Fighting the Bite during Pandemics: Florida Mosquito Control District Capabilities during the COVID-19 crisis

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Abstract

Background

The national wide lockdown order imposed in early April 2020 due to the COVID-19 outbreak has complicated mosquito control activities across the United States (US), and Florida is no exception. Mosquito control districts and public health programs are the first line of defense against mosquito-borne pathogens in the state of Florida. The purpose of study is to understand how the COVID-19 outbreak has impact the capabilities of mosquito programs to implement key mosquito measures to mitigate emergence and/or re-emergence of arthropod-borne arboviral diseases.

Methods

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

Results

Of the recruited programs, 77 completed the survey (85.6% response rate; 77/90). 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. Except for arbovirus surveillance, most programs either fully or partially performed larval (61.8%) and adult (78.9%) surveillance; and for *Aedes aegypti (71.9%, n = 46), Aedes albopictus (85.9%, n = 55), Culex quinquefasciatus (88.2%, n = 60), and Culex nigripalpus (90.5%, 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 questions 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], and is in close proximity to Latin American where viruses such as Zika and dengue viruses are endemic [2, 10]. Surveillance is a key aspect of effective mosquito control and prevention [2, 11, 12], and 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 outbreak has complicated mosquito control activities [14], and questioned how we should manage mosquito control programs in the wake of pandemics. 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” [15] to reduce the risk of mosquito-borne disease. Yet, the National Association of County and City Health Officials (NACCHO) reported COVID-19 impacts on mosquito programs that operate under the auspices of local health departments [21], despite the importance of mosquito control as a basic public health function.

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 crisis. Our findings will shed light on Florida mosquito control districts and program, the first line of defense against mosquitoes-borne pathogens in the state’s capabilities as well as challenges in carrying out mosquito control activities 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 mosquito programs (n=27) via email. Representatives of mosquito control districts and 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 χ² test. Ordinal data collapsed into groups and analyzed as dichotomous groups, a conservative approach when using non-parametric tests.

CC, the nature of self-reported changes to practice and characteristics of the respondents.

Results

Mosquito district/program characteristics

Of the recruited programs, 77 completed the survey (85.6% response rate; 77/90). 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 (Fig. 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
Characteristics of responding mosquito control districts during the COVID-19 outbreak, Florida, USA, June 2020

| 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 outbreak? | |
|--------------------------------------|---|---|
| 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 outbreak affect your FY2020-2021 budget? | |
|---------------------------------------------------|---|---|
| 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 outbreak, 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 outbreak will affect their fiscal year (FY) 2020/2021 budgets, 82.9% (n = 58) indicated no or that they were not sure. There is also large variation in the levels of main vector surveillance and control activities performed (Table 2). For example, while most programs did not perform arbovirus surveillance using flocks of sentinel chickens (80.8%, n = 59) or mosquito pooling (78.1%, n = 57), the majority maintained larval and adult surveillance during the COVID-19 outbreak (61.8%, n = 68 vs 78.9%, n = 56). Except for health departments, more than half of the responding programs (53.7%, n = 36) used tidal surveillance $p < 0.041$, while 35 (49.3%) of programs monitored temperature, wind and daylight, with 19 (29.2%) using rain gauges for surveillance, $p < 0.041$. Prior studies have noted the importance of climatic factors such as temperature, humidity, and rain in influencing mosquito abundance and transmission [13, 22, 23].
Table 2
Arbovirus surveillance activities conducted during the COVID-19 outbreak, Florida, USA, June 2020

