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of the Florida Mosquito Control Association

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Vol 32, No 1 Spring 2021

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About the Covers:

Penny Peper demonstrates to younger brother Gus how to dip for and identify mosquito larvae in their neighborhood pond.

Photo by Steven T Peper

Cover A: "Catching"

Cover B: "Counting"

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Hail from the (Editor-in-) Chief

by Stephen L Sickerman

THANKS

In addition to all the many accomplishments of Ary Faraji, AMCA Immediate Past President, please include the title of *Wing Beats* Editor-at-Large. Not only were most of the articles in our Winter 2020 all-Utah issue at his behest, but he also contributed the photo used on the cover. If memory serves, we first discussed this dedicated edition two years ago, at the 2019 AMCA Annual Meeting in Orlando. But this sort of task was nothing new to Dr Faraji, as he was also responsible for our all-New Jersey issue, way back in Winter 2012. So thank you again, Ary, for your excellent editorial assistance!

OOPS

Sharp-eyed readers may have noticed last issue that we provided incorrect contact information for one of our authors. Here is Gary Hatch's actual title, email and mailing address:

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While we obviously can't go back and fix all the printed copies, we've been able to correct the error in our digital edition, which you can now access at: https://indd.adobe.com/view/f21f7b93-8e47-4815-8c8e-68cf041c1868

BELATED THANKS

Four years ago, way back in May 2017, *Wing Beats* Associate Editor David Dame wrote: *"I have edited most, if not all, of the WB articles since its inception [in 1990] and I'm getting a little long in the tooth. Nearing my 86th birthday I sense that I can still provide adequate service but am not as attentive as I can recall having been in the past. So, I am ready to step down when you have found a suitable replacement. Following retirement from editing WB articles, I will be available for special problem articles if you need my counsel."*

Somehow it doesn't seem fitting that Dr Dame was able to retire without a shout out in the pages of *Wing Beats*. So at last, here's that long overdue and well-deserved thank you, Dave, for your many years of dedication, scientific sensibility and friendship.

Three years ago, at the 2018 Annual Meeting in Kansas City, AMCA President Wayne Gale presented this Editor with the Presidential Citation. Yours truly was completely gobsmacked and flabbergasted – words that shall never again grace these pages – and clambered to the stage to utter unprepared words of acceptance. It turns out that this citation was not for driving 45 in a 25-mph zone, but rather for significant contributions to this association. So thank you, Wayne, for bestowing this recognition. *One is glad to be of service!*

ADDITIONAL THANKS

If it truly takes a village to raise a child, it definitely takes a committee to publish a magazine. You see their names on the *Wing Beats* Table of Contents page each issue, the volunteers whose efforts help coordinate, edit and proofread this publication. Without their steadfast assistance there would likely be no magazine at all.

Director of Advertising: Steven Peper - who communicates with our industry partners and coordinates the submission of advertising graphics

Circulation Editor: Barbara Bayer - who keeps tabs on the current address of almost 4,000 subscribers and maintains the spreadsheet that is the *Wing Beats* mailing list

Without sounding like a broken record (that's the analog version of a glitchy mp3 file), if you have a new address or wish to start or discontinue your subscription, please inform our Circulation Editor at barbebayer@gmail.com.

Associate Editors: Aaron Lloyd, Bruce Morgan, Carl Boohene and CAPT Peter Obenauer - who critically examine and review each submitted manuscript, offer constructive comments and help prepare them for publication

Editorial Review Board members: Roxanne Connelly, Stan Cope, Scott Crans, Mustapha Debboun, David Lawson, Dennis Moore, Steve Mulligan and Milton Sterling - who provide editorial oversight and assurance that each and every *Wing Beats* article is suitable for publication

To all the many volunteers from years past – a long list that includes the likes of Marin Brouillard, Dennis Moore and Jack Petersen – I offer my sincere appreciation and gratitude.

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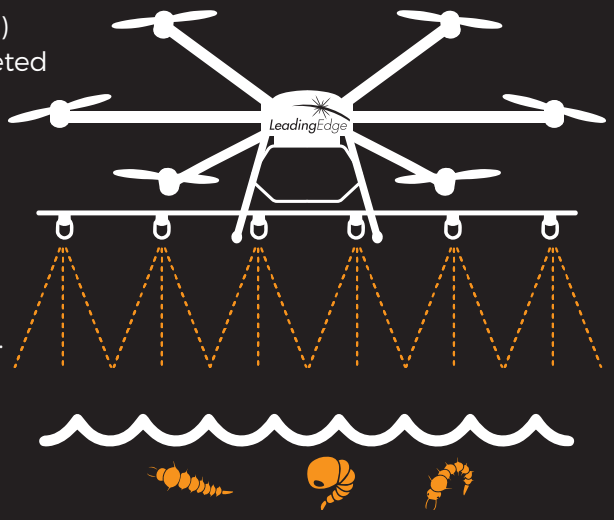

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Investigating the Possibilities of Unmanned Aircraft Systems (UAS) in Mosquito Control Operations

by Kelly Middleton and Liz Sarson

Unmanned Aircraft Vehicles (UAV), Unmanned Aircraft Systems (UAS), or drones – these vehicles by any name are simply game-changers for vector control. The technology provides a solution for some concerns and challenges surrounding mosquito management efforts both on the ground and in the air. Consider the ability to fly over a protected marsh to obtain surveillance imagery and then treat hard to reach or very targeted areas without ever setting foot into the sensitive habitat. Applicators, regulators, and the public are finding value and an appreciation for the new technology.

Vector control is evolving rapidly, and it's exciting to be a part of this shift. The industry is led by solid scientific methodologies and highlighted by federal agencies as critical links in our country's public health preparedness network. Many vector control programs across the United States are embracing UAS in the management of mosquitoes and realizing improved efficiencies across all departments, and reduced liabilities at a time when many agencies find themselves stretched increasingly thin.

Bringing technology and science together has been the maxim of Leading Edge Aerial Technologies (LEAT) since its inception. In 2014, the company launched the PrecisionVision suite of hardware and software for UAS aerial spray systems and imagery, specifically designed to help vector control programs, but with capabilities for many other industries.

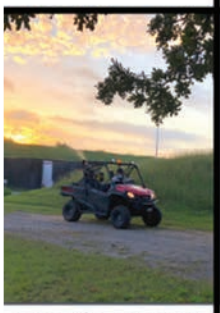
"There is tremendous excitement around this new technology," says LEAT CEO and chief pilot Bill Reynolds, "as well as the expected challenges industries encounter while undergoing a paradigm shift in day-to-day operations. But we're well on our way into the future of vector control in the US." This innovative spirit was recently honored at the American Mosquito Control Association's (AMCA) 2021 Annual Meeting, where Reynolds received the Industry Award. The award recognized the significant advances his research, inventions, products, and UAS technologies have made to increase mosquito and vector control operations' efficiency and effectiveness, thereby aligning with the association's goals to protect public health. Multiple presentations at the AMCA Annual Meeting demonstrated the value of UAS technology in vector control and provided unique use situations that reinforce its efficiencies in mosquito control operations.

Regulatory hurdles surrounding the use of UAS for surveillance, as well as for aerial pesticide applications over public lands, seemed daunting in the early years. Still, Reynolds and key stakeholders at several flagship vector control programs worked with legislators and the Federal Aviation Administration (FAA) to ensure this technology became available. In 2015, Leading Edge filed for, and received, the first FAA 333 Exemption to use UAS in mosquito control. LEAT routinely supports public agencies through the process of writing an application for, and successfully attaining, their FAA Certificate of Authorization (COA). Today, agencies in more than 20 states now incorporate UAS into their surveillance and control programs.

As with all significant advancements, there is a learning curve and technological obstacles to overcome. The PrecisionVision line was designed and engineered based on field experience, and being built in the United States may prove to be an advantage, as many federal and state agencies prohibit the use of some UAS products made outside the country.

The actual benefits of UAS integration are best exemplified by the stories of three mosquito control districts leading this industry forward.

Figure 1: Leading Edge PrecisionVision® 35X with a granular payload system.

			ACRES/HR	ACRES/DAY*	
	Application Equipment	Payload Type	Coverage	Maximum Coverage	
 PrecisionVision UAS	UAS 25 LB. PAYLOAD	GRANULAR	38	220	
	UAS 25 LB. PAYLOAD	LIQUID	14	98	
					PrecisionVision UAS Potential Productivity Increase Acres/Day
 Aquatic or Land ATV	BACKPACK	GRANULAR	17 - 22	30 - 60	266% - 633%
	SEEDER	GRANULAR	16 - 30	60	266%
	BACKPACK	LIQUID	7 - 15	20 - 60	63% - 390%
				*includes prep and cleanup	

UPPER ACRE RANGES OF GROUND BASED VEHICLES ARE CALCULATED VALUES BASED ON SWATH WIDTH AND GROUND SPEED. THESE VALUES MAY NOT BE REPRESENTATIVE OF ACTUAL ACRE VALUES.

Figure 2: UAS vs traditional mosquito control ground treatment equipment. Data provided by LEAT and SYMVCD.

PIONEERS IN UAS INTEGRATION: A BLENDED APPROACH

The Sacramento-Yolo Mosquito and Vector Control District (SYMVCD), with offices in Elk Grove and Woodland, CA, is one of the country's first districts to start a UAS program and quickly realized the many benefits. Covering a sizable two-county region consisting of urban to agricultural habitats, SYMVCD now owns and operates seven UAS units. Additionally, SYMVCD contracts with LEAT to provide applications via UAS over larger acreage areas such as flooded rice fields, managed wetlands, and riparian areas, treating more than 5,800 acres over the past two years.

"Early in the program," said SYMVCD Ecological Management Supervisor and UAS Program Manager, Marty Scholl, "it became clear to the District that UAS imagery units not only provided an 'eye in the sky' benefit to the District technicians, but could provide technical analysis of potential mosquito sources, habitats, and current field conditions such as wind speed, temperature, and humidity." Utilizing the many integrated tools available, SYMVCD now has easy access to general aerial imagery, precision mapping and topographic modeling, mosquito source reducing best management practices project design analysis, and UAS-based mosquito control applications and support.

According to Scholl, SYMVCD worked closely with the FAA to receive many airspace and flight waivers and was one of the first governmental agencies to get an approved COA for UAS pesticide applications. One of their remote pilots holds the required California Department of Pesticide Regulation's Vector Control Technician Unmanned Aircraft Pest Control pilot certificate.

For smaller projects, SYMVCD currently uses five survey-grade UAS units coupled with real-time GPS correction to analyze slope and drainages of problematic areas. It uses this information to guide treatment plans, source reduction projects, and landowner relations. While still in the field, imagery can be stitched together, providing one large scalable image analyzed for spray block polygon design, providing accurate real-time information for treatment decisions. If immediate treatments are required, the spray block is uploaded to one of two larger application UAS units based upon the actual acres that need to be treated.

UAS provide a real benefit in wetlands and sensitive riparian habitat, and over rice fields where access is often

Figure 3: UAS real-time PrecisionVision Ground Control Station (GCS) software, depicting a flight plan.

severely limited by regulatory agencies or the challenges of the terrain itself. These sites are typically too small for conventional treatment by aircraft, or only require partial or targeted treatments. UAS are ideally suited for these particularly sensitive habitats as they leave no 'footprint' when compared to ground operations.

