Fighting the Bite during a Crisis: Capabilities of Florida Mosquito Control Districts during the COVID-19 Pandemic

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Research article

Keywords: Fight the bite, arbovirus, United States, survey, Culex, Zika, Aedes

Posted Date: October 16th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-48111/v2>

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Version of Record: A version of this preprint was published at BMC Public Health on April 8th, 2021. See the published version at <https://doi.org/10.1186/s12889-021-10724-w>.

Abstract

Background: The national wide lockdown order imposed in early April 2020 due to the COVID-19 pandemic complicated mosquito control activities across the United States (US), and Florida is no exception. Mosquito control programs are the first line of defense against mosquitoes-borne pathogens in the state of Florida. The purpose of this study was to examine the capabilities of Florida mosquito programs to implement key mosquito measures during the COVID-19 pandemic.

Methods: In a self-administered online survey, we examined capabilities of all Florida mosquito control programs during the COVID-19 pandemic (both state-approved mosquito districts (N=63) and open programs (N=27). Descriptive statistics were used to summarize information about the characteristics of responding programs, as well as the implemented mosquito control and surveillance activities. We used bivariate analysis to compare the characteristics of these responding programs and the self-reported mosquito measures.

Results: Of the recruited mosquito control programs, 77 completed the survey (85.6% response rate; 77/90). Of these, 57.5% (n=42) were Board of County Commissioners (BOCC) mosquito control programs, 21.9% (n=16) were independent tax district programs, 13.7% (n=10) were municipal mosquito control programs, and only 6.8% (n=5) were either health or emergency department mosquito control programs. Except for arbovirus surveillance, most programs either fully or partially performed larval (61.8%) and adult (78.9%) surveillance; and for *Aedes aegypti* (85.2%, n=54), *Aedes albopictus* (87.3%, n=55), *Culex quinquefasciatus* (92.1%, n=58), and *Culex nigripalpus* (91.9%, n=57).

Conclusions: Findings underscore the importance of ongoing mosquito control activities and suggests that Florida mosquito control programs are vigilant and have significant capability to handle potential mosquito-borne disease threats, but arbovirus surveillance systems; laboratory testing of mosquito pools and testing of human and nonhuman specimens for arboviruses are needed during pandemics as well.

Background

There is no question that mosquito-borne diseases pose a special challenge to public health practitioners and mosquito control districts (1-3), owing to their complex nature (biological transmission complexity) (4), and potential to transmit infectious agents that can lead to mosquito-borne diseases, such as malaria, dengue fever, chikungunya, Zika fever, and West Nile fever(5). In Florida, *Aedes* and *Culex* continue to be major vector genera (6-8), with the State of Florida having been ground-zero for local transmission of Zika and Dengue viruses (9). The state is also in close proximity to Latin American where viruses such as Zika and dengue viruses are endemic (2, 10). Therefore, surveillance as a key aspect of effective mosquito control and prevention (2, 11, 12) is particularly important in economically depressed subtropical areas of the United States (US) that institutionally struggle to sustain mosquito-control efforts (13).

Now the national wide lockdown order imposed in early April 2020 due to the COVID-19 pandemic has complicated mosquito control activities (14), and questioned how we should manage mosquito control programs in the wake of pandemics or crisis. The Centers for Disease Control and Prevention (CDC) underscore the importance of initiating or continuing the delivery of mosquito control and public health organization services during public health emergencies and responses to natural disasters in order to reduce the risk of mosquito-borne disease(15). Despite the importance of mosquito control as a basic public health function, the National Association of County and City Health Officials (NACCHO) recently reported COVID-19 impacts on mosquito programs that operate under the auspices of local health departments [21].

This, coupled with major funding and capacity gaps, may put pressure on some already struggling programs, and may exacerbate timely and effective response to (re)emergent arboviral diseases in the future (16). Therefore, to understand the challenges inherent in implementing mosquito activities during a pandemic, we assessed the capabilities of Florida state-approved mosquito control districts and open programs to carry out mosquito control activities at a time when Florida was still under heightened awareness of and lockdown over the COVID-19 pandemic. Our findings will shed light on the capabilities of Florida mosquito control programs, the first line of defense against mosquitoes-borne pathogens as well as will shed light on challenges experienced by these programs to carry out mosquito control during a pandemic.

