


Original Research

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Retrospective Assessment of Preparedness for Mosquito Control Post-Hurricane Florence in North Carolina

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Abstract

Objectives: Ideally, mosquito control programs (MCPs) use surveillance to target control measures to potentially dangerous mosquito populations. In North Carolina (NC), where there is limited financial support for mosquito control, communities may suffer from mosquito-related issues post-hurricane due to lack of existing MCPs. Here, study objectives were to (1) investigate the emergency response of a subset of NC counties post-Hurricane Florence and (2) develop guidelines and policy recommendations to assist MCPs in post-hurricane mosquito control response.

Methods: A survey was administered to a subset of eastern NC counties (an area previously impacted by hurricanes) with various levels of MCPs (from none to well-developed).

Results: All respondents indicated that having Federal Emergency Management Agency (FEMA) training would be helpful in developing a post-hurricane emergency response plan for mosquito control. There was concern related to a lack of knowledge of emergency control methods (eg, aerial/ground, adulticiding/larviciding) post-hurricane. MCP structure (eg, infrastructure, resources, operational plans/policies) could facilitate response activities and help ensure necessary emergency financial support from agencies such as FEMA.

Conclusions: Mosquito control post-hurricane protects public health. Public health and other agencies can be networking resources for MCPs. Policy recommendations include implementation of routine FEMA assistance training workshops to improve an understanding of processes involved in assistance and reimbursement.

Hurricanes and flooding affect mosquito habitats and may influence the transmission of vector-borne pathogens and predictions about infectious disease epidemiology.^{1,2} An initial flooding event resulting from a hurricane or tropical storm typically reduces adult mosquito abundance and washes away existing immature mosquitoes. However, saturated areas may trigger hatching of existing mosquito eggs and also create new mosquito oviposition sites, resulting in increased abundance starting approximately 7 days post-hurricane that often needs to be addressed with adulticides.³ Increases in mosquito occurrence and abundance can boost mosquito-human contact, hence enhancing the potential risk of pathogen transmission.⁴ The risk of arbovirus transmission may, in some instances, be delayed by months after a flooding event due to a variety of behavioral, ecological, and interacting biotic and abiotic factors.^{5,6} Furthermore, an increase in mosquito abundance does not always result in arbovirus transmission; hence, spatiotemporal factors, vector competence, vector blood feeding preference, preventive measures, and other factors must also be considered in risk assessments.^{4,7} West Nile virus (WNV), dengue virus (DENV), malaria, and other mosquito-borne pathogens may be public health concerns after disasters, depending on the region.⁸ Provisions to mitigate these potential threats must begin at local levels in environmental/public health services such as mosquito control programs (MCPs).^{3,9} Some areas have no MCP due to limited funds, lack of community/political support, and/or other reasons.¹⁰ Financial support for MCPs may come, in part, from local, state, and/or federal sources (eg, Centers for Disease Control and Prevention [CDC], Federal Emergency Management Agency [FEMA]). FEMA is responsible for coordinating response, recovery, and communication between federal agencies and the public following disaster events.^{3,9,11,12}

The lack of MCPs in the United States (US) has resulted in a reactive and delayed approach and response to disasters, with emergency managers, environmental/public health programs, and other health professionals handling mosquito issues post-disaster.^{9,13,14} This lack of continuity in MCP personnel with technical skills and historical data have negatively impacted surveillance systems and our ability to proactively defend against vector-borne disease

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outbreaks.^{14,15} Reliable funding sources for MCPs allow for efficiency in mosquito control through long-term surveillance and trained staff.^{3,16} Relationships cultivated among environmental/public health and mosquito abatement services allow innovation, creativity, and diversity of perspectives in how state and local agencies direct their programs and strategize mosquito-borne disease control, and the incorporation of abatement activities into public health services.¹⁶ Public awareness (or lack thereof) of mosquito control can be enhanced by high quality MCP outreach and can facilitate (or hinder, if no support) successful MCPs; hence, local taxes and fees should be considered as another revenue source.^{3,17,18}

