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Supplementary Issue: Disease Vectors

Emergency Mosquito Control on a Selected Area in Eastern North Carolina After Hurricane Irene

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ABSTRACT: Natural disasters such as hurricanes may contribute to mosquito abundance and, consequently, arbovirus transmission risk. In 2011, flooding from Hurricane Irene in eastern North Carolina (NC) resulted in increased mosquito populations that hindered recovery efforts. Budget shortfalls in NC have reduced the functionality of long-term mosquito surveillance and control programs; hence, many counties rely on the Federal Emergency Management Agency for post-disaster mosquito control. This pilot study examines mosquito abundance pre- and post-aerial insecticide spraying at eight study sites in Washington and Tyrrell Counties in rural eastern NC after Hurricane Irene. Percent change was calculated and compared for traps in areas that received aerial pesticide application and those that did not. Traps in spray zones show decreases in mosquito abundance when compared to control traps (treatment: −52.93%; control: 3.55%), although no significant differences ($P = 0.286$) were found in mosquito abundance between groups. Implications of reactive rather than proactive mosquito control responses are discussed.

KEYWORDS: mosquito control programs, hurricane Irene, disaster assistance

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Introduction

Vector-borne diseases are responsible for ca. 17% of all infectious diseases globally with over 1 billion people infected and 1 million deaths recorded annually.[1] The global issue of vector-borne disease must first be addressed at the local level.[2] Mosquitoes are the most common vector, having the ability to transmit >100 pathogens, many of which can cause life-threatening symptoms such as encephalitis, meningitis, and hemorrhagic fever.[1,3] Investment (eg, financial, staffing, etc) in public health research and infrastructure is important for controlling threats such as vector-borne disease.[4] In the United States (US), mosquito control programs (MCPs) protect public health by suppressing nuisance mosquitoes and those that transmit pathogens.[5–8] However, some regions do not have MCPs and/or budget cuts have reduced resources because of which programs may be ineffective.[6,9]

There are >60 mosquito species found in North Carolina (NC), some of which carry pathogens such as La Crosse virus, Eastern equine encephalitis virus, and West Nile virus (WNV), among others.[10,11] There are 43 out of 100 NC counties that have reported human cases of mosquito-borne diseases, yet NC has lost state-level funding for vector control, causing many local MCPs to operate under a smaller staff with limited surveillance and control activities.[9] In 2011, numerous statutes relating to vector control were repealed, including the Public Health Pest Management Section, which served as the primary state-level source of vector control expertise, funding, and response.[9,12] In 2014, the remainder of state-level vector controls were also repealed.[13] Currently, there is no state-level support for mosquito control, creating an extra burden for local emergency managers, MCPs, public works, and public health programs, all of which may play a role in mosquito control (James Bjorneboe, personal communication).

Effective MCPs use surveillance-based targeted control as their primary tool to prevent epidemics by reducing mosquito populations implicated in pathogen transmission and suppressing nuisance mosquitoes.[2,4,6,9,11,14] An effective MCP may (1) monitor/reduce mosquito abundance, (2) monitor vertebrate and invertebrate infection rates, (3) identify and target high-risk regions for control (areas with higher likelihood of mosquito–human interaction), and (4) monitor the efficacy of control measures.[11,14] Programs without arboviral surveillance data make decisions with limited knowledge[14] and may experience delays in outbreak response.[15]

Attempts to reduce the burden of vector-borne diseases were successful during the 1940s through the 1970s, particularly with the use of pesticides and habitat management.[1] However, success of these programs in controlling or eliminating mosquitoes and other vectors and the pathogens they transmit resulted in complacency in decision-makers and reductions in resources.[1] Lack of financial support and infrastructure for preventative public health actions such as vector surveillance and control have encouraged reliance on reactive measures such as pesticides. This reactive stance is one of the primary reasons vector-borne diseases have reemerged throughout the world.[1,16] MCPs are an integral component of environmental and public health programs, and their importance to public health is often underestimated.[5,9,17] These MCPs often experience funding cuts because of their inability to generate revenue.[6] The introduction and rapid spread of WNV through the US since 1999 resulted in the creation of many MCPs[7] and a major boost in government funding to combat the disease.[6,18] However, the interest in WNV has waned in recent years and MCPs budgets have declined.[6,9] A 2012 survey of local health departments in the US showed that vector control was one of the top three environmental health services for which budget cuts negatively impacted services for the public.[19] The same study estimated that 12.7% of vector control programs have been reduced or discontinued in recent years. This is despite the fact that sustained MCPs increase efficiency in emergency response and can be successful at a national average of $2.40 per person per year[15] when compared to vector-borne disease outbreak responses that typically cost millions of dollars.[20–22]

