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About the Cover: Shane Guin, Crew Chief with MosquitoZone International, checks standing water for Anopheles larvae in a spoil area outside the security fence of Camp 7, a pipeline construction and management work camp located in the Southern Highlands of Papua New Guinea. Photo taken September 15, 2013 by Stephen Sickerman.

Important note from the Editor-in-Chief

Sharp-eyed readers will note that the AMCA logo is missing from the cover and references to AMCA have been removed from the Table of Contents.

This action was taken after the Florida Mosquito Control Association decided not to renew the Wing Beats Profit Split Agreement between FMCA and AMCA, a situation we hope is only temporary.

Until a new agreement is reached, all Wing Beats readers – including AMCA members – will continue to receive their copies without charge, and any manuscripts submitted will be considered without regard to association affiliation.

In other words: Keep Calm and Carry On.

More details will be provided next issue.
Conspiring Invasive Species?
The Case of Tiger Mosquitoes and Apple Snails
by Nathan Burkett-Cadena and Thomas R. Unnasch

Figure 1: A Limpkin, Aramus guarauna, and apple snail shell midden at Lettuce Lake Park, Hillsborough County, FL.
INTRODUCTION

Apple snails, *Pomacea insularum*, and Asian tiger mosquitoes, *Aedes albopictus* Skuse, are considered two of the top 100 “World’s Worst” invaders (Lowe et al. 2000). Apple snails are large aquatic gastropods native to tropical America that have been introduced throughout the world as escapees from aquaculture operations (Mochida 1991) and/or pet trade (Cowie 1993), with devastating agricultural effects, especially for rice in Southeast Asia (Cowie 2002). The Asian tiger mosquito, a vector of dengue virus and Chikungunya virus (both human pathogens), has likewise been introduced throughout the world. Native to eastern Asia, this mosquito began invading the rest of the globe in the late 1970s and is now firmly established on all continents except for Antarctica and Australia (Lounibos 2002; Benedict et al. 2007; Enserink 2008). In the US the Asian tiger mosquito is primarily considered an urban pest, utilizing water-holding man-made containers and feeding largely on human blood (Lounibos 2002). It therefore easily adapts to new locations, as long as human hosts and larval development sites are available (Lounibos 2002). The current work reports on a curious association between these two invasive organisms in Florida, USA, in which Asian tiger mosquitoes utilize in the empty apple snail shells, adapting to a novel larval habitat (snail shell) that is a consequence of the invasive snail’s establishment.

METHODS AND PRINCIPAL FINDINGS

Upon discovering mosquito larvae in a partially water-filled shell of the apple snail, *Pomacea insularum*, on the banks of the Hillsborough River, Florida, an exploratory survey of the area was conducted to determine whether or not this unusual interaction was commonplace. Apple snail shells are deposited on land when Limpkins, *Aramus guarauna* (L), medium-sized wading birds, capture snails in shallow water, then carry them to land to consume the fleshy inards; see Figure 1.

Upon discovering mosquito larvae on four days spanning 3.54 km of riverbank, inspections along the Hillsborough River, included floodplain forest, mobile road, footpath, or kayak and islands (Cottam 1936); see Figure 2. Middens (20-40 shells) not uncommon of empty shells), with large middens often create middens (piles of shells that harbored larvae, the distribution of the various aquatic stages (larval instars and pupae) was also variable. Early-instar (1st and 2nd) larvae could be quite numerous, with 19-21 individuals collected from three shells. Late-instar (3rd and 4th) larvae were less abundant than early-instar larvae, but still common, with 10-14 late-instar larvae collected from seven shells. Pupae were not common, most frequently encountered in pairs. The sex ratio of adults reared from the shells was approximately 1:1 (52.1% males; 48.0% females). No statistically significant relationships were found between shell size or water volume and the presence (logistic regression: shell size: $c^2=0.255$, $P=0.6136$; water volume: $c^2=0.739$, $P=0.3898$) or abundance (linear regression: $F_{1,53}=3.11$, $P=0.0834$) of Asian tiger mosquito larvae.
mosquito immatures, suggesting that *Ae albopictus* larvae can tolerate considerable variation in habitat size.

To gain a rough estimate of the potential mosquito productivity due to apple snail shells, we calculated the number of mosquitoes (immatures) in snail shells per meter of riverbank (nearly all snail shells were found within five meters of the water's edge). For our survey areas (data combined from all sites), larval productivity was found to be 1.63 per meter of river. If these estimates are representative for the entire Hillsborough River, then we can expect that apple snail shells will contribute 154,533.33 *Ae albopictus* to the environment along the river's length (9.5 km).

Since many small container habitats (including snail shells) are dry completely during rainless periods (Trpis 1973), it is unlikely that shells serve as mosquito larval development sites during the dry season.

During one of the collecting forays (20 August) an *Ae albopictus* female was observed hovering over a water-containing *Pomacea* shell (that also contained immature mosquitoes; see Figure 3. The female proceeded to land on the inner surface of the shell, just above the water line, allowing her activities to be photographed; see Figure 4. Examination of the resulting photographs (demonstrating characteristic egg-laying abdominal posture) indicates that the female was actively ovipositing on the surface of the shell.