The integration of UAS technologies provides superior and highly targeted mosquito control operations while significantly increasing field efficiencies, decreasing response times, and reducing operating costs. Contracting with LEAT for larger, more routine applications allows SYMVCD to focus on smaller surveillance or treatment efforts requiring immediate attention.

EQUIPMENT FOR MOSQUITO CONTROL BY MOSQUITO CONTROL PROFESSIONALS

The Lee County Mosquito Control District (LCMCD), in Lehigh Acres, Florida, was an early and eager adopter of UAS technology. Assistant Director Aaron Lloyd noted that LCMCD has active mosquito larval sites in large swamp and marsh habitats in, or immediately abutting, residential neighborhoods, which present surveillance and control challenges. Historically relying heavily on manned helicopters and fixed-winged aircraft, LCMCD needed easier and safer access to these urban-edge habitats. Having inspectors hike in on foot, or use 4-wheel vehicles, to access sites was time and labor intensive, and meant placing team members in harm's way – from injury to bites from the very disease-carrying mosquitoes they sought to control. LCMCD

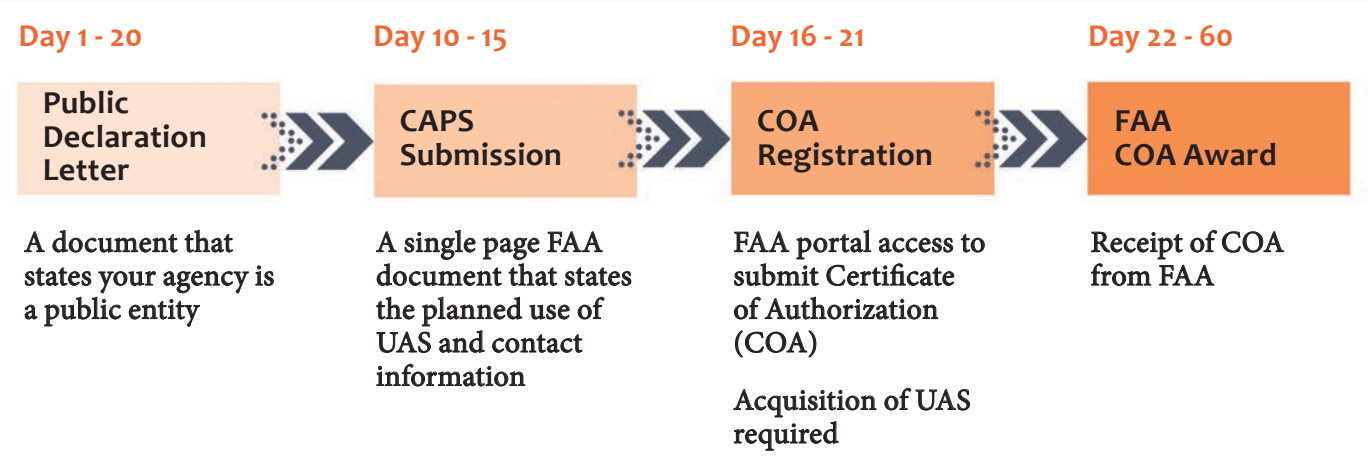


Figure 4: Typical timescale for obtaining a Public Aircraft Operation FAA Certificate of Authorization (COA).

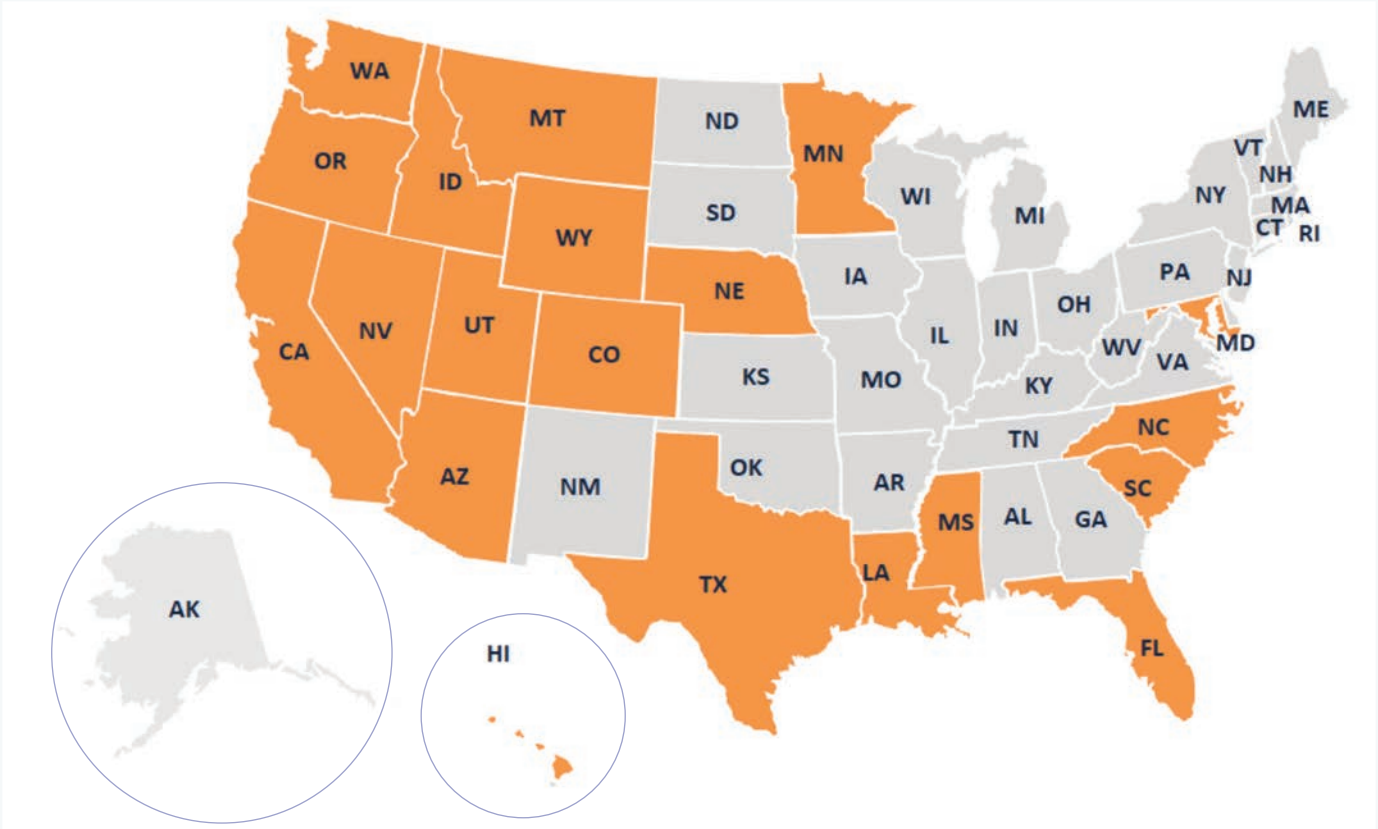


Figure 5: Map higlighting states that use PrecisionVision UAS technology for aerial applications of adulticides, larvicides, algaecides, herbicides, fungicides and pheromones and for seeding and pollination.

hoped to incorporate UAS technology to treat these areas in a quiet and efficient manner that was also less disturbing to homeowners than low-flying aircraft. LCMCD started looking for "...a company that understood mosquito control, could offer customer support beyond the purchase, and provide a seamless implementation of the UAS software with [their] current data management program," stated Lloyd. LCMCD chose LEAT's PrecisionVision UAS solution (aircraft plus software) as it met "all of [their] criteria."

Initially, securing the required FAA Part 107 Remote Pilot Certificates and COAs proved to be difficult and time consuming for LCMCD, but with Reynolds' assistance as an experienced liaison with the FAA, was able to apply for and receive a COA. Today, LCMCD has five UAS Part 107 certified pilots on staff who also hold the Aerial Applicator Licenses additionally required by the Florida Department of Agriculture and Consumer Services to make treatments from UAS.

Aside from larvicide treatments, LCMCD found an unanticipated benefit of the UAS and its integrated surveillance and multispectral systems which "...put eyes on areas that inspectors cannot reach by foot," Lloyd said, "providing them a view that allows for increased application efficiency without the cost of operating a helicopter." The first integration of Precision Vision software with LCMCD's existing MapVision Enterprise presented some early challenges, noted Lloyd, but LEAT's responsiveness and dedication to ensuring these systems do integrate and operate at their optimum levels has been much appreciated.

LCMCD currently sprays five to fifty-acre larvicide polygons with the UAS and is exploring the addition of a dedicated drone team to make better use of this technology. These areas are not conducive for aerial treatment by helicopter and "the drone fits right in the sweet spot," says LCMCD biologist and remote pilot Nick Lefkow, "right between where it gets a little too difficult for us to treat by hand and a little too small to treat by helicopter."

UNMANNED AERIAL SYSTEMS FOR MOSQUITO AND WEED CONTROL

David Herter, supervisor for both the Bannock County Mosquito Abatement District and Bannock County Noxious Weed Control programs in Pocatello, ID, is no stranger to employing UAS technologies for multiple benefits. Initially using drones to search out water sources, staff quickly saw the benefit of also using a drone to apply larvicides, leading to the purchase of their first application drone and soon thereafter, a larger platform able to quickly change from liquid to granular applications.

Figure 6: Leading Edge PV35 lifting off for remote larviciding application.

"We were amazed at the effectiveness of the UAS and its software. We are able to treat 5-acre plots in 2.5 minutes, instead of hours using traditional equipment," said Herter, which has "... allowed the County to become much more diverse in its ability to control mosquitoes." The software has made reporting and mapping applications simple. This helps ensure the County applies only the amount of product necessary and only where it needs to be applied. It also makes future budgeting for chemicals much easier, according to Herter.

In 2019, Bannock County became the first to use UAS technology to target both weeds and mosquitoes, the two programs splitting the UAS purchase cost. This technology allowed quick surveillance and treatments in areas previously inaccessible, enabling the agencies to "dramatically step up their program." Herter finds the future of UAS inspiring, with "the thought of being able to identify mosquitoes or noxious weeds from a drone and then control them all in one flight."

GLOBAL PERSPECTIVES FOR THE 21ST CENTURY

Programs around the world are realizing the benefits of unmanned aircraft, from public health to delivering food and medicines into inaccessible areas. In Africa, the use of drones allows health workers to cover 50-60 hectares (123-148 acres) per day in their battle to manage malaria, improving productivity by more than 100%. Brazil is experimenting with the use of drones to release lab-reared sterile insect technique (SIT) mosquitoes, finding the process 5-10 times more effective than dispersing mosquitoes by ground vehicle, while also minimizing damage to mosquitoes during deployment.

Thanks to the pioneering spirit of innovative thinkers who have paved the way forward, UAS technologies are no longer relegated to the wish lists of public agencies. With demonstrated safety, environmental, and economic benefits, vector control programs across the US are bringing technology and science together and moving their programs solidly into the future.

For more information, please visit www.LeaAerialTech.com.

ACKNOWLEDGMENTS

Thank you to the Sacramento Yolo Mosquito and Vector Control District, the Lee County Mosquito Control District, and the Bannock County Mosquito Control and Noxious Weed programs for sharing their experience incorporating UAS technologies into their operations.