Method

Study design

In June 2020, a cross-sectional survey was conducted using an anonymous electronic self-administered survey distributed to all Florida state-approved mosquito districts (n=63) and open programs (n=27) for a total of 90 programs. A team from the University of Miami conducted the survey, at a time when the state was in a COVID-19 “full phase 1 re-opening plan”(17), and on a 2-3 month postponement of the arbovirus surveillance program as the state virus laboratory in Tampa was redirected for COVID-19 response.

Survey Instrument

The survey instrument was refined from previous similar studies to address the study objectives (16, 18-20) (Supplemental File 1). The survey was pilot tested with four mosquito districts and distributed using the online survey software Qualtrics. We obtained a list of agency contact information from the Florida Department of Agriculture and Consumer Services (FDACS).

The questionnaire consisted of 45 questions divided into six sections: mosquito district characteristics (8 questions); staffing levels (4 questions); mosquito program capabilities and challenges (19 questions); program budgets (4 questions); COVID-19 communication (1 question); participant demographics and partnership needs (9 questions). Almost all but 10 questions consisted of closed-ended questions, which allowed respondents the opportunity to provide further detail if the ‘other, please specify’ option was

selected from the multiple choices. The closed-ended questions were multiple choice, categorical, dichotomous and Likert-type questions with five-point rating scales.

Study population

We recruited all Florida mosquito control districts (n=63) and open mosquito programs (n=27) via email. Representatives of mosquito control districts and open programs were contacted directly and were asked to complete the survey by July 6. We sent follow-up reminders weekly during the first two weeks in June, and every three days during the third and fourth week. Follow-ups constituted of both email and telephone calls. The survey closed on July 6, 2020. Program respondent anonymity was maintained and the researchers blinded by using the web-based survey tool (Qualtrics) for collection and collation of data.

Data analysis

Survey responses were analyzed using IBM SPSS Statistics, version 26.0 (21). We used descriptive statistics to summarize information about characteristics of responding mosquito control districts and programs, implemented mosquito control and surveillance activities. Bivariate analysis was used to compare the characteristics of responding mosquito control districts and programs and the self-reported mosquito measures performed. Characteristics including respondents' mosquito program capabilities such as arbovirus, population, environmental surveillance and routine control of domestic mosquitoes including challenges were analyzed using the χ^2 test or Fisher's exact test.

Results

Mosquito district and program characteristics

Of the recruited mosquito programs, 77 of 90 mosquito programs completed the survey (85.6% response rate). Five state-approved programs did not respond to the survey: one was due to a death of the mosquito director; one had the person responsible for mosquito activities reassigned to COVID-19 response, one did not have a person responsible for mosquito activities at the time of the survey and two did not respond. The excluded totaled four programs, including two that indicated not having a mosquito program (Baker and Lafayette Counties), and two with missing information on relevant measures. The final sample was 73 programs (58 state-approved mosquito control districts and 15 open programs (Figure 1).

Of the responding programs, 57.5% (n=42) were Board of County Commissioners (BOCC) programs, 21.9% (n=16) were independent tax districts, 13.7% (n=10) were municipal programs, and only 6.8% (n=5) were either health or emergency departments (Table 1).

Table 1

Organizational Structure	n	%	95% CI
Board of County Commissioners (BOCC)	42	57.5	(46.6 – 69.9)
Municipal	10	13.7	(6.8 – 21.9)
Independent Tax District	16	21.9	(12.3 – 31.5)
Health Department or other department	5	6.8	(1.4 – 13.7)
Program Type			
State-approved program	58	79.5	(69.9 – 89.0)
Open programs	15	20.5	(11.0 – 30.1)
Did you operate during the pandemic?			
Yes, fully open and operating	44	60.3	(49.3 -72.6)
Partially operating with limited activities	27	37.0	(24.7 – 47.9)
No, closed operation until further notice	2	2.7	(0.0 – 6.8)
To what extent has COVID-19 affected your mosquito activities?			
High	4	7.5	(1.9 – 15.1)
Medium	12	22.6	(11.3 – 34.0)
Low	37	69.8	(56.6 – 81.1)
Did you carry out non-chemical control activities?			
Yes	37	54.4	(42.6 – 67.6)
No	29	42.6	(30.9 – 55.9)
Not sure	2	2.9	(0.0 – 7.4)
Did you conduct pesticide resistance testing?			
Yes, full capacity	11	16.2	(7.4 – 25.0)
No, we did not	51	75.0	(64.7 – 85.3)
Yes, limited capacity	4	5.9	(1.5 – 11.8)
Do not have a program or not applicable	2	2.9	(0.0 – 7.4)
Will the pandemic affect your FY2020-2021 budget?			
Yes	12	17.1	(10.0 – 25.7)
No	22	31.4	(20.0 – 42.9)
Not sure	36	51.4	(38.6 – 62.9)