No larvae of other mosquito species were encountered during this survey, although at least three other container-inhabiting species are sympatric. The yellow fever mosquito, *Aedes aegypti* (L), another invasive vector species, and the (native) eastern treehole mosquito, *Aedes triseriatus* (Say) often co-inhabit larval habitat of *Ae albopictus* in the Tampa Bay area (Juliano et al 2004; Lounibos et al 2001). *Toxorhynchites rutilus*, whose larvae prey upon larvae of other container-inhabiting mosquitoes, are also found in small containers in the area (Campos and Lounibos 2000). *Aedes albopictus* has the capacity for slow development and starvation resistance under
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conditions of limited larval resources (Barrera 1996), traits that are adaptive in food-limited snail shells. Females of _Ae albopictus_, and three other species (Mansonia titillans, Psorophora ferox, and Wyeomyia mitchelli) attempted to bite the author during field sampling.

Based on geographic records and shell morphology (Rawlings et al 2007), it is overwhelmingly likely that the Island apple snail, _Pomacea insularum_ (d'Orbigny), is the snail species whose shells serve as larval development sites for the Asian tiger mosquito in Hillsborough County, FL. All of the examined shells were channeled, with distinct sutural channels between adjacent whorls, a feature unique to _P insularum_ among the _Pomacea_ found in the area (Rawlings et al 2007). _Pomacea insularum_ is firmly established in the Hillsborough River drainage (Rawlings et al 2007). Although one species of apple snail is native to Florida – the Florida apple snail, _Pomacea paludosa_ (Say) – the native apple snail lacks sutural channels characteristic of the shells examined in the current study (Thompson 1984).

Our study is not the first to document mosquitoes utilizing empty snail shells for larval development. In fact, several African mosquito species are specialized for occupying the empty shells of the terrestrial giant African snail, _Achatina fulica_ Bowditch, including one _Aedes_ (Stegomyia) species (Lounibos and Munstermann 1981) and several species of _Eretmapodites_ (Lounibos 1980). _Aedes calceatus_, on the Kenya coast, even has the propensity for ovipositing in the inner whorls of _A fulica_ shells, which retain water longer than the highly exposed opercular opening of the shell (Lounibos and Munstermann 1981). _Aedes aegypti_, notable vector of yellow fever and dengue, was found to utilize _A fulica_ in east Africa (Trpis 1973). Between 11 and 35% of land snail shells held mosquito larvae, similar to the percentages of apple snail shells found to harbor larvae in the current study (23.1% of total shells). Chan et al (1973) found _Aedes_ spp (either _albopictus_ or _aegypti_) larvae in mollusk shells in Singapore, although the shells were not identified. The African land snail has been introduced into Florida and has recently gained a firm foothold in parts of Miami-Dade County, FL. It is likely that empty shells of this snail are occupied by _Ae albopictus_ and/or _Ae aegypti_ larvae in parts of south Florida where the land mollusk has established.

While it may not be too surprising that container-inhabiting mosquitoes may utilize water-holding shells of land snails as oviposition and larval development sites, our finding that an invasive mosquito exploits the shell of an invasive fully aquatic snail is quite novel. Since apple snails do not normally live (and die) on the land (as does _A fulica_), their empty shells would not be available to mosquitoes were it not for the predatory acts of the Limpkin. These birds physically create larval habitat for mosquitoes by removing snails from the water, transferring the snails to dry land, then extracting the snail's flesh from the shell. The direct interaction between Limpkins and apple snails results in an indirect interaction between Limpkins and Asian tiger mosquitoes.

In summary, this work documents how one invasive organism, the apple snail, is exploited by another invader, the Asian tiger mosquito, a vector of human pathogens. That _Ae albopictus_ was found to
commonly utilize discarded apple snail shells as larval development sites, while no other container-inhabiting species were found to do so, is a testament to the incredible adaptability and invasive potential of this vector mosquito. These two organisms, originally from different continents, have no known interactions in life, yet Asian tiger mosquitoes utilize the shells of dead apple snails, exploiting this unique larval habitat. Additional surveys are needed to determine whether or not Asian tiger mosquitoes utilize shells of apple snails in other regions where the snails are established, and if the shells of other snail species, including the native Florida apple snail and the invasive land snails, contribute to mosquito proliferation in Florida and elsewhere.

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Global Partnerships for Malaria Vector Control
by Michael Macdonald, Jo Lines and Konstantina Boutsika

The Roll Back Malaria (RBM) Partnership was launched in 1998 by the World Health Organization (WHO), United Nations Children’s Fund (UNICEF), United Nations Development Fund (UNDP) and the World Bank, in an effort to provide a coordinated global response to malaria. A basic tenant of RBM is the recognition that malaria control is not the sole purview of the Ministry of Health, but requires a broad and diverse partnership among malaria endemic countries, bilateral and multilateral development partners, the private sector, non-government organizations, foundations and academia.

Currently, the RBM Secretariat is hosted by WHO in Geneva and includes eight working groups, plus four subregional networks for Africa http://www.rollback-malaria.org/. The eight working groups include advocacy and “harmonization” as well as technical working groups such as case management, monitoring and evaluation, and the Vector Control Working Group (VCWG).

In the early years of RBM the VCWG was known as the Working Group on Insecticidal Nets (WIN), and focused almost exclusively on the scale-up of insecticide treated mosquito nets (ITNs) in Africa. In 2010 the group was reconstituted and greatly expanded to encompass a broader range of entomology and vector control and now includes more than 500 members on the mailing list, with over 200 attending the annual meetings, working across eight different “work streams,” as described in this article.

CURRENT MALARIA CHALLENGES AND THE RBM VCWG: WHAT CAN WE LEARN FROM THE AMERICAN MOSQUITO CONTROL ASSOCIATION?

