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A SURVEY OF PROGRAM CAPACITY AND SKILLS OF FLORIDA MOSQUITO CONTROL DISTRICTS TO CONDUCT ARBOVIRUS SURVEILLANCE AND CONTROL

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ABSTRACT. Effective and efficient surveillance systems are key for preventing arthropod-borne diseases. We examined the capacity of Florida mosquito control districts (both state-approved and open programs, $n = 90$; 48.9% response rate). Questions centered on budgets, staffing levels, equipment, vector control measures, and staff perceptions of own agency's capacity to implement routine surveillance and vector control activities. Bivariate analyses indicate that districts with relatively large budgets have advanced capacities regarding staffing levels, employee specialties, mosquito control equipment, conduct routine surveillance and vector control yet they serve only a small proportion of the population. Independent tax districts' average annual budgets were 9 times higher than Board of County Commissioners programs in fiscal year 2017–18. Most respondents indicated that staff is appropriately trained, and has timely access to information and needed equipment for mosquito surveillance and control. Slightly more than half of respondents feel they are understaffed. Perceived understaffing may compromise mosquito surveillance and control efforts in some districts.

KEY WORDS Arboviruses, GIS, United States, variation, Zika, ZIKV

INTRODUCTION

Surveillance is the backbone of arthropod-borne disease prevention and control (Eldridge 1987, Fernandes et al. 2018, Moise et al. 2018a), and is particularly important in economically depressed subtropical areas of the USA where institutions struggle to sustain mosquito control efforts (Moise et al. 2018c). Climate change and income inequality are projected to further strain mosquito control efforts and increase human exposure to mosquito-transmitted diseases (Ng et al. 2019, Ryan et al. 2019). Mosquito surveillance and control are ongoing in Florida, and diverse programs (both state-approved and open programs) are the 1st line of defense against mosquito-borne pathogens.

In Florida, mosquito control funding is generally from county and local city governments, with only 1–2% of the total funding coming from the state budget. State funding is based on a tier system (Tier I, II, and III), with Tier III programs (those with less than a million dollars in annual budgets) receiving the most state funding and Tier I mosquito control districts receiving minimal support (programs have annual budgets of more than $3 million). The only exceptions occur during a major disease outbreak or a disaster (such as a hurricane), when the state and the Federal Emergency Management Agency (FEMA) might provide additional support. Tier II programs have annual budgets of $1 million to $3 million. In addition, reimbursements from FEMA are problematic due to long wait times.

To ensure public protection from the emergence and reemergence of mosquito-borne viral diseases, mosquito control and public health experts have called for better data and a review of mosquito surveillance and control systems and capacity since the introduction of West Nile virus (WNV) in the USA (Hadler et al. 2014, Gerding et al. 2016, Rund et al. 2019). While Florida has dealt with other outbreaks in the past (e.g., Saint Louis encephalitis, WNV) (Day and Curtis 1999, Day and Stark 2000, Day 2001, Reisen et al. 2008), and continues to monitor the prevalence of arboviruses often year-round, the 2016 Zika virus (ZIKV) disease and 2019 dengue fever outbreaks underscore the importance of conducting mosquito control district capacity reviews.

The objective of this study is to assess the capacity of Florida mosquito control districts to conduct timely, effective surveillance and control, focusing on budgets, staffing levels, equipment, the functional range of vector control activities, and staff perceptions of their agency's ability to implement such activities. To the best of our knowledge, this study is the 1st systematic, statewide survey of mosquito districts in Florida on critical capacity issues that affect surveillance and control efforts.

MATERIALS AND METHODS

A cross-sectional survey was conducted through self-administered, online questionnaires to all Florida state-approved mosquito districts and open programs

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between March and May 2017, a time when the state was still under heightened awareness of and general concern over the 2016 ZIKV outbreak (Moise et al. 2018b). Several survey items were adapted from the surveys of Hadler and colleagues on institutional capacity for surveillance, prevention, and control of WNV, and other arbovirus infections in the USA (Hadler et al. 2014, 2015). New questions tailored to the Florida context were included in the survey, which was pretested with 4 mosquito district organizational structures.

