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AERIAL BUFFER APPLICATIONS OF NALED FOR ADULT MOSQUITO CONTROL, ST. JOHNS COUNTY, NORTHEASTERN FLORIDA

WHITNEY A. QUALLS, STEVEN SMOLEROFF, DANA SMITH AND RUI-DE XUE

Anastasia Mosquito Control District, 120 EOC Drive, St. Augustine, FL, 32092

ABSTRACT. Aerial applications of pesticides for adult mosquito control have emerged as effective tools in integrated mosquito management due to wider reach compared with ground-based methods. A key determinant for efficacy is the *swath* or line of spray deposition. This study aimed to assess the potential of aerial *buffer* sprays, which specifically target mosquito habitats, in comparison to traditional full-area aerial and ground-based applications. The efficacy and cost implications of these methods were evaluated in hot spot areas of St. Johns County, FL. Mosquito populations in 4 areas, 2 for buffer aerial (St. Johns County Golf Course and World Golf Village), 1 for full aerial (Flagler Estate), and 1 for ground-based (Elkton) treatments, were assessed using the Centers for Disease Control and Prevention light traps baited with octenol. Following treatments, mosquito population reductions and service request changes were evaluated. For aerial applications, the organophosphate naled was used, while ground applications used the pyrethroid Aqualuer® 20-20. Buffer aerial applications averaged 668.5 ha, significantly smaller than full aerial treatments (3750.2 ha). Cost and volume for buffer applications were notably lower ($1,998.47 and 34.1 liters) than full treatments ($10,558.40 and 180.6 liters). Mosquito populations post-treatment showed a 63.6% reduction for buffer applications, 59% for full aerial applications, and a 52% increase for ground-based treatments. Service request reductions were varied, with a slight increase (0.13%) after buffer aerial treatments and substantial reductions after full aerial (29.4%) and ground applications (87.5%). Buffer aerial applications demonstrated potential as an effective and cost-efficient method for mosquito control in targeted habitats. Although further evaluations are essential, such strategies could reshape mosquito management practices in regions similar to the Anastasia Mosquito Control District of St. Johns County.

KEY WORDS Aerial, innovation, mosquito control, naled, swath width

INTRODUCTION

Aerial adult and larval mosquito control is an important component of the integrated mosquito management toolbox. One benefit of using aerial over ground-based control efforts for mosquitoes is the swath dimensions and position are not limited by obstacles such as street separation. Swath width and spray line separation are determined by a balancing of factors, such as release altitude, flow rate, wind speed, and habitat type. Under ideal conditions, they support a uniform deposition of the pesticide approximating the intended application rate, for example, measured in ounces per acre (Mount et al. 1988, Latham and Barber 2007). For aerial adulticide applications, most swath widths are around 300 m but can vary between 150 and 800 m. In comparison, most ground ultra-low volume (ULV) applications are effective over 150–200 m downwind of application. However, the most commonly used active ingredient (AI) for aerial applications is naled, an organophosphate. Given that public concern for this class of AI is high, even when applied for emergency disease or disaster response (Damalas and Eleftherohorinos 2011), potential development of aerial programs with naled for routine nuisance or vector mosquito control is highly limited and subject to scrutiny.

Organophosphates and pyrethroids are the major pesticide classes certified for adult mosquito control in the USA (US Environmental Protection Agency [EPA] 2022). Due to the quick breakdown of naled in the environment, lower toxicity to aquatic organisms, and greater potential efficacy, Anastasia Mosquito Control District (AMCD) of St. Johns County, FL, uses this adulticide in the newly developed aerial program (US EPA 2021). As the aerial program developed, the idea of treating areas as we do service requests (Davidson et al. 2016, Davis et al. 2022) with ground barrier vegetation treatments (Qualls et al. 2012) resulted in the decision to evaluate aerial *buffer* sprays as an effective application for reducing mosquito populations and limiting the amount of naled applied. In contrast to traditional broad-area aerial applications, the proposed aerial buffer treatments will target habitats where mosquitoes are developing, resting, and nectar-feeding in wooded areas around residential subdivisions. Thus, we hypothesize that because the aerial buffer approach will only treat source areas where mosquitoes may be most spatially concentrated, and not entire subdivisions or cities where mosquitoes become more spatially dispersed as they seek blood meals, the AMCD aerial program could reduce pesticide use, save money, be at least as effective as full-area or ground-based treatments, and gain increased public support.

