Journal of the American Mosquito Control Association, 41(3):115–118, 2025

2025 AMCA PRESIDENTIAL ADDRESS: BEST MANAGEMENT PRACTICES FOR TECHNOLOGY ADOPTION FOR SURVEILLANCE AND CONTROL OF MOSQUITOES[1]

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ABSTRACT. Each year, the American Mosquito Control Association (AMCA) annual meeting features a program designed to highlight the various research, collaborations, and innovations that impact our programs throughout the USA. The AMCA meeting in San Juan, Puerto Rico, from March 3 to 7, 2025, gave our members and local professionals a new perspective on the battle against mosquito-borne diseases. In recent years, there have been local outbreaks of dengue fever, Zika virus, and chikungunya virus in this US territory. The mosquito control professionals and local citizens welcome, support, and collaborate and may also benefit from the national and international meeting. We thank the program committee, local arrangement committee, and AMCA Board for their collaboration in making the meeting attractive, which resulted in more than 970 registrations worldwide. The European Mosquito Control Association showcased European expertise in mosquito control at this event, strengthening ties with AMCA. With the rapid development of technology, including artificial intelligence, robotic techniques, and tools, mosquito control professionals will face new challenges and opportunities for exploration. I want to take this opportunity to promote and encourage members to adopt best management practices for the effective use of technology in the surveillance and control of mosquitoes and other disease vectors.

KEY WORDS Best management practice, control, surveillance, techniques, technology

As a member of the AMCA since 1992, I would like to remind myself of the mission of the AMCA. I have attended most of the annual meetings in various locations, as well as the legislative meetings in Washington, DC. My career and professional growth have been closely tied to the AMCA, and I have benefited from its support. My mission has been to combat mosquito-borne diseases through teaching, research, operations, and administration for over 40 years. I am pleased to have been elected as the AMCA President and to serve our members. It is a dream, an incredible and unforgettable journey in my career. My passion for the job and professional service in the field of biology and control of mosquitoes began after I suffered from mosquito-borne malaria when I was a teenager in the early 1970s. After completing my medical education, I pursued a master's degree in human parasitology and medical entomology, followed by a Ph.D. in medical entomology, with a focus on the physiology and ecology of vector mosquitoes. Throughout my professional career in the past many years, I have been fortunate to have had several great mentors who provided me with direction, inspiration, leadership, and dedication in the field. They are Wenzhong Zhang (my mentor for the master's degree), Baolin Lu (my mentor for the Ph.D.), and John D. Edman (my mentor for postdoctoral training), who invited me to the USA. Additionally, I am fortunate to have several professional mentors and supervisors. They are Arshad Ali, who asked me to come to Florida, the so-called capital city of mosquitoes, Donald R. Barnard, Research Leader, who hired me to work at the United States Department of Agriculture (USDA) Center for Medical,

[1] Presentation given at the 91st Annual Meeting of the American Mosquito Control Association, San Juan, Puerto Rico, March 3–7, 2025.

Agricultural, and Veterinary Entomology, Mosquito and Fly Research Unit, Gainesville, Florida, for 10 years and helped me to become a permanent resident and become 1 US citizen. Next was Robert Betts, former Director of the Anastasia Mosquito Control District (AMCD) of St. Johns County, Florida, who hired me as the Entomologist at the AMCD, St. Augustine, Florida, then the Board of Commissioners (5 ladies: Emly Hummel, Mary Willis, Rita Cornwell, Beth Bowen, and Barbare Bosanko) of the Anastasia Mosquito Control District, who appointed me as the District Director after 2 years at the District in 2005. Since 2005, I have worked with more than 28 different commissioners, learning from each other, collaborating, and working together to make our small program have a state, national, and even international impact through applied research, technology adoption, education, and centralization. Additionally, I am fortunate to have a dedicated staff team and employees, as well as family and collaborators from federal, state, universities, and the industry worldwide, who have worked together to support my career and our district programs.

