

REGIONAL SURVEY OF MOSQUITO CONTROL KNOWLEDGE AND USAGE IN NORTH CAROLINA

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ABSTRACT. Mosquitoes are a nuisance and can transmit pathogens to humans and other animals, resulting in notable morbidity and mortality. Organized mosquito control programs conduct surveillance, source reduction, treatment of mosquito oviposition sites, and adulticiding to protect public health. However, in some regions, there has been a decline in county and municipal mosquito control programs, and homeowners increasingly contract with private mosquito control companies or address mosquito-related issues themselves at the household level. The extent to which these services are being used, the potential for mosquito and/or insecticide exposure around the home, and the access to these services by individuals of different socioeconomic categories are not known. We conducted regional (western, central, eastern) assessments of public perception and knowledge of mosquito control services in a variety of communities of different socioeconomic categories (low, moderate, high) and types (urban, suburban, rural) in 3 North Carolina counties. We also assessed the respondents' basic knowledge of mosquito-borne diseases. Most respondents thought mosquito control was important to protect against both nuisance mosquitoes and mosquito-borne disease. The majority of people would pay \leq \$50/year for mosquito control and most thought this should be covered by municipal/county taxes. Many respondents (31%, 95% confidence interval [CI] 26–35%) personally undertake mosquito control on their properties, but only 5.3% (95% CI 3.1–7.5%) contract with professional mosquito control services, with no significant differences between region, community type, or socioeconomic category in the proportion using private mosquito control services. While there were significant differences between factor levels (3 regions, 3 community types, 3 socioeconomic categories) in some responses, there were no significant differences observed between respondents, regardless of factor level, in the willingness to contribute funds to a community-based mosquito control program.

KEY WORDS Knowledge, mosquito-borne disease, practices

INTRODUCTION

Effective mosquito control programs suppress nuisance and pathogen-bearing mosquitoes to protect public health (Palmisano et al. 2005, Del Rosario et al. 2014). However, public opinion and support for mosquito control programs may vary (Stewart et al. 2009) and this is likely dependent on the extent to which mosquitoes pose a nuisance and/or cause disease risk in communities. In 2011, North Carolina's Public Health Pest Management section within the Department of Environment and Natural Resources was eliminated due to state budget cuts, removing state-level capacity and coordination of vector-borne disease surveillance, control, and education (Del Rosario et al. 2014). In 2014, additional

budget cuts eliminated the remaining state-funded mosquito control resources (i.e., "state aid" for municipal and county programs), putting the entire administrative and financial burden of mosquito control at the local level (e.g., county, municipality) (Del Rosario et al. 2014). The removal of state funds for mosquito control in North Carolina brought into question the use of outdoor residual insecticide spraying by private pest control operators (i.e., "backyard mosquito control"), paid by individual homeowners, as an alternative approach to mosquito control, but population-based estimates of use are lacking.

Limited studies have shown differences in effectiveness of residual barrier sprays against some mosquito species (e.g., Cilek and Hallmon 2006, Trout et al. 2007, Cilek 2008, Hurst et al. 2012, VanDusen et al. 2015). The same studies show that the effectiveness of barrier sprays depends on factors such as application frequency, weather patterns, type/availability of vegetation in residential yards, and formulated product used. As mosquitoes can develop resistance to active ingredients, including ingredients commonly used in residual barrier treatments (e.g., Richards et al. 2017), surveillance-based targeted control using an integrated mosquito management approach is the best practice.

Due to the abundance and invasion of pestiferous peridomestic mosquitoes (e.g., the invasion of *Aedes albopictus* (Skuse) into the USA by 1985), the

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reduction in municipal mosquito control programs, and the increase in public awareness about arboviruses (e.g., La Crosse virus [LACV], West Nile virus [WNV], dengue virus [DENV], chikungunya virus [CHIKV], Zika virus [ZIKV]), private pest control operators and businesses offering mosquito control services are increasing in number and demand, and some community residents directly contract with these companies for mosquito control. A recent survey of the US mosquito control market reported that >4.6 million mosquito barrier treatments were conducted by pest or lawn control operators in 2016 and that 93.3% of the private mosquito control service revenue was generated from residential accounts (Pest Control Technology 2017).