In this investigation, we evaluate 1) aerial buffer applications to determine if this type of application can reduce mosquito populations and service requests in comparison to full-area aerial applications and ground ULV applications and 2) the costs per total acres treated as a function of efficacy across the treatment types.

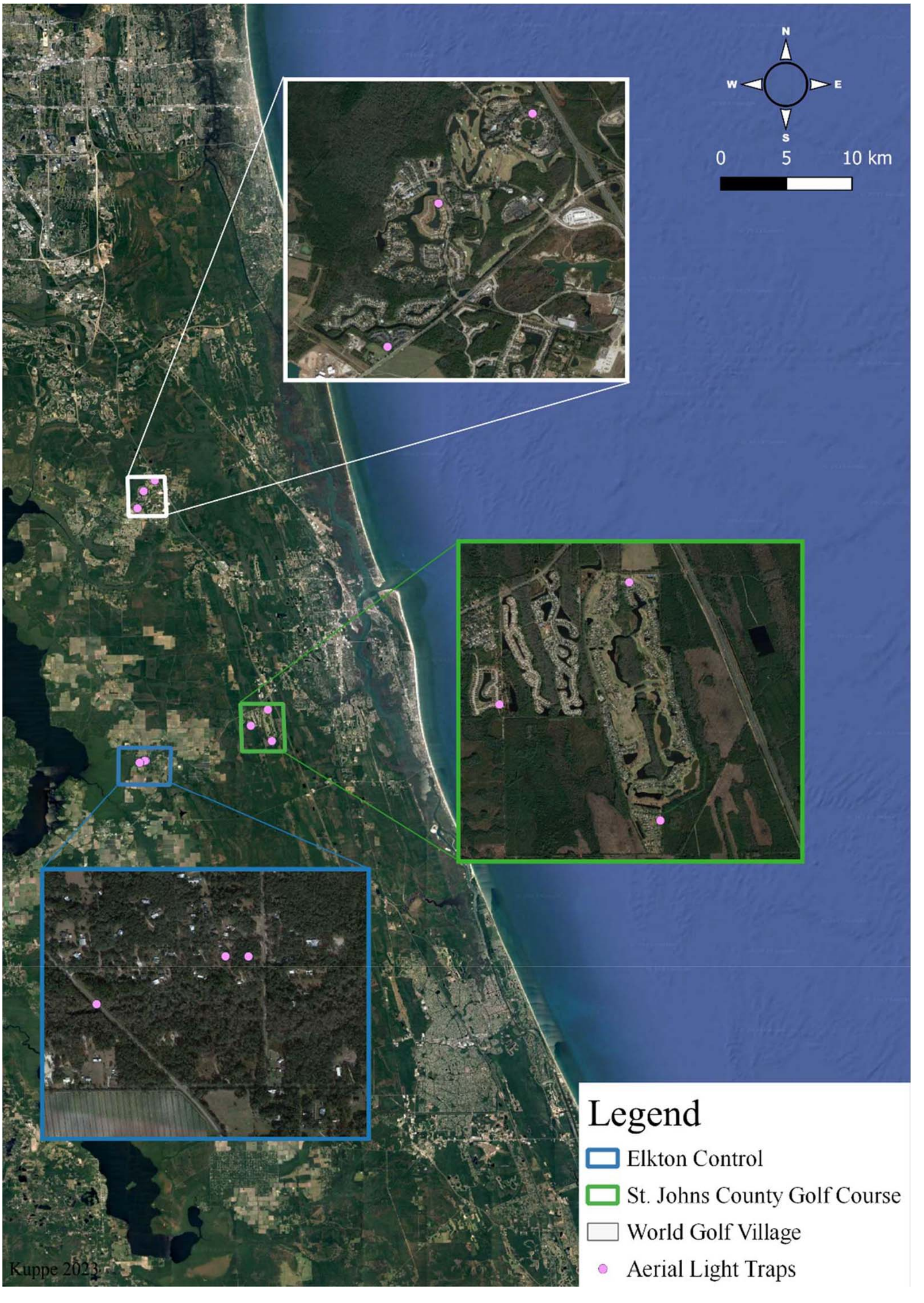

Fig. 1. The location of the 2 buffer aerial spray sites (St. Johns County Golf Course and World Golf Village) and the control site (Elkton).

MATERIALS AND METHODS

For this evaluation, 2 hot spot areas, identified by the AMCD based on mosquito populations and service requests, were selected for buffer aerial applications (St. Johns County Golf Course [SJGC] and World Golf Village [WGV]). One area was selected for a full aerial application treatment (Flagler Estate [FE]), and 1 area was selected as a ground ULV control site (Elkton) in St. Johns County, FL (Fig. 1). At each of these sites, 3 Centers for Disease Control and Prevention (CDC) light-emitting diode light traps (John W. Hock, Gainesville, FL) baited with octenol lure stripes (BioSensory, Inc., Putnam, CT), were operated weekly from May to October 2021 to evaluate adult mosquito populations. When AMCD's adult trap thresholds were met (Table 1), these hot spot areas were treated using either a buffer aerial application, full aerial application, or ground ULV application, and the percentage of reduction was calculated using pre- and posttreatment CDC light trap mosquito counts. For the aerial applications, naled (Dibrom® Concentrate; AMVAC, Newport Beach, CA) was used. For the ground ULV applications, a pyrethroid, Aqualuer® 20-20 (AL; Value Garden Supply, St. Joseph, MO; AI: 20.6% permethrin) was used.

