a gap in the reported number of WNV positive mosquito pools from Air Force and Army installations to their respective state public health departments. The number of WNV positive mosquito pools not reported to ArboNET varied by year and branch of service; however, it was as high as 86% by the Army installations (2012) and 81% by the Air Force installations (2015). The lack of reported WNV mosquito pools represented a gap in the national arboviral surveillance system. The data gained by surveillance performed by military installations is extremely valuable, especially as funding cuts decrease the ability for individual state health departments to perform mosquito surveillance. If reported, the data from Department of Defense installations could enable state health departments to determine mosquito control measures, direct public education campaigns, and determine the mosquito species present in the area.

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