The factors that determine whether individuals will pay for mosquito control (public or private) have not been well defined, nor are there readily available data on the number of households in need of and/or using these services. A study conducted in New Jersey determined the cost for supporting an effective area-wide mosquito control program to control *Ae. albopictus* (including public education, intensive larvicide/adulticide campaign in early spring months) in 2011 would be an annual cost of approximately \$21/household (Shepard et al. 2014). A separate survey-based study carried out in Washington, DC, in 2010 found that residents classified as low-income households were more motivated (i.e., bothered by mosquitoes frequently) to control mosquitoes than residents of high-income households (Dowling et al. 2013).

Community engagement by mosquito control programs may play a role in increasing the level of public support for these programs (Kolopack et al. 2015). The extent of household- and community-level exposure to mosquitoes (whether nuisance or potential vectors of pathogens) may also be a factor in the level of community support for mosquito control (Thuilliez et al. 2014). However, we have sparse data on current levels of community knowledge and beliefs towards mosquito control, and where data exist, they tend to be restricted to 1 locality (Dowling et al. 2013, Shepard et al. 2014). Furthermore, the use of private, household-based mosquito control is likely dynamic.

To generate current, population-based data for North Carolina on mosquito control practices, attitudes, and beliefs at a household level, we conducted a mail-survey in North Carolina. We sought to determine: 1) factors that determine whether or not people are willing to pay for mosquito control services; 2) knowledge of mosquito-borne diseases and usage of mosquito control techniques in North Carolina communities; and 3) the extent to which differences exist in communities in different regions (western, central, eastern), socioeconomic categories (low, moderate, high), and community types (urban, suburban, rural). We view this as a baseline assessment of community knowledge, use,

and receptiveness to mosquito control practices across North Carolina.

MATERIALS AND METHODS

Study sites

Publicly available property data, extracted from property tax rolls, were collected from 3 counties representing 3 different regions in North Carolina: eastern coastal plain (Pitt), central piedmont (Wake), and western mountains (Henderson): 1) Pitt County Online Parcel Information System: <http://gis.pittcountync.gov/opis>, 2) Wake County Real Estate Property Data Files: <http://wakegov.com/tax/realestate/redatafile/pages/default.aspx>, and 3) Henderson County Geographic Information Systems: <http://www.hendersoncountync.org/gis/taxdownload.html#>. These counties differ in levels of governmental support for mosquito control and population. Wake County is the most populous (1,046,791) (US Census 2016a), with large urban areas (includes Raleigh, the capital of North Carolina) and lacks any governmental mosquito control. Pitt County has the next highest population (177,220 people) (US Census 2016b) and has a small, but active mosquito control and surveillance program (1 full-time staff member) run by the Pitt County Department of Environmental Health. Henderson County is the least populous (114,209 people) (US Census 2016c), and has a mosquito control program within the Environmental Health Program (part-time; <0.4 full-time equivalent) housed within the Department of Public Health.

Communities within each county were classified by socioeconomic category based on the 33% and 66% breaks of the 2015 market values for all Pitt County properties, which were the lowest of the 3 counties: 1) low (\leq \$80,000), 2) moderate (\$80,001–150,000), or 3) high ($>$ \$150,000). These breaks were used to simplify the process of comparing property values between counties. Community types were classified as: 1) urban (neighborhoods within city limits), 2) suburban (i.e., neighborhoods just outside of city limits), or 3) rural (sparsely populated areas outside of suburban areas) based on municipality type (as labeled by the fire services district). Data sheets were sorted to eliminate land parcels containing only land and no residence. After each data sheet was arranged by county, socioeconomic category, and community type, a random sequence was created for each sheet (www.random.org). Efforts were made to include single-family residences, rather than residences within apartment complexes, and to contact property owners rather than tenants, if these differed.

Survey instrument

A 27-question survey was developed and mailed to households (450 per county \times 3 counties = 1,350). Surveys included a self-addressed stamped envelope

addressed to the investigator. Once each survey was completed and returned to the investigator, a \$5 gift card was mailed to the respondents as an incentive for completing the survey. Surveys included questions designed to measure demographics, knowledge of mosquito-borne diseases, personal experiences with mosquito-borne disease, personal protection methods against mosquitoes, and perceptions about the funding source and amount necessary for mosquito control. The survey and study design was approved through the East Carolina University Institutional Review Board (Registration No. 00001149) and reliance agreements were executed for North Carolina State University and Western Carolina University (Federal Wide Assurance No. 00000213).