| Did you conduct arbovirus surveillance during COVID-19? | Yes, full capacity n (%) | No, we did not (%) | Yes, limited capacity n (%) | \( \chi^2 \) | P-value |
|----------------|--------------------------|--------------------|--------------------------|----------|----------|
| **Using flocks of sentinel chickens** | | | | | |
| Board of County Commissioners (BOCC) | 3 (7.1) | 34 (81.0) | 5 (11.9) | 5.999 | 0.423 |
| Independent Tax District | 1 (6.7) | 14 (93.3) | 0 (0.0) | | |
| Municipal | 0 (0.0) | 8 (100.0) | 0 (0.0) | | |
| Health Department or other department | 1 (25.0) | 3 (75.0) | 0 (0.0) | | |
| **Using mosquito pooling** | | | | | |
| BOCC | 7 (17.1) | 32 (78.0) | 2 (4.9) | 4.171 | 0.654 |
| Independent Tax District | 1 (7.1) | 12 (85.7) | 1 (7.1) | | |
| Municipal | 0 (0.0) | 9 (100.0) | 0 (0.0) | | |
| Health Department or other department | 0 (0.0) | 4 (100.0) | 0 (0.0) | | |
| **Larval surveillance** | | | | | |
| BOCC | 20 (47.6) | 16 (38.1) | 6 (14.3) | 6.515 | 0.368 |
| Independent Tax District | 9 (69.2) | 2 (15.4) | 2 (15.4) | | |
| Municipal | 2 (25.0) | 5 (62.5) | 1 (12.5) | | |
| Health Department or other department | 2 (40.0) | 3 (60.0) | 0 (0.0) | | |
| **Adult surveillance** | | | | | |
| BOCC | 27 (64.3) | 6 (14.3) | 9 (21.4) | 11.096 | 0.085 |
| Independent Tax District | 9 (60.0) | 2 (13.3) | 4 (26.7) | | |
| Municipal | 5 (55.6) | 4 (44.4) | 0 (0.0) | | |
| Health Department or other department | 2 (40.0) | 3 (60.0) | 0 (0.0) | | |
| **With rain gauges** | | | | | |
| BOCC | 14 (35.0) | 23 (57.5) | 3 (7.5) | 13.140 | 0.041 |
| Independent Tax District | 11 (73.3) | 1 (6.7) | 3 (20.0) | | |
| Did you conduct arbovirus surveillance during COVID-19? | Yes, full capacity | No, we did not (%) | Yes, limited capacity | χ² | P-value |
|--------------------------------------------------------|---------------------|--------------------|-----------------------|----|---------|
|                                                        | n (%)               | n (%)              |                       |    |         |
| Municipal                                              | 3 (37.5)            | 4 (50.0)           | 1 (12.5)              |    |         |
| Health Department or other department                  | 1 (25.0)            | 3 (75.0)           | 0 (0.0)               |    |         |
| **Tidal surveillance**                                  |                     |                    |                       |    |         |
| BOCC                                                   | 8 (20.5)            | 30 (76.9)          | 1 (2.6)               | 13.376 | 0.037  |
| Independent Tax District                               | 9 (64.3)            | 5 (35.7)           | 0 (0.0)               |    |         |
| Municipal                                              | 1 (12.5)            | 7 (87.5)           | 0 (0.0)               |    |         |
| Health Department or other department                  | 0 (0.0)             | 4 (100.0)          | 0 (0.0)               |    |         |
| **Temperature, wind and daylight was monitored**       |                     |                    |                       |    |         |
| BOCC                                                   | 18 (42.9)           | 18 (42.9)          | 6 (14.3)              | 7.147 | 0.307  |
| Independent Tax District                               | 6 (40.0)            | 7 (46.7)           | 2 (13.3)              |    |         |
| Municipal                                              | 3 (30.0)            | 7 (70.0)           | 0 (0.0)               |    |         |
| Health Department or other department                  | 0 (0.0)             | 4 (100.0)          | 0 (0.0)               |    |         |

**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* (71.9%, n = 46), *Aedes albopictus* (85.9%, n = 55), *Culex quinquefasciatus* (88.2%, n = 60), and *Culex nigripalpus* (90.5%, n = 57). In some areas, *Aedes aegypti* has not been identified hence no control measures for this species were performed (eight BOCC programs, on independent tax district and one health or other department program). Likewise, one independent tax district reported the same for *Aedes albopictus* and *Culex nigripalpus*. Except for rain gauge and tidal surveillance, a chi-square test of independence showed no statistically significant difference in the proportion of programs who performed mosquito measures by organizational structure (Table 3).
Table 3
Arbovirus control activities conducted during COVID-19 outbreak, Florida, USA, June 2020

