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OPERATIONAL NOTE

THE IMPACT OF HURRICANE IRMA ON OUR COMMUNITY AND THE COLLIER MOSQUITO CONTROL DISTRICT'S MISSION

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ABSTRACT. The Collier Mosquito Control District, located in southwest Florida, is uniquely positioned in a subtropical environment between the Gulf of Mexico and Everglades National Park. The District's mission is focused on the control of disease vector and nuisance mosquitoes in Collier County, which is accomplished through integrated mosquito management. Hurricane Irma made landfall in the county on September 10, 2017, leaving in its wake tremendous property and infrastructure damage, and it also disrupted communications and airport operations. These factors greatly affected the District's operations and its ability to meet its mission. In addition, the lengthy loss of electrical power forced most residents outdoors, increasing their exposure to mosquitoes. From challenges in completing poststorm treatments to outdated policies that caught us off-guard, the event prompted a new hurricane policy and plan to ensure improved preparedness for the next natural disaster. The poststorm environment also provided a rich foundation for research into mosquito populations after tropical disturbances of this scale. Here we report the impact on the District's aerial mosquito control operations, changes to internal policies, and mosquito population abundance following Hurricane Irma.

KEY WORDS Hurricane, natural disaster, operations, policy, poststorm response

On September 10, 2017, Hurricane Irma made a second landfall in Florida after roaring through the Caribbean and the Florida Keys, impacting communities in southwest Florida, including Collier County (Fig. 1) (ESRI 2019, 2020).[1] Although hurricane activity was nothing new for the Collier Mosquito Control District, having seen impacts by Hurricane Wilma in 2005 and Hurricane Charley in 2004, experiences learned from Irma made evident that updated policies and procedures were needed. Much had changed at the District, including personnel and the addition of new technologies since the original hurricane procedures were created, but our mission remained the same: to control disease-vector and pestiferous mosquitoes. Furthermore, before Irma we did not have the predictive capabilities to determine floodwater mosquito population numbers, primarily those of *Culex nigripalpus* Theobald, following a hurricane.

When Florida-based organizations prepare for a tropical disturbance, policies and procedures typically provide structure to the activities leading up to the day of impact. In September 2017, we turned to the District's hurricane policy and began preparing for a predicted category 4 or 5 storm. After reviewing the policy and plan, it became evident that the documents were more a set of outdated guidelines. They had not been updated since Hurricane Wilma (2005)—more than 10 years earlier—and we were out of practice. Additionally, operations had evolved, leadership had changed, and new employees had joined the District during the decade.

Preparing for the storm with an outdated policy and associated procedures proved to be the first of many challenges the new leadership team faced. With 4 days until the predicted impact, District facilities and vector control materials need to be secured, and employees needed time to prepare their own homes. We discovered during the response to Irma that several critical topics were not addressed in the outdated policy, including determining staff responsibilities and compensation, making on-the-spot decisions, and quickly crafting answers to difficult questions.

Given that much had changed operationally since the last hurricane, many details were lacking in the District's policy and plan. For example, use of the BG-Counter (Biogents AG, Regensburg, Germany), delicate weather-sensing equipment, and best practices for "scattering" aerial assets all had presented themselves during the past decade. During prestorm preparation, we quickly realized that we required significantly more time and personnel to collect stationary traps and weather stations from field locations throughout the District. Concurrently, we made attempts to strategically relocate aircraft—each to a different location—in order to avoid damage to the entire fleet. However, we experienced difficulty moving aircraft to multiple areas less likely to