Agency representatives were recruited through emails and phone calls, seeking a representative most knowledgeable of the agency's surveillance and control activities to complete the survey. We regularly followed up by telephone and through emails to enhance response rates and representation by mosquito district organizational structure. Despite these efforts, only 2 municipalities responded. Therefore, information about their program capacity was obtained from the Florida Department of Agriculture and Consumer Services (FDACS), and are excluded from some analyses (e.g., budgets, surveillance and control activities, and perceived capacity).

The current analysis is constrained to questions on mosquito district characteristics, including service population and area extent, staffing levels and expertise, available equipment, budgets, and perceived capacity to implement mosquito surveillance and control. On funding, participants were asked for annual budgets for fiscal year (FY) 2014–15, FY 2015–16 (before and after the ZIKV outbreak), and if their mosquito district had a contingency fund for emergencies allowing them to mobilize adequate trained personnel and other resources to respond rapidly to disease outbreaks and health emergencies. To capture budget increases associated with the ZIKV outbreak, which peaked in late summer to early fall of 2016, months after many counties in Florida had already formulated their upcoming year's budget months, FY 2017–18 mosquito control district budgets were used instead of FY 2015–16. Assessed were current staffing based on the number of personnel (direct hires or contractors) working as $\geq$50 percentage full-time equivalents (FTEs) on surveillance and control, and on the total number of FTEs and perceived gaps by function and expertise (e.g., entomologist, laboratory staff, mosquito and other environmental surveillance staff). Detailed methods for measuring staffing levels are described elsewhere (Hadler et al. 2014, 2015). The University of Miami Institutional Review Board (IRB) determined that this study did not require IRB review since it posed the lowest amount of risk to potential subjects.

Descriptive statistical analysis was performed using IBM SPSS Statistics, version 26.0 (IBM Corp., Armonk, NY). Confidence intervals (CI) were calculated as 90% CI using the χ^2 test for dichotomous variables and make a preliminary comparison of capacities by mosquito district organizational structures (e.g., Board of County Commissioners [BOCC] versus independent tax district). A Likert scale was used to examine the self-reported practices of each responding program based on adult mosquito surveillance, testing mosquito pools for arbovirus presence using own or outside laboratories, and whether programs followed a calendar-based schedule for control. Also examined was the use of adulticides in fogging and spraying to control adult mosquitoes, larviciding, and other community-based source reduction. For simplicity, the 5-point Likert scale responses were reduced to 3: always or almost always, sometimes, and rarely or never.

To control for the size of the served population, the per capita costs of mosquito control (annual budget total per service population) were computed. District service areas were classified as urban or rural based on the 2010 Census Urban and Rural Classification and Urban Area Criteria (US Census Bureau 2010), as follows: 1) urban service areas (50,000 or more persons, $n = 28$ districts); 2) urban-cluster service areas (25,000–50,000 persons, $n = 13$ districts); and 3) rural service areas (<2,500 persons, $n = 1$ district). In Florida, many rural agricultural counties and mosquito districts have larger land area but low population density compared with urban mosquito districts.

RESULTS

Of the 90 districts and open programs recruited for the survey, 44 responded (a 48.9% response rate). The response rate was calculated after accounting for those mosquito districts with incomplete responses to survey questions ($n = 29$) and those that declined to complete the survey ($n = 17$ mosquito agencies). Representatives of the responding mosquito control districts completed the survey online, except one open program whose representative filled out and returned a paper questionnaire. Representatives responding to the survey were executive directors, directors, assistant directors, managers, or supervisors, depending on each district's leadership structure. On education, 45% of the responding representatives had a master's degree, 31% a bachelor's degree, and 24% had lower than a 4-year college education.