The AMCD has 3 Bell 206B3 helicopters (Bell Texton Inc., Fort Worth, TX) each with a specific function for aerial mosquito control: adulticiding, larviciding, and serving as a surveillance and support aircraft. The adulticide aircraft is equipped with high skids, an ISOLAIR adulticide tank (Isolair Helicopter Systems, Andalusia, AL), holding up to 202 liters of naled with 2 Micronair AU6539 (Micron Sprayers Ltd., Bromyard, Herefordshire, United Kingdom) electric atomizers, with a set distance at 67% of the rotor disk. This unit is calibrated for a 305-m swath width from an altitude of 90 m with an airspeed between 80 and 90 knots. This produces an application rate of 0.04 lb/acre (∼3.99 kg/ha), with the droplet spectrum characterized at a diameter volume (Dv) $0.5 < 60$ µm and Dv $0.9 < 115$ µm.

The AMCD has 14 dual-duty full-sized trucks that have both larviciding and adulticiding capacity. The trucks are equipped with a 75-liter chemical tank with ULV or high-pressure adulticide units. The units have variable pumps calibrated for AL at a 1:5 ratio of AL:water at an application rate of 0.02 lb/acre (∼1.99 kg/ha). The general swath is 91 m with wind speed 1–16 km/h (1–10 mph), and the droplet spectrum was characterized to be Dv $0.5 < 30$ µm and Dv $0.9 < 50$ µm.

The mosquito population data set (pre- and posttreatment) was normalized by adding 1 to each data point to get rid of any zeros in trap collections. The percentage of reduction of mosquito counts by each treatment event was calculated using pre- and posttreatment trap counts. Data

Table 1. Anastaisa Mosquito Control District's developed thresholds for aerial applications of pesticides to control adult mosquito populations.