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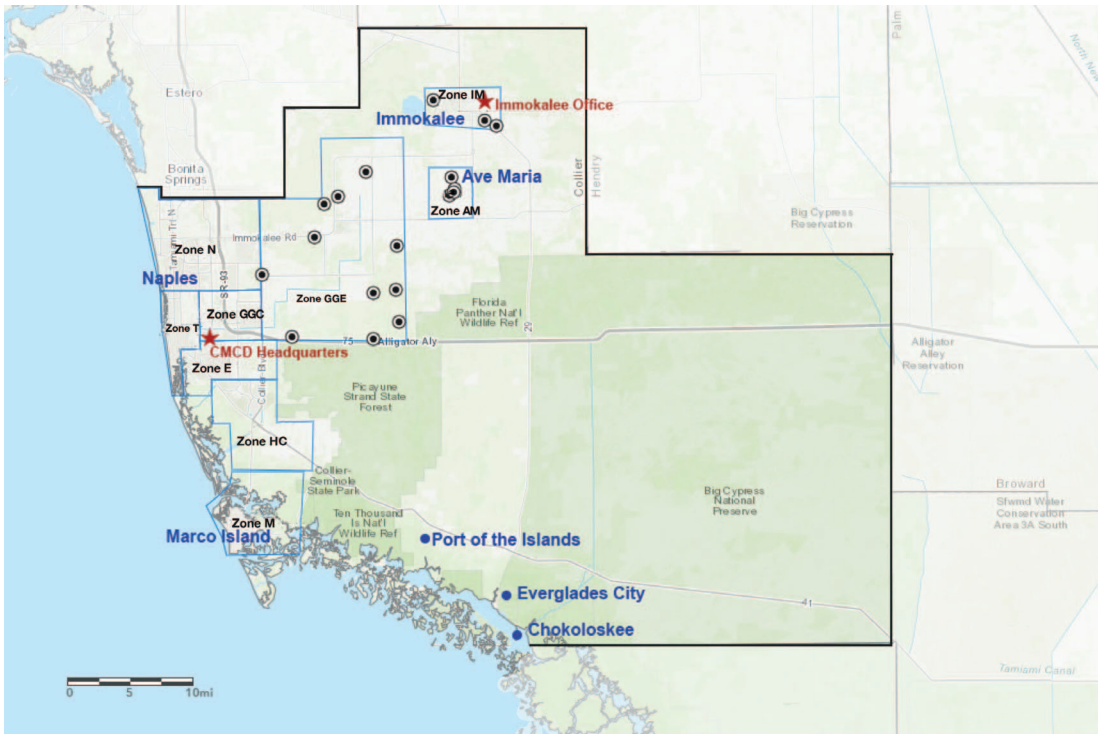

Fig. 1. Map of Collier County, Florida, including Collier Mosquito Control District boundaries and zones (blue outline), District headquarters and Immokalee satellite location (red stars), landing rate locations (gray bullseye) in Golden Gate Estates (Zone GGE), Ave Maria (Zone AM), and Immokalee (Zone IM). Also included are Port of the Isles, Everglades City, and Chokoloskee.

receive significant impacts from Irma, given the storm's projected path.

A critical update not addressed in the original plan was the Federal Emergency Management Agency (FEMA) flood map, which indicated that our entire campus at the western side of the Naples Airport (Fig. 1) could experience up to 5 ft of water (FEMA 2012). Assets were moved inside buildings to higher shelving and floors, and insecticides remained in the only elevated building on the campus. The threat of floodwater also created the question of whether we would be able to resume operations poststorm. The predicted path of Hurricane Irma presented unique difficulties in planning where to take our aerial assets. Forecast models had the storm moving directly up the Florida peninsula, leaving little option but to move them out of state.

The day after the storm hit, new challenges began to unfold. Fortunately, the predicted storm surge did not occur. The storm's category 3 sustained winds, with gusts of 142 mph recorded at the Naples Airport (National Weather Service 2017), proved to be the greatest destroying force. Not only were most roads impassable, but electricity outages were widespread, law enforcement imposed a curfew, and the airport was closed to all air traffic except federal relief aircraft. The closures and nighttime curfews extended for multiple days until roads were cleared, creating challenges beyond our scope of preparation: mosquito surveillance was not possible, and our aerial fleet couldn't immediately return to Naples.