In 2017, every county in Florida had some form of mosquito control program. Some counties, such as Bay, Lee, Monroe, and Walton, had mosquito programs that operate under both counties and independent districts. Forty-eight (53%) were state-approved and operated under BOCC or county, and 28 (31%) were municipal or open programs. Of all the mosquito districts and open programs assessed ($n = 90$), two-thirds (58 or 64%) are county-run with some form of state-approved program. Fourteen (16%) are special tax independent districts. Programs operating under the BOCC and county were the most

Table 1. Characteristics of Florida mosquito control districts surveyed in 2017.[1]

Variables	Count (%)	90% CI (proportion)
Organizational structure ($N = 44$)		
Municipality (city or town)	2 (4.44)	(0.01–0.08)
County department	14 (31.11)	(0.24–0.38)
Operates under the Board of County Commissioners	15 (33.33)	(0.26–0.40)
Independent special taxing district	13 (29.54)	(0.22–0.36)
Years of operation ($N = 44$)		
0–15 years	4 (8.88)	(0.05–0.13)
16+ years	40 (88.88)	(0.84–0.94)
Service area (population, $N = 42$)		
Urban service areas (50,000 or more persons)	28 (66.66)	(0.59–0.74)
Urban-cluster areas (at least 2,500 but <50,000 persons)	13 (30.95)	(0.24–0.38)
Rural areas (<2,500 persons)	1 (2.38)	(0.00–0.05)
Service area (mi^2, $N = 40$)		
Less than 500 mi^2	15 (37.5)	(0.30–0.45)
More than 500 mi^2	25 (62.5)	(0.55–0.70)
Size (budget 2014, $N = 39$)		
Less than $100,000	7 (17.94)	(0.12–0.24)
$100,000–$500,000	7 (17.94)	(0.12–0.24)
$550,000–$950,000	9 (23.07)	(0.16–0.30)
$1 million–$7 million	14 (35.89)	(0.28–0.44)
More than $10 million	2 (5.12)	(0.02–0.09)
Size (budget 2016, $N = 39$)		
Less than $100,000	5 (12.82)	(0.07–0.18)
$100,000–$500,000	8 (20.51)	(0.14–0.27)
$550,000–$950,000	8 (20.51)	(0.14–0.27)
$1 million–$7 million	15 (38.46)	(0.31–0.46)
More than $10 million	3 (7.69)	(0.03–0.12)
Has contingency fund for emergencies ($N = 30$)		
Yes	13 (32.50)	(0.25–0.39)
No, not sure or don't not know	17 (67.50)	(0.60–0.752)

[1] The frequency and proportion or percentage of every response were assessed based on the total number of responses to each specific question.

common, each constituting about a third of responding mosquito control districts—33% and 31%, respectively (Table 1). Some county programs were part of a health department (4) or an emergency department (1). Twenty-seven percent (90% CI, 22–36%) were independent districts, and the remainder were municipal programs (4%; $n = 2$). The majority (91%; $n = 40$) of responding districts had been in operation for >16 years. Two-thirds (66%) of responding districts served urban areas and 31% served urban-cluster areas.

Funding sources and levels varied considerably. Funding came mainly from the respective county budgets and property taxes (for independent districts). County programs had lowest average annual budgets, $697,402 (approximately $1.64 per capita), during FY 2014–15 and $1,723,803 ($4.06 per capita) during FY 2017–18. In contrast, independent programs had average budgets of $6,253,148 (9.0 times higher) or $27.01 per capita and $7,453,081 (4.3 times higher) or $32.20 per capita during FY 2014–15 and FY 2017–18, respectively. Per capita program budget ranges were $2.37–$27.01 in FY 2014–15 and $3.23–$32.20 in FY 2017–18. The annual budget for one BOCC program—Miami-Dade County's Mosquito Control Division—increased 9 times more than its annual budget before the 2016 ZIKV outbreak. Although the mean annual district budgets for BOCC and county programs increased slightly between the 2 fiscal budget years, they remained low, relatively. Mean county program budgets, however, increased significantly (by 40% while serving a relatively large average population of 424,259), whereas that of independent districts decreased only slightly over the period (Fig. 1). With only 2 municipalities responding, we excluded municipal budgets from analysis, though the programs tended to serve populations of larger than 500,000 persons. Two-thirds of responding districts indicated not having, or not knowing if their agency had, a contingency fund for control emergencies, including for responding to mosquito-borne viral disease outbreaks.

