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1st Virtual and 7th PAMCA Conference & Exhibition 2021

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20 - 22 September 2021

Virtual Conference

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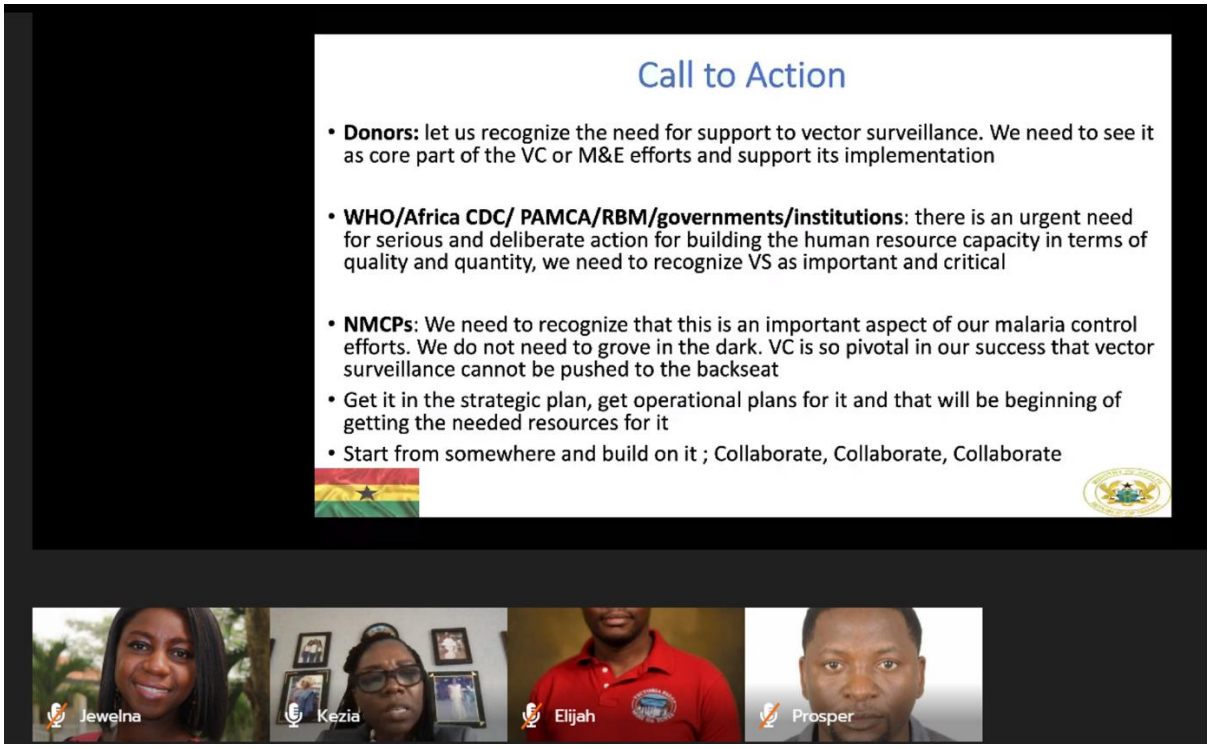
Day 1: 20th September 2021

Opening Ceremony and Keynote Address:

The opening ceremony of the 1st Virtual and 7th Pan-African Mosquito Control Association (PAMCA) Conference was moderated by **Silas Majambere** (Director of Scientific Operations, PAMCA). He welcomed all attendees and highlighted the theme of the conference – "Empowering local institutions to set the agenda for the elimination of vector-borne diseases". Majambere then invited **Charles Mbogo** (President of PAMCA), **Samuel Dadzie** (Chairman, PAMCA Local Organizing Committee – LOC, Ghana) and **Prosper Chaki** (Executive Director, PAMCA) to share with the audience their opening remarks. They thanked the sponsors and all attendees, giving the reason for the virtual conference – COVID-19. They also highlighted the need for a coordinated multisectoral approach in fighting vector-borne diseases, in the face of multiple outbreaks of mosquito-borne diseases.