Aerial thresholds			
Nuisance/vector	Hot spot areas	Positive sentinel animal (chicken, mosquito, horse, human)	Landing rate counts for mosquitoes not attracted to Centers for Disease Control and Prevention (CDC) light traps
a. Based off of abundance—75 mosquitoes per trap (3 times the base of 25 mosquitoes per trap night). c. This would indicate the fog zone on which the trap is placed should be aerially adulticided.	a. Aerially larvicide first; then b. Use CDC light traps—if light traps are not at 75 mosquitoes per trap; then c. If we receive 35 service requests within 48 h within a 5-mi radius of the hot spot, we will aerially adulticide the fog zones.	Positive chicken, mosquito, horse, or suspected or confirmed human case of a mosquito arbovirus found in a fog zone will be aerially adulticided.	Examples: *Aedes taeniorhynchus* and *Psorophora ferox*; 9 mosquitoes in 1 min at 3 or more locations within the fog route will initiate an aerial adulticide mission in that fog zone.

Table 2. The total amount of hectares treated by month for each application type in 2021.

	St. Johns Golf Course (buffer)	World Golf Village (buffer)	Flagler Estates (full aerial application)	Elkton control (ground ULV only)
July	778	407	No application	No application
August	1,169	778	3,059	177
September	742	No application	4,441	245
October	305	498	No application	No application
Total (hectare) treated	2,994	1,683	7,500	422

were analyzed using IBM® SPSS® Statistics (IBM Corp., Armonk, NY) version 20. The Kruskal–Wallis test was used to compare the distribution of the percentage of reduction of the 2 aerial treatments, buffer and full.

RESULTS

Trapping began in May of 2021, but mosquito populations did not reach AMCD's aerial thresholds until July 2021 (Table 1). Following the aerial thresholds being met, the buffer aerial sites were treated 4 times at the SJGC and 3 times at the WGV. Two passes were performed for a total of 609-m swath for each buffer application made. The full aerial application site (FE) was treated twice during the study period. Twenty-four passes were performed for a total of 7,315-m swath for each full aerial application. The Elkton ground ULV site was treated 4 times. Table 2 shows the breakdown by site and by month of the total acres treated by each method. The average buffer application was 668.5 ha, while the average full aerial application was 3,750.2 ha. Table 3 shows the total cost and liters of product used for the aerial applications by month. The cost (based solely on product used) for the buffer aerial applications averaged $1,998.47, compared with the full aerial application average cost of $10,558.40. The average number of liters of naled used for the buffer treatment was 34.1 liter per mission compared with the full aerial treatment of 180.6 liter.

Adult population reduction

The Elkton ground ULV site had the most mosquitoes collected with 8,936 trapped, representing 24 species in 8 genera during this study period. A total of 17,511 mosquitoes, representing 25 species in 8 genera, were collected at the SJGC. There were 3,413 mosquitoes, representing 19 species in 7 genera, collected during the study period at the WGV site. There were 3,824 mosquitoes, representing 10 species in 4 genera, collected at the FE site. Table 4 shows the percentage of reduction in adult mosquito populations following each aerial (buffer or full treatment) and ground ULV application. Overall, there was a 63.6% reduction in mosquito populations following the buffer aerial applications (combining SJGC and WGV mosquito collections). For the full application (FE), there was a 59% reduction in mosquito populations. The ground ULV application sites had a 52% increase in mosquito populations post-treatment during the study period. Although the buffer application resulted in a greater percentage of reduction, there was no significant difference between the different treatments.

Service request reduction

A total of 72 service requests came from the study sites during this aerial buffer evaluation. When comparing the number of service requests pre- and post-aerial applications (total number of service requests 1 wk before aerial treatment and total number of requests 1 wk after the aerial applications), there was an increase (0.13%) in the aerial buffer application versus a 29.4% reduction at the full aerial application site (FE) in service requests. Following the ULV applications, Elkton site, there was an 87.5% reduction in service requests.

Table 3. The total cost per month and the total liters used per application type.[1]

	St. Johns Golf Course (buffer in liters)	World Golf Village (buffer in liters)	Flagler Estates (full aerial application; in liters)
July	$2,324.18 (39.7)	$1,219.64 (20.9)	No application
August	$3,503.97 (59.8)	$2,324.18 (39.7)	$7835.79 (134)
September	$2,213.50 (37.8)	No application	$13, 281.00 (227)
October	$914.18 (15.6)	$1,489.69 (25.5)	No application
Total cost (liters of product used)	$8,955.83 (152.9)	$5033.51 (86.1)	$21,116.79 (361)

[1] Cost calculations were based off of the price of naled per liter (2021 cost breakdown was $58.56/liter).