Findings on staffing showed that the available staff were largely appropriately trained and skilled but their numbers were considerably inadequate. Most (61%; $n = 24$) and 52% ($n = 20$) of question-specific respondents indicated that they did not have adequate staff to conduct effective mosquito surveillance and control, respectively. The mean number of full-time employees among all responding districts was 3.8, with a wide range of 1–24. Ironically, programs with a small number of personnel tended to provide services to larger, mostly rural populations. The total

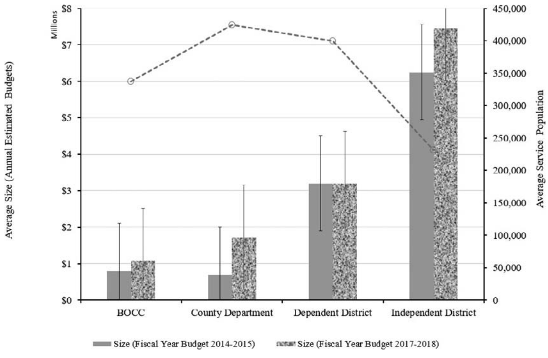

Fig. 1. Average annual budgets by mosquito control district organizational structure by average service population, Florida, 2014 and 2016. Budgets used are for fiscal years 2014–15 (before the 2016 Zika virus [ZIKV] outbreak) and 2017–18 (after the 2016 ZIKV outbreak).

number of full-time employees (including <50% FTEs) for the 44 responding districts was 235 (Table 2). Medical entomologists represented only 5% of the personnel, and laboratory technicians 11%. These 2 categories had the highest perceived staffing gaps. This cadre of staff performs essential, advanced entomological and epidemiological control functions whose implementation such staffing shortages undermine. Most employees (58%) worked on surveillance or other environmental functions, including administrative activities (26%), but even this category operated at two-thirds of perceived needs. One county had only 1 full-time employee.

District respondents are neutral, disagree, or strongly disagree that staffing levels are inadequate to carry out key surveillance and control functions (47.6%: 90% CI, 0.53–0.69; $n = 20$), $P < 0.045$. However, 88.1% (90% CI, 0.91–0.98; $n = 20$) agree or strongly agree that current staff were appropriately trained, $P < 0.948$, and 78.6% (90% CI, 0.75–0.88; $n = 33$) that staff had timely access to the information needed for key control measures, $P < 0.860$ (Table 3). We had asked respondents to also report on their knowledge regarding *Aedes aegypti* (Linnaeus) or *Ae. albopictus* (Skuse) control in the aftermath of the 2016 ZIKV outbreak. A majority of respondents (78.6%, 90% CI, 0.79–0.90; $n = 33$) agree or strongly agree that staff is knowledgeable about how to evaluate new methods for *Aedes* control. Most respondents (69.0%, 90% CI, 0.67–0.81; $n = 29$) also agree or strongly agree that staff has the necessary control equipment.