With the rapid development of technology, including artificial intelligence (AI) (Nayak et al. 2023), drone and robotic techniques, and tools, mosquito control professionals and AMCA members will face new challenges and opportunities in the next few years (Javed et al. 2024b, Xue et al. 2024). Adopting technology for surveillance and control of vector mosquitoes requires a best management practice (BMP) framework (Xue and Zhao 2023) that ensures efficiency, cost-effectiveness, and sustainability. A structured BMP approach for integrating new technologies into disease vector control programs includes a needs assessment and feasibility study, such as defining objectives to identify whether the technology aims to improve surveillance, control, decision making, or operational efficiency, assessment of vector ecology and epidemiology to evaluate local transmission risks and vector population dynamics, and assessing feasibility to consider cost, training requirements, infrastructure, and regulatory approvals. Additionally, one should consider engaging stakeholders to consult with public health officials, researchers, community leaders, and funding agencies. The selection of appropriate technology involves choosing tools based on surveillance methods such as Smart Traps (e.g., the BG-Sentinel counter and AI-powered egg and larvae counters [Javed et al. 2024a, Wang et al. 2024] and the gravid *Aedes* trap with automated counting), AI-driven image recognition for mosquito species identification and counting (Bai et al. 2025), environmental sensors, geographic information system (GIS)-based mapping, metagenomics (McCarthy 2024), e-DNA/RNA tech (Soler et al. 2025), and polymerase chain reaction testing for pathogen detection. Control technologies include biological and biorational control methods, such as *Wolbachia*-infected mosquitoes (e.g., World Mosquito Program, MosquitoMate), sterile insect technique (SIT) (Aldridge et al. 2024, Bouyer 2024), genetic control, such as GMO (Oxitech), clustered regularly interspaced short palindromic repeats (CRISPR)-based gene drive editing for vector population suppression (Häcker and Schetelig 2018, Naidoo and Oliver 2025), chemical control with AI-optimized ultra-low-volume (ULV) spraying and spraying robots and drones, attractive targeted sugar bait (ATSB), physical control with drone-assisted larval habitat mapping and insecticide application (Yu et al. 2024), and clever larval traps with IoT (Internet of Things) connectivity. Pilot testing and data validation include field trials with deploy technology in controlled environments to assess effectiveness, operational feasibility, and acceptance. These trials are compared with traditional methods to ensure that the new technology outperforms or complements existing approaches. Additionally, data validation is conducted to ensure accuracy in mosquito species identification, the detection of dengue and other pathogens from mosquitoes, and the efficiency of pesticide delivery. Also needed is integration with decision support systems such as real-time data analytics, and the use of GIS-based dashboards for tracking mosquito populations, weather conditions, and dengue outbreaks, predictive modeling and AI technology to implement machine learning for trend analysis and early warning systems, automated reporting, and improving communication between field teams and public health agencies and citizens. Capacity building and training will include workforce training to educate personnel on the proper use of new technologies, and community involvement to promote citizen science initiatives, such as mobile apps for mosquito reporting (e.g., mosquito-borne disease and risk alert), interagency or governmental collaboration, and partnering with research institutions, tech developers, media, and public health agencies. Regulatory compliance and ethical considerations will adhere to national and international regulations to ensure environmental safety, public health guidelines, and community acceptance. Public awareness campaigns will be conducted through various media to address concerns about genetically modified mosquitoes and AI-driven surveillance. Performance monitoring and continuous improvement involve surveys, data-driven evaluations, and regular assessments of the technology's impact on reducing mosquito populations and the incidence of mosquito-borne diseases. Additionally, a cost-benefit analysis will be conducted to ensure long-term financial sustainability, and iterative improvements made to adjust strategies based on feedback from field operators, entomologists, and epidemiologists.

The successful adoption of technology for vector mosquito surveillance and control requires a structured approach, as mentioned above, to integrate cutting-edge tools with scientific validation, regulatory compliance, community engagement, and traditional control methods. By following these best management practices, mosquito control programs can maximize efficiency, enhance decision making, and ultimately reduce pathogen transmission.

AI technology is one of the most advanced tools available today (Nayak et al. 2023, Weng et al. 2024, Xue et al. 2024). AI tools for vector mosquito surveillance include surveillance and data analysis through mosquito image recognition and classification (Bai et al. 2025), such as Microsoft AI for Earth, which utilizes computer vision to identify mosquito species. We have an AI-powered smartphone app for citizen-based mosquito reporting (MozzWear, Singapore) and deep learning models, trained on image datasets (e.g., TensorFlow-based mosquito classification): geospatial mapping and predictive modeling. The Google Earth Engine analyzes environmental factors (temperature, rainfall, and vegetation) to predict mosquito outbreaks. The National Aeronautics and Space Agency (NASA) is developing a method to use satellite imagery to map areas at risk for dengue and other diseases. EpiRisk AI predicts disease spread based on human mobility and mosquito data. Automated traps and IoT-enabled surveillance include the BG-Counter (BioGents), a IoT-connected mosquito trap with real-time species identification. The CDC smart trap uses sensors and AI to classify mosquito species. Drone-based detection of mosquito breeding sites and mapping techniques are also available.