Data analyses

Frequency tables were created for each survey response and bar graphs were created to visualize the responses. When percentages were reported, 95% confidence intervals (CI) were also included. Statistical analyses were carried out using SPSS (IBM, New York, NY) and differences with $P < 0.05$ were considered statistically significant. Chi-square analyses were used to analyze survey results for most questions. If fewer than 5 responses were received for any question, then a Fisher Exact test was used for the analysis of responses for that question.

RESULTS

Response rate

Out of the 1,350 surveys mailed, 47 were returned as undeliverable. The following numbers of completed surveys ($N = 415$ total) were received from Pitt ($N = 140$), Wake ($N = 143$), and Henderson ($N = 132$) counties representing an overall 32% response rate, with no significant differences in response rate by county. Of the 415 surveys received, we were not able to code the addresses for 13 respondents; hence, these surveys were categorized and analyzed by county only.

Characteristics of survey respondents

Most survey respondents were classified as white (non-Hispanic) (86%, 95% CI: 83–89%) and were between 50–69 years old (52%, 95% CI: 47–57%) (Table 1). We received similar response rates from both males and females. Similar response rates were observed between urban, suburban, and rural communities (Table 2). However, more responses were received from residences classified in the high socioeconomic category (46%, 95% CI: 41–51%) compared with those classified in low (24%, 95% CI: 20–29%) or moderate (29%, 95% CI: 25–34%) socioeconomic categories.

Mosquito exposure and bite protection

We observed significant differences between counties in respondents' recollection of being bitten by mosquitoes in their back yard ($\chi^2 = 14.33$; $df = 2$; $P = 0.006$). Pitt County (94%, 95% CI: 90–98%) and Wake County (95%, 95% CI: 92–99%) respondents showed the highest percentages of respondents being bitten, with Henderson County (84%, 95% CI: 78–90%) showing the lowest number. No significant differences were observed between respondents from different counties, community types, or socioeconomic category in their use of long pants, long-sleeved shirts, or repellents to protect against mosquito bites.

Significant differences ($\chi^2 = 6.27$; $df = 2$; $P = 0.044$) were observed in the use of mosquito repellents between different ages of respondents. Respondents that were ≥ 60 years old were less likely (responded "no" to wearing repellent) (24%, 95% CI: 18–31%) to wear insect repellent compared with respondents 18–39 (19%, 95% CI: 9–28%) or 40–59 (14%, 95% CI: 8–19%) years old.

Mosquito control by respondents

Table 3 shows that, for all counties, community types, and socioeconomic categories, removal of empty containers (e.g., tires, flowerpots, birdbaths) was a common method (67%, 95% CI: 63–72%) for reducing mosquito abundance. Female respondents (72%, 95% CI: 66–78%) were significantly ($\chi^2 = 5.00$; $df = 1$; $P = 0.025$) more likely to remove empty containers compared with male respondents (62%, 95% CI: 55–69%). There were no significant differences between counties or community types in removal of empty containers that could potentially hold water. However, a significant difference in removal of containers was noted between socioeconomic categories ($\chi^2 = 8.61$; $df = 2$; $P = 0.014$). Respondents in the moderate (76%, 95% CI: 69–84%) socioeconomic category were most likely to remove containers, followed by respondents in low (67%, 95% CI: 58–77%) and high (60%, 95% CI: 53–67%) socioeconomic categories.

No significant differences were observed between counties, socioeconomic categories, or community types in the use of drainage systems for storm water, wearing appropriate clothing, wearing insect repellent, or cleaning gutters of leaves. Some respondents commented that they also used other methods for avoiding mosquito bites, e.g., staying inside, lighting citronella candles/torches, using a mosquito (and other insect) collection device in the backyard, planting lemongrass (*Cymbopogon* spp.) and marigold (*Tagetes* spp.) plants, dryer sheets, taking vitamin B, operating a fan on the porch, screened porch, installation of gutter guards to prevent debris, handheld propane fogger, hose/sprayer to treat yard for insects.

Approximately 31% of total respondents personally applied insecticides to their properties to target

Table 1. Characteristics of survey respondents by age, gender, and ethnicity. *N* = 415.