Emergency Management Post-Disaster

Hurricanes Florence (2018), Irma and Maria (2017), Matthew (2016), Irene (2011), Katrina (2005), and others left counties and states with damaged infrastructures, flooding, storm debris, and financial debts. FEMA is responsible for immediate assistance with mosquito control issues after a disaster.^{11,19,20} The Robert T. Stafford Disaster Relief and Emergency Assistance Act ensures aid provided by the federal government to state/local governments responsible for relieving suffering and damages caused by a disaster.²¹ The FEMA Public Assistance Program provides funding to states, local governments, and nonprofit groups for emergency response.¹¹ Upon declaring an emergency disaster, Public Assistance can reimburse funding for mosquito control when considered a public health threat.²¹ The county or other entity must first pay the fee in full and then go through the FEMA assistance reimbursement process.

To be eligible for the FEMA reimbursement program, applicants must present legal responsibility and be in a disaster-declared area. Eligibility includes (1) evidence of an increased level of pathogen-transmitting mosquitoes within the disaster area; (2) abundance of pathogen-transmitting mosquitoes influenced by standing water created from the disaster; (3) elevated potential for pathogen transmission and exposure, as arboviral disease is detected through sentinel animals from disaster-impacted regions pre-disaster occurrence; (4) a significant increase in mosquito abundance impacting emergency response workers; and (5) increased secondary infections in the general public verified by medical facilities due to exposure to mosquitoes.²¹ The guidance document, Public Assistance Program and Policy Guide (PAPPG), Appendix G, Mosquito Abatement, FP 104-009-2, is usually reviewed by mosquito control directors to discuss expenses eligible for reimbursements.²⁰ To our knowledge, there are no published minimum criteria for eligibility. If an area does not have an existing MCP, it is possible that representative data can be used from MCPs in surrounding areas. It is also possible to hire external contractors to collect pre- and post-treatment surveillance data after a natural disaster if there is no MCP. In NC, there is currently a renewable 3-year state-level contract with a private contractor (<https://www.ncdps.gov/our-organization/emergency-management/disaster-recovery/public-assistance/mosquito-abatement-contract>). When activated by counties, this contract ensures that a qualified contractor will help with mosquito surveillance and control activities post-disaster. Data and application documents are uploaded and submitted through an online FEMA grant portal. Information submitted to the FEMA grant portal is sent to FEMA for review followed by a state-level review.

Since Hurricane Katrina made landfall in Louisiana (LA) in 2005, the emergency preparedness within state/federal public

health infrastructure has been tested.^{22,23} The aftermath of Hurricane Katrina revealed the lack of storm preparedness operated within public health organizations in many southeastern states.²² Disasters that result in flooding, structural damage, power outages, and other unsuitable living conditions may result in recovery personnel and residents impacted by mosquitoes.²³ Hurricane Matthew (2016) had a major impact on the US, lingering on the coastlines of Georgia (GA), NC, South Carolina (SC), and Florida (FL), and causing an estimated US \$10.4 billion in damage. Hurricanes Irma and Maria impacted Puerto Rico in 2017.²⁴ Florida experienced hurricane/tropical storm activities, resulting in a large emergence of salt marsh mosquitoes, *Aedes taeniorhynchus*.²⁵ Hurricane Maria affected 3.4 million inhabitants in Puerto Rico. Power outages, drinking water shortages, delayed medical assistance, and other disaster-related issues warranted aid from global-scale disaster relief organizations.^{26,27} The US Virgin Islands (USVI) experienced their first Zika virus (ZIKV) outbreak after Hurricanes Irma and Maria.²⁷

On September 14, 2018, Hurricane Florence made landfall as a Category 1 storm in Wrightsville Beach, NC, impacting coastal NC, SC, and Virginia (VA), leading to 53 deaths (including 41 deaths in NC).²⁸ In NC, VA, and SC combined, approximately US \$16–40 billion in damage (ie, 93% of damage was to structures) resulted from Hurricane Florence.²⁸ Hurricane Florence was among the top 10 hurricanes in terms of monetary loss reported in the United States due to uninsured losses from residential flooding.²⁸ NC used over US \$3.5 billion of state/federal funding toward recovery efforts from Hurricanes Matthew and Florence.²⁹ In eastern NC counties (eg, Robeson, Columbus, Cumberland, Craven, New Hanover), there have been multiple instances of record-breaking flooding in recent years.²⁹ After Hurricane Florence, counties received record amounts of rainfall that caused major flooding throughout eastern NC and an increase in mosquitoes that oviposited in flood waters.³⁰ The NC governor (Roy Cooper) designated US \$4 million to 27 counties within the federal disaster declaration after Hurricane Florence. There is currently a lack of consistency in MCP funding across NC; hence, challenges in coordination of emergency mosquito control response occurred.