Table 4. Total percentage of reduction in mosquitoes collected (before and after) different application type by month. Three traps were placed and used for the percentage of reduction of the aerial sites, and 2 traps were located within the Elkton control site for the percentage of reduction calculation.

	St. Johns Golf Course (buffer)	World Golf Village (buffer)	Flagler Estates (full aerial application)	Elkton control (ground ultra-low volume only)
July	63 (852/314)	64 (1,117/401)	No application	No application
August	70 (2,412/725)	27 (783/571)	54 (848/386)	+0.8 (241/452)
September	84 (264/41)	No application	78 (165/29)	+1.2 (37/81)
October	93 (153/11)	98 (94/2)	No application	No application

DISCUSSION

To our knowledge, this is the first study evaluating the use of aerial buffer applications for mosquito control. Previous efficacy trials using aerially applied organophosphates typically report high levels of mosquito reduction (Kilpatrick et al. 1970, Britch et al. 2018). Although our study did not achieve the same high reduction rates, we observed a mosquito reduction of over 63.6% in the buffer-treated site, compared with 59% in the fully treated site. These results suggest that further research is warranted to assess whether aerial buffer applications could be a viable, routine treatment option for aerial mosquito control applications.

New developments often require extensive land clearing, particularly for residential subdivisions. This process frequently creates low-lying areas surrounded by woods and dense vegetation, which provide ideal habitats for mosquitoes to breed, rest, and feed. After heavy rainfall (7–12 cm), mosquito populations can surge, causing considerable nuisance for nearby residents, especially those living close to wooded areas (Davis et al. 2022). These areas pose challenges for ground-based mosquito control efforts due to limited accessibility. However, ground-based barrier spraying on vegetation surrounding subdivisions and golf courses has proven effective for controlling adult mosquito populations (Qualls et al. 2012, Qualls et al. 2013). Aerial buffer applications work on similar principles, treating the perimeters of residential areas such as ground barrier applications of public health pesticides. Although aerial buffer sprays do not use insecticides registered for barrier vegetation treatments (e.g., Talstar P, AI bifenthrin), this method targets mosquitoes in resting and host-seeking areas. If applied at optimal times, aerial buffer spraying could serve as an additional and effective control method for these challenging areas without having to spray over heavily residential areas.

Rotary-wing aircraft offer high maneuverability and the ability to fly lower and slower, making them well suited for precision treatments in complex terrains, such as wooded areas, wetlands, and urban neighborhoods. The ability to hover and quickly adjust altitude allows for targeted applications, ideal for buffer treatments around residential areas or specific breeding sites (Bonds 2012). Furthermore, helicopters do not require runways and can operate from smaller, less developed areas, making them highly adaptable to remote or urbanized regions (Rose 2001). Precision makes rotary-wing applications invaluable for targeting specific zones, where mosquito activity is high, such as isolated breeding habitats.

Our findings suggest that aerial buffer applications are not only effective but also cost-efficient, highlighting the potential as an alternative mosquito control strategy. The cost and volume of adulticides required for buffer applications were significantly lower than those needed for full aerial treatments, making this approach a promising option for targeted mosquito control in specific habitats. This reduction in chemical use could decrease the overall environmental impact and address public concerns associated with broad-scale adulticide applications (Damalas and Eleftherohorinos 2011).

Further research is needed to optimize this aerial buffer method and confirm its effectiveness across diverse environmental conditions and mosquito species. In addition, public education and engagement are essential for addressing concerns and fostering acceptance of both full and buffer aerial applications for effective mosquito control.

In conclusion, aerial buffer applications show considerable promise as an effective and cost-efficient approach for controlling mosquito populations in targeted habitats. With continued evaluation and refinement, these strategies have the potential to enhance integrated mosquito management practices in regions similar to those managed by the AMCD.

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