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New Life for Old Ideas: Combining Modern Technology with Eggshell Sampling Techniques to Identify Saltmarsh Mosquito Production Sites in Collier County, FL

by Keira J Lucas, Peter Brake, Rachel B Bales, Robin King, Andrea McKinney, Chris Laidlaw-Bell, Patrick Linn and Scott A Ritchie

The black saltmarsh mosquito, *Aedes taeniorhynchus*, is a common mosquito species found in the eastern coastal areas of the United States. Females lay eggs in moist soil of the salt marsh and mangrove swamps just above the water line where eggs are influenced to hatch by rainfall or high tide (Ritchie & Addison 1992). The majority of spring larvicide and adulticide applications performed by Collier Mosquito Control District (CMCD), located in southwest Florida, are due to these highly aggressive biters. The coastal metropolitan areas of the District – including Naples, Marco Island and Goodland – are uniquely situated with the southern portion of the county, lined by mangrove swamps, saltmarshes and barrier islands of the Ten Thousand Islands National Wildlife Refuge, Everglades National Park and Rookery Bay National Estuarine Research Reserve. Adult female *Ae taeniorhynchus* not only emerge from local mangrove swamps within CMCD, but are carried into its boundaries by wind from as far as 60 miles (Harden & Chubb 1960) from larval habitat within these surrounding federal lands; see Figure 1. Their high fecundity, rapid development and migratory behavior place *Ae taeniorhynchus* as one of the top pestiferous mosquito species in the State of Florida.

With massive amounts of larval habitat surrounding metropolitan areas, a challenge faced by CMCD is to identify saltmarsh and mangrove swamps within the vicinity of CMCD that contribute to large populations of *Ae taeniorhynchus* adults. These high production sites are candidates for pretreatment by aerial larviciding, using extended-release granule products. Because this species disperses rapidly and migrates long distances from emergence sites, plans for larval control of *Ae taeniorhynchus*, and similar floodwater species, can be based on egg distribution surveys through a technique known as "eggshelling."

EGGSHELL SAMPLING

Eggshell sampling – or "eggshelling" –

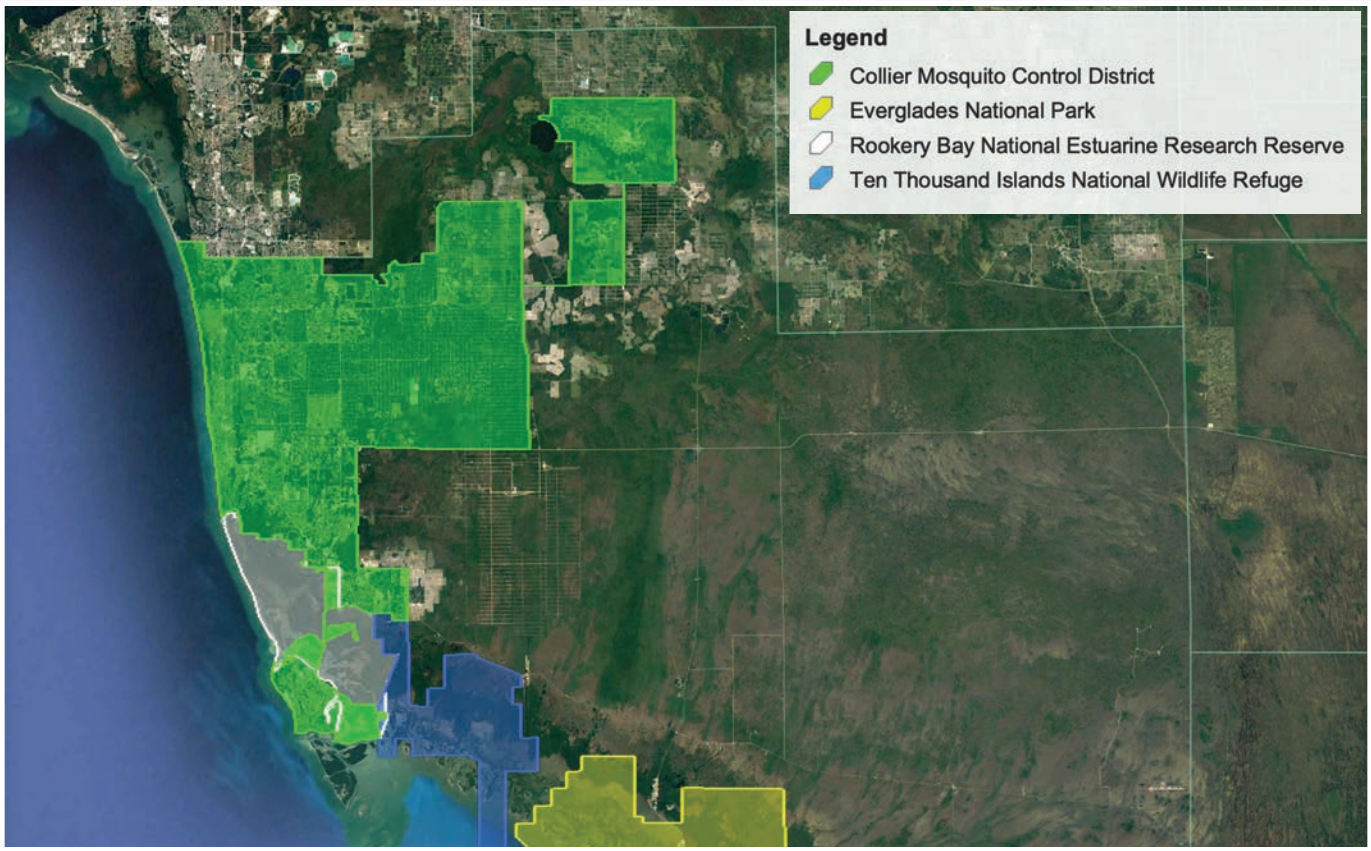

Figure 1: Google Earth map showing disjunct Collier Mosquito Control District boundaries within Collier County and federally-protected lands.

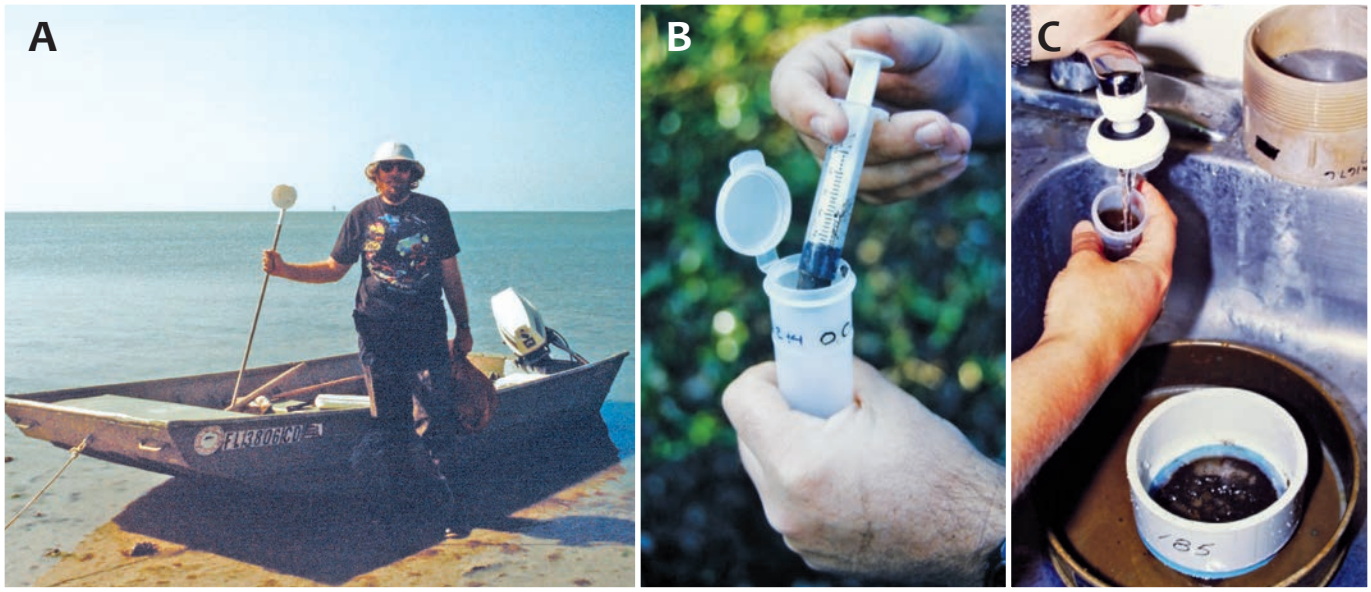

Figure 2: Eggshell sampling at CMCD in late 1980s to early 1990s: A) Scott Ritchie, former CMCD Director of Research, inspecting mangrove swamps in search of potential *Aedes taeniorhynchus* habitat and soil sample collection sites in Goodland, Florida; B) CMCD staff collecting mangrove soil samples for separation of eggs/eggshells; and C) CMCD staff processing mangrove soil by selective sieving to identify newly hatched eggs/eggshells.

and separating them from soil was first described by Horsfall (1956). Because eggs represent a "concentrated and stable" life stage for *Aedes* mosquitoes, Horsfall developed a process to identify habitat through egg distribution surveys. The surveys involved the separation of eggs and eggshells from soil by sieving and floatation in a saturated salt solution. This eggshell sampling can serve as an index for both historical and/or current production sites (Horsfall 1956; Lopp 1957). However, the highly organic peat-rich soil of the mangrove forest contains low-density peat particles that prove difficult to separate through Horsfall's floating method (Ritchie & Johnson 1989).

During Scott Ritchie's tenure as Director of Research at CMCD, Ritchie and Johnson (1989) developed several methods of egg separation that allowed for the visual isolation of new or recently hatched *Ae taeniorhynchus* eggs from small organic particles; see Figure 2. In general, their revised method processed soil by selective sieving, leaving low-density peat-rich matter and accompanying eggs and eggshells. Newly laid and hatched eggs are then visually isolated from the peat particles and relic shells with bleach – resulting in fresh melanized eggs and eggshells on a bleached background of organic particles and relic eggshells. For the identification of historical information, the selective floatation method using water can be used to isolate and identify relic eggs and eggshells (Ritchie & Johnson 1991; Ritchie & Jennings 1994). More recent progress on the

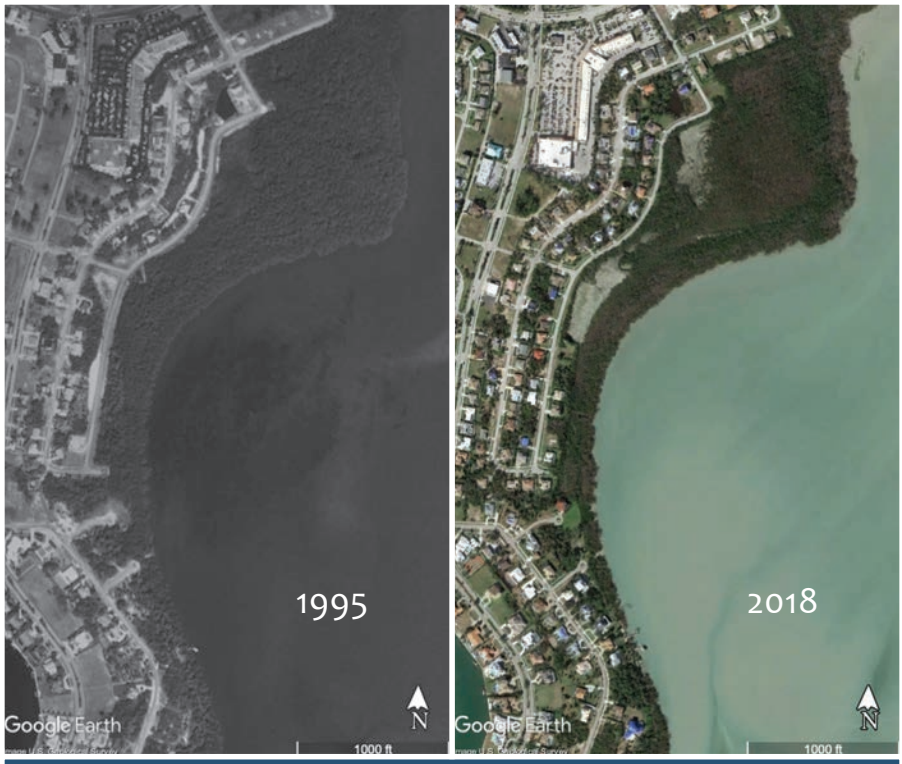

Figure 3: Google Earth images of the CMCD Dogwood swamp research site in Marco Island, FL displaying the coastal landscape and mangrove die-off to the area since 1995.