Limited studies have assessed administrative needs within local environmental and public health organizations in NC regarding MCPs. Consequently, the objectives of the current study are to (1) investigate the emergency response of a subset of NC counties post-Hurricane Florence and (2) develop guidelines to assist counties in preparing for post-hurricane mosquito control response. The central hypothesis is that, with mosquito surveillance structure in place, documentation of mosquito control emergency response activities can occur, hence ensuring the possibility of emergency financial support.

Methods

A 14-question survey (Appendix) was developed by investigators to assess mosquito control procedures conducted after Hurricane Florence (East Carolina University UMCIRB 19-001426). In August 2019 (ca. 1-year post-Hurricane Florence), copies of the survey were emailed to the following 7 NC counties: Brunswick, Pender, New Hanover, Pitt, Craven, Robeson, and Columbus. These representative counties were selected based on government-funded reimbursements, county size, and functionality of MCP (Table 1). Surveys were emailed to mosquito control leadership personnel known through the professional network of the NC

Table 1. NC counties selected to participate in survey via email, 2019 and state assistance post-Florence

County	County Assistance (USD)	Population	Per Capita Assistance (USD)	Area (sq mile)	Functional MCP
Brunswick*	199,913	142,820	1.40	1050	Yes
Columbus*	66,617	55,655	1.20	954	No
Craven	173,899	102,139	1.70	774	Yes
New Hanover	148,587	234,473	0.63	328	Yes
Pender	58,047	63,060	0.92	933	Yes
Pitt*	202,172	180,742	1.12	655	Yes
Robeson	324,992	130,625	2.49	951	No

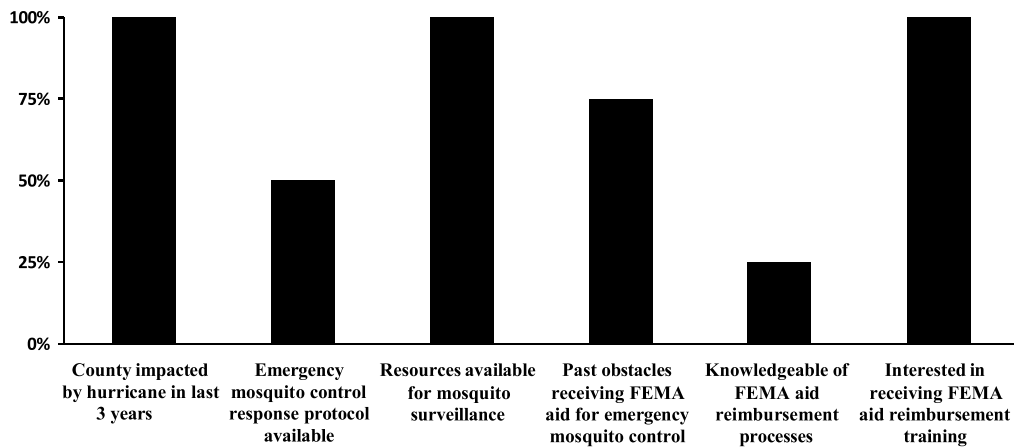


Figure 1. Key findings from 4 eastern North Carolina counties that responded to the survey.

Mosquito and Vector Control Association (www.ncmvca.org). Job titles included Mosquito Control Supervisor, Health Director, Environmental Health Supervisor, Environmental Health Specialist, and Vector Program Manager. If the county did not have an MCP, the survey was emailed to county Environmental Health personnel who would be tasked with overseeing a mosquito control response post-hurricane. One person from each agency completed the survey in each case.