Without air conditioning, people were living with open windows and spending more time outdoors, thus increasing human contact with mosquitoes. This was particularly the case in the southern portion of the county where the storm made landfall. The small town of Everglades City (Fig. 1) was decimated, and many of the older homes were deemed uninhabitable. Because the winds damaged numerous cellular relay towers, communication proved challenging, and the Florida Department of Agriculture and Consumer Services struggled to reach us with a request to treat south of Everglades City (i.e., outside District boundaries) where utility workers, mostly out-of-state contractors, begged for relief from the thick clouds of mosquitoes.

The lobby of the Administration building on our Naples Campus served as headquarters for many days. District operations, finance, surveillance, cleanup, and communications worked with a small generator that powered a few floor fans and laptops. Although we had city water, the main obstacle to full operational capacity was the lack of electricity. Our whole-building generator was 30 years old and

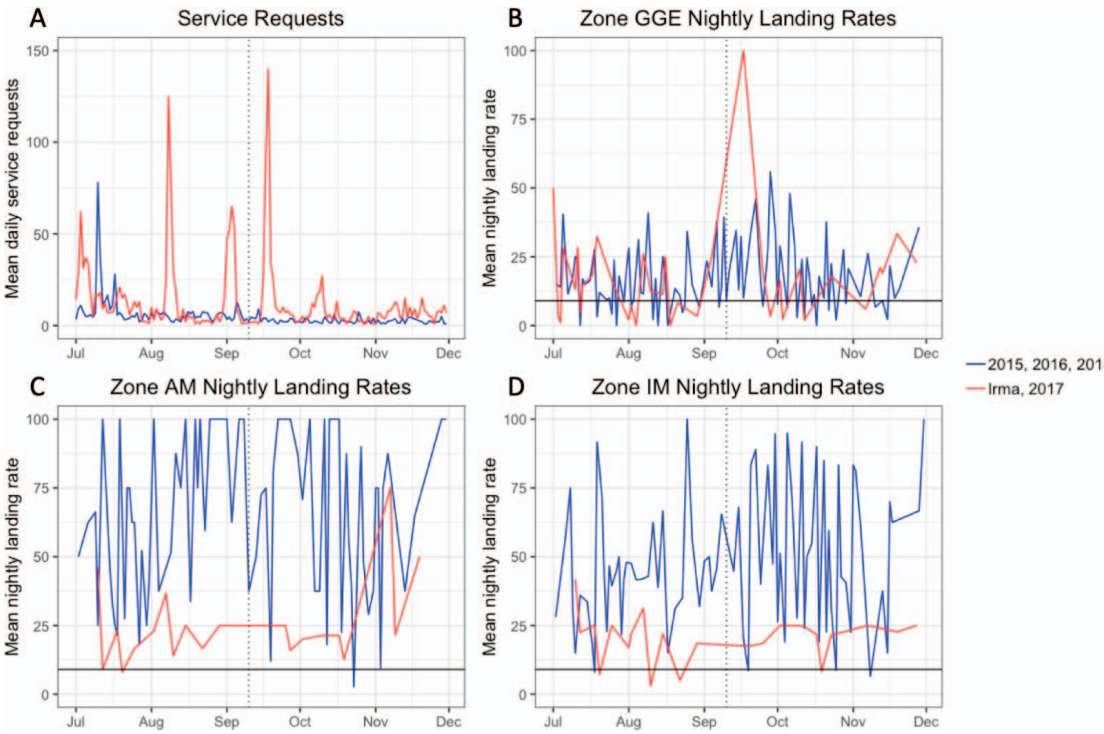

Fig. 2. Service request and mosquito population density during peak hurricane season (July– November). (A) Mean number of service requests made to the District per day. Blue line represents the 3-year mean number of requests per day for the 2 years prior to and 1 year following Hurricane Irma; red line represents the number of requests per day during the year of Hurricane Irma. (B–D) Mean nightly landing rates (NLRs), the number of mosquitoes landing on a technician during a 5-min period after dusk, for 3 areas in the eastern portion of the District most prone to freshwater flooding: (B) Zone GGE, (C) Zone AM, and (D) Zone IM. Blue line represents the mean NLR per night for 2 years prior to and 1 year following Hurricane Irma; red line represents the mean NLR per night during the year of Hurricane Irma. Horizontal solid black line represents the landing rate threshold value (NLR = 9) required for treatment justification. Vertical black dotted line marks September 10, 2017, when Hurricane Irma made landfall in Collier County.

highly unreliable. At least 3 days of full productivity were lost.