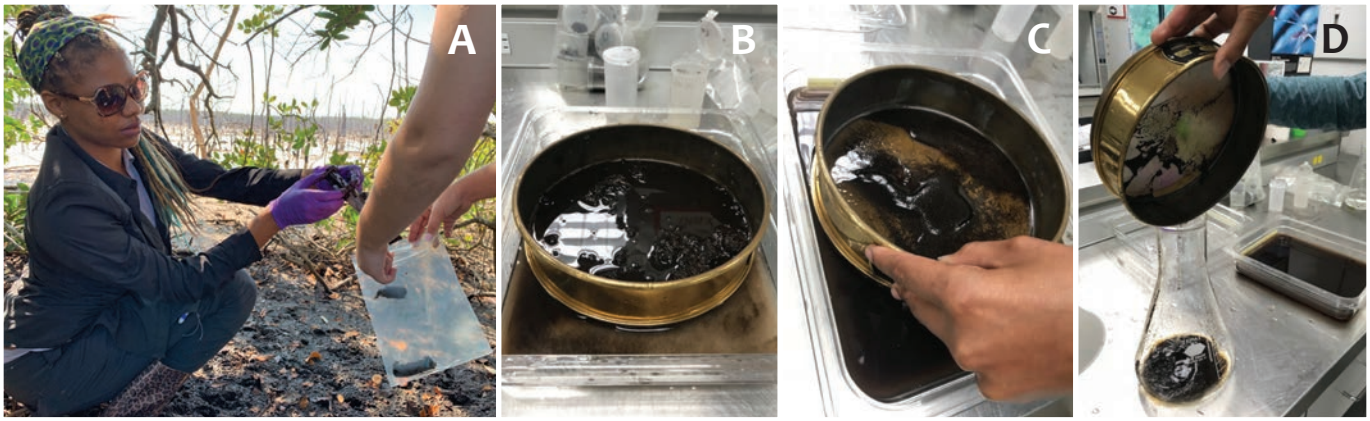

Figure 4: Outline of the eggshell sampling and processing method used for the identification of fresh eggs or newly hatched eggshells: A) Collect and pool soil samples in the field; B) In the lab, remove large organic material using a 600 µm sieve, then discard large organic material; C) Pour caught material through a 150 µm sieve; and D) Flush material into a flask using 50% sodium hypochlorite solution and allow to bleach for 2-3 minutes. Observe immediately under microscope. Peet and relic eggshells bleach white, while fresh and newly newly hatched eggs remain melanized.

floatation method distinguishes relic versus new eggs/eggshells through visual scoring of color, allowing the simultaneous identification of historical and current production sites (Turner 2002). These methods do not employ bleach and can be performed using a simple laboratory beaker, rather than a separatory sieve.

Eggshell sampling has been used by mosquito control districts to identify active and historical production sites. In the early 1990s CMCD's research team assisted several mosquito control programs in identifying potential saltmarsh mosquito production sites. One such eggshell sampling trip to the Turks and Caicos Islands identified that their historical ditching program restricted *Ae taeniorhynchus* oviposition to a narrow zone within the mangrove forest. Further, eggshell sampling has been used to identify preferred larval development sites by an Australian saltmarsh mosquito, *Ae vigilax* (Turner & Streever 1997; Dale et al 2002, 2008). It has subsequently been used to measure the impact of runnelling and saltmarsh modification on production of this mosquito (Dale et al 2014).

BRINGING BACK "EGGSHELLING" TO COLLIER COUNTY

In an effort to map and identify current *Ae taeniorhynchus* production sites within mangrove swamps in Collier County, CMCD brought back the "eggshelling" methods developed by Ritchie and Johnson. We were fortunate that most of Scott Ritchie's original materials were stored away in a cabinet in CMCD's laboratory, which assisted the research department in developing a revised eggshelling strategy using previous publications and old research tools. We began by visiting an old research site previously used by Ritchie due to its fruitful production of *Ae taeniorhynchus* – designated Dogwood swamp because it runs adjacent to Dogwood Drive; see Figure 3. While the landscape of the former research site has changed substantially since the 1990s, the area is still one of the most prolific production sites in Marco Island. When entering the Dogwood swamp one is immediately bombarded with hundreds of *Ae taeniorhynchus* ready for a blood meal at any time of year, even in mid-January.

We collected soil samples from Dogwood swamp, and through trial and error, drafted a protocol for identification of *Ae taeniorhynchus* eggs from mangrove soil, using the bleach method for isolation of newly hatched eggshells; see Figure 4. Nine equidistantly spaced soil samples collected from a 1 square foot plot using a 60 cubic centimeter (cc) plastic syringe are pooled into a plastic bag and returned to the lab for processing. The pooled sample is weighed, along with three 10 cc subsamples, and used to determine the total volume of the pooled sample, as follows:

$$\textit{Volume of pooled sample (cc)} = \frac{\textit{Weight of pooled sample (g)}}{\textit{Average weight of subsample (g)}} \times \textit{Volume subsample (cc)}$$

Processing involves the selective sieving and bleaching of peat and other organics. Large organic material is removed and discarded using a 600 micrometer (µm) sieve, with smaller peat particles, sand and eggs/eggshells collected in a catch pan. Smaller peat particles and eggs/eggshells are poured from the catch pan into a 150 µm sieve, with high-density sand remaining in the original catch pan. With the sand discarded, the peat particles and eggs/eggshells captured by the 150 µm sieve are then flushed from the sieve into a large Erlenmeyer flask using a 50% household bleach solution. The material is bleached for 2-3 minutes, or until the peat becomes yellow in color, poured through the 150 µm sieve and rinsed with water. Fresh eggs and eggshells are then visualized under

Figure 5: Identification of potential *Aedes taeniorhynchus* production sites using UAV technology in combination with eggshelling at the Dogwood swamp: A) Orthomosaic map; B) VARI map captured by the DJI Mavic Pro Platinum UAV; and C) Graph showing eggshell sampling results for each location.

a microscope and counted. The total number of fresh eggs and/or eggshells can then be determined by volume as follows:

$$\textit{Total eggs or eggshells per 500 cc} = \frac{\textit{Total number of eggs or eggshells}}{\textit{Volume of pooled sample (cc)}} \times 500 \text{ cc}$$

While a value of >0.05 eggshells/cc indicates that a site is likely to produce significant mosquito numbers (Addison et al 1992), this index was developed using the water floatation method and includes the isolation of relic eggshells. Operational indices have not been developed using the bleach method.

COMBINING AN OLD TECHNIQUE WITH NEW TECHNOLOGY

While Ritchie and Johnson's eggshelling method is of great utility and can be performed any time of year with relatively inexpensive equipment, it can also be labor intensive and time consuming. Identifying sampling sites historically required a combination of visual searches via aerial flyovers

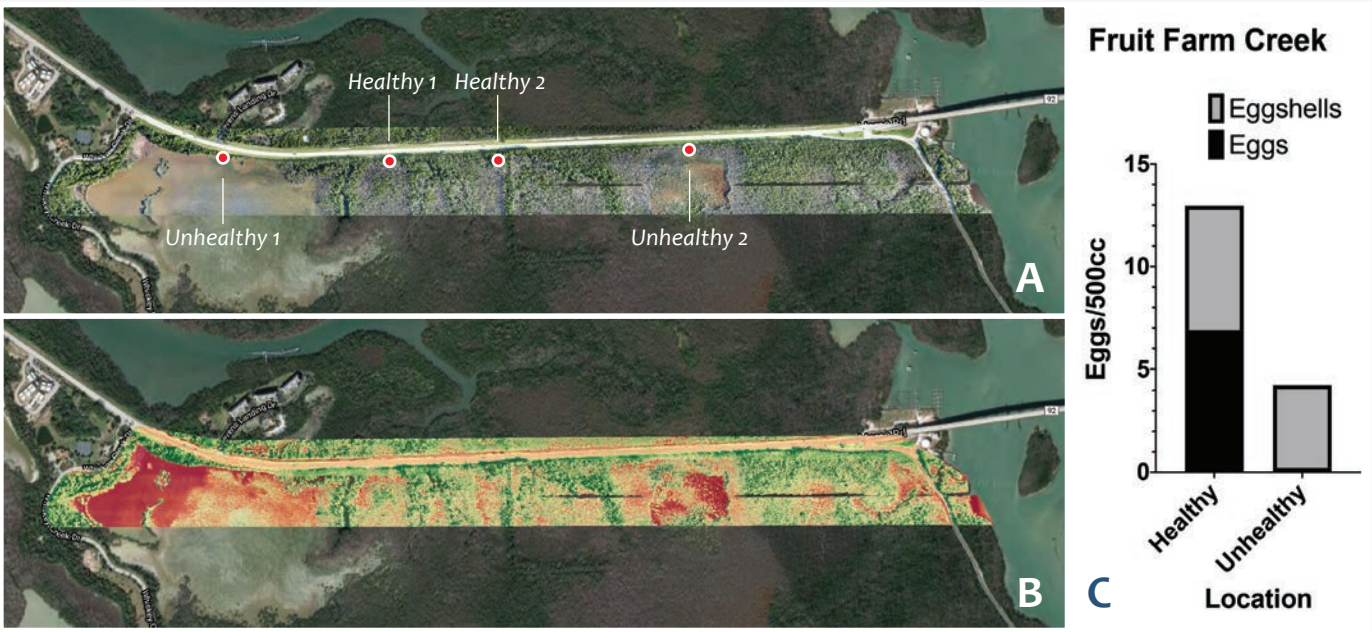

Figure 6: Identification of potential *Aedes taeniorhynchus* production sites using UAV technology in combination with eggshelling at Fruit Farm Creek: A) Orthomosaic map; B) VARI map captured by the DJI Mavic Pro Platinum UAV; and C) Graph showing eggshell sampling results for healthy versus unhealthy mangroves.