The keynote talk on "*Empowering local institutions to set the agenda for the elimination of vector-borne diseases*" was given by **Florence Larbi** (Zoomlion Ghana Limited, Ghana), who stood in for Joseph Siaw Agyepong (Jospong Group of Companies, Ghana). She started by highlighting the burden of vector-borne diseases (VBDs) in Africa and globally, with a staggering 17% of all infectious diseases and one million deaths annually. The emergence and re-emergence and drivers of VBDs, particularly dengue in Africa was also discussed. Larbi pointed out the positives in increased coverage and use of vector control tools, as was observed in the decline of malaria between the years 2000 and 2015. She, however, emphasized that VBDs are multifaceted, hence requiring intersectoral and multisectoral approaches to control them. She outlined ways by which local institutions can be empowered for VBDs elimination. Larbi concluded that VBDs can be eliminated by coordinated and well-tailored efforts involving all stakeholders in vector control.



Plenary Session 1: Strengthening National Malaria Control Programs capacity for vector surveillance for malaria elimination

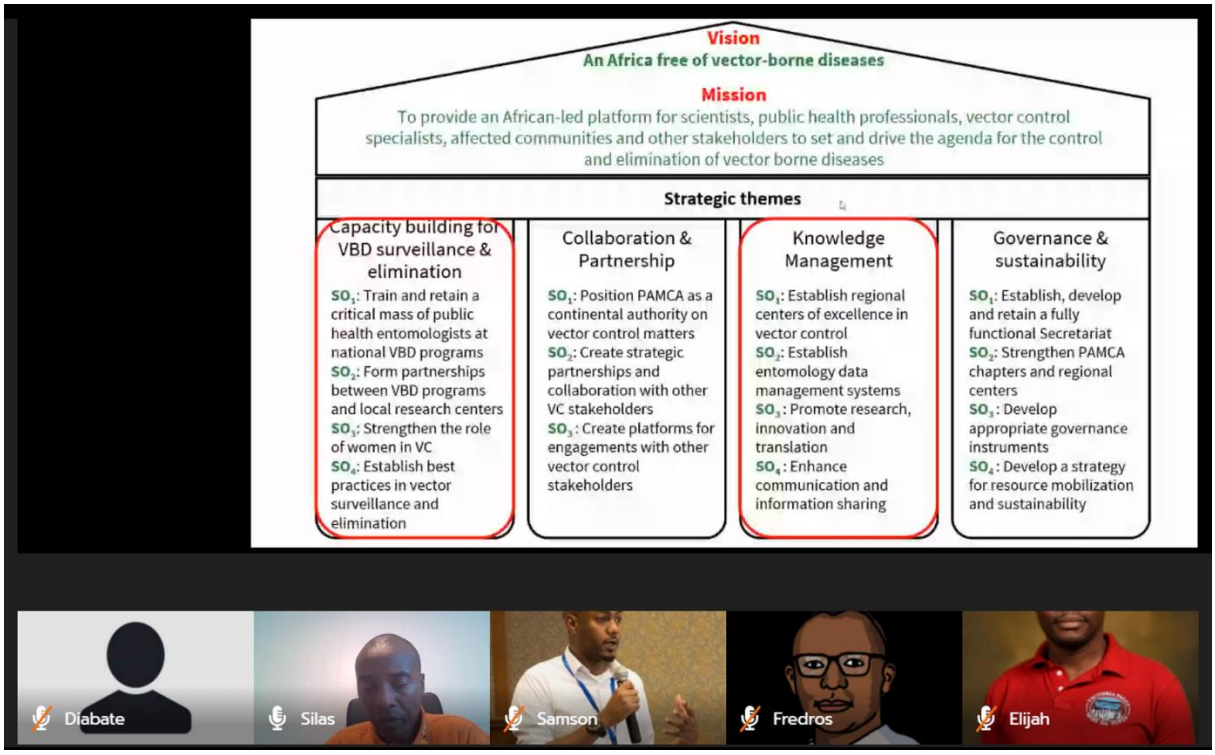
Keziah Malm (National malaria Control Program - NMCP, Ghana) presented vector control as a core intervention in the fight against malaria especially in high-burden countries Africa-wide which has mainly involved insecticide treated nets (ITNs) and indoor residual spraying (IRS). She recommended that malaria surveillance be implemented as a core intervention including the identification of vectors, species diversity, habitats and monitoring the impact of implemented control measures. She mentioned that according to Russel et al., 2020, 80% of countries use vector data for decision making, the remaining 20% don't, mostly due to inadequate finances and human resources. Ghana has already launched entomological surveillance in 30 insecticide resistance monitoring sites amongst which 20 sentinel sites are also used for entomological surveillance. A wide range of entomological indicators were monitored such as vector diversity, abundance, among others. Malm mentioned the example of the National Insecticide Resistance Monitoring Partnership (NIRMOP) as a case study conducted in the Obuasi-Ashanti region in Ghana. NIRMOP brings together researchers and partners in malaria vector control to plan, conduct, and evaluate results of insecticide resistance testing at sentinel sites throughout the country. The project has produced some preliminary findings highlighting gaps in the entomological surveillance involving limited funding, lack of capacity in entomology amongst others that need to be filled. To end the presentation, she made a call to action to donors, WHO, Africa CDC, NMCP, PAMCA, RBM, governments and other stakeholders to collaborate and develop a strategic plan and also build capacity in vector control that could lead to informed decision-making for better vector control management strategies.