The AI tools and innovations for vector mosquito control include genetic and biological vector control as well as biorational control. *Wolbachia*-based control releases *Wolbachia*-infected *Aedes aegypti* (L.) to reduce dengue transmission (Ye et al. 2015) (World Mosquito Program and MosquitoMate). The company uses AI to mass rear and release sterile male mosquitoes (Verily's Debug Project). The CRISPR Gene Drive and SIT include genetically modified *Ae. aegypti* that suppress populations (Oxitec Friendly™ Mosquitoes). IAES uses Radiation to sterilize male mosquitoes (International Atomic Energy Agency Sterile Insect Technique [IAEA SIT] Program). AI-optimized insecticide applications include AI that adjusts pesticide release based on real-time mosquito density [ULV] drone spraying. The use of AI-driven modeling can optimize the placement of bait stations (ATSB).

Numerous case studies of successful technology adoption exist worldwide. For example, Brazil uses *Wolbachia* and AI-driven dengue prediction; implemented *Wolbachia*-infected *Ae. aegypti* in Rio de Janeiro and Niterói; used AI models (Google Earth Engine and local epidemiological data) to predict dengue hotspots, and dengue cases reduced by 69% in treated areas. Singapore uses Intelligent Mosquito Surveillance and AI; The National Environment Agency (NEA) deployed Gravitraps and AI-based mosquito image recognition (Javed et al. 2024b); used AI-powered fogging drones to target high-risk areas; real-time vector monitoring and optimized insecticide use; and Malaysia uses IoT-based mosquito traps. Sensor-equipped mosquito traps (Mosquito Buster) were deployed in Kuala Lumpur (Oliveira and Mafra 2024). AI was used to analyze trap data and predicted outbreaks, enabling early detection of dengue risk areas and targeted vector control (Ningrum et al. 2024, Rajak et al. 2024).

More funding resources will become available from federal, state, and private companies for the adoption of vector mosquito technology in the future, such as state grand challenges for development, to fund innovative vector control tools. The US National Institutes of Health (NIH)) support research on mosquito-borne diseases. The Bill and Melinda Gates Foundation focuses on AI-driven disease surveillance and vector control. The European Research Council (ERC) funds vector control research in dengue-endemic areas. The Google AI Impact Challenge supports AI-driven health projects. The Wellcome Trust provides grants for research on infectious disease prevention. Grand Challenges Canada funds novel mosquito control technologies.

In the past year, AMCA promoted new technology through various channels, including webinars, Zoom meetings, national and regional meetings, symposia, and publications. The AMCA strengthened the mission of education, training, leadership, and information exchange. An online emergency response BMP has been updated with six new modules, and the BMP and training modules are closely integrated. The AMCA promoted the media and national communication strategy with emphasis on "yesterday's threat is today's solutions, and they utilize the CDC grant funding to expand capabilities and resources for surveillance and prevention of the Oropouche virus and aerial deposition modeling. The AMCA strengthened its voice and remains a priority in the legislative agenda, and promotion and expansion of collaboration with other related associations (Entomological Society of America [ESA], Society of Vector Ecology [SOVE], National Association of City and County Health Officials [NACCHO], European Mosquito Control Association, and India's SOVE), nationally and internationally. The AMCA provided partial funding for me to attend the Indian SOVE meeting and present an overview of AMCA at their international conference in India in late January 2025. The AMCA signed a memorandum of understanding with the EMCA for collaboration on training and information sharing. The World Health Organization–Tropical Diseases Research (WHO-TDR) funded me to attend the EMCA communication training in early December 2024. These accomplishments are based on the hard work, support, and collaboration of all AMCA board members, as well as each committee, office staff, and technical advisor.

I am reminded of the passion and firm belief that the work we are doing saves lives. We must invest in the education and development of the workforce, as well as next-generation tools such as gene editing, robotics and automation, AI technology, and ongoing engagement with policymakers and stakeholders. I encourage members to stay informed about new technology and to consider running for an officer position or joining a related committee to support the association at different levels.

Thank you for entrusting me with this role and for standing with me in the fight against mosquitoes and mosquito-borne diseases. It is the honor of a lifetime to have served as your association president. Let's stay together, innovative, and committed to a healthy future.

ACKNOWLEDGMENTS

Thanks to the Board of AMCA, all committee chairs and members, the AMCA headquarters staff, the management company, technical advisor, and all members for their support and collaboration. Thanks to the Board of Commissioners of the Anastasia Mosquito Control District, St. Augustine, Florida, and all staff and employees for their support and cooperation.

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