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and subsequent inspections on foot to identify the mangrove shelf of the high marsh, where *Ae taeniorhynchus* oviposits. This "needle-in-a-haystack" approach redirects CMCD aircraft from control missions and occupies a significant amount of time from technicians and biologists. Further, individual processing of each sample in the laboratory requires a skilled biologist to sieve and bleach massive amounts of samples. We have significantly reduced this labor-intensive process by pooling samples from each potential production site noted above, taking only 20 minutes per pool to process and visually inspect for eggs.

Aerial and ground-based inspections to find potential *Ae taeniorhynchus* production sites for eggshell sampling have been replaced with unmanned aerial vehicle (UAV) technology. CMCD currently uses a DJI Mavic Pro Platinum UAV (SZ DJI Technology Co Ltd, Nanshan, Shenzhen, China) to map probable *Ae taeniorhynchus* habitat. Flight missions are planned and collected images are analyzed with DroneDeploy mapping software (DroneDeploy Inc, San Francisco, CA). From the imagery produced by the drone's orthomosaic mapping process, the plant health algorithm known as Visible Atmospherically Resistant Index (VARI) is used to identify the relative location of the mangrove shelf, which in turn identifies the area where *Ae taeniorhynchus* eggs can be found. In general, VARI measures the "greenness" of an image, with large healthy plants – in our case, mangroves – reflecting more green light than smaller or unhealthy plants, water or dry grassland. With this mapping technology, the high marsh of the mangrove swamp can be pinpointed to provide a useful starting point for eggshell sampling.

This process was used to inspect and map the Dogwood swamp; see Figure 5A. We then assessed plant health using VARI algorithms and used the transition zones between green (large healthy plants) and red (smaller or unhealthy plants and dry grassland) to pinpoint areas of the high marsh for soil sample collections; see Figure 5B. Soil samples were pooled and processed in the lab as described above. A large number of fresh eggs (3.74-47.98 eggs/500 cc) and newly hatched eggshells (5.68-28.66 eggshells/500 cc) were identified from all three sampling sites; see Figure 5C. These data indicate the Dogwood swamp continues to be a production site for *Ae taeniorhynchus* and thus to be targeted for pretreatment applications.

FRUIT FARM CREEK

Changes to the natural hydrology in the mangrove swamp near Marco Island, designated as Fruit Farm Creek, resulted in the death and decay of large groups of trees in 1995. From an operational standpoint, we questioned whether this unhealthy swamp was sustainable for *Ae taeniorhynchus* production. Using UAV technology, we created orthomosaic maps and assessed plant health using VARI algorithms for the area in question; see Figure 6A&B. With a clear picture of the current decayed forest locations, we performed eggshell sampling near unhealthy/decayed locations and healthy mangrove areas. Eggshell sampling detected a larger number of fresh eggs (3.90-11.48 eggs/500 cc) and eggshells (5.20-7.65 eggshells/500 cc) within healthy mangrove habitat, while unhealthy areas had relatively little fresh eggs (0.00-1.10 eggs/500 cc) and eggshells (0.00-9.70 eggshells/500 cc); see Figure 6C. While these areas may have been historical *Ae taeniorhynchus* production sites before the mangrove die off, the unhealthy ecosystem is likely unfavorable for *Ae taeniorhynchus* production due to the lack of proper drainage and tidal flow. These unhealthy areas have now been excluded from the CMCD's larviciding treatment maps. With restoration projects of the area underway, CMCD will continue to map using UAV technology and perform eggshell surveys to determine resurgence of *Ae taeniorhynchus* habitat in these restored areas.

CONCLUSION

Eggshell sampling methods still represent one of the most effective ways to map and identify *Ae taeniorhynchus* production sites. While larvae can disperse rapidly upon hatching and adult

females migrate long distances seeking a blood meal, eggs typically remain concentrated at production sites. Further, sampling and processing methods can be used in a variety of ways, such as identifying historical habitat, detecting current production sites for larval control, track changes in egg concentrations over time, or identify how extreme weather events and subsequent "flushing" may impact egg concentrations and larvae/adult production. While these approaches may seem labor intensive and time consuming, modern technology has allowed us to more efficiently collect soil samples for egg and eggshell isolation. With inclusion of new technologies into our integrated mosquito management programs, innovative and more efficient methods of identifying and targeting mosquito habitat will begin to surface. The combination of UAV technology and plant health algorithms represents one such method that serves as a cost effective, low-labor and efficient process to pinpoint areas of interest for eggshell sampling collections and to assist vector control programs with targeted planning of larvicide missions.

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A Dozen Years Later: Updating a Comparison of Mosquito Control Between Four Degrees of Latitude on the "Right" Coasts of Florida and Australia

by Douglas B Carlson and Pat ER Dale

This article consists of discussions, interviews and correspondence with the following contributing authors, mosquito control professionals from Australia and Florida: David Allaway, Mark Call, Cecily Draper, Caroline Efstathion, Joseph Faella, Brian Falkner, Gary Goode, Glenn Henderson, Russell Manby, Andrew Mayfield, Mark Positano, Jason Sherriff, Martin Shivas, Miranda Tressler and Rui-De Xue.

INTRODUCTION

About 12 years ago, Dale et al (2008a) compared mosquito control programs located between the latitudes of 26 and 30 on the central east coasts of Florida and Australia. These subtropical areas have similar estuarine habitats, experienced rapid development over the past half-century and regularly experience the need for mosquito control for nuisance and occasionally mosquito-transmitted pathogens. The authors felt it is timely to again review mosquito control management in these similar climatic zones on different continents to provide an update on how circumstances and some important issues have evolved over the past dozen years. About 2 years ago, a complementary paper, which is also pertinent to this article, dealt with how mosquito control and coastal development have co-existed and matured in these two regions over the past half-century (Carlson et al 2019). In Florida, the area encompasses nine contiguous mosquito control programs, ranging from the city of St Augustine in the north (St Johns County; 29° 53' N, 81° 19' W) to Ft Lauderdale in the south (Broward County; 26° 07' N, 80° 08' W) – and referred to in this paper as East Central Florida (ECF); see Figure 1. The population of this region totals approximately 5.5 million. In Australia, the region extends in the north from Noosa (26° 28' S, 153° 06' E) in Queensland south to Grafton (29° 38' S, 152° 58' E) in the state of New South Wales (NSW) – referred to as East Central Australia (ECA); see Figure 1. ECA has a total population of approximately 3.6 million (2019). Communication between mosquito control programs in Florida and one on Queensland's Gold

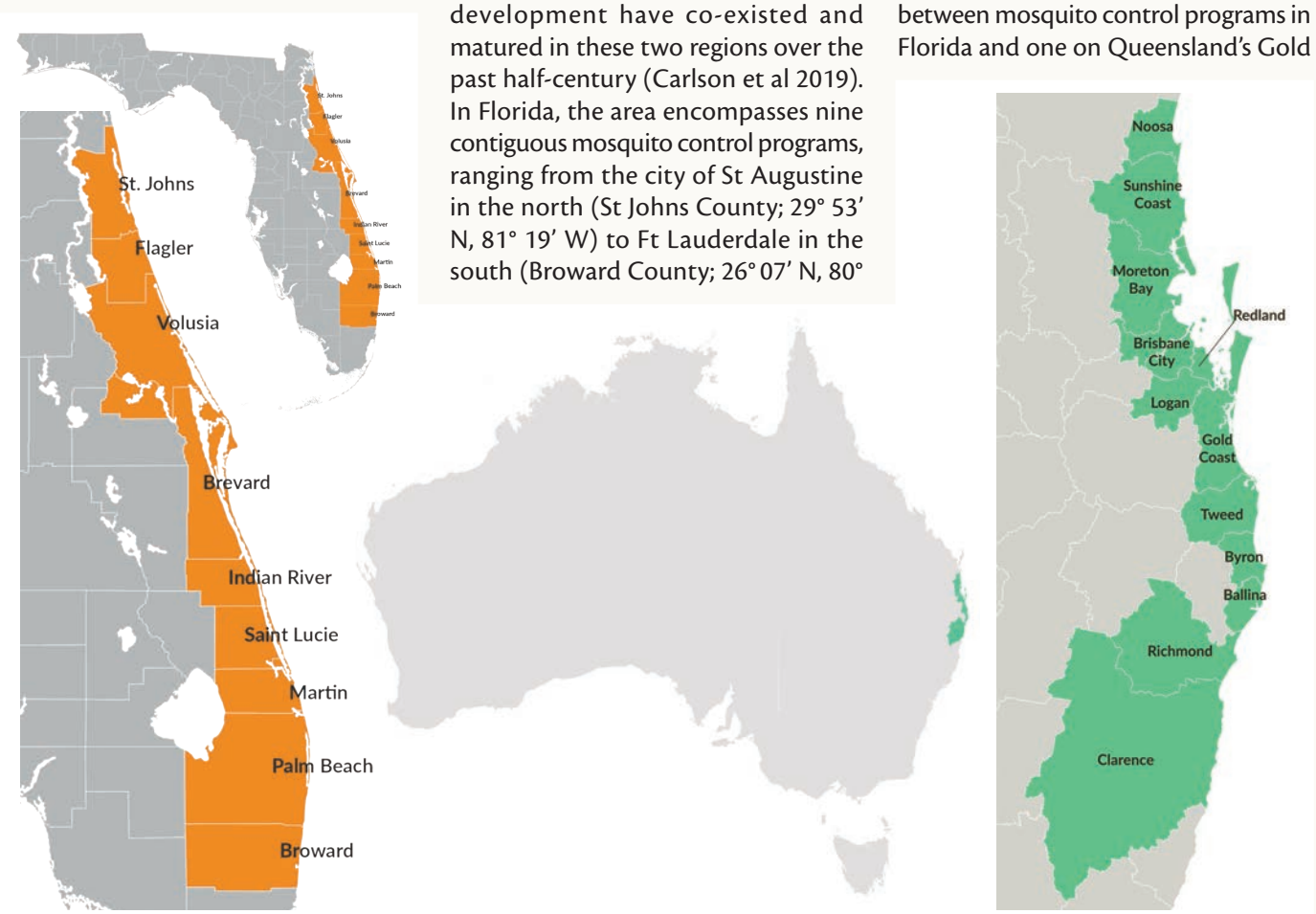

Figure 1: Maps of Florida (*left*) and Australia (*center and right*), highlighting districts with mosquito control programs along their respective east central coasts. Graphics by Jenna Ingebretsen

Coast has occurred over the past 50+ years. This paper provides an update since 2008 and has added perspectives from mosquito control directors/managers in Florida and Australia.

COMPARISON OF ECF AND ECA

CLIMATE AND HYDROLOGY

Both areas experience tropical to temperate conditions with the hot rainy summers being ideal for producing large mosquito populations. This has been especially apparent with both areas experiencing record summertime heat over the past several years.

Along ECF, the Indian River Lagoon, an environmentally sensitive and protected lagoonal estuary extending over 157 mi (251 km), is a significant producer of saltmarsh mosquitoes. The Indian River Lagoon's semi-diurnal tides have a mean range of 0.6 ft (0.2 m) with the annual tidal variation of about 2.5 ft (0.8 m). Annual rainfall is about 55 inches (1400 mm). In ECA, extensive intertidal wetlands with semi-diurnal tides range from 1.0 to 1.8 m (3.3 to 5.1 ft), with the annual tidal variation being about 2.5 m (8.2 ft). Sea level is rising by about 3.5 mm (0.14 in) per year. Annual rainfall is approximately 1000 mm (40 in). As in Florida, these wetlands are protected at several governmental levels.