Malaria control efforts over the past decade have shown remarkable success. According to the 2012 WHO World Malaria Report, between 2000 and 2010, malaria mortality rates fell by 26% globally and by 33% in the WHO African region; an estimated 1.1 million malaria deaths were averted, in large part due to the scale up of vector control, especially the deployment of insecticide treated mosquito nets and indoor residual spraying (http://www.who.int/malaria/en/). These fragile gains are now seriously threatened by insecticide resistance, by diminishing financial support, by our inability to prevent transmission beyond the reach of our traditional treated mosquito nets and indoor spraying (especially in areas of the Mekong Region were there is emerging drug resistance), and by the capacity needs of national programs to implement entomological monitoring and optimize their scant resources for vector control. This is a critical time for global malaria control efforts and for communities that are now at greater risk for a resurgence of malaria illness and death.

Complementing the normative and policy-setting functions of the WHO Global Malaria Programme (GMP), the VCWG is an essential forum where the diverse partners of the vector control community, from ministries of health, academia, industry and the private sector, foundations, bi-lateral, international and non-government organizations can come together, reach a common understanding and develop the necessary networks and activities to overcome these challenges.

Central to this is capacity for entomological monitoring is information management, including GIS, and monitoring and evaluating control efforts. While the contexts, resources and vector ecology may be far different than where many of the AMCA members work, there are still some basic skills that apply to both. On a strategic level, malaria control is not much locally-adapted. It often incorporates two technologies, insecticide treated mosquito nets (ITNs) and indoor residual spraying (IRS), with methods of deployment that are more or less completely standardized and uniform. One of the icons of global malaria efforts, Dr José Nájera, has famously said “Before DDT, malariologists were trained as problem solvers, after DDT malariologists were trained as solution implementers.” Dr Nájera has advocated for strengthening “professional cadres that can adapt the strategy to the local epidemiology
and that can develop an effective surveillance system deeply rooted in the communities” (Nájera et al 2011). Moreover, many malaria-endemic countries in Africa and Asia depend on external funding and external control. It may take many years, but eventually, vector control in these countries will also have to move to more integrated and locally adapted methods, designed and managed by local experts – as in local mosquito abatement districts in the United States.

On a more tactical level, many of the tools used for mosquito surveillance and mobile technology for mapping and information management can have immediate application as national programs try to gain efficiencies through vector mapping and risk area stratification.

The Vector Control Working Group is structured around eight complementary work streams:

**INSECTICIDE RESISTANCE**

2012 saw the launch of the Global Plan for Insecticide Resistance Management, where members of the work stream were core contributors for its development and roll-out. The work stream is completing a review on impact of insecticide resistance to be published soon. With a focus on implementation, the work stream will work closely with the Africa Network for Vector Resistance, and other regional networks in the Americas, Eastern Mediterranean, Asia and the Western Pacific to support country capacity for monitoring and development of resistance management strategies.

**OUTDOOR MALARIA TRANSMISSION**

The work stream has expanded its geographical focus beyond the Mekong to include partners in Africa working on entomological studies of vector species shifts and behavior, and the development of protective clothing, topical and spatial repellents. In 2014, work stream efforts will include standard designs to evaluate entomological parameters of biting time and place; designs for evaluation of repellents; risk assessments for treated clothing; and formative research to improve adherence to personal protective methods.

**CONTINUOUS LONG LASTING INSECTICIDAL NET (LLIN) DISTRIBUTION SYSTEMS**

A critical work stream to help countries develop strategies to maintain coverage with constrained financial resources. The focus is on documenting best practices and updating strategic decision making documents to prioritize distribution avenues and targets, to build capacity and diversify funding support.

**DURABILITY OF LLINS IN THE FIELD**

LLIN physical net survival, both attrition and durability, is emerging as one of the key issues in maintaining coverage. The work stream works closely with WHO and industry to coordinate and compile laboratory and field data on LLIN durability that will inform procurements based on “value for money,” product quality improvement and replenishment strategies to maintain coverage.

**CAPACITY BUILDING FOR INDOOR RESIDUAL SPRAYING**

This work stream has built strong ties to the private sector, who are in many countries a core partner of the national IRS program. The work stream has been strong in advocacy, training materials and reporting systems. Looking to the future, there will be production of training modules for all phases of IRS planning, implementation and evaluation, and close collaboration with the Insecticide Resistance and Integrated Vector Management/Entomological Monitoring work streams.

**LARVAL SOURCE MANAGEMENT**

The LSM work stream has completed case studies and supported the development of the WHO LSM Operational Manual, which will soon be published. LSM is being implemented across a large number of countries, but sometimes without a strong quality control, monitoring and impact evaluation component. The LSM work stream is working to improve the evidence-base for rational investments in larval control, to support country discussion making processes as well as facilitating collaborations with agriculture, urban planning, housing and civil engineering sectors that impact surface water management and potential vector breeding sites.

**OPTIMIZING EVIDENCE FOR VECTOR CONTROL INTERVENTIONS**

This work stream focuses on three main areas: reviews, identification of gaps and testing guidelines for new vector control paradigms (in collaboration with the Innovative Vector Control Consortium); review of
interactions of more than one vector control intervention (eg, ITNs and IRS); and updating on developments in new vector control technologies. Clear protocols and efficient monitoring strategies are essential to rationalize and optimize our vector control investments.

ENTOMOLOGICAL MONITORING AND INTEGRATED VECTOR MANAGEMENT

The IVM work stream had a very active year with the publication of the IVM Handbook and other guides from WHO as well as training materials and other support in Latin America and Africa from the USAID-funded IVM Project. The work stream is focusing on more efficient vector control delivery systems and guides to countries to develop functional national entomological surveillance systems.