Findings showed wide variation in implementation levels of main vector surveillance and control activities. A large majority of independent districts conducted all the surveillance and control activities assessed, most frequently (66.7–83.3% always or usually), except for source reduction (only 5 of 12 did it always or usually). Thus, all the 12 independent programs responding to the question reported conducting adult mosquito trapping always or usually, compared with 11 of 14 (78.6%) and 8 of 13 (61.5%) of responding county and BOCC programs, respectively. Almost all responding independent programs (83.3%) also reported always or usually testing mosquito pools for general arbovirus presence in-house, whereas only 6 of 14 (46.9%) and 5 of 13 (38.5%) of county and BOCC programs, respectively, did the same (Table 4). Still, half or more responding county and BOCC programs trapped mosquitos and routinely sprayed for mosquitos, and used adulticides or larvicides, always or usually, though higher percentages of county programs did so than BOCC ones. However, county programs appeared to show wider variability. They had 2 activities, which half the responding districts never or rarely performed while BOCC programs had none reaching 50%. For responding county programs, source reduction was their rarest activity (7, half, sometimes performed it) compared with only 5 of 13 (38.5%) BOCC programs (Table 4). None of these variables was significant in bivariate analysis.

Because only 2 municipalities responded, we reviewed records ($n = 28$) of their surveillance and control activities obtained from the FDACS. We observed marked variation in practices although overall, they revealed a precarious capacity status. For example, programs in 6 municipalities (Baker, Hamilton, Highlands, Lafayette, Marion, and Suwannee) activate only during natural disasters or in the event of heightened mosquito-borne threats. Two programs engaged contractors for control services;

Table 2. Full-time equivalents (FTEs) and specialties of personnel required to carry out the various functions among respondent mosquito control districts, May–August 2017.

Personnel category	2017 actual FTEs	Additional staff needed to achieve full capacity[1]	Operational capacity versus need, 2017 (%)	Increase needed (%)
Medical entomologist	12	17	41.4	141.7
Laboratory technicians	26	26	50.0	100.0
Mosquito/environmental specialists	136	62	68.7	45.6
Surveillance, administrative staff	61	29	67.8	47.5
Total	235	134	63.7	57.0

[1] Defined as the ability to have an environmental surveillance system that includes mosquito surveillance to routinely monitor arboviral activity in larval and adult mosquitoes in all parts of the jurisdiction in which, based on experience, there is the potential for human outbreaks of arbovirus disease.

Table 3. Respondent perceptions of own mosquito control district capacity to implement control measures.[1]

Indicate your level of agreement regarding each of the following statements ($N = 42$)	Agree or strongly agree		Neutral/disagree or strongly disagree		
	Count (%)	90% CI	Count (%)	90% CI	*P*-value
Staff are knowledgeable about how to evaluate new methods for *Aedes* control	33 (78.6)	0.79–0.90	6 (14.3)	0.09–0.21	0.860
Staff is capable of integrating information	33 (78.6)	0.75–0.88	6 (14.3)	0.11–0.24	0.860
Staff is appropriately trained	37 (88.1)	0.91–0.98	2 (4.8)	0.01–0.08	0.948
Staff has timely access to information needed about vector control measures	34 (81.0)	0.81–0.92	5 (11.9)	0.07–0.18	0.384
Staffing levels are adequate to carry out mosquito surveillance	19 (45.2)	0.3–0.46	20 (47.6)	0.53–0.69	0.045*
Staffing levels are adequate to carry out mosquito control	19 (45.2)	0.4–0.56	20 (47.6)	0.43–0.59	0.045*
Agency has the right equipment to carry out mosquito control	29 (69.0)	0.67–0.81	10 (23.8)	0.18–0.32	0.701

[1] Forty-two mosquito district representatives responded to this set of questions and were therefore included in the analysis. Three mosquito districts had missing values. We conducted bivariate analyses using the χ^2 test for dichotomous variables and the *t*-test for continuous variables.
* $P < 0.05$.

Table 4. Level of implementation of main vector surveillance and control activities for those mosquito control districts responding to this question by organizational structure.