ESTUARINE VEGETATION

Mangrove vegetation and saltmarshes dominate in both locales. In ECF, the black mangrove *Avicennia germinans*, red mangrove *Rhizophora mangle* and white mangrove *Laguncularia racemosa* are most common; see Figure 2. In ECA, mangroves line the estuarine coast with grey mangrove *Avicennia marina* dominating; see Figure 3. In both locations the intertidal saltmarsh is vegetated by halophytes including seashore saltgrass *Distichlis spicata*, and succulents American glasswort *Salicornia virginica* and saltwort *Batis maritima* in ECF; see Figure 4. In ECA, saltmarshes are primarily vegetated with the grass, saltwater couch *Sporobolus virginicus* and the succulent, beaded samphire *Salicornia quinqueflora*; see Figure 5.

MOSQUITO PRODUCTION

In both ECF and ECA, the high saltmarshes are capable of producing extremely large populations of saltmarsh mosquitoes – *Aedes taeniorhynchus* and *Ae sollicitans* in ECF and *Ae vigilax* in ECA. Other major mosquito-producing habitats within ECF include pastures producing *Psorophora columbiae,* with *Culex nigripalpus* remaining the most abundant species. *Mansonia* and *Coquillettidia* species periodically pose a problem with *Ae aegypti* and *Ae albopictus* regularly encountered, particularly in urban settings. Other species of significance include *Ae atlanticus, Ae infirmatus* and *Cx salinarius.* Citrus groves have historically produced large numbers of several mosquito species in ECF, such as *Ae vexans*, *Ps columbiae* and *Cx nigripalpus* (Curtis 1985). However, citrus greening disease – caused by the bacteria *Candidatus* Liberibacter and transmitted by the Asian citrus psyllid *Diaphorina citri* – has decimated the citrus industry in many parts of the state over the past decade (Tabachnick 2015), and to some degree, mosquito production from these areas has been reduced.

In ECA, saltwater mosquito habitats include tidally flooded saltmarshes and mangrove swamps (Jeffery et al 2005; Dale et al 2008b). Freshwater mosquito habitats include marshes and swamps – with *Melaleuca* species – with some constructed wetlands for stormwater and secondary sewage effluent (Russell 1999). These constructed wetlands have the potential to produce mosquitoes if not properly designed and effectively maintained. The primary mosquito species of human health importance is *Cx annulirostris,* found in freshwater ephemeral pools; other species of importance include *Ae notoscriptus, Ae procax, Verallina funerea, Cx sitiens, Cq linealis, Cq variegata* and *Ae multiplex*.

Figure 2: Mangrove-dominated impoundment in Indian River County, Florida.

Figure 3: Mangrove-dominated landscape in Nudgee, Queensland, Australia.

VECTOR-BORNE DISEASES

As described in Dale et al (2008a), several mosquito-borne pathogens can occur in both areas. West Nile virus (WNV) has received the most attention in ECF, with *Cx nigripalpus* being the principal vector. St Louis encephalitis (SLE), also vectored by *Cx nigripalpus*, and eastern equine encephalitis (EEE), transmitted by *Culiseta melanura*, can also occur sporadically. The occasional introduction of dengue, chikungunya and Zika to southern Florida over the past decade has increased control efforts directed to the container mosquitoes *Ae aegypti* and *Ae albopictus*.

The two main mosquito-borne viruses affecting humans in ECA are Ross River virus (RRV) and Barmah Forest virus (BFV) (Russell 2002). The main vectors of RRV are *Ae vigilax* and *Cx annulirostris*, while BFV has been isolated from *Ae notoscriptus* and *Ae procax*, and both viruses have been isolated from *Ve funerea*. Approximately 4,000 cases of RRV occur yearly in ECA (Queensland), representing around 50% of the total for Australia.

PROGRAM COMPARISONS

The nine ECF programs were originally created to control saltmarsh mosquitoes, but their current scope has broadened to include freshwater mosquito control and arbovirus surveillance and response. The most significant source reduction impact was the creation of approximately 40,000 acres of impoundments between 1955 and 1970, the majority of which are now managed via rotational impoundment management (RIM); see Figure 6. RIM permits seasonal reconnection of the marsh to the Indian River Lagoon with summer flooding by mosquito control programs (Carlson et al 1999), allowing the impounded marsh to provide many of its natural marsh functions (Brockmeyer et al 1997). Effective ground and aerial larviciding and adulticiding programs have been part of these integrated pest management programs for decades (Lloyd et al 2018).

Mosquito control in Queensland commenced in 1959, though little progress was made until the 1980s, with the formation of the first Contiguous Local Authority Group (CLAG), an alliance between local authorities and the Department of Health. The advantages of ongoing cooperation between contiguous local Councils has been widely recognized. Of the 16 local governments in New South Wales (NSW), Tweed Shire is the only one that conducts mosquito control directly and it is associated with the contiguous Gold Coast group. Source reduction efforts in this region have led to the peculiarly Australian concept known as runnelling, a type of shallow channel, using an open marsh water management approach; see Figure 7. Larviciding is a major component of the programs in ECA, whereas adulticiding is not common.

GOVERNANCE

As might be expected, there are contrasts in funding and governance.

In Florida, funding may be through independent taxing districts established by an act of the Florida Legislature, or through a county budget with programs developed at the discretion of the local communities. Anastasia (in St Johns County), East Flagler, and Indian River Mosquito Control Districts (MCD) are independent taxing districts, having their own elected board of commissioners who annually set a tax rate on property to fund their programs. East Volusia, Brevard, and St Lucie MCDs are dependent districts and governed by the county Board of Commissioners. Martin, Palm Beach and Broward mosquito control programs are part of their county government. Florida mosquito control programs are governed by laws originally adopted by the Florida Legislature in 1949. Florida Statutes Chapter 388 provides the basic governance and establishes the Florida Department of Agriculture and Consumer Services (FDACS) to oversee mosquito control programs with Chapter 5E-13 defining the rules under which programs operate (Lloyd et al 2018).

Figure 4: Herbaceous saltmarsh habitat in Indian River County, FL

Figure 5: Herbaceous saltmarsh habitat in Coombabah and Redlands, Queensland, showing *Sporobolus* / *Salicornia* marsh and dry runnels (*left*), and Salicornia marsh and invading mangroves (*right*).

Mosquito control is mandatory in Queensland, but not in NSW. Funding is derived from local government via a general rate on land. Within the local government body, mosquito control usually is under a Health Department. In 1993, the Tweed Council's mosquito unit collaborated with Council planning staff to develop Australia's first Development Control Plan (DCP). The DCP outlined local biting insect problems and addressed issues designed to minimize those associated with commercial and residential development.

In Queensland, mosquito control is carried out by local government through the Public Health Act 2005. Beginning 1919, NSW state legislation empowered councils to carry out mosquito abatement, but the State Government introduced a new Local Government Act in 1993, with general, non-mandatory guidelines that require lands to be put in a "safe and healthy condition," without specific reference to mosquitoes. The Act reduces the power of its predecessor, with enforcement of mosquito orders against NSW landowners at times proving to be difficult.

REGULATIONS

Source reduction work in wetlands – such as installation of dikes, culverts and pump stations, and runnelling – has the potential to negatively affect natural resources, thus they typically require governmental permits. In ECF and NSW (in ECA), permits may be required from multiple agencies. In Queensland however, applications are usually administered by one assessment manager. In ECF, federal permits are issued by the US Army Corps of Engineers and state approvals are typically provided by one of the State's five water management districts. Mitigation banks are commonly used as a means to provide mitigation credits for wetland impacts.

In Queensland, source reduction by runnelling does not require a permit, as it is classed as "accepted development" under the Queensland State Planning Act 2016. In NSW, all works, including source reduction, on Crown lands require a permit from the Department of Industry - Lands, and if on intertidal lands, permits are needed from the Department of Primary Industries - Fisheries.

CURRENT ISSUES

The completion of this paper has come at a time when the world is deep into a COVID-19 pandemic. In just several months, this situation has changed the world in numerous ways including how mosquito control is carried out now and likely into the future. To some degree, COVID-19 has impacted most of the topics discussed below although it was not specifically mentioned by the Australians. This probably reflects how COVID-19 is impacting the areas differently at this point in time. To provide a more local and practical perspective we asked our "panel" of mosquito control managers to provide comments on some issues presented to them, and to also mention topics they currently find important.

Several suggested topics were provided to the contributing authors for consideration and they were encouraged to add others; any unsolicited comments by the participants were also included. The Florida Section below is a synthesis of information provided by the 7 mosquito control managers within ECF's "4 degrees of latitude." The Australia Section that follows compiles information provided by the 8 mosquito control managers within ECA's "4 degrees of latitude."

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Figure 6: Aerial view of impoundment, Brevard County, ECF.

Figure 7: Aerial view of runnel site, ECA.

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AMCD's flight program is in its second year of operation. Outfitted for surveillance, larviciding, and adulticiding, the flight crew is responsible for a county of just over 380,000 acres.

AMCD Flight Crew (L to R):
Mike Phillips, helicopter pilot/CFI, **Dana Smith**, Chief Pilot/Aviation Manager, and **Ralph Bruner**, A&P/IA. All three are also FAA drone pilots.

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makes accomplishing this difficult. We have been fortunate over the years that our industry partners, along with research and development efforts from a number of institutions and industries, continue to bring new technologies and products to our doorstep. Recent examples of this include sterile insect technique (SIT), *Wolbachia*-infected male mosquito release, genetically modified organisms (GMO), attractive toxic sugar bait (ATSB) possibilities, and autocidal gravid ovitraps (AGO) and other different trapping systems from such companies as Mosquito Magnet, Biogents and In2Care. This situation is made even more difficult by the public's desire for "green" products, whose typically higher cost may make them a challenge to include in many programs' budgets. However, products listed by the Organic Materials Review Institute (OMRI) may be helpful to use in or near agricultural settings. Some in the public believe we have an incentive to continue to use pesticides and not to consider alternatives, though most of us would agree that is not true, following the belief that we must avoid the inclination to "just spray".

The increasing use of drones will likely become more common as time goes on, though it is likely that with increased use of this technology there will be more regulations impacting both drone and low-flying aircraft applications. Biological control is often popular with the public and in some situations can provide benefits. Brevard and Anastasia MCDs have implemented ambitious *Gambusia* stocking programs, each through the use of a hatchery. This will likely help gain public trust by attempting to reduce pesticide use to some degree.

CLIMATE CHANGE & SEA LEVEL RISE

Rising sea level, likely a result of climate change, is increasing flooding periods along Florida's east coast. This can also result in increased water coverage that requires attention by mosquito control agencies. Denser mangrove canopies – especially red mangroves – are well-established in southern portions of Brevard County, making larvicide applications challenging. However, red mangroves persevere better during severe storms, likely a result of their prop root system. In northern portions of this 70+ mile (112 km) long county, where vegetation is historically less dense, larvicide treatments continue to provide good results. However, some denser mangrove stands have been observed further north in recent years, encroaching where herbaceous saltmarsh ecosystems were traditionally dominant.