2014 will be a pivotal year for malaria control and the VCWG. The challenges are growing and gains seen over the past decade fragile. At the same time there are new opportunities, linkage to the operationally-focused organizations, new WHO advisory groups for vector control and the growing networks of public health entomologists and vector control professionals in both regional societies, such as the Pan African Mosquito Control Association and the Asian Collaborative Training Network for Malaria and national networks in such as Nigeria, Zambia and, soon, Myanmar.

These networks, including linkages to the members of the AMCA, provide an opportunity for building capacities to better respond to insecticide resistance; optimize resources for vector control; and help build a new generation of public health entomologists and vector control professionals.

The VCWG is truly a partnership organization, with the diversity, creativity and commitment needed to address these complex challenges and to achieve our common vision. The membership is open to any and free. There is an annual general meeting currently held in Geneva in early February, with other work stream meetings held in various locations as the opportunities and needs arise. More detailed information on the VCWG is available on the website http://www.rollbackmalaria.org/mechanisms/vcwg.html.

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In 1945, Chamberlin and Lawson attached a funnel net to the fender of a 1930s Ford Model B, and the very first truck-mounted mosquito trap was created; see Figure 1. Since then, the design has been improved, but the objective remains the same: sample the population of flying insects. The truck trap is unique in that it employs a non-attractant and passive collection method that can be used to capture mosquitoes during their first migratory flight after emerging as adults, or appentential flights in search of a blood meal or ovipositing site. The truck trap has a low level of sampling bias because it does not affect mosquito flight with a visual or olfactory cue.

Bidlingmayer was the first to use the Truck Trap to measure quantifiable changes in the flight activity of several species of mosquitoes. In his 1966 publication he showed that the flight activities of the Black Salt Marsh Mosquito, *Aedes taeniorhynchus*, varied with illumination intensities throughout different moon phases. His largest collections were made during periods of full moon. His data are in contrast to the collections from light traps, since light traps visually compete with lunar illumination, thus resulting in lower capture rates. Mosquito biologists use the truck trap to better understand mosquito behavior and the factors affecting it, which can then be incorporated in developing better control methods.

For example, Carroll and Bourg (1977) ran a truck trap experiment to sample the relative abundance of species in a densely populated subdivision of New Orleans. After conducting four trials, they found that fifteen species followed the same pattern of flight activity, with peak numbers occurring at the twilight of sunset and sunrise, and so adjusted their adulticiding missions accordingly.

The Lee County Mosquito Control District, Lehigh Acres, FL, continues to deploy truck traps every evening from May to October to determine migration patterns, male to female brood hatch ratio, and where to send their spray trucks.

We wanted to determine the most effective time to start our truck spray missions, and whether it was possible to achieve increased kill by sending more trucks out at peak *Aedes taeniorhynchus* flying time. To find these answers, we developed an experiment that focused on our ability to measure population changes throughout an evening using the truck trap.

**MATERIALS AND METHODS**

The trap was constructed to the same specifications as described in Bidlingmayer’s 1966 paper. It is 7 feet wide at the mouth, 2 feet high and 10 feet long, tapering into a 4x4 inch square to which we’ve attached a small 2 inch diameter aluminum pipe, which filters the catch into a thin 11 x 20 inch no-see-um net; see Figure 2.

We selected an area of the Lower Keys that is a consistent landing rate count location, has a weekly CDC light trap set nearby, and...
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is off-limits to other non-official motor vehicles, in order to avoid unnecessary delays in our trials. The route itself is a 3.5 mile loop that borders salt marsh to the west and north, and hardwood hammock on its east and south. At a vehicle speed of 15 mph, it takes approximately 15 minutes to complete each loop.

In general, each trial commenced 15 minutes prior to sunset. We began this experiment starting an hour before sunset, but quickly realized that no mosquitoes were caught if the sun was out. Since our aim was to catch mosquitoes, we modified the initial protocol. At the start of each loop, a net was attached to the end of the aluminum pipe, and start time recorded. Following loop completion, the time was recorded and the net quickly replaced with the next one in sequence. This would be repeated for each loop, approximately 20 for each trial. Nineteen trials in all were completed from summer 2012 through summer 2013; fifteen evening trials, four morning trials (starting at 2:00 am through 15 minutes post-sunrise), with two all-night trials.

RESULTS

In total, we caught 12,837 mosquitoes, with 95% being *Ae taeniorhynchus*. Other species included *Deinocerites cancer*, *Anopheles atropos*, *Ae condole scens* and *Culex melanoconian* spp. Male mosquitoes made up 19% of the total catch. There were three trials when we caught less than 100 mosquitoes per night and four runs when we caught over 1,500 mosquitoes within four hours of trapping; see Figure 3. In total, we averaged 755 mosquitoes for four hours of trapping or 2.8 mosquitoes per minute. Compare that to the average CDC light trap with CO₂ averaging 0.44 mosquitoes per minute in the nearby area, and you can see how efficiently the truck trap is at sampling the population of active mosquitoes. The adults may not yet be host seeking, but still valid for approximating the mosquito population.

CONCLUSIONS

Using the information obtained from our truck trapping trials, we were able to justify modifications to our ground control operations. First, through all 16 evening trials in no instance were mosquitoes caught anytime before sunset, and no significant numbers were caught prior to a half-hour after sunset. Therefore, we recommend spraying begins no earlier
than a half-hour after sunset. We also found that 93% of mosquitoes were caught between a half-hour and three hours after sunset, with a dramatic decrease in numbers after 3.25 hours post-sunset. Thus, it may be wise to send out more trucks during those three hours post-sunset in order to maximize targeted kill, rather than one truck taking a night-long route.