Organizational Structure	n	%	95% CI
Can you hire interns/seasonal workers?			
Yes	16	25.4	(15.9 – 36.5)
No	47	74.6	(63.5 – 84.1)
Are staffing levels inadequate due to furloughs or lockdown?			
Yes	8	12.3	(4.6 – 21.5)
No	57	87.7	(78.5 – 95.4)
Did you communicate with state/local public health departments?			
Yes	50	71.4	(60.0 – 81.4)
No	20	28.6	(18.6 – 40.0)

Note: Excluded are four programs with missing data and those that do not have mosquito programs (e.g., Barker and Lafferty County). Health department includes emergency management programs.

Nearly all responding programs (97.3%, n=71) indicated performing mosquito control activities either fully or partially during the COVID-19 pandemic, and only 7.5% (n=4) reported being highly impacted by COVID-19. Three quarters of respondents (75.0%, n=51) did not perform arboviral surveillance (send mosquito pools for testing). It seems possible that these results are due to the redirection of the state health laboratory in Tampa to COVID-19 response, and similarities of testing supplies needed for COVID-19 and mosquito pool testing.

Mosquito program capabilities for arbovirus, population, environmental surveillance

When asked whether the COVID-19 pandemic will affect mosquito control programs' fiscal year (FY) 2020/2021 budgets, 82.9% (n=58) indicated no or that they were not sure (results not shown). There is also large variation in the levels of main vector surveillance and control activities performed (Table 2). For example, while most mosquito control programs (both state approved and open programs) did not perform arbovirus surveillance using flocks of sentinel chickens (84.1%, n=58) or mosquito pooling (83.8%, n=68), the majority maintained larval and adult surveillance during the COVID-19 pandemic (61.8%, n=68 vs 78.9%, n=71). More than three-quarters of mosquito control programs (70.8%, n=65) did not conduct arbovirus surveillance using tidal surveillance, while 35 (49.3%) of programs monitored temperature, wind and daylight. Of the responding mosquito programs, 36 (53.7%) used rain gauges for surveillance, $p<0.022$. Climatic factors such as temperature, humidity, and rain have been linked to mosquito abundance and transmission (13, 22, 23).

Table 2

Arbovirus surveillance activities conducted during the COVID-19 pandemic, Florida, USA, June 2020

Did you conduct arbovirus surveillance during the COVID-19 pandemic using the following:	Yes, full or limited capacity n (%)	No, we did not conduct this arbovirus surveillance activity n (%)	<i>Fisher's exact test</i> <i>P-value</i>
Using flocks of sentinel chickens			
Board of County Commissioners (BOCC) Programs	9 (21.4)	33 (78.6)	0.110
Other Mosquito Programs	2 (7.4)	25 (92.6)	
Using mosquito pooling			
Board of County Commissioners (BOCC) Programs	9 (22.0)	32 (78.0)	0.102
Other Mosquito Programs	2 (7.4)	25 (92.6)	
Larval surveillance			
Board of County Commissioners (BOCC) Programs	26 (61.9)	16 (38.1)	0.588
Other Mosquito Programs	16 (61.5)	10 (38.5)	
Adult surveillance			
Board of County Commissioners (BOCC) Programs	36 (85.7)	6 (14.3)	0.081
Other Mosquito Programs	20 (69.0)	9 (31.0)	
With rain gauges			
Board of County Commissioners (BOCC) Programs	17 (42.5)	23 (57.5)	0.022
Other Mosquito Programs	19 (70.4)	8 (29.6)	
Tidal surveillance			
Board of County Commissioners (BOCC) Programs	9 (23.1)	30 (76.9)	0.145
Other Mosquito Programs	10 (38.5)	16 (61.5)	
Temperature, wind and daylight was monitored			
Board of County Commissioners (BOCC) Programs	24 (57.1)	18 (42.9)	0.088
Other Mosquito Programs	11 (37.9)	18 (62.1)	