Vector-borne disease epidemics are most likely to occur in regions unprepared to handle the challenges these outbreaks present, whereas areas with effective surveillance methods are more likely to prevent epidemics.[23] Factors that increase the risk of vector-borne pathogen transmission following natural disasters include susceptible hosts, overwhelmed public health services, and disruptions in routine mosquito-control operations.[24] Emergencies strain resources (eg, equipment and staffing) and MCPs rely on effective planning and emergency response rather than help from federal sources.[15] An established and organized MCP greatly enhances recovery efforts rather than relying on emergency response measures.[15] However, when additional resources or funding is needed, the Federal Emergency Management Agency (FEMA) helps coordinate disaster preparation, assistance, and recovery for state and local jurisdictions that do not have the resources or have become overwhelmed following a disaster. State and local jurisdictions may apply for reimbursement of emergency actions through FEMA.[25] Eligibility for FEMA reimbursement includes providing evidence that mosquito abundance, particularly those mosquitoes known to be pathogen vectors or nuisance biters, is markedly higher following the disaster than in the months and years prior.[26] This typically requires surveillance data from multiple years – something localities without MCPs may not have. Additionally, FEMA requires data on prior pesticide use for comparison purposes following a disaster.[26]

In August 2011, Hurricane Irene moved up the eastern coast of the US and made landfall as a Category 1 hurricane at Cape Lookout, NC. The hurricane caused widespread flooding, wind damage, and power outages, and affected eastern NC for weeks.[27] From 2011 through 2012, residents from 38 NC counties received >$160 million in disaster assistance from the state and federal levels.[28] After Hurricane Irene, mosquito abundance increased throughout eastern NC counties as standing water provided oviposition sites and temperatures reached daily highs above 26 °C. Abundant mosquito populations may hinder post-hurricane recovery and reconstruction efforts by impeding emergency management and response services, becoming a nuisance to the community, and creating conditions conducive to the spread of arboviruses.[26,29] In many eastern NC counties, aerial pesticide spraying was conducted to suppress adult mosquitoes, hence reducing public health risks. Consequently, this study investigates the consequences of reactive rather than proactive mosquito control using case studies of two counties in rural eastern NC following Hurricane Irene.

Materials and Methods

Study sites. Study sites in Washington and Tyrrell Counties (Table 1) in eastern NC were utilized for this study. Both counties are bordered to the north by the Albemarle Sound. The areas/populations of Washington and Tyrrell Counties are 901 km^2/13,228 people and 1,007 km^2/4,407 people, respectively. Both counties have Tier-1 status, ie, poorest in the state.[11] In Washington and Tyrrell Counties, 23% and 29% of people, respectively, live below the federal poverty line, compared to the state average of 16%.[30] Washington and Tyrrell Counties were significantly impacted by Hurricane Irene with precipitation totaling 35.5 and 21.5 cm, respectively.[31]

Table 1. Trap locations in Washington and Tyrrell Counties.

SITE DESCRIPTION	LATITUDE/LONGITUDE	TRAP NO.
Washington County		
Pettigrew State Park	35 47'21.77"/-76 21'32.86"	C-1
Cherry St. – Mary Church	35 50'38.47"/-76 21'24.27"	C-2
Summerby	35 56'26.51"/-76 32'28.51"	C-3
Plymouth Airport	35 48'32.94"/-76 45'47.49"	C-4
Tyrrell County		
Alligator – Old 64	35 56'32.35"/-76 06'51.05"	T-1
Oakwood Cemetery – Columbia	35 55'28.6"/-76 14'53.11"	T-2
Gum Neck	35 43'33.07"/-76 06'59.58"	T-3
Travis Road	35 54'13.30"/-76 18'36.55"	T-4

Tornadoes occurred in the town of Creswell in Washington County[32] and city of Columbia in Tyrrell County.[27] Both counties requested and received individual and public assistance funds from FEMA.

Mosquito surveillance. Centers for Disease Control and Prevention light traps were baited with ca. 1 kg of dry ice. Traps were set at eight sites in Washington County (N = 4 sites) and Tyrrell County (N = 4 sites) where adult mosquitoes were prevalent (Table 1). Each trap was set for an approximately 12-hour period from 1900 hours to 0700 hours. Pre-spray surveillance was conducted for two nights (ie, October 9–10, 2011). Data on temperature and precipitation were obtained from NCDC for weather stations nearest each trap site.[31] Weather data were collected: Washington County: Plymouth 5 E weather station, Roper, NC; Tyrrell County: Columbia Ag Gum Neck weather station, Columbia, NC. Overnight low temperatures for the first night of trapping (October 9) were 14 °C for Washington and Tyrrell Counties. Traps were set at all four sites in both counties (N = 8 sites total), the first pre-spray night; however, traps were set at only four sites in Washington County, the second pre-spray night. This was due to travel expenses and safety concerns from high densities of mosquitoes (ie, landing counts of ca. 50 mosquitoes/min). The low temperature for the second night (October 10) of pre-spray trapping (Washington County only) was 18 °C, and 0.025 cm of precipitation was recorded.[31] Aerial spraying (Donald's Flying Service, Pantego, NC) of Trumpet EC pesticide (78% naled [active ingredient], 22% petroleum distillate and emulsifier) occurred overnight on October 15 for all sites in Washington County and all but the Alligator (T-1) and Gum Neck (T-3) sites in Tyrrell County. The T-1 and T-3 sites were used as controls. Traps were set at all eight sites in both counties two days post-spray (October 17). The overnight low temperature for post-spray trapping was 13 °C for both counties and no precipitation was detected.[31]