Since the truck trap does not discriminate against any flying insects, we did make note of the other insects that were caught along with the mosquitoes. Unsurprisingly, we found that dragonflies did appear in our early evening catches, but were not flying after sunset when we caught the majority of mosquitoes. This confirms the long held belief among mosquito control operations that dragonflies are not adequate for mosquito control, since they are not feeding when mosquitoes are most abundant. Dragonflies and additional Odonata were released unharmed when caught in our nets. Moths, termites, ant lions, lacewings, and other nocturnal Diptera were caught throughout the night, but in very small numbers. Only one very confused Key Deer ran into the back end of the truck, but quickly recovered and ran away without leaving a dent.

Overall, we felt that the truck trap was a valuable tool to maximize the effectiveness of truck-mounted ULV insecticide applications to control Aedes taeniorhynchus populations. We will continue to use the truck trap in order to gain understanding of population changes throughout our truck spraying areas. It has also served as a new public relations tool since it always provokes stares from other drivers on the highway.

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The Entomological Society of China (ESC), Beijing Institute of Microbiology and Epidemiology (BIME), Suzhou CDC, and Jiangsu Provincial CDC hosted the 3rd International Forum for Surveillance and Control of Mosquitoes and Mosquito-borne Diseases and the 8th ESC’s Medical and Veterinary Entomology Congress in Suzhou, Jiangsu, China, May 27-31, 2013. The meeting theme was the impact of globalization on mosquito-borne diseases.

The meeting provided an opportunity to discuss mosquito-borne disease status and future challenges caused by globalization, transportation, and commercialization. Other objectives were to share information about research and management of vector mosquitoes and mosquito-borne diseases, to promote new techniques and methods for surveillance and control of mosquitoes and mosquito-borne diseases, and to identify possible areas of worldwide collaboration for research and development of new methods and techniques for surveillance and control of mosquitoes and mosquito-borne diseases.

More than 30 leading scientists in the fields of mosquito surveillance and control of mosquito-borne diseases from sixteen countries were invited to give presentations in three morning panel sessions and ten afternoon symposia. The morning panel sessions focused broadly on the impacts of globalization and migration on diseases and disease vectors, vector-borne diseases, and the latest developments in surveillance and control of vectors and vector-borne diseases. The topics of the symposia included: 1) epidemiology, vector competence and surveillance; 2) integrated vector management; 3) diseases and vector surveillance; 4) vector taxonomy and distribution; 5) genetics, molecular biology and physiology; 6) biology, behavior and ecology; 7) personal protection and repellents; 8) insecticides and toxicology; 9) technology, new products, and equipment; and 10) legislation and professional associations.

A total of 30 presentations were given in the 3 panel sessions, and 50 presentations were given in the 10 symposia. The meeting attracted about 200 attendees from 16 countries, 30 Chinese provinces, and 15 private companies achieving both national and international attention. Oral presentations were English only.

![Figure 1: Participants at the 2013 International Forum for Surveillance and Control of Mosquitoes and Mosquito-Borne Diseases, Suzhou, China.](image)
Three projectors (the center screen was in English and 2 side screens were in translated Chinese) were used to facilitate communication. The program was printed in both English and Chinese. The presentations and abstracts were brought together on a single DVD that was distributed to all participants. All participants in the 1st day were photographed together in front of the hotel; see Figure 1. All international scientists and participants were invited to visit the old water town, Tongli, Suzhou after the meeting.

Tong-Yang Zhao, Professor and Director of the Department of Vector Biology and Control, BIME, Beijing, China and Rui-De Xue, Director of Anastasia Mosquito Control District, St Augustine, FL, opened the meeting and moderated the first panel session; see Figure 2. Dr Xue also gave the conference presidential address, “Impacts of globalization on mosquito-borne diseases and future challenge.”

Ming-Hao Zhou, Director of the Jiangsu CDC, gave the welcome address and Paul Reiter, Professor, Institute Pasteur, Paris, France, presented the keynote address on the impact of globalization on vector mosquitoes entitled “A mollusk on the leg of a beetle: human activities and the global dispersal of vectors and vector-borne pathogens;” see Figure 3.

The presentations at the conference covered a broad range of topics. A copy of conference program, including a list of the speakers and the titles of their presentations, can be found on the conference web site at http://www.mosquitoforum.net/EN/column/column353.shtml. The talks generated great interest and spirited discussion among the attendees; see Figure 4. Three of the four participants from Florida, USA provided 7 presentations.

Chun-Xiao Li made some concluding remarks at the end of the conference about the meeting’s programs and success. She expressed thanks and appreciation to the meeting hosts and organizers, funding organizations/associations, companies, hotel, all speakers, moderators and attendees. The program committee has decided that the 4th...
International Forum for Surveillance and Control of Mosquito and Mosquito-borne Diseases will be held in Guangzhou, China, May 25-29, 2015.

The committee meeting for the Asian Society of Vector Ecology and Mosquito Control (ASVEMC, www.asiansvemc.org) was held in Suzhou before the International Forum. The officers for the society were installed by William Walton, President of the Society for Vector Ecology, and the ceremony of the ASVEMC establishment was conducted prior to the international forum. ASVEMC will sponsor/co-organize the 4th International Forum with the ESC, BIME, and Guangdong Provincial CDC.
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A Brief Review of Residual Barrier Applications on Vegetation against Mosquitoes
by Adriane N Tambasco

The application of a residual pesticide onto vegetation or other natural or man-made surfaces for the control of disease vectoring and nuisance mosquitoes has been found to be effective as a barrier, preventing mosquitoes and other insects from moving into an area surrounded by the treatment. Such treatments provide a method of control by targeting resting mosquitoes where the intent is to reduce the adult insect population, not to eliminate it. Barrier spraying limits the application of pesticides to a small portion of the total area and thus allows the applicator to cover large areas and reduce application costs (Hoffmann et al 2009).