Characteristic	<i>n</i> (%)	95% CI ¹
Age group (years)		
18–29	14 (3.4)	1.6–5.1
30–39	51 (12.3)	9.1–15.4
40–49	51 (12.3)	9.1–15.4
50–59	109 (26.3)	22.0–30.5
60–69	107 (25.86)	21.6–30.0
≥70	82 (19.8)	15.9–23.6
Unknown	1 (0.2)	0.0–0.7
Gender		
Male	207 (49.9)	45.1–54.7
Female	205 (49.4)	44.6–54.2
Unknown	3 (0.7)	0.0–1.5
Ethnicity		
White (non-Hispanic)	357 (86.0)	82.7–89.4
Black (non-Hispanic)	31 (7.5)	4.9–10.0
Hispanic or Latino	5 (1.2)	0.2–2.3
Asian or Pacific Islander	6 (1.4)	0.3–2.6
American Indian or Alaskan Native	5 (1.2)	0.2–2.3
Multiracial	2 (0.5)	0.0–1.1
Middle Eastern	5 (1.2)	0.2–2.3
Unknown	4 (1.0)	0.0–1.9

¹ CI, confidence interval.

mosquitoes (Table 3). No significant differences were observed in personal application of insecticides to properties between counties or community types; however, significant differences were observed between respondents from different socioeconomic categories ($\chi^2 = 8.45$; *df* = 2; *P* = 0.015). Respondents in the moderate socioeconomic category (40%, 95% CI: 31–49%) were more likely to apply insecticides on their properties than those in the high (34%, 95% CI: 24–43%) or low (24%, 95% CI: 18–31%) socioeconomic categories.

Twenty-two total respondents (5%, 95% CI: 4–8%) reported they contracted with professional pest control operators for mosquito control and other arthropod-related services (e.g., ants, spiders, fleas, ticks). There were no significant differences observed between counties, community types, or socioeconomic categories in the reported contracting of professional pest control services.

Importance of mosquito control

Significantly more respondents from each county, community type, and socioeconomic category indicated that mosquito control was important (classified as either very important or important) compared with other choices (neither important nor unimportant; unimportant) (Fig. 1).

Knowledge of municipal or county mosquito control program

We observed significant differences in awareness of municipal/county mosquito control programs within counties ($\chi^2 = 25.94$; *df* = 2; *P* < 0.0001) and community types ($\chi^2 = 9.64$; *df* = 2; *P* = 0.008). No differences in awareness were observed between socioeconomic categories. Respondents in Pitt County (19%, 95% CI: 12–25%) were more likely to be aware of a mosquito control program, followed by Henderson (10%, 95% CI: 6–17%) and Wake (1%, 95% CI: 0–2%) counties.

No significant differences were observed between counties, community types, or socioeconomic categories in the notification of respondents for mosquito control treatments or the desire to be notified; most respondents reported that they were not notified yet they desired to be notified.

When respondents were asked if they had the opportunity to opt out of mosquito control treatments, significant differences were observed between different counties ($\chi^2 = 7.92$; *df* = 2; *P* = 0.019), but not between different community types or socioeconomic categories. Respondents in both Henderson (65%, 95% CI: 44–86%) and Wake (67%, 95% CI: 40–93%) counties indicated not having the opportunity to opt out of sprays, while more respondents from Pitt County (92%, 95% CI: 84–100%) also were not able to opt out of sprays.

No significant differences were observed between counties, community types, or socioeconomic categories in the desire to opt out of sprays, with most respondents (≥74%) indicating they would not want to opt out of mosquito control treatments. Likewise, no significant differences were observed between counties, community types, or socioeconomic categories in knowing or wanting to know

Table 2. Characteristics of survey respondents in 3 North Carolina counties.

	Henderson		Wake		Pitt		Total	
	<i>n</i> (%)	95% CI ¹	<i>n</i> (%)	95% CI	<i>n</i> (%)	95% CI	<i>n</i> (%)	95% CI
Community type								
Urban	42 (32)	24–40	46 (33)	25–41	41 (31)	23–39	129 (32)	28–37
Suburban	44 (33)	25–41	42 (30)	23–38	48 (36)	28–45	134 (33)	29–38
Rural	46 (35)	27–43	50 (36)	28–44	43 (33)	25–41	139 (35)	30–39
Socioeconomic category								
Low	31 (24)	16–31	40 (29)	21–37	27 (21)	14–28	98 (24)	20–29
Moderate	41 (31)	23–39	33 (24)	17–31	44 (34)	25–42	118 (29)	25–34
High	60 (46)	37–54	65 (47)	39–55	60 (46)	37–54	185 (46)	41–51

¹ CI, confidence interval.