Note: Other mosquito programs includes independent tax district, municipal and health department or other department mosquito programs

Mosquito program capabilities for routine control of domestic mosquitoes

Despite the wide variation in performed mosquito activities, both state-approved and open programs either fully or with limited capacity performed control activities for *Aedes aegypti* (85.2%, n=46), *Aedes albopictus* (87.3%, n=55), *Culex quinquefasciatus* (92.1%, n=58), and *Culex nigripalpus* (91.9%, n=57). In some areas, *Aedes aegypti* has not been identified hence no control measures for this species were performed (eight BOCC mosquito control programs, one independent tax district and one health department program). Likewise, one independent tax district reported the same for *Aedes albopictus* and *Culex nigripalpus*. Except for rain gauge, a Fisher’s exact test of independence showed no statistically significant difference in the proportion of programs that performed mosquito measures by organizational structure (Table 3).

Table 3

Arbovirus control activities conducted during COVID-19 pandemic, Florida, USA, June 2020

Did you engage in routine control of these domestic mosquitoes during the COVID-19 pandemic?	Yes, full or limited capacity n (%)	No, we did not conduct this arbovirus surveillance activity n (%)	Species not identified in the area n (%)	χ^2	P-value
<i>Aedes aegypti</i>					
BOCC Programs	28 (71.8)	3 (7.7)	8 (20.5)	3.373	0.185
Other Mosquito Programs	18 (72.0)	5 (20.0)	2 (8.0)		
<i>Aedes albopictus</i>					
BOCC Programs	34 (89.5)	4 (10.5)	0 (0.0)	1.889	0.389
Other Mosquito Programs	21 (80.8)	4 (15.4)	1 (3.8)		
<i>Culex quinquefasciatus*</i>					
BOCC Programs	35 (92.1)	3 (7.9)	0 (0.0)		0.666
Other Mosquito Programs	23 (92.0)	2 (8.0)	0 (0.0)		
<i>Culex nigripalpus</i>					
BOCC Programs	35 (92.1)	3 (7.9)	0 (0.0)	1.548	0.461
Other Mosquito Programs	22 (88.0)	2 (8.0)	1 (4.0)		

Note: BOCC, Board of County Commissioners; Other mosquito programs, includes independent tax district, municipal and health department or other department mosquito programs; *, Fisher's exact test

Discussion

Although the risk of arboviral diseases in Florida is high, mosquito control programs in the state are vigilant and have significant capability to control potential mosquito-borne disease threats as evidenced by their surveillance and control efforts implemented during the COVID-19 pandemic. We observed a relatively impressive first line of defense against the effects of mosquito-borne disease arboviruses – mosquito control, so much that there is some form of state-approved mosquito control district and/or open mosquito program within each of Florida's counties. The mandate for these programs is to not only fight pest mosquitoes but also fight species of mosquitoes that have potential to transmit mosquito-borne pathogens (24, 25).

While we observed marked differences in the level of performed mosquito control activities, most mosquito programs (both state-approved and open programs) performed mosquito control activities either fully or partially particularly larval and adult surveillance during a time when the world was facing great challenges due to the COVID-19 pandemic. The majority of programs also engaged in routine control of domestic mosquitoes such as *Aedes* species of mosquitoes that can cause *Aedes*-borne arboviruses like dengue virus (DENV), chikungunya virus (CHIKV), yellow fever virus (YFV), and Zika virus (ZIKV) including *Culex* species of mosquitoes that can cause *Culex*-arboviruses like SLEV and WNV. In addition, mosquito surveillance is enhanced by the existence of ongoing meteorological, climatological, and water table monitoring (26). This demonstrates that although Florida mosquito control programs have a long history and experience with the *Culex*-arbovirus systems, they are also capable of providing mosquito control against *Culex* species as evidenced by the quick mitigation of the 2016 ZIKV outbreak (27).