Perich et al (1993) described the following five conditions that must be met in order for barrier application to be effective at controlling mosquitoes: 1) the mosquito species must rest in a sylvatic habitat, fly into open urban areas to bloodfeed, and then return to the sylvatic area to rest; 2) clear demarcation must exist between the sylvatic area and the human dwelling zone; 3) mosquito larval habitats should not be located inside the perimeter of the barrier treatment zone; 4) the insecticide used must have long residuality; and 5) adult mosquitoes must contact the insecticide.

A thorough investigation of the treatment area is required when considering a barrier application. If the aforementioned criteria cannot be met, other mosquito control efforts used in conjunction with barrier application may still provide a sufficient level of control. Current research being conducted at the Florida Keys Mosquito Control District (FKMCD) has shown that the addition of residual barrier application to their integrated pest management regime has provided effective control against long range, nuisance mosquitoes, even with the presence of mosquito production sites located within the treatment zone.

There have been recent studies focusing on evaluation of various insecticides applied to vegetation as barriers against...
different mosquito species. In Santa Rosa Beach, FL bifenthrin (TalstarOne, 7.9% active ingredient [AI]) treated vegetation produced an overall reduction of mosquitoes in the treatment area by 91-95% one week post treatment (Cilek 2008). Researchers in Carteret County, NC found that vegetation treated with permethrin reduced mosquitoes for 8 days following the treatment, which was significantly different (P<0.01) from malathion-treated vegetation (Anderson et al 1991). Trout et al (2007) found bifenthrin (TalstarOne, 7.9% AI) and lambda-cyhalothrin (Demand CS, 6.3% AI) treated vegetation significantly reduced mosquito populations for one month following the treatment. FKMCD has been conducting barrier treatment applications in Key Largo, FL using bifenthrin (Wisdom TC Flowable, 7.9% AI) and deltamethrin (Suspend Polyzone, 4.75% AI) since May of 2012. Initial results show a post application reduction in mosquito populations of over 98% at 24 hours and over 91% after 6 days using bifenthrin, which was significantly better than that of deltamethrin, showing an initial 24 hour post treatment reduction of 18% and 59% reduction after 6 days (FKMCD unpublished data).

There have also been recent studies evaluating various techniques and equipment used for such barrier applications. Hoffman et al (2009) evaluated electrostatic and conventional sprayers and their effectiveness for barrier applications. They determined that sprayers which produced larger droplets were significantly better at controlling mosquitoes than those producing smaller droplets for deposition onto vegetation. Additionally, sprayers with a high velocity air stream at nozzle discharge proved significantly better than sprayers with lower air velocity. Spray penetration into the target canopy and deposition of the spray onto the vegetation are two very important considerations for residual barrier applications. Larger droplets are better suited for barrier application while smaller droplets have the ability to float around and escape deposition onto the target vegetation (Hoffman et al 2009). FKMCD has purchased a gasoline powered AI Mist Sprayer to perform barrier applications in the District, which produces droplet sizes of 300-350 μm; see Figure 1.

When discussing coverage using a barrier application, focus is the matrix as a whole as opposed to variations across an individual target area. Untreated sections of vegetation in the treatment area will allow for mosquitoes to rest on vegetation that has no residual chemical. The higher the coverage of barrier application onto the vegetation, the greater the chances for mosquitoes to acquire a lethal dose of insecticide while contacting the vegetation. There is no one size fits all approach to mosquito control. Residual barrier applications should be performed in conjunction with other mosquito control methods to make up a sound integrated pest management regime.

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Moses Lakes Mosquito Control District

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Marin Brouillard, Biologist
Johnny Appezzato, Director of Operations
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Prince William County Mosquito and Forest Pest Management (formerly Gypsy Moth and Mosquito Control) provides gypsy moth, mosquito, and fall cankerworm monitoring and control services throughout Prince William County, Virginia. Like most mosquito control programs, we collect a lot of field data. As a result, over the past several years, an effort has been made to provide a more systematic approach to capture monitoring and treatment activities. The old system of collecting data on paper forms and transferring information into multiple databases was becoming inefficient and ineffective. In addition, the volume of paperwork and inability to monitor program activities in real-time resulted in goals not being met. This article provides an overview of the larval mosquito control component of our new system, how we went about developing it and how it currently functions.

Historically, we used GPS devices, paper maps, spreadsheets and forms to collect inspection and treatment data. Our information collection was so large that our staff might have several binders with them in the field. Data were then recorded on paper forms and transferred to multiple electronic spreadsheets where existing errors were duplicated and new errors were generated. We were increasingly frustrated with having to enter the same data numerous times in various formats. This cost valuable time and often led to delays in implementing mosquito control. Also, staff and management were unable to effectively monitor field activities to determine if goals were being met. New state and federal regulations, such as NPDES (National Pollutant Discharge Elimination System) requirements, required our program to be able to provide precise records of chemical use in a timely fashion. Existing paper records were unreliable. A new system was sorely needed.