Table 3. Which of the following actions have you taken or plan to take to protect yourselves from mosquitoes?

	Total (%)	95% CI ¹
Removal of empty containers such as tires, flowerpots, birdbaths	279 (67)	63–72
Use of drainage system for storm water, such as ditches	92 (22)	18–26
Personal application of pesticides targeting mosquitoes	128 (31)	26–35
Personal protection by wearing appropriate clothing	184 (44)	40–49
Personal protection by wearing insect repellent	309 (75)	70–79
Hiring professional mosquito control services	22 (5)	3–7
Cleaning gutters of leaves, pine needles, and other debris	190 (46)	41–51
Other	38 (9)	6–12
None	26 (6)	4–9

¹ CI, confidence interval.

what is being sprayed by mosquito control programs. Most respondents did not know what was being sprayed, but would like to be informed on this.

Funding for mosquito control

Significant differences were observed between respondents from different counties in their willingness to pay for mosquito control because of either

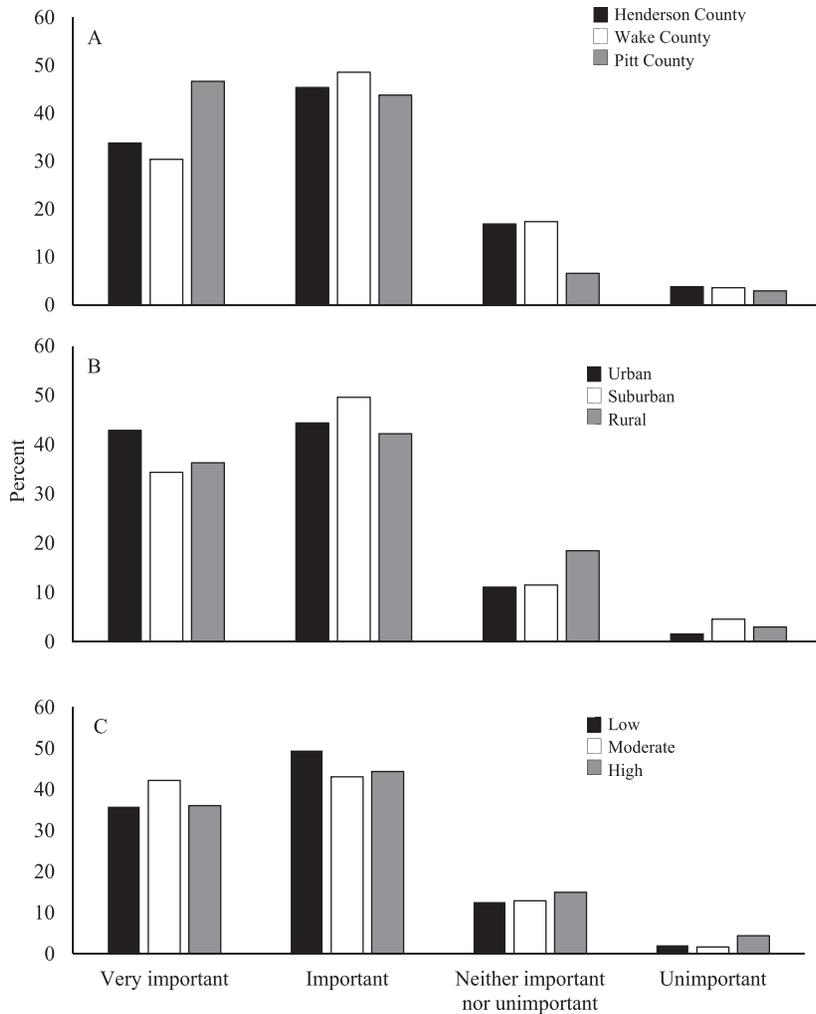


Fig. 1. How important is mosquito control to you? Responses are organized by (A) county, (B) community type, and (C) socioeconomic category.