	Level of agreement					
	Always or usually		Sometimes		Rarely or never	
	Count (%)	90% CI	Count (%)	90% CI	Count (%)	90% CI
County programs ($n = 14$)						
Trap adult mosquitoes	11 (78.6)	0.67–0.89	2 (14.3)	0.04–0.23	1 (7.1)	0.00–0.14
Tests mosquitoes on-site	6 (46.9)	0.29–0.56	3 (21.4)	0.1–0.32	5 (35.7)	0.22–0.48
Mosquitoes tested off-site	3 (21.4)	0.10–0.32	7 (50.0)	0.36–0.63	4 (28.6)	0.16–0.4
Follows a calendar-based schedule	3 (21.4)	0.10–0.32	4 (28.6)	0.16–0.4	7 (50.0)	0.36–0.63
Routinely spray for mosquitoes	9 (64.3)	0.51–0.77	3 (21.4)	0.10–0.32	2 (14.3)	0.04–0.23
Routinely use adulticides	11 (78.6)	0.67–0.89	3 (21.4)	0.10–0.32	0 (0.00)	0.00–0.00
Routinely use larvicides	9 (64.3)	0.51–0.77	5 (35.7)	0.22–0.48	0 (0.00)	0.00–0.00
Employs source reduction	6 (42.9)	0.29–0.56	7 (50.0)	0.00–0.14	1 (7.1)	0.36–0.63
Board of County Commissioners programs ($n = 13$)						
Trap adult mosquitoes	8 (61.5)	0.43–0.70	1 (7.7)	0.00–0.14	2 (15.4)	0.04–0.23
Tests mosquitoes on-site	5 (38.5)	0.22–0.48	0 (0.0)	0.00–0.00	6 (46.2)	0.29–0.56
Mosquitoes tested off-site	3 (23.1)	0.36–0.63	2 (15.4)	0.04–0.23	2 (15.4)	0.04–0.23
Follows a calendar-based schedule	2 (15.4)	0.04–0.23	3 (23.1)	0.10–0.32	6 (46.2)	0.29–0.56
Routinely spray for mosquitoes	7 (53.8)	0.36–0.63	3 (23.1)	0.10–0.32	1 (7.7)	0.00–0.14
Routinely use adulticides	7 (53.8)	0.36–0.63	3 (23.1)	0.10–0.32	1 (7.7)	0.00–0.14
Routinely use larvicides	8 (61.5)	0.43–0.70	2 (15.4)	0.04–0.23	1 (7.7)	0.00–0.14
Employs source reduction	4 (30.8)	0.16–0.4	5 (38.5)	0.22–0.48	2 (15.4)	0.04–0.23
Independent special district programs ($n = 12$)						
Trap adult mosquitoes	10 (83.3)	1.00–1.00	0 (0.00)	0.00–0.00	1 (8.3)	0.00–0.13
Test mosquitoes on-site	10 (83.3)	0.59–0.83	0 (0.00)	0.00–0.00	1 (8.3)	0.00–0.03
Mosquitoes tested off-site	1 (8.3)	0.00–0.14	1 (8.3)	0.00–0.14	9 (75.0)	0.51–0.77
Follows a calendar-based schedule[1]	8 (61.7)	0.43–0.70	2 (16.7)	0.04–0.23	1 (8.3)	0.00–0.14
Routinely spray for mosquitoes	8 (66.7)	0.43–0.70	2 (16.7)	0.04–0.23	1 (8.3)	0.00–0.14
Routinely use adulticides	8 (66.7)	0.43–0.70	3 (25.0)	0.10–0.32	0 (0.00)	0.00–0.00
Routinely use larvicides	8 (66.7)	0.43–0.70	3 (25.0)	0.10–0.32	0 (0.00)	0.00–0.00
Employs source reduction	5 (41.7)	0.16–0.40	6 (50.0)	0.22–0.48	0 (0.0)	0.00–0.00

[1] Follows calendar-based schedule for pesticide application. The reported percentages and associated confidence intervals are for the surveyed districts who responded to the question of interest ($n = 42$). Of these, two were municipalities (open programs) and did not indicate information about their organizational structure. Not all surveyed mosquito districts responded to all questions. We conducted bivariate analyses using the χ^2 test for dichotomous variables and the *t*-test for continuous variables, and none of the variables is significant at $P < 0.05$.