In 2010 we conducted a trial of “off the shelf” mosquito control data management software. Although the principles of mosquito control are similar throughout the country, each program is slightly different. As a result, even though the products we evaluated were an improvement, we determined that a more customized system was needed. With this in mind, we wanted to build a system unique to our program practices. The objective was to improve the data collection process. This would lead to more accurate and readily available data, resulting in better management practices and decisions. Improvements in the data collection process would also hopefully lead to an increase in staff morale. Staff had stated for many years that the existing data collection was failing to meet our vision of providing the “best service” to the residents of Prince William County.

In mid-2010, we met with upper-management to discuss the existing data collection process and began researching potential solutions. A team representing various agencies studied the existing process for several months and suggested improvements. For example, a high rate of entry...
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errors was observed when data were transcribed from paper to a database. Additionally, our field technicians were spending, on average, 7 hours a week doing data entry. The team felt that an electronic data entry device that stored information on a server in a “Cloud” would resolve many problems associated with data entry and reconciliation. Further, the device needed to be hand-held and easy to use, with multiple features such as GPS, internet capability, camera, and expandable to meet future needs. Several hardware and software options were considered. We contacted information technology consultants to determine the time frame and costs of program development and implementation.

By early 2011, a consultant was identified to assist solely with software programming. During the next three months, staff members and the consultant held numerous meetings. We provided data forms, GIS (geographic information system) shapefiles and information regarding existing workflow practices and reporting requirements. We also had extensive discussions about privacy, data security, data backup and future requirements. After careful consideration of the software components, hardware was then chosen that best addressed our requirements, programming capability, training requirements and cost of implementation.

We developed a field inspection and data collection mobile application for larval control, using iPad tablets to streamline daily workflow to include sites needing recurring inspection, which are available via a GPS-enabled map interface. The application is user-friendly and allows the field user to complete an inspection using customized data forms, set a re-inspection date, and generate a reminder for re-inspection. The application allows citizen requests to be assigned to specific technicians within minutes. It also allows for new larval habitats to be mapped and entered into the application in real time.

![Figure 2: Accessing the treatment form directly through the Map interface, which shows mosquito larval habitats in blue.](image)

![Figure 3: Executive report for Adult surveillance.](image)
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Field data are collected and stored in the Cloud and can be downloaded, edited, and viewed in the County’s enterprise GIS at any time. Users can work in an occasionally-connected or disconnected scenario where a cellular connection is not available or limited. The application also has an “in-office” component that allows us to produce “executive reports,” graphs, charts, and real-time field summary data.

The pilot phase began in the fall of 2011. Staff received the new mobile device programmed with the custom designed workflow and were provided very basic training on its use. They performed normal work functions, employing the new application to assist them. Real data were collected and audited to identify errors. Feedback was sought from the staff and provided to the consultant if any software programming changes were necessary. Improvements were made based on this feedback. At the end of 2011, the pilot phase was complete and all known issues had been resolved.

The new application was exclusively used during the 2012 mosquito season. The field technicians were accustomed to the application, and our work load increased. The application was a great success during the season and only minor bugs occurred, which were reconciled by the consultant in a timely fashion. With a full year of use under our belts we contacted the consultant in the winter and made a few enhancements to the application. We added a tool allowing technicians to obtain a more accurate measurement of the treatment area. We also added an adult ID form to the tablet to record lab data for mosquito identification, along with a few custom reports, and other minor tools.

The primary cost during initial development was related to the software programming. The total cost of development incurred during the first year was $25,750, with $22,000 spent on programming and $3,750 for staff time. This cost includes forms and reports for 3 pests, mosquitoes, gypsy moths and fall cankerworms. The enhancements made during and after the 2012 season cost an additional $20,000. We estimate future annual operating costs to be under $7000, this will include the annual cellular data plan cost for 9 iPads and Cloud services.

The application has been very well received by our staff and management. Below is a list of results and successes:

- The number of data entry errors has decreased.
- Staff surveyed responded positively, including those averse to change. They appreciated the convenience and efficiency of the system, spending less time doing “paperwork,” data entry and even route planning. They also liked that the device was easy to use and could be personalized. Support and buy in for this program has led to a palpable increase in morale.
- It has allowed staff to spend more time in the field, which in turn means that they can increase the number of sites surveyed per day.
- The average number of surveys completed per day has increased by 15 - 20% compared to previous years.
- The ability to monitor activities in real-time has allowed staff and management to be more effective in their use of time.
- Less paper and ink are used for printing.

This application has improved the data collection process and enhanced the effectiveness of our work. Not only have we reduced the number of data entry errors and the amount of time spent in reconciliation, but we have increased our ability to be more responsive to the needs of our residents. All of the information required to do the job effectively is located on a single shared platform. Any staff member can respond to a request for service even though the request originates outside their area of direct responsibility. The application has also resulted in data being readily accessible by any staff member, which helps to facilitate effective decision making on the part of the staff and increases their level of responsibility. The use of this new application has increased the amount of time available to collect data and perform pest control activities, which is our core focus.

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You are no doubt by now aware that the Farm Bill, upon which pesticide user groups expended a considerable amount of energy, finances and political capital, no longer contains language that would exempt public health pesticide usage from National Pollutant Discharge Elimination System (NPDES) requirements. This is the result of a final conference report from Senate and House Farm Bill conferees. Amendments cannot be made to the agreement. Thus the NPDES requirements will remain in effect for mosquito control organizations until further notice.