Symposium Session 1:

Parallel symposium 1 - Strengthening entomological surveillance capacity towards malaria elimination in sub-Saharan Africa

This symposium looked at Pan-African Mosquito Control Association (PAMCA) efforts in strengthening entomological surveillance capacity. Three countries participated in this program at different levels and each country represented their progress. **Silas Majambere** (PAMCA, Kenya) and **Samson Kiware** (PAMCA, Kenya) talked about PAMCA's plans in ensuring an Africa that is vector-borne disease-free. Majambere and Kiware presented PAMCA's activities which centered on capacity building and knowledge management. PAMCA aims to train entomologists at National Malaria Control Program (NMCP) and district level while also fostering better collaborations between research institutions and NMCP. PAMCA is also working towards the goal of localizing decision making and data management so that they are not outside driven but are generated to respond to local needs. Activities in Burkina Faso was represented by **Abdoulaye Diabate** (Institute for Research in Health Sciences - IRSS, Burkina Faso), Cameroon was represented by **Charles Wondji** (Centre for Research in Infectious Diseases - CRID, Cameroon) and lastly, Tanzania was represented by **Fredros Okumu** (Ifakara Health Institute - IHI, Tanzania). **Ghislaine Aquedeogo-Ametchie** (PAMCA, Kenya) from Ivory Coast talked about the people involved in vector surveillance in the three countries. The three countries partaking in the program lacked entomologists at NMCP level, district level and facility level. The research institutions (CRID, IRSS and IHI) with support from PAMCA conducted training of vector surveillance specialists with the collaboration of the Ministry of Health at the district level. Aquedeogo-Ametchie reported that less than half of the people involved in vector surveillance in the three countries were trained entomologists with a third being women. Most of the entomologists had PhD acquired from their countries and the vast majority worked in research institutions and universities. There was a collaboration between the Ministry of Health, which was the implementing body and research institutions with support from funders who provided the interventions. Data was

stored using archaic data servers with the exception of Tanzania which had better databases. The general conclusion was that all three countries had insufficient human resources.



Parallel symposium 2 - Vector surveillance during the New Nets Project pilot evaluations: Estimating the entomological impact of next-generation insecticide-treated nets in high-transmission malaria endemic countries