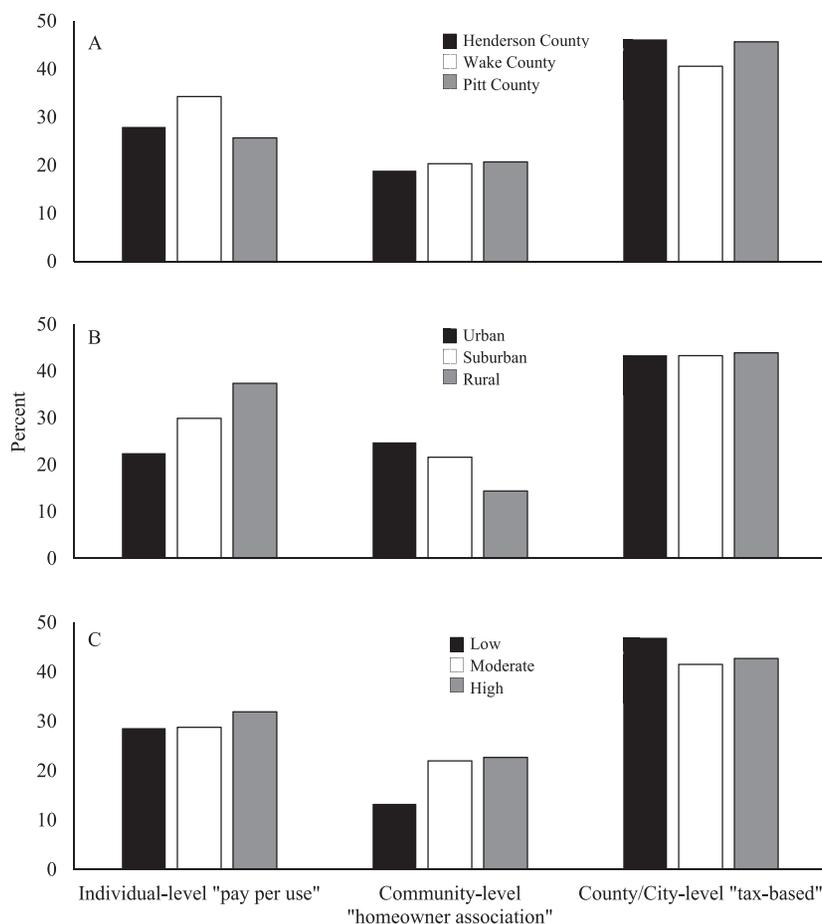


Fig. 2. If you are willing to pay for mosquito surveillance and control, should it be individual "pay per use," community-level "neighborhood and/or homeowner's association," or county/city "tax-based" system? Responses are organized by (A) county, (B) community type, and (C) socioeconomic category.

fear of mosquito-borne disease (51%, 95% CI: 46–56%) or nuisance mosquitoes (48%, 95% CI: 44–53%). Henderson County respondents ranked highest in fear of mosquito-borne disease, while Pitt County ranked highest in stating that nuisance mosquitoes would convince them to pay for mosquito control. No significant differences were observed between respondents of different community types or socioeconomic categories for willingness to pay for mosquito control due to disease or nuisance.

For respondents that were willing to pay for mosquito control, respondents from different counties or socioeconomic categories did not have significant differences in the overall preferred method for payment (individual pay per use, homeowner's association, taxes). For this question, respondents were allowed to choose >1 response. We observed significant differences ($\chi^2 = 7.09$; $df = 2$; $P = 0.029$) between community types in the "individual pay per use" choice as the preferred method of payment for mosquito control. Respondents in rural (37%, 95% CI: 34–52%) communities

were more likely to choose this method, compared with suburban (30%, 95% CI: 25–41%) or urban (23%, 95% CI: 16–32%) respondents. No significant differences were observed between respondents of different community types for the other methods of payment (homeowner association or taxes). Regardless of county, community type, or socioeconomic category, most respondents that were willing to pay for mosquito control thought this should be a service funded by county/city taxes (43–44%), rather than an individual-level pay-per-use system (29–30%), or at the community level (e.g., homeowner's association) (20%) (Fig. 2). Some respondents commented that the existing tax base (e.g., property tax) should be used to pay for this service, rather than adding a new tax earmarked for mosquito control.