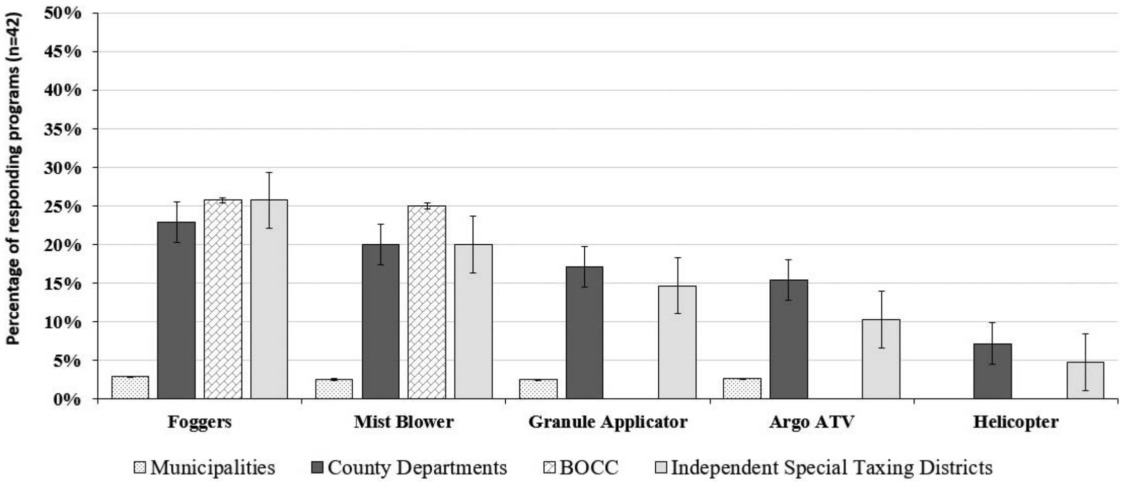

Fig. 2. Percentage of equipment by mosquito control district organizational structure, Florida, 2017.

one had aerial spraying capability. Seven implemented baseline surveillance, 6 control, while 9 adulticiding.

Findings further revealed wide disparities in equipment across mosquito district organizational structure. Some municipal programs owned hardly any of the key equipment surveyed, whereas 3 counties—2 BOCC and 2 independent programs—had helicopters (5 in one independent district alone). One in 5 (20%; $n = 44$) responding programs indicated having fogging equipment and mist blowers for killing adult mosquitoes, the most commonly owned equipment. Some independent and county programs owned all assessed equipment—granule (pesticide) applicators, all-terrain vehicles, helicopters, foggers, and mist blowers (Fig. 2).

DISCUSSION

This study offers new insights on the capacity of Florida mosquito control districts to prevent or detect and control mosquito-borne arboviruses in Florida. Although Florida has developed relatively effective mosquito surveillance and control systems as a 1st line of defense against such outbreaks, it has done so on generally limited mosquito district budgets, staffing levels, and perceived program capacity. While each Florida county has some form of mosquito control, wide variation in capacity across mosquito district organizational structure revealed funding, staffing, and strategic operational limitations that need further attention. Capacity disparities included counties having both approved and open, Tier I and II programs. Whereas 6 municipal programs become operational only during natural disasters or disease outbreaks, and 1 county program had a single full-time employee.

The observed funding and capacity gaps raise concerns about the ability of most Florida mosquito districts to respond timely and effectively to (re)emergent arboviral diseases in the future. These findings reflect ongoing concerns over long-term adverse impacts of reduced funding on capacity and the preparedness of states to detect and control arboviral diseases (23, 27). Although the small increase in mean annual program budgets during FY 2015–16 versus 2018 was unlikely to undermine the capacity of the generally well-funded independent programs, the low mean budgets of county programs—a time when the state was still under heightened awareness of, and general concern over, ZIKV—was more alarming. Even with the slight mean budget increase for BOCC programs, they remained the lowest funded mosquito districts and a continuing cause of concern. Practitioners themselves affirm these capacity concerns, especially staff numbers for conducting surveillance and control. In addition, while only one-third (32%) reported having a contingency fund, this is not surprising considering that many government agencies in Florida are not allowed to roll over funds from one fiscal year to the next (spend it now or lose it). This illuminates a structural barrier to establishing such a fund, especially for BOCC programs, and the need for more creative solutions.