Florida's mosquito control capabilities maybe attributed to the very nature of the ongoing mosquito control programs with permanent personnel, including several research projects that have been implemented over the years on mosquitoes and mosquito-borne diseases. These efforts combined, may have enhanced mosquito control capabilities as it relates to effective, efficient, and environmentally good mosquito control (28). However, the observed lack of arbovirus surveillance for serology and pool testing limits the generation of evidence about when to anticipate a surge in arbovirus infection and in mosquito control programs' ability to detect or monitor arbovirus presence. This finding was also reported by Hadler et al. in their "assessment of arbovirus surveillance 13 years after the introduction of WNV in the US" (29). It is critically important to improve arbovirus surveillance, build the capacity of mosquito control districts and programs laboratories capacity to allow programs to investigate the circulating strains of arboviruses and to establish viral genomic databases as a reference for current and future research.

Limitations

The study had many limitations, primarily stemming from its design as a cross-sectional and self-report survey, a typical limitation of survey studies(30). Self-report can be affected by different biases, since the respondents may tend to give the expected answer or that those who consented to participate in the study were not a representative sample (e.g., those who participated may have been less busy). However, when properly structured and implemented as was done in this study, self-report provided valuable information on the views, and opinions of mosquito programs regarding their capabilities to implement key mosquito measures to mitigate emergence and/or re-emergence of arthropod-borne arboviral diseases during the COVID-19 pandemic. Moreover, the response rate was high (85.6%). In addition, we did not measure the capabilities of mosquito control programs from the perspective of residents or beneficiaries (e.g., whether the number of mosquitos decreased or increased in Florida). This is an important issue for future research. We are also aware that other factors not directly examined in the study might also be important. For example, many environmental and geographical factors create differential vector densities and levels of human exposure (1, 13, 18, 31, 32), resulting in differentiated surveillance and control needs(2, 16).

Conclusion

Our findings suggest that despite the imposed COVID-19 lockdown, the vast majority of responding programs in Florida did not cease mosquito control operations. Those that remained open were mostly BOCC, municipal and independent tax district programs. However, the impact of COVID-19 testing was evident on arboviral surveillance (serology and pool testing) due to the redirected state laboratory in Tampa. This study highlights the importance of ongoing mosquito control activities and suggests that Florida mosquito control programs are vigilant and have significant capability to handle potential mosquito-borne disease threats as evidenced by their continued surveillance and control efforts during the COVID-19 pandemic, and mitigation of the 2016 Zika disease pandemic. Findings have implications for local and state mosquito programs including national associations as they work towards mitigating the impacts that COVID-19 has had particularly on health department programs.

Abbreviations

FL: Florida

WNV: West Nile virus

BOCC: Board of County Commissioners

FDACS: Florida Department of Agriculture and Consumer Services

IRB: Institutional Review Board

CDC: Centers for Diseases Control and Prevention.

Declarations

Acknowledgements

We thank participating Florida mosquito control districts and open programs, and the four directors who reviewed and pilot tested the survey. This paper is dedicated to the memory of Billy Padgett, the Mosquito Program Director for Dixie County, Florida, who died, tragically at the time of this survey due to Covid-19. We would like to thank the many public health professionals who are working behind the scenes and on the front lines, and making an remarkable impact during this global pandemic.

Ethics approval and consent to participate

The Institutional Review Board (IRB) at the University of Miami determined that this study did not require IRB review since it posed the lowest amount of risk to potential subjects, was exempt from IRB approval and informed consent was not obtained from study participants.

Funding

This research was supported in part by the CDC (<https://www.cdc.gov/>) Grant 1U01CK000510-03): Southeastern Regional Center of Excellence in Vector-Borne Diseases: The Gateway Program. The funder (CDC) had no role in the design of the study, the collection, analysis, and interpretation of data, or in writing the manuscript.

Availability of data and materials

The datasets generated and/or analyzed during our study are not publicly available since the data could potentially identify some of the respondents when linked to other data but are available from the corresponding author on reasonable request.

Authors' contributions

MIK was responsible for study design, developed the research questions and objectives for this study and performed analysis as well as wrote the manuscript. WRL, RX and CM led the data cleaning and data exploratory. OV was responsible for reviewing the manuscript for important intellectual content. All authors read and approved the final manuscript.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

Figure 1

Florida Mosquito Control Districts that responded to the survey conducted in June 2020 by program type

Supplementary Files

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