Mosquitoes were collected and identified to species using a standard key.[33]

Calculations. The percent change in total mosquito population at each trap site was calculated to evaluate the effectiveness of aerial spraying for adult mosquito knockdown. Because two nights of surveillance were conducted in Washington County but not Tyrrell County, the two pre-spray nights were averaged and used to calculate percent change.

$$\text{Percent Change} = \frac{\text{Post-Spray Mosquito Abundance} - \text{Pre-Spray Mosquito Abundance}}{\text{Pre-Spray Mosquito Abundance}} \times 100$$

Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS, version 20.0) (2011, IBM Corp, Armonk, NY). Sites were grouped based on treatment (received aerial spray) or control (did not receive aerial spray). Because of the small sample size, an Independent Samples Mann–Whitney U test was used to determine significant differences ($P < 0.05$) between treatment and control sites.

Results

Mosquito collections. A total of 23,069 mosquitoes representing 23 species were collected during pre- and post-spray surveillance in Washington and Tyrrell Counties. There were 9,668 mosquitoes collected over three nights in Washington County (n = 8,753, two nights pre-spray; n = 915, one night post-spray). In Washington County, *Psorophora columbiae* (n = 4,910) was the most abundant species, followed by *Aedes vexans* (n = 2,141) and *Culex salinarius* (n = 858). A total of 13,401 mosquitoes were collected over two nights in Tyrrell County (n = 6,729, one night pre-spray, n = 6,672, one night post-spray). In Tyrrell County, *Cx. salinarius* (n = 6,197) was the most abundant species collected, followed by *Culex pipiens* (n = 4,123) and *Culiseta melanura* (n = 690).

Efficacy of emergency control measures. Aerial pesticide spraying resulted in decreased mosquito abundance for most study sites. Four sites (Washington County: C-1, C-2, C-3; Tyrrell County: T-4) showed >50% reduction in mosquito abundance. Two sites (Tyrrell County: T-1, T-2) showed an increase in mosquito abundance following aerial spraying. The T-1 site was a control site (no aerial spraying); however, T-2 received aerial spraying.

Statistical analysis. The means of percent change in pre- and post-spray trap counts are (% change ± standard deviation): treatment −52.93 ± 45.40 (median = −73.88); control 3.55 ± 23.58 (median = 3.55). No significant differences (P = 0.286) were found in mosquito abundance between treatment and control groups.

Discussion

Hurricane Irene affected eastern NC for months following the initial flooding event in August 2011. In the current study, Washington and Tyrrell Counties were eligible for federal emergency vector control reimbursement due to potential pathogen vectors affecting emergency response efforts. Mosquitoes require approximately seven days to complete a gonotrophic cycle following flooding events including hurricanes.[25] However, aerial spraying was conducted in these counties almost two months after Hurricane Irene due in large part to funding insecurity and a lack of local funding available, as both counties are among the poorest in the state. No clinical arbovirus cases were observed in humans following the hurricane; however, it is difficult to track asymptomatic cases. Potential vectors were abundant and emergency workers were likely exposed to mosquito bites while repairing damaged homes, etc.

After aerial spraying was conducted in Tyrrell and Washington Counties, mosquito populations dropped substantially (20 to nearly 100%) at most study sites. Despite this, a few sites experienced only minor reductions in abundance following spraying. These differences could be due to variation in topography hindering spray operations and/or variation in timing of eclosion of mosquitoes between sites as we did not monitor immature mosquitoes or adult mosquito age at trap sites. Trap sites not receiving aerial spraying continued to experience substantial mosquito populations. The results indicate that aerial spraying can be an effective method of emergency mosquito control once adult populations have reached large numbers, even months after a flooding event, although recovery and emergency efforts would have likely benefited from control of adult mosquitoes much earlier.

The elimination of state funds supporting local MCPs in NC has burdened resource-poor counties unable to conduct routine surveillance and control. In the current study, financial insecurity in Washington and Tyrrell Counties hindered recovery efforts following Hurricane Irene due to insufficient planning and resources for mosquito control. Many local mosquito and vector control programs are facing similar issues[6] and it is important to continue to track the status of local MCPs. Washington and Tyrrell Counties are currently reliant on reactive measures, despite the known benefits of proactive surveillance and targeted control. There are no comprehensive studies that examine the extent to which counties with limited financial resources function without mosquito control. The current study was limited to two counties requesting assistance following Hurricane Irene; however, looking at other counties with different socioeconomic and geographic characteristics would provide a more thorough analysis for future study.

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Dedication

The authors would like to dedicate this article to the late Dr. Alice Anderson, whose enthusiasm and passion for environmental health was an inspiration to all those around her.

Author Contributions

Conceived and designed the experiments: AA, JH, SR. Analyzed the data: JH. Wrote the first draft of the manuscript: JH. Contributed to the writing of the manuscript: AA, JH, SR. Agree with manuscript results and conclusions: AA, JH, SR. Jointly developed the structure and arguments for the paper: AA, JH, SR. Made critical revisions and approved final version: AA, JH, SR. JH and SR reviewed and approved the final manuscript.

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