Each survey question was analyzed, and questions were grouped into 5 categories for post hoc analysis: (1) disaster impact experience, (2) program management, (3) MCP networking, (4) FEMA assistance, and (5) FEMA obstacles. Further categorization of survey responses was Implemented, which retrospectively provided data for 4 additional questions for a total of 18 questions. Analysis of responses showed the extent to which counties were affected by the FEMA mosquito abatement reimbursement processes (Supplemental Table). Percentages were placed in a separate column and computed by dividing the frequency of each response classified as “Yes” or “No” response by investigators by the calculated response total (Supplemental Table). A figure was constructed to display some of the key findings from the survey (Figure 1).

Results

Of the 7 counties invited to participate, 4 counties responded to the survey (57% response rate). The mosquito control supervisor (counties with MCP) or person who would oversee organizing a post-hurricane mosquito control response (counties without MCP) completed the survey.

Survey Responses

Each survey question was categorized, and results were tabulated (Supplemental Table). Key findings are shown in Figure 1. The Disaster Impact Experience category showed that all 4 respondents (100%) had experienced increased mosquito abundance related to hurricanes within the 3 years prior to the survey (ie, Hurricanes Dorian [2019], Florence [2018], and Matthew [2016]). For the Program Management category, half of respondents (50%; Brunswick and Pitt Counties) indicated having existing emergency response protocols, and all (100%) indicated that improvements in emergency response plans were needed. All 4 respondents (100%) indicated resources are available for mosquito surveillance; however, there is a continual need for improvements to establish and/or maintain MCPs (ie, funding, equipment, personnel, protocols).

Two respondents (50%; Brunswick and Pitt Counties) indicated having assisted neighboring counties post-hurricane, and 1 surveyed county (25%; Columbus) had received mosquito control assistance from another county (ie, Brunswick) post-hurricane. In the previous 3 years, only 1 county (25%; Brunswick) had applied for FEMA assistance (ie, after Hurricanes Matthew and Florence). In a follow-up conversation with Brunswick County, investigators learned that the FEMA reimbursement process (from entering data into the portal to reimbursement check) can take 3 months to a year. This timing depends on how well the program collects the required data; hence, excellent record keeping is needed to ensure reimbursement. In the case of Brunswick County, the request for FEMA reimbursement was submitted less than a month after the response to Hurricane Florence. However, FEMA requested additional information from Brunswick County 3 times, delaying

the reimbursement process. This timeline is expected to vary between different programs, depending on record keeping, organization, and familiarity with the FEMA documentation/processes required.

All respondents (100%) indicated interest in receiving training on FEMA-related reimbursement processes. All respondents (100%) indicated their emergency response contacts included local, regional, and/or state Environmental/Public Health Services contacts. Two respondents (50%) had trouble with the FEMA application process post-Florence, and the other 2 respondents (50%) did not have difficulty receiving FEMA assistance. Of those not having difficulty receiving FEMA assistance, 1 county (25%) did not apply for FEMA assistance. All respondents going through the FEMA reimbursement process had difficulty providing documentation. All respondents (100%) indicated that training on FEMA reimbursement processes would be beneficial prior to a hurricane season.

Limitations

The sample size was a limiting factor for this baseline study. A future study could be informed by this study and increase the sample size by including additional counties, including areas outside of eastern NC. Focus groups could be convened to collect data as part of a structured discussion with representatives from additional MCPs. Since the survey was administered approximately 1 year after Hurricane Florence, respondents may have experienced recall bias if appropriate records were not available for review.

Discussion

Here, all 4 surveyed counties had previous hurricane-related mosquito issues. However, half of respondents believed their emergency response protocols post-hurricane in relation to mosquito abatement processes were unsuccessful. Respondents showed apprehension and/or difficulty in applying for FEMA mosquito control assistance, and this may have contributed to their not applying for assistance. This should be explored in a future study. The relationship between effective emergency response protocols post-disaster and difficulty receiving FEMA assistance corresponded with their responses in the categories evaluating their experiences with FEMA assistance processes.

Local MCPs within environmental/public health programs or elsewhere that serve the public must be supported financially to ensure the most effective post-emergency response. This practice ensures a proactive rather than reactive response that benefits public health and makes financial sense. Hurricanes will inevitably continue to impact areas like eastern NC, and strategic planning is an important part of emergency preparedness.