Decades of work on the saltmarsh impoundment systems of St Lucie, Indian River and Brevard Counties has resulted in significant reductions in mosquito production, along with natural resource enhancements. Impending threats to this important permanent control resource include recent years' severe storms, and in particular hurricanes, which have caused widespread damage to the dike system. It is anticipated that the predicted rise in sea level will exacerbate threats to these fragile earthen berms. Recently, some tides are showing higher-than-normal peaks, along with more frequent high marks, which can be challenging for some healthy mangrove stands. In St Lucie County, storm impacts over the past several years have necessitated assistance totaling almost $7 million to help offset repair costs.

Impoundments along Florida's Indian River Lagoon in St Lucie County are known for their beauty, conservation values and recreational amenities, in addition to their primary intended function of source reduction control of saltmarsh mosquitoes. Beginning with their creation in the mid-1950s, these environmentally sensitive wetlands have helped to boost public safety, tourism, recreation, conservation, and economic opportunities over a span of 150 miles (240 km). Local governments will need a strong financial commitment to maintain the very systems that strongly contributed to making development in this region possible. Throughout Florida, it is likely that small communities will experience economic difficulties in responding to rising water levels, possibly resulting in increased mosquito populations. Additionally, increasing storm intensity and generally unstable weather conditions may decrease the windows of opportunity to conduct both ground and aerial control operations.

Another result of climate change may likely be a longer "mosquito season," requiring pesticide treatments to occur more frequently throughout the year. Arbovirus surveillance may also become a year-round occurrence in Florida. Pesticide budgets will likely need to increase to combat this longer duration of high mosquito activity.

PESTICIDE RESISTANCE

A concern with the regular application of any pesticide is the possibility of the insects developing resistance to it. In Florida there is a paucity of information on resistance levels throughout the state, but with work to date demonstrating widespread mosquito resistance to both remaining classes of adulticides. That is especially worrisome with the container mosquitoes *Ae aegypti* and *Ae albopictus*. Better mapping of the situation has been identified as a tool to follow the trends as they occur. An identified priority is to accommodate data sharing among the agricultural, mosquito control and general pest control industries to track pesticide resistance, which is likely occurring due to the same active ingredients widely used by these professions. A recent example of this is the agricultural use of aerially applied permethrin to combat citrus greening, along with permethrin being a common ground adulticide for mosquito control. Additionally, better access is needed to resistance testing services and funding for in-house analysis by programs which are interested in pursuing it. A better understanding of the

current situation is important to prepare for the future.

REGULATORY CHANGES

The fact that mosquito control has done such a good job in making areas near wetlands habitable has inadvertently encouraged development closer to mosquito producing habitats. Residents moving there frequently have unrealistic expectations with regard to mosquito annoyance (Carlson et al 2019).

Regulations in our industry are necessary but addressing unnecessary or duplicative rules and regulations needs to be a priority. While the mosquito control profession has always been accepting of regulatory authority, when taken to the extreme it can stifle progress and limit source reduction efforts, as well as the development of new products.

Environmental considerations along Florida's Indian River Lagoon continue to be important for several programs covered in this paper. With dike and shoreline erosion problems as discussed above, permitting incentives to stabilize shorelines with "living shoreline" methods rather than traditional hardening continue to attract public attention. For some time, there has been a need for increased staffing in mosquito control agencies to handle these initiatives and permitting requirements, with the addition of natural resource scientists and environmental permitting specialists.

FINANCIAL & ECONOMIC CONSIDERATIONS

The current COVID-19 pandemic has brought to light some situations impacting our profession. Facing short-term budgetary reductions in tax revenues due to COVID-19 may reduce the local property base which generates taxes to support mosquito control. There may be higher operational costs and lower tax revenues in coming years. In an operational sense, some programs are experiencing staffing challenges due to possible exposure to the virus. Erring on the side of caution, some programs are having employees quarantine due to the possibility of exposure to an infected person, thus making it difficult for the program to fully carry out their mission.

A challenge some programs face is that expanding the service area does not always come with a concomitant increase in funding to accomplish it. Additionally, in some programs which are part of the county government, the finance staff are frequently not well versed in mosquito control's needs to carry out their mission. In some instances, they do not even recognize that environmental conditions such as rainfall and tidal events drive mosquito populations.

GLOBALIZATION EXOTIC SPECIES AS VECTORS

The fact that the world is being impacted by COVID-19 helps highlight the situation that mosquito control has faced for years. That is evidenced by exotic arboviruses such as chikungunya and Zika that have made their way to Florida over the past several years. Because we cannot predict these occurrences, control of vectors transmitting these viruses is typically difficult to achieve, as it is time consuming, yet is an immediate priority when it occurs. Research is needed to help mosquito control agencies better prepare and respond to these unforeseen events, along with more tools to respond to these situations. Given that the world is increasingly becoming a smaller place due to travel, an international goal of reducing poverty and improving living conditions could limit interaction between vectors and the public. As frequently is the case, public education efforts to better inform the populace as to how they can help their situation is constantly needed.

AUSTRALIA SECTION

EMERGING TECH & PRODUCTS

Little concern was raised about emerging technologies, though there was some interest in the use of drones. However, the use of the helicopter for aerial treatment and of adulticides are aspects of current technology perceived to be vulnerable. For example, if a major technical problem were to arise or the helicopter provider were to pull out of the market, a significant gap in the ability to provide adequate mosquito control services could occur. The system is "on a knife edge" between treatment success or failure, with no backup existing because of implementation costs, an issue exacerbated by climate change, as it seems there no longer is an "off season."

Adulticiding is an issue and a challenge, as the general Australian public's view is that it would be preferable to find alternate or better methods for adult mosquito (and midge) control. The cost of adulticiding is also a consideration, and therefore not universally employed. At least one program noted that adulticide use had increased over

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the years in its region, but for areas where it is not used, ultra low volume (ULV) fogging programs are deemed to be prohibitively expensive and not sustainable.

CLIMATE CHANGE & SEA LEVEL RISE

Climate change was not identified as a high priority, perhaps reflecting that it cannot be controlled by mosquito managers. However, extreme weather patterns – especially rain – associated with climate change have posed challenges both in extending the mosquito season and expanding mosquito habitats. Specifically, saltwater flooding due to sea level rise along the coastal strip is likely to lead to increasing mosquito problems. There is an opportunity to develop management plans to mitigate climate change impacts that would also minimize mosquito production.

GLOBALIZATION
EXOTIC SPECIES AS VECTORS

The potential risk of *Ae albopictus* occurring in the region raised concerns about what to do if the species became permanently established. The importance of surveillance was recognized, along with the need for improved trapping and processing methods for exotic mosquitoes and for timely analysis for detecting viruses. International arrivals at the Sunshine Coast airport could lead to an increased risk of incursion of exotic mosquitoes in the area from overseas, raising concerns is that there was no plan to deal with this challenge.

An exotic incursion of *Ae albopictus*, for example, would become a top priority – considered by some to be "a massive challenge" – involving the collection and collation of massive amounts of information. Staff across the various councils would need specific training for consistency of control measures, such as barrier treatments around houses. The challenge for state government agencies like Queensland Health is to be more proactive in supporting mosquito control.

EDUCATION AND COMMUNICATION

Overall, there is an issue of "reality versus expectation" for both the public and elected representatives. Councilors are the political arm of local government, influencing how resources are allocated across diverse areas. Council's messages to the public should be specifically designed to inform people about mosquito issues, so that residents understand the behavioral changes needed to reduce mosquito problem themselves. It would be useful to confirm that public and elected stakeholders have received and understood these informational messages. Time and opportunity are needed to educate stakeholders about mosquito control and considerable officer time is used by educating households individually, one at a time.

Public misinformation about mosquito production sites is a problem, with some residents not realizing that they may be contributing to their problem with containers or tires collecting water around their homes. There is also misinformation about "fogging," the term generally used by the public to refer to ULV treatments, and the associated negative "information" in social media can create a challenge. Additionally, newcomers from interstate and overseas areas are not accustomed to mosquitoes, and thus expect mosquito control to solve their problem, when that is not always the case.

Councilors from within a local government come from diverse backgrounds and may lack knowledge of mosquito control programs, their operations, and what can be expected. Therefore, complaints about fogging or aerial control costs from the public are simply passed on to the attention of the mosquito control unit, rather than being explained at the outset.

LOSS OF INSTITUTIONAL MEMORY

Without succession planning, the loss of institutional memory is a high priority and challenge. As staff members age, field work can become a workplace health and safety issue, and when they retire, there is a challenge in maintaining skills and knowledge in the unit and retaining knowledge of many topics. This is particularly important, because recent and on-going changes in technology mean that even greater skills are needed than in years past.

Other related challenges include dealing with the potential impact of diminishing the perceived value of the mosquito control profession, as key people leave, taking with them experience and skills. This may have the potential for people to not see mosquito control as a desired career pathway, so they move on to other careers, with a loss to the mosquito control community.

TRAINING

No matter one's job description, more training is needed. Operators knowledgeable about performing their job and interacting with the public, would like to broaden their skills by learning about subjects such as pathogen transmission and vector competence. Improved training is also needed for new employees, as no specific entomological instruction is currently provided. In practice, new employees may be paired with an experienced officer to learn on-the-job, which is often not time efficient. Additionally, for some, there is little or no opportunity to meet with other mosquito control workers in the region.

RESPONSIBILITIES & WORKLOADS

There is a broad area of issues related to job responsibilities and workloads and how their demands and needs are changing, including changes to workplace health and safety requirements, environmental regulations,

and staff expertise. As information technology becomes more complex and computer systems change, there is an ongoing need for information technology (IT) specialists. Some areas have experienced expansion of job responsibilities – such as working on private lands, along with dealing with vegetation and pest animal control – and this has implications for time and personnel resources. Understaffing is a high priority issue for some. For example, when demand is high a small team may have difficulty coping, and other aspects of the program may need to be reduced. There are risks that mosquito control functions will suffer if key operators are out sick. Personnel need proper qualifications to deal with technology and products, and replacement employees cannot be drafted from other areas.

PLANNING

Ideally there would be no residential development close to mosquito habitats, but new large "greenfield" developments continue to be constructed within the flight range of *Ae vigilax*, *Ae procax* and *Cx annulirostris*, typically with no provision for buffers or any other form of mitigation. Additional resources for mosquito management are then required in such areas, and often mosquito control becomes aware of this only after the development is constructed and complaints flood in. In Queensland, this is due to there being no formal process for local government land use planning and development assessment to communicate with mosquito control. This results in new developments limiting access to treatment sites and new residential areas designed without consideration of mosquito habitat, with little public education on these issues. Questions remain about retrofitting existing settlements and who will pay for such measures. The main challenge is in establishing processes for development approval that seriously take into consideration mosquito issues. Integrated collaboration within council and with stakeholders is needed in order to accomplish this important task.

POSITIVES OF MOSQUITO CONTROL

On a positive note, one manager stated that being in mosquito control is very enjoyable, so "positives of mosquito control" was added to the list for ECA contributors. Several reported that they enjoyed mosquito control work, as the diversity, complexity and problem-solving aspects of the job are interesting, though challenging. Several mentioned that they appreciate the science that underpins operational control. The unique mosquito control community is important, in that colleagues are valued, and help is freely provided. Employees gain from networking, conferences, workshops and the Mosquito Control Association of Australia (MCAA). The wide variety of professional expertise is an asset with the sharing of ideas. Some respondents were appreciative of the level of knowledge gained from the Mosquito and Arbovirus Research Committee (MARC), MCAA and local personnel. Finally, providing a valuable service to the community is very satisfying.

