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Modeling Risk and Prevention of West Nile Virus at a Military Installation in the United States using Fuzzy Boolean Logic

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Abstract: *Fuzzy Logic and a Fuzzy Logic Control System were used to predict and identify areas for control of arthropod-borne viruses. Bird species and mosquito landing counts were conducted to determine high risk areas for West Nile virus at the Edgewood Area, Aberdeen Proving Ground, Maryland, US. The level of risk West Nile Virus varied geographically in the installation. The fuzzy logic control system was developed to identify where and when mosquito control should be conducted to prevent an outbreak of West Nile Virus .*

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I. Introduction

West Nile virus (WNV), family Flaviviridae, was first identified in the United States in 1999.[1] West Nile virus is an arbovirus, principally transmitted by mosquitoes in the genus *Culex*, with passerine birds serving as the natural reservoir. Transmission to humans, horses and other mammal species occurs through a bridge mosquito species, such as *Cx. salinarius, Cx. pipiens* and *Cx. restuans* are the primary vectors in the northeastern U.S.[2] Over the next decade WNV spread across North America and is now endemic. The first case of WNV in Maryland was reported in 2001, between 2001 and 2016 there have been 334 reported cases.[3]

Because of the threat of WNV to military personnel from arboviruses, a study was conducted to evaluate the risk of WNV occurring at the Edgewood Area, Aberdeen Proving Ground, Maryland. Identifying the risk of vector-borne diseases and implementing integrated vector management at Edgewood is of significant public health value. Once the risk of an infectious disease is determined, medical and preventive measures can be taken to reduce the threat to military personnel and their families.

METHODS

There are approximately 1,000 people living on Edgewood Area, Aberdeen Proving Ground, with nearly 15,000 people working both areas of Aberdeen Proving Ground.[4] Nearly 20,000 retirees and their families use the recreational facilities at Edgewood. Ten sites consisting of Oak forest, Pine forest, and Ecotone were identified for the study. Bird species at the 10 sites were identified using binoculars and vocalization during June. Mosquito numbers at the sites were determined using landing counts during June and July. Data was analyzed using Statistica software, ArcGIS, and the BioAgent Transport and Environmental System.

II. Results And Discussion

A WNV Prevention Model was developed (Table 1) based on Takagi Sugeno Fuzzy/Boolean Logic.[5] Twenty-eight species of birds were identified using vocalization and visualization, with varying risk as serving as reservoirs for WNV. Based on bird species composition and mosquito landing counts, the 10 sites varied in their potential for WNV (Table 2 and Figure 1). West Nile virus is difficult to predict and control.[6] Therefore, developing a method to predict and identify sites for control of WNV could assist military public health personnel in accomplishing their mission essential task of protecting military personnel and their families. The Fuzzy Logic controller was used to identify at what point mosquito control should be conducted to reduce the risk of WNV infection rising to high levels and posing a higher risk to the human population. By implementing a Fuzzy Logic control system, public health officials can optimize integrated vector management while reducing the amount of pesticide in the environment and by reducing cost. For example, instead of spraying the entire mosquito season, areas can be prioritized as to risk of WNV.

Military personnel and their families are also at risk from infection by vector-borne diseases at military installations in the U.S. For example, high risk areas for *Yersinia pestis*, the etiologic agent of bubonic plague, were identified at the United States Air Force Academy installation, with some sites adjacent to family housing on the base.[6] During the first 9 months of 2016, one active duty soldier was diagnosed with WNV. [7] Over 20,000 *Culex* species for WNV from military bases in the Atlantic region were tested by the Department of Defense Army Laboratory, Public Health Center. Fifty-nine pools tested positive for WNV from military

installations in North America. The positive pools were collected from the Washington DC area, Walter Reed National Military Medical Center and the Naval Support Center in MD, Fort Hamilton, NY and Fort Belvoir, VA.

Poor and minority neighborhoods are often at higher risk of WNV.[8, 9] Officers and enlisted military personnel, and their families, often live at different areas on military installations and may be at different risk from WNV and other vector-borne diseases. For example, in an unpublished study conducted by the author, family housing for lower-enlisted families was at high risk for Lyme borreliosis based on the density of the vector species, I*xodes scapularis*. This was disclosed to leadership at the installation, however, there was a failure to act on this information due to a lack of will by leaders to work across departments. At Edgewood, officer quarters are located in the southwest and enlisted quarters are located in the northeast. Although surveillance was not conducted directly in these housing areas, preliminary observation may indicate that enlisted personnel and their families are at higher risk from WNV. The variation in risk of vector- borne diseases based on location of housing is not limited to the United States. In Uganda, the author observed lower enlisted personnel and their families living in base housing adjacent to habitat conducive to high mosquito populations. Further investigations to determine risk vector-borne diseases based on geographic and demographic factors on military installations is suggested.