By September 15, the airport was reopened, our aerial fleet had returned, most roads were passable for surveillance, and our larvicide treatments resumed. Larviciding residential areas became a priority because debris was piled along roadsides: horticultural waste, building fragments, trash cans, and water-soaked furniture provided mosquito habitat that was increasing by the day. Furthermore, the rains accompanying Hurricane Irma had flooded existing containers and mosquito larvae habitat. The District utilized Vectobac WDG® (Valent Biosciences, Libertyville, IL), a formulation of *Bacillus thuringiensis israelensis* (Barjac), from our Buffalo Turbine sprayer (Buffalo Turbine, Springville, NY) to target disease vector species breeding within these habitats.

The development of a robust adult mosquito population due to increased floodwater within our inland communities (Fig. 1) was also a concern; however, poststorm surveillance revealed that the populations were similar to those in previous years (Fig. 2B–2D). Service requests spiked in the week after Irma and remained elevated in the weeks following the hurricane (Fig. 2A). In most areas of the District, there was no evidence of a corresponding increase in nightly landing rates (primarily *Cx. nigripalpus*) relative to typical conditions during the late summer and early fall (Fig. 2C, 2D). The one notable exception occurred in the Golden Gate Estates (Zone GGE) (Fig. 1), where there was a brief spike on September 17, which was immediately addressed once the District was able to resume aerial adulticide treatments (Fig. 2B). Increased mosquito landing rate counts in Zone GGE may have corresponded to its proximity to the Picayune Strand State Forest, which is not within the District boundaries. Assuming that the increase in service requests directly reflects human encounter rates, we concluded that this may have been caused by a combination of factors, including increased outdoor activity during cleanup efforts, open windows due to the lack of air conditioning, and/or a lack of familiarity with or tolerance for typical mosquito densities by out-of-state contractors. Unfortunately,

the operational logistics noted above prevented the District from collecting more comprehensive landing rate and trap data; therefore we cannot be certain which of these factors was most significant. However, similar results were observed after Hurricanes Irma and Maria in Puerto Rico with no significant difference in mosquito captures in comparison with those in the previous years (Barrera et al. 2019). Another study following Hurricane Katrina suggests that outdoor cleanup and reconstruction activity after hurricanes may lead to increased exposure to mosquito populations (Caillouet et al. 2008).

When operations returned to normal, we developed a fully revised hurricane plan and policy (Supplemental Information 1).[2] Contributions were made by each department within the District to produce a thorough day-by-day plan for both storm preparation and recovery. The policy provides leadership and staff with salient guidance when a tropical weather event is expected to affect the area. Specific actions and procedures are spelled out, with personal safety of staff being of paramount importance. Both the plan and policy will be evaluated each year prior to hurricane season and revised to keep up with changes in District structure and technological advances.

In addition to creating a new policy and plan, office space has now been secured near the Immokalee Airport (Fig. 1), which provides a satellite location where operations and surveillance can continue if the Naples location were to be destroyed or deemed inaccessible. A new whole-building generator has been installed at the District's Administration building, and satellite phones were purchased to improve communication among key staff during emergencies when cellular service isn't available.

While Hurricane Irma greatly impacted Collier County in 2017, it brought a tremendous gift in the spring of 2018 when the District experienced a population crash of the black saltmarsh mosquito, *Aedes taeniorhynchus* (Wiedemann), due to Hurricane Irma's impact on the coastal landscape in Collier County (Lucas et al. 2019). The reduction in our 2018 saltmarsh mosquito season (April–June) provided operational relief and allowed the District to focus on enhancing our hurricane policies and procedures.

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[2] The most recent version of Collier Mosquito Control District's Hurricane Policy and Plan is available upon request. Please contact CMCD Executive Director Patrick Linn at plinn@cmcd.org.