The State of Florida's ability to contain the 2016 ZIKV disease outbreak under relatively low or declining local mosquito-fighting budgets (Ajelli et al. 2017, Manrique et al. 2017) might be more a testament of programs essentially performing miracles with little than it was about the sufficient capacity of individual programs. In particular, the combined, coordinated federal and state support, including additional federal funding from the Centers for Disease Control and Prevention and state funding from the Florida Department of Health and FDACS, and efforts that went beyond control activities alone, were critical in limiting the spread of the deadly virus. It is probable that without these combined response efforts and resources, the ZIKV could have spread faster and farther. The FDACS's deployment of Spot Teams, often on a cost-recovery basis, also offers a swift and collaborative response to control mosquito-borne diseases (Moise et al. 2018a) that other states can learn from. The capacity gaps identified in this preliminary study can help to better target the spot teams and other support to the areas and programs of most need, including those with limited funding, personnel, and equipment.

The authors acknowledge the positive changes in Miami-Dade County Mosquito Control Division's capacity since the 2016 ZIKV outbreak, such as the addition of 42 new staff positions by 2017, including a director (Miami-Dade County, unpublished report, 2017). However, it remains unclear if other Florida mosquito control districts have implemented, or have plans for implementing, similar efforts. We plan to undertake an additional study to investigate this issue.

The current study has some limitations, beginning with the bias toward questions dealing with the control of domestic mosquitoes, especially *Ae. aegypti* and *Ae. albopictus*. Obviously, for many Florida mosquito districts, domestic mosquito surveillance and control is a high priority. Further, we did not ask what type of surveillance is used by the districts. As a rule, the routine testing of mosquito pools for arbovirus presence is usually not a productive approach since in Florida the incidence of the arbovirus is typically too low in the mosquito populations to be detected. In addition, we do not compare urban and rural agencies, a fruitful area for further work, nor does our designation of urban and rural programs account for the degree of urban development and size of the mosquito jurisdiction, which might affect capacity. The limited sample size for some types of programs, particularly municipal ones, also limited more robust statistical analysis and comparison beyond basic descriptive statistics. Perspectives of respondents might include self-bias, e.g., on funding and staffing levels. In addition, we are 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 (Moise et al. 2016, 2018b, 2018c; Ajelli et al. 2017), resulting in differentiated surveillance and control needs. Moreover, of the responding surveyed agencies, all but one independent district were located on the eastern and western coasts of Florida, in low-lying farmlands and wetlands. Geographical location might also influence these districts' mosquito control practices more than population density or budgets.

Despite these limitations and its exploratory nature, this study offers insights into the organizational capacity of Florida's mosquito control districts to tackle mosquito-borne arboviruses. Preparing for unexpected outbreaks requires going beyond surveillance to strengthening research and enhancing control programs, and human, financial, and infrastructural resources–based capacity (Fournet et al. 2018). Mosquito districts must also be prepared to deal with the psychological challenges expected to surface during disease outbreaks, namely, fear and panic. A well-trained staff, effective communication regarding the risks of exposure to mosquito-borne diseases, and a swift, well-coordinated public health response will also be key in promoting a healthy public reaction. In conclusion, our findings illustrate that improved, locally informed understanding of these capacity disparities in funding structure and levels, staffing levels and quality, equipment, and their limitations on strategic operational choices, range, and balance of activities is essential for developing targeted, needs-based capacity interventions. They also highlight how these factors can potentially undermine effective mosquito surveillance and control as primary tool for arboviral disease control. The authors intend to use these findings to develop a short survey to be administered every 3 years to monitor capacity changes across mosquito control districts in Florida.

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