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Table 1. Fuzzy Logic Model for Prediction and Control of West Nile Virus (WNV)

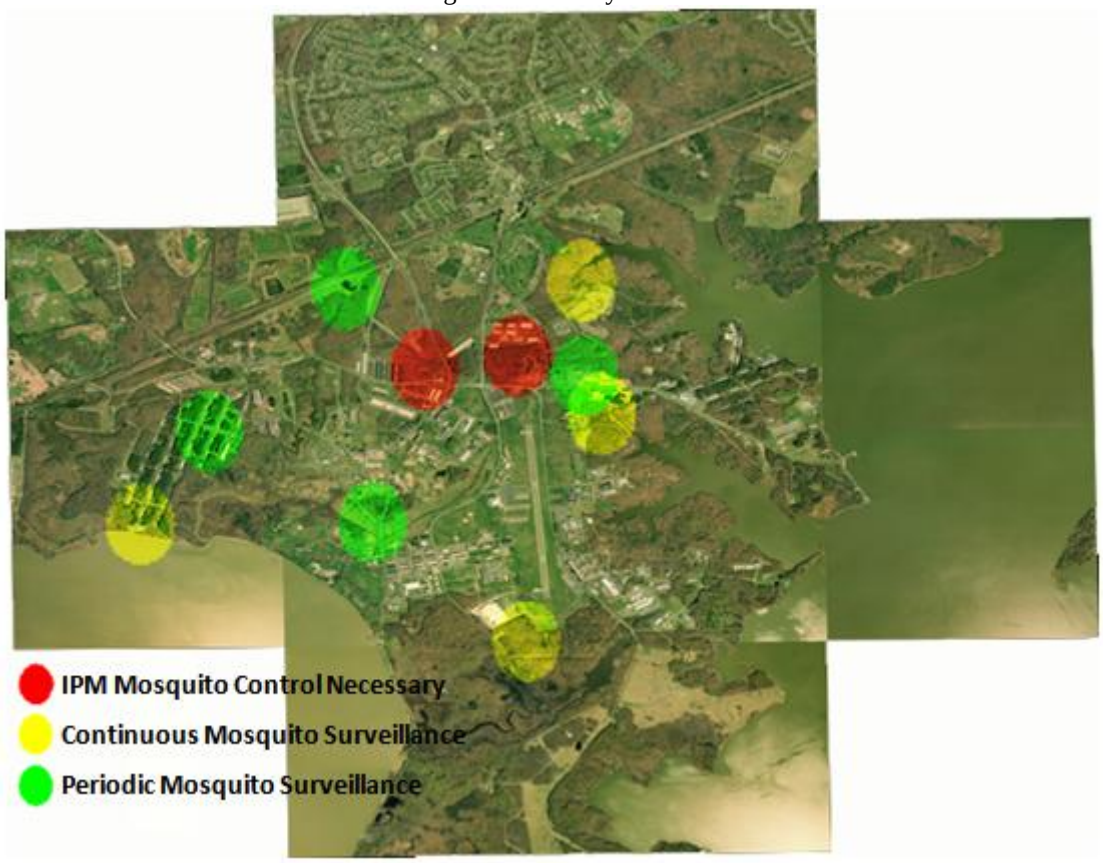
Bird Risk = Σ (fuzzy (wnv antibody x flock)) = BR
Mosquito Risk = Σ (fuzzy (ornithophilic x homophilic)) = MR
High WNVP = 3.65
Moderate WNVP = 2.77
Fuzzy Logic Control Measures for Prevention: WNVPrevention = 3.5

Table 2. Bird Risk and Mosquito Landing Counts and Risk of West Nile Virus at the 10 test sites at the Edgwood military installation.

Site	BirdRisk	Mosq	WNVR
1	1.800	29	2.8
2	1.500	13	1.6
3	1.100	10	1.2
4	1.200	25	3.8*

5	1.700	9	3.6*
6	1.600	4	2.4
7	1.600	7	1.7
8	1.500	43	3
9	1.200	51	2.5
10	1.000	9	1

Figure 1. Levels of Risk of West Nile Virus and recommendations for integrated pest management at 10 sites at the Edgewood military installation.



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