I must emphasize that this setback came about despite an enormous expenditure of legislative and regulatory resources by a great number of stakeholders, including the AMCA. Although the reasons for this breakdown will probably never come to light, the NPDES problem was in all likelihood used as a bargaining chip in the deliberations, with it being surrendered as a means for political interests to obtain higher stakes considerations for subsidies, food stamp programs and the like – but we don’t know. Rep. Tim Bishop (D-NY) reveals the primary environmentalist objection to the exemption as: “[i]t is simply incorrect to say applying a FIFRA-approved pesticide in accordance with its label is a surrogate for protecting water quality.” At any rate, a fix will not likely occur in the Senate as long as Senator Barbara Boxer (D-CA), who strongly opposes the pesticide exemption, remains in the majority as chair of the Environment and Public Works Committee.

The EPA Office of Pesticide Programs (OPP) was at best equivocal, while the Office of Water (OW), charged with implementing the program, had no choice but to follow the mandate, despite lacking the resources to effectively do so. In addition, the article uses the terms “chemical manufacturers and industry groups” and disregards “end-users” such as mosquito control in describing the stakeholders opposed to removal of exemption language. To me this appears to be consciously painting the opposition in an unfavorable corporatist light, while neglecting its profound and compelling public health implications.

The bill is not entirely without merit, though, as it does include positive language related to Endangered Species Act risk assessments, directing EPA and the Services to provide two reports to Congress on their actions to implement the recommendations from the National Academies of Sciences Report last year.

So, we must look to the future for relief. To this end a few initiatives are afoot. First, a coalition of 162 organizations and professional associations representing pesticide end-users, including the AMCA, drafted the following letter to key House and Senate Committee Chairs expressing both frustration and displeasure with the removal of bill language exempting applications of federally-registered pesticides from NPDES requirements:

“As negotiations of the Conference Committee on the farm bill end, the undersigned organizations voice our tremendous disappointment that House and Senate agricultural leaders ignored the burden and liability of the double regulation of pesticides used to protect public health, the nation’s food supply, natural resources, infrastructure and green spaces.

Even with tremendous support among conferees, it seems the ‘Reducing Regulatory Burdens Act,’ HR 935, will not be included in the final Farm Bill Conference Report. We are very frustrated that – despite both the House and Senate Agriculture Committees
having voted in favor of this legislation - a few activist-minded Members of Congress have been allowed to hold hostage a simple provision overwhelmingly supported by state regulators and needed by small businesses, farms, municipalities, counties, and agencies legally responsible for protecting public healthy

The language would have corrected the duplicative requirement by specifying that Clean Water Act National Pollutant Discharge Elimination System (NPDES) permits are not needed for the lawful application of pesticides already regulated under Federal Insecticide, Fungicide & Rodenticide Act (FIFRA).

We are saddened that the Conferees failed to provide this regulatory relief. Pesticides are critical tools we use to protect crops from destructive pests, and to manage mosquitoes and other disease carrying pests, and invasive weeds that choke our waterways and shipping lanes, impede power generation, and damage our forests and recreation areas. Action from Congress to remove the permits’ burden and legal risk is long overdue. We will continue to push for a remedy to correct this burden.”

While not having any immediate impact on the Farm Bill at this point, it at least notifies legislators that end-users are not happy with the result and are determined to renew efforts to seek legislative relief in the future. We will not go quietly in the night.

The second initiative, where you can and MUST provide input, is in the form of a survey e-mailed to all AMCA members asking for recipients to provide comprehensive NPDES cost data that could be provided to legislators, that would clarify the extent to which NPDES compliance costs have had an impact on your efforts to protect public health. You might recall that I made an entreaty for this information last year after being contacted by Bob Gibbs (R-OH), the author of the original House Bill exempting pesticides from NPDES, who wanted to emphasize the costs this program entailed on cash-strapped public health entities. Unfortunately, I received an embarrassingly abysmal response – only 27 cost estimates from over 1400 e-mail recipients.

Congressman Gibbs was none too pleased. A great many mosquito control districts felt it was no great fiscal burden at present – and the environmentalists opposing the exemption language agreed and hammered this point home again and again during Farm Bill conference deliberations. One of their chief arguments against the exemption was that the costs attendant to NPDES compliance were minimal and could easily be absorbed. Based on the paltry amount of data I could compile from those few who took the time to respond, we could not provide a compelling disputation of that opinion to those who felt their environmental bona fides were at some level of jeopardy. We simply could not make a persuasive case that the costs of NPDES compliance outweighed the risks to legislators being branded anti-environment if they voted for the exemption.

Angela Beehler, AMCA’s estimable Legislative and Regulatory Committee Chair, has recently sent out a survey designed to obtain a far more comprehensive estimate of NPDES compliance costs. She has provided a thorough list of costs that may not have occurred to previous survey recipients and I strongly advise all involved in mosquito control to take the requisite time to enumerate ALL costs incurred or likely to occur as a result of NPDES. One of the major costs that appears to have escaped some of those surveyed are those involving attendance at workshops, webinars and conferences where NPDES issues were discussed. Even if one was to attend the conference anyway, the presentation time devoted to NPDES prevented some other subject from being addressed. That time expenditure is a cost directly attributable to NPDES. There are numerous other examples of costs – and they are all important to document. Even if they are minimal, when multiplied by the over 700 districts and 1000 municipal/county entities that perform mosquito control nationwide, they add up to a considerable sum of money that could be better utilized elsewhere in protecting the nation’s health.

The fact is, we can either demonstrate unreasonable costs well beyond foreseeable benefits as an undeniable rationale for a legislative fix, or we can wait until one of our districts is sued to bring the problem to a head. I prefer the former, but it will take considerable work and is most assuredly worth the effort.

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