One of the objectives here was to develop guidelines and policy recommendations to assist MCPs in post-hurricane mosquito control response. The following brief synopsis of items helps guide those recommendations.

1. Description of Targeted Area for Insecticide Application

A summary of the target area must be provided to FEMA by MCPs. This includes topography, mosquito species and habitats, and public health threat. Mosquito action thresholds may also be provided as supplementary information for target species as they relate to disaster impact on citizens in the area. Before adulticide

and/or larvicide applications are conducted post-disaster, mapping targeted areas for application is required to help determine expense. MCPs should consult with FEMA (in coordination with natural resources and agricultural departments) prior to treatments.²⁰ Treatment area maps must also be provided in supporting documentation for FEMA assistance to be reviewed by US Fish and Wildlife Services for endangered species (eg, excluding state/federal parks). Ideally, these maps are developed and approved in advance of a disaster and updated periodically.

2. Insecticide Treatment Details

Frequency, duration, and timing of treatment may be used to support the need for FEMA assistance demonstrating areas treated with ground-based adulticide (includes routes, mileage, acreage, number/duration of treatments post-hurricane for municipalities experiencing an increase in mosquito activity). Local policies, plans, and procedures should indicate purpose and restrictions (ie, public notice and exemptions from treatments, insecticide label considerations).

Public assistance eligibility requires the use of insecticides registered/approved by EPA to use in urban areas for mosquito control. The insecticide must be used according to the instructions provided on the label of the approved chemical, and precautions must be taken, as instructed on the Safety Data Sheet. Insecticides must be applied by a certified applicator.¹¹

3. Verification From a Local Medical Facility

Applicants must provide documentation verifying that public health is threatened in the impacted area due to increased direct exposure to secondary infections from mosquito contact among the public and with high priority for those with weakened immune systems.¹¹

4. Equipment

Equipment rates are determined by FEMA as a federal guideline to assist in a financial assessment of mosquito control equipment costs.¹¹ The listed equipment rates account for all Robert T. Stafford Disaster Relief and Emergency Act qualified ownership and equipment operation costs. Counties can be reimbursed for equipment usage through an approved list of FEMA equipment rates.

5. Endangered/Threatened Species or Habitat

Treatment areas require preapproval and/or other consultation through a FEMA Environmental Historic Preservation Advisor State Public Assistance Officer.¹¹ FEMA receives consultation from US Fish and Wildlife Service or National Fisheries Service on endangered species prior to permitting insecticide treatments to prevent possible destruction or harm to human and protected populations.²⁰

6. Mosquito Surveillance Data

Surveillance data estimate mosquito population density and/or vector-borne disease incidence before and after a disaster. Adult and larval mosquito surveillance and mosquito landing count data (number of mosquitoes landing on a person per minute) may be used as FEMA surveillance documentation to show increase in or areas with no mosquito abundance. For areas with no MCP, regional data from other programs can be used, or pre- and post-treatment data can be collected by qualified contractors.

The post-hurricane reporting and reimbursement process may be overwhelming, especially for MCPs that are not fully operational due to lack of funding or areas with no MCP. We examined the emergency response of 4 NC counties impacted by Hurricane Florence and developed guidelines that may assist counties in FEMA application processes to receive reimbursement for mosquito abatement opportunities in the future. Results indicate a need for improvement in managing the application processes for FEMA assistance.

Conclusion

Mosquito surveillance and control protects public health. Public health and other agencies can be networking resources for MCPs. Although we surveyed NC counties with a wide range of MCPs (from none to well-developed), the small sample size limits our conclusions. Findings from the survey indicated most respondents had previously encountered trouble during the FEMA reimbursement process, few were knowledgeable about the process, and all programs would like to have more information about the process. Consequently, our recommended guidelines include that MCPs and related organizations in areas impacted by disasters (eg, hurricanes) implement routine FEMA assistance training workshops to improve preparation and understanding of requirements for reimbursement in advance of a disaster. Mosquito control personnel should have a working knowledge of tools such as the FEMA grant portal to ensure application processes are expedited.

Supplementary material. To view supplementary material for this article, please visit <https://doi.org/10.1017/dmp.2023.168>

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Competing interests. The authors declared they have no conflicts of interest.

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