|                  | Yes, full capacity n (%) | No, we did not n (%) | Yes, limited capacity n (%) | Species not identified in the area n (%) | $\chi^2$ | $P$-value |
|------------------|--------------------------|----------------------|-----------------------------|-----------------------------------------|---------|-----------|
| **Aedes aegypti**|                          |                      |                             |                                         |         |           |
| BOCC             | 20 (51.3)                | 3 (7.7)              | 8 (20.5)                    | 8 (20.5)                                | 11.613  | 0.236     |
| Independent Tax District | 9 (60.0)                | 2 (13.3)             | 3 (20.0)                    | 1 (6.7)                                 |         |           |
| Municipal        | 4 (57.1)                 | 3 (42.9)             | 0 (0.0)                     | 0 (0.0)                                 |         |           |
| Health Department| 2 (66.7)                 | 0 (0.0)              | 0 (0.0)                     | 1 (33.3)                                |         |           |
| **Aedes albopictus**|                        |                      |                             |                                         |         |           |
| BOCC             | 23 (60.5)                | 4 (10.5)             | 11 (28.9)                   | 0 (0.0)                                 | 5.638   | 0.776     |
| Independent Tax District | 8 (53.3)                | 2 (13.3)             | 4 (26.7)                    | 1 (6.7)                                 |         |           |
| Municipal        | 5 (62.5)                 | 2 (25.0)             | 1 (12.5)                    | 0 (0.0)                                 |         |           |
| Health Department| 2 (66.7)                 | 0 (0.0)              | 1 (33.3)                    | 0 (0.0)                                 |         |           |
| **Culex quinquefasciatus**|                      |                      |                             |                                         |         |           |
| BOCC             | 25 (65.8)                | 3 (7.9)              | 10 (26.3)                   | ~                                       | 6.222   | 0.399     |
| Independent Tax District | 12 (80.0)                | 0 (0.0)              | 3 (20.0)                    | ~                                       |         |           |
| Municipal        | 4 (57.1)                 | 3 (7.9)              | 10 (26.3)                   | ~                                       |         |           |
| Health Department| 2 (66.7)                 | 0 (0.0)              | 1 (33.3)                    | ~                                       |         |           |
| **Culex nigripalpus**|                          |                      |                             |                                         |         |           |
| BOCC             | 25 (65.8)                | 3 (7.9)              | 10 (26.3)                   | 0 (0.0)                                 | 10.034  | 0.348     |
| Independent Tax District | 12 (80.0)                | 0 (0.0)              | 2 (13.3)                    | 1 (6.7)                                 |         |           |
| Municipal        | 4 (57.1)                 | 2 (28.6)             | 1 (14.3)                    | 0 (0.0)                                 |         |           |
| Health Department| 2 (66.7)                 | 0 (0.0)              | 1 (33.3)                    | 0 (0.0)                                 |         |           |
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 that were carried out during the COVID-19 outbreak. 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 program within each of Florida’s counties whose mandate is to fight pest mosquitoes and 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 programs (97.3%, 71 of 73), (including state-approved mosquito control districts and open mosquito programs) performed mosquito control activities either fully or partially particularly larval and adult surveillance during a time when the world is facing great challenges due to the COVID-19 outbreak. 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 [29]. This demonstrates that although Florida mosquito programs have a long history and experience with the *Culex*-arbovirus systems, these programs have the capability to provide mosquito control against *Culex* species as well, and as evidenced by the quick mitigation of the 2016 ZIKV outbreak [26].

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, which combined may have enhanced mosquito control capabilities as it relates to effective, efficient, and environmentally good mosquito control [27]. However, the lack of arbovirus surveillance for serology and pool testing observed during the COVID-19 crisis limits the generation of evidence about when to anticipate a surge in arbovirus infection and in 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 [28]. It is critically important to improve arbovirus surveillance, build the captivity 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.

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 outbreak, and mitigation of the 2016 Zika disease outbreak. 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

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.

Availability of data and materials

The datasets supporting the conclusions of this article are available upon reasonable request to the first author.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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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.

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Figures
Figure 1

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

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