No significant differences were observed between respondents of different counties, community types, or socioeconomic categories in the amounts they would be willing to pay for mosquito control. Respondents were willing to pay the following amounts per year to eliminate mosquitoes in their

yards: \leq \$50 (63%, 95% CI: 59–68%), \$100 (20%, 95% CI: 16–23%), \geq \$300 (5%, 95% CI: 3–7%), no response (12%, 95% CI: 9–15%).

Knowledge of mosquito-borne disease

No significant differences were observed between respondents of different counties, community types, or socioeconomic categories in the belief that ZIKV or WNV were issues in their respective communities. Respondents did not believe that these viruses were of concern in their communities. No significant differences were observed between respondents of different counties or community types in thinking that DENV was an issue in their respective communities. However, significant differences were observed between respondents of different socioeconomic categories for this question ($\chi^2 = 12.18$; $df = 2$; $P = 0.034$). Here, respondents categorized as either low (54%, 95% CI: 46–66%) or moderate (53%, 95% CI: 37–56%) socioeconomic category showed greater concern (responding “yes” or “maybe” as a community issue) about DENV, followed by those classified as high (43%, 95% CI: 36–51%) socioeconomic category.

Significant differences were observed between respondents from different counties in thinking that LACV was an issue ($\chi^2 = 10.40$; $df = 2$; $P = 0.034$). In this case, Pitt County (67%, 95% CI: 59–75%) respondents were ranked highest for concern (responding “yes” or “maybe” as a community issue) for LACV, followed by Henderson (57%, 95% CI: 48–66%) and Wake (53%, 95% CI: 45–61) counties. No significant differences were observed for concern about LACV between respondents from different community types or socioeconomic categories.

DISCUSSION

In the current study in North Carolina, 44% (95% CI: 39–49%) of respondents believed that mosquito control should be funded using existing county/municipal taxes. In a separate survey-based study (although the survey question was framed differently), most respondents from Key West, FL (85%), and fewer respondents from Tucson, AZ (38%), agreed or strongly agreed that mosquito control was the homeowner’s responsibility (Haenchen et al. 2016). At the time of the aforementioned survey (in 2012), DENV was circulating in Florida and WNV was present in Arizona. Clearly, differences are observed between different communities in the USA about the role of mosquito control and funding source. These difference could be due, in part, to differences in perceptions of disease risk.

In the current study, responses from most participants about how much they were willing to pay for mosquito control (when given the following choices: \leq \$25, \$25, \$50, \$100, \$300, $>$ \$300) fell into the \leq \$50/year range. However, we did not ask how much was actually spent by participants. A

previous New Jersey study showing an estimated cost of a mosquito control program targeting *Ae. albopictus* at approximately \$21/household per year (Shepard et al. 2014) is in line with our estimate. Other studies have shown that 51% of Key West, FL, residents, 45% of Tucson, AZ, residents, and 41% of Madison, WI, residents were willing to pay at least \$100/year for mosquito control (Dickinson and Paskewitz 2012, Dickinson et al. 2016). The Wisconsin study further analyzed the population and determined that residents were more willing to pay to control nuisance mosquitoes, compared to targeting only WNV-infected mosquitoes (Dickinson and Paskewitz 2012).

Our finding that approximately 31% of respondents personally apply insecticides to their properties for mosquito control implies that a large proportion of residents may be directly handling insecticides to control mosquitoes. This finding indicates that more detailed information needs to be collected to better assess personal and household practices. For example, additional evidence is needed in order to determine whether respondents included personal protection (i.e., application of repellents) as part of their responses, what they defined as insecticides, how specific the insecticide product was to mosquito control, and the frequency and doses of these applications. We did not quantify how much money is spent annually by North Carolina homeowners on insect repellents for their bodies/clothing and insecticides they apply to their properties, but this figure would be another assessment of people’s willingness to pay for mosquito control.

Regardless of county, residents in the low socioeconomic category may be at higher risk of mosquito-borne disease if they do not have adequate funding for mosquito control (whether by personal use on property or by contracting with private companies) and there is no local municipal or county mosquito control program. However, we did not observe differences in responses to personal mosquito control usage by socioeconomic status. Although no regional, socioeconomic, or community-level differences were observed in the use of insect repellent, wearing appropriate clothing, or other personal or household protection methods, a number of alternative practices (e.g., planting grasses or plants, taking vitamin B, using citronella candles, and using insect collecting devices) were reported. This suggests a desire by the public to avoid mosquito bites and the need for increased public health messaging to relay evidence-based practices and promote available educational and control resources.