DISCUSSION

Mosquito control operations in ECF and ECA have adapted to both biophysical and social changes. The biophysical environment has responded to climate changes with increasing density and distribution of vegetation, with an accompanying need for flexibility to adjust in mosquito management. Population growth has continued and demand for residential land has meant encroachment towards mosquito habitats thus causing increased challenges for mosquito control agencies. Mosquito control professionals continue to be dedicated to their work and many of them have been in this role over many decades. This paper demonstrates that among the managers in ECF and ECA, there was broad agreement on many current issues, yet their views differed, reflecting the nature of these two antipodal areas.

CONCLUSIONS

As previously noted by Dale et al (2008a), the greatest strength of mosquito control remains the commitment and sense of camaraderie among mosquito control personnel, which is important in continuing a strong allegiance to the profession, enthusiasm for their work and satisfaction in providing a valuable public service. In the second half of the 20th Century, tremendous successes in mosquito control occurred between 26 and 30 degrees of latitude in ECF and ECA – but there are lessons to be learned, room for improvement and challenges to come.

DEDICATION

This paper is dedicated to the memory of Clive Easton (Tweed Shire, NSW), William Opp (FDACS and Lee County MCD) and Jack Salmela (Brevard MCD), all of whom played important roles over the past 50+ years in supporting mosquito control practices with environmental awareness.

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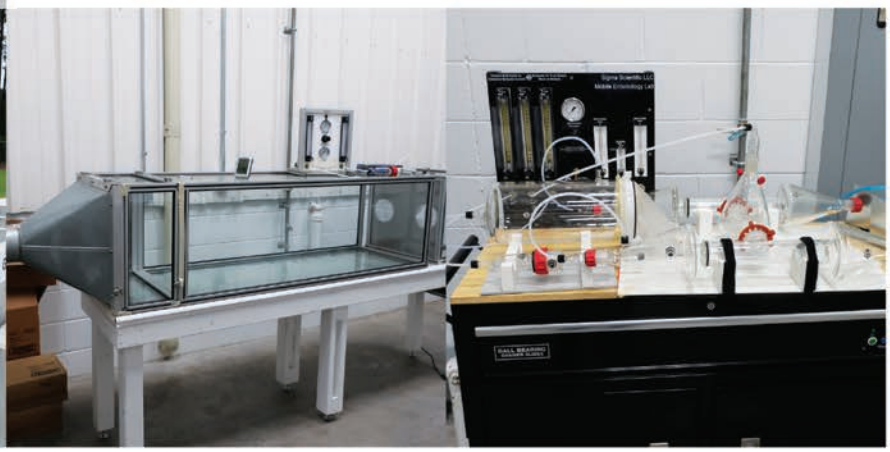

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All Federal Agencies Should Support the Nationwide Campaign to Protect the Public from Vector-Borne Diseases

by David Brown

In September 2020, the Centers for Disease Control and Prevention (CDC) released the formation of a new initiative called "A National Public Health Framework for the Prevention and Control of Vector-Borne Diseases in Humans" (CDC 2020). In this release CDC stated that "Americans are at an increasing risk of vector-borne disease, and the United States is not adequately prepared to respond." In their coordinated approach they describe how five federal departments – the Environmental Protection Agency (EPA), Department of Health and Human Services (HHS), Department of Defense (DOD), Department of Agriculture (USDA) and Department of the Interior (DOI) – have developed a workplan to protect the nation from morbidity and mortality from vector-borne diseases. The agencies identified under the DOI umbrella are the National Park Service and US Geological Survey. Notably absent is the US Fish and Wildlife Service (USFWS).

I have a problem with this.

At the 2021 AMCA Virtual meeting, Bill Meredith – Past President of AMCA and Chair of the USFWS subcommittee in the Legislative and Regulatory Committee – gave a presentation on the continued resistance of USFWS to recognize the need to proactively conduct mosquito control activities on refuge land. Similar concerns have also been echoed by many mosquito control districts across the United States. These districts are frustrated with trying to work with the refuge system to ensure mosquito populations are kept at appropriate levels to prevent severe biting pressure or disease transmission when a pathogen presents itself. Roadblocks to control include, but are not limited to, appropriate access to conduct surveillance, identifying only certain mosquito control options that can be used, and in some cases not allowing any treatment or surveillance until a pathogen presents itself. In addition to these restrictions, when control is warranted, it is often to the tune of several tens of thousands of dollars that are generally not reimbursed.

To be fair, most if not all federal agencies pay "in lieu" taxes as opposed to the regular property taxes or benefit assessments that fund mosquito control operations. But to be clear on this point, the dollars received from these "in lieu" taxes are not sufficient to pay for the mosquito control issues that emanate from that federal property.

The Mission Statement of the USFWS is as follows: "Working with others to conserve, protect and enhance fish, wildlife and plants and their habitats for the continuing *benefit of the American people*." Their Values Statement is: "The US Fish and Wildlife Service values strong conservation partnerships focused on restoring, connecting and conserving landscapes that sustain both wildlife populations *and people*. We are a learning organization, fostering and rewarding innovation and *calculated risk-taking*." I added the *italics* in the two statements above to ask a couple of questions.

If the USFWS mission is to work with others to conserve, protect and enhance fish, wildlife and plants and their habitats for the continuing *benefit of the American people*, why hasn't DOI included the USFWS to work together to address the mosquitoes that are produced on property they own and

Figure 1: The US Fish and Wildlife Service did not participate in CDC's national vector-borne diseases workplan.

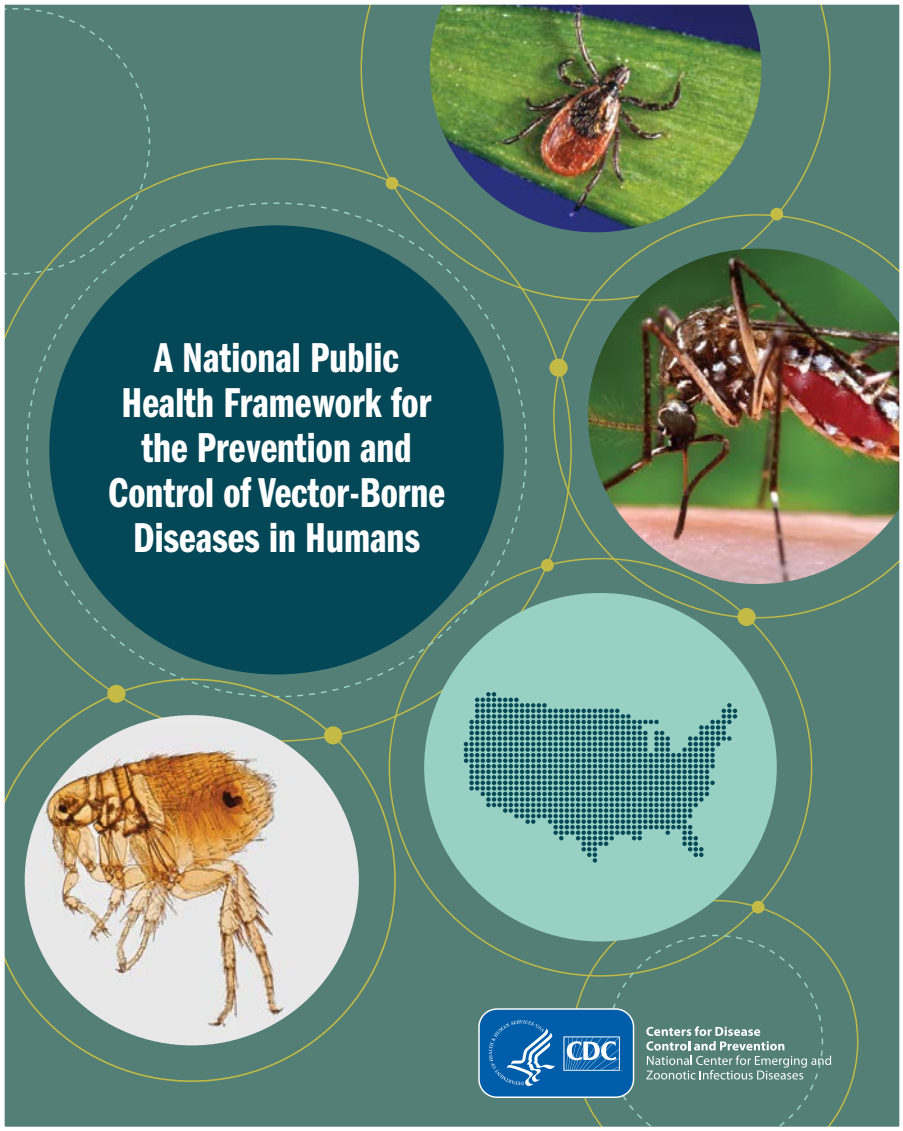

Figure 2: Additional information on the CDC's "A National Public Health Framework for the Prevention and Control of Vector-Borne Diseases in Humans" is available at https://www.cdc.gov/ncezid/dvbd/framework.html.

manage? Doesn't DOI recognize the role USFWS could have in protecting public health, and even animal health, from mosquitoes and other vectors?

My view is that it is a bit unrealistic to have a National Framework for Public Health for Vector-borne Diseases if we have sections of the federal government unwilling to partake in the process or affirm the results of those that are trying to move this forward. We know that the USFWS is concerned about pesticide uses on their properties. All of us in the mosquito control world know that EPA does not register pesticides until a thorough examination of the product is conducted. EPA's review of pesticides as part of the registration process is to provide clear directions on the label for effective product performance while *minimizing risks to human health and the environment.* I do not know about you, but that last part would seem to fit within a sister agency that fosters and rewards "innovation and calculated risk taking." In addition, that same mantra would seem to fit very nicely with many of the presentations by Dr Robert Peterson, a researcher focused on agricultural and biological risk assessment. More specific to our activities, he examines human health risks from West Nile virus compared to risks from the use of insecticides to control mosquito vectors of the virus.

In his Keynote Address at the 2021 AMCA virtual meeting, Dr Peterson outlined how risks from mosquito control applications of pesticides are at such low levels of concern that it simply does not warrant the fears from the general public, or in this case, a federal agency that rewards calculated risk taking that would ultimately protect human health.

I'm looking forward to having AMCA members address the growing threat to public health with CDC. I also look forward to the day we can get ALL of the components of the federal government behind this effort. In the meantime, I recommend contacting your local leaders informing them of this disparity, since public health responses and the financial burdens associated with them start at the local level.

Stay safe, and let's work together to protect public health in 2021.

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Option A: Lab in a Box A complete *qPCR* lab in a box (pictured below) containing all necessary equipment, plus tests for WNV, WEE, SLE, Zika, dengue, chikungunya and malaria.

Option B: Tests Optimized to *Your* PCR Equipment Our tests also run on most open-source PCR equipment. We're set up to be either a full-service provider or a test supplier.

Our Next Step Let us show how you can service your districts with the best modern technology available. We're confident its speed-to-result, accuracy and affordability will help you bring better, faster solutions to the communities you serve.

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