Residents of Pitt and Henderson counties were more aware of mosquito control services in their counties and concerned about LACV than other arboviruses. Increased awareness could be because both Pitt and Henderson counties have tax-funded mosquito control programs. The pattern of awareness followed the level of investment of each county, with Pitt having the largest investment and the highest

awareness. The concern about LACV may also be influenced by mosquito control activity and due to Henderson County being endemic for LACV. Likewise, more human cases associated with eastern equine encephalitis virus and WNV are prevalent, although at very low rates, in eastern North Carolina (where Pitt County is located). La Crosse virus is endemic in western North Carolina and human cases reported in other counties within North Carolina often have a history of travel to endemic areas. From 2006 to 2015, LACV was responsible for the majority (>80%) of human arboviral cases in North Carolina (Byrd 2016). The observation that Pitt County residents were concerned about LACV rather than other arboviruses known to occur with their county suggests a need for education and outreach services to the general public. Similarly, most residents did not know which insecticide was being sprayed by their county program, but stated they would like to know. Residents of Pitt and Henderson counties also have the opportunity to directly opt out of sprays, although some respondents did not appear to know this was an available option. Taken together, these data suggest that effective communication to the public about local disease risk, mosquito control benefits and options, and homeowner protection methods should be increased.

We found that older (≥ 60 years old) respondents were less likely to use insect repellent than younger respondents. This age group has a higher risk of experiencing severe disease, should they become infected with neurotropic mosquito-borne viruses other than LACV. For instance, people >50 years old infected with WNV are at high risk of developing encephalitis (CDC 2017).

Communication to stakeholders is an important component of a successful mosquito control program (Thuilliez et al. 2014, Kolopack et al. 2015). In many cases, routine public engagement and education campaigns about surveillance and control efforts and services provided may increase public support for well-managed community-focused programs. In the current study, only respectively 19% (95% CI: 12–25%) and 10% (95% CI: 6–17%) of respondents in Pitt and Henderson counties, where municipal/county mosquito control programs exist, were aware of the programs. It is likely that the public would be interested in learning the basics of mosquito biology, and how to prevent/reduce mosquito oviposition sources, hence reducing nuisance mosquitoes and the probability of mosquito-borne disease in communities. Community organizers and environmental/public health agencies should encourage stakeholders (e.g., homeowners, businesses) to take a more active role in voicing awareness and support for municipal/county mosquito control programs. In addition, private pest control operators may be recommended as an alternative, especially when public programs are underfunded or not available. As we continue to experience emerging and reemerging mosquito-borne diseases in the USA, leadership is needed to facilitate

communication between public/environmental health personnel, mosquito control operators, and the public to improve community protection.

Some limitations of our study are as follows. First, at the time of the current survey (in mid-2016), WNV had been periodically detected in North Carolina, imported cases of DENV and CHIKV had been detected in North Carolina (although not highly publicized), and ZIKV was prominently publicized. A severe case of La Crosse encephalitis in an 11-year-old boy was also highly publicized in regional (western North Carolina) news media during the survey period. The emergence of ZIKV in the USA in 2016 may have influenced some survey responses (due to increased news coverage and public health messaging) and this should be considered when interpreting our findings. Second, this is a small-scale study that surveyed residents from only 3 counties in North Carolina. We surveyed only homeowners in North Carolina; hence, results may not represent residents that may be renting properties. Our assessment of socioeconomic status category, using property value as a proxy, may not capture the real purchasing power of a household, and thus may poorly link with responses about willingness to pay. Furthermore, residents classified in the high socioeconomic category were overrepresented since they responded to the survey to a greater degree in all 3 counties. Mail-in surveys may also bias towards older people, and we did have the largest response from people over the age of 60. An increased sample size including additional counties across North Carolina might change the survey response summary and should be evaluated further. We did not assess the amount of time survey respondents spent outdoors each day and/or the type of landscape (with respect to mosquito habitat) in which residences were located.

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