The session was moderated by **Okefu Okoko** (National Malaria Elimination Programme - NMEP, Nigeria), who gave a brief background of the New Nets Project (NNP). The NNP uses 4 surveillance indicators to evaluate the impact of next-generation insecticide-treated bed nets (ITNs) distributed under the project: epidemiological, anthropological, durability monitoring of ITNs and entomological indicators. The NNP was designed to accelerate the scale-up of next-generation, dual active ingredient ITNs and provide evidence of their efficacy, effectiveness as well as cost-effectiveness. The goal of this symposium was to share the progress of the pilot NNP in 4 participating countries: Burkina Faso, Rwanda, Mozambique and Nigeria, represented by **Wamdaogo Guelbeogo**, (National Center for Research and Training on Malaria - CNRFP, Burkina Faso), Emmanuel **Hakizimana** (Rwanda Biomedical Center, Rwanda), **Dalcisaria Marrenjo** (National Malaria Control Programme - NMCP, Mozambique) and **Adedapo Adeogun** (Nigeria Institute for Medical Research - NIMR, Nigeria). They distributed Interceptor G2 (IG2), Piperonyl Butoxide (PBO), Royal Guard (RG) and standard ITNs, as well as combined standard ITNs plus indoor residual spraying (IRS). Similar tests and methods including susceptibility tests, human landing catches, CDC light traps are used across all the study areas. Baseline reports indicated that the most abundant anopheline in the four study countries is *Anopheles gambiae* s.l*,* followed by *Anopheles funestus* and then, other *Anopheles* species. Indoor and outdoor biting ratios are similar in most of the pilot areas, skewed towards outdoor biting but seem not to be significantly different. Nightly biting patterns also differed between areas, from the early night (19:00 to 20:00) to early morning (2:00 to 6:00), although there were some common trends in the biting timings observed. However, pyrethroid resistance profile is moderate to high across the study areas, depending on insecticide exposure, with the exception of Rwanda where pyrethroid resistance was very low. All four countries reported variations in ITNs coverage to households after the net

distribution campaigns. However, the 'use given access' proportion is encouraging across the study countries.

Scientific Sessions:

Parallel session 1: Vector surveillance, entomological capacity and National Malaria Program support

Jessica Amegee Quach (Liverpool School of Tropical Medicine - LSTM, UK) began her talk by introducing the Partnership for Increasing the Impact of Vector Control (PIIVeC) as a multinational programme aimed at developing and training postdoctoral fellows to build reliable evidence for informed vector control strategies. Her research aimed at assessing the effectiveness of the programme in accelerating the development of the fellows' expertise in addition to evaluating the factors that have hindered or enhanced their contribution towards the programme's success. The four-year study used a mixed methods approach to collect data. From her study, Amegee Quach found that four overlapping factors contributed to the fellows' expertise development. These included the mentoring structure and attributes of the programme, the flexibility and high diversity of support, professional and personal development opportunities, the individual personalities and intrinsic motivation and the quality of the fellow-advisors' relationship and institutional working environment. She concluded the talk by stating that there is an increase in the use of research consortia models that aimed at developing leadership and expertise among scientists. Furthermore, multifaceted interventions formed a vital support approach for postdoctoral fellows for them to develop varying critical capacities and transferable skill sets. In the end, Amegee Quach emphasised the importance of having diverse professionals supporting postdoctoral fellows in order to provide them with a holistic approach in regards to training and perspective in order to hone an array of skills that would position the fellows' research outputs in national, regional and international contexts.

Alex K Musiime's (Infectious Disease Research Collaborations, Uganda) presentation was about a study conducted in the historically high malaria transmission district of Tororo, Uganda, where intensive vector control measures were implemented starting with LLIN distribution in October 2013/2017 followed by sustained IRS (bendiocarb and actellic) in December 2014 - 2019. IRS intervention led to a decline in microscopic parasitaemia from 34.9% before intervention to 1.8% in the 5th year of implementation. Also, acute respiratory infection, gastrointestinal illness and housing improvements and their potential impact on malaria transmission were assessed 5 years after IRS implementation. There was a marked reduction in entomological metrics after IRS, for example from 218 to 0.42 infective bites/person/year. Two cohort studies from September 2017 to October 2019 with approximately 100 households per cohort, as well as the longitudinal participant follow-up and entomological monitoring, was conducted involving CDC light traps every two weeks and routine participant/sick visits every 28 days. Mean daily human biting rate was correlated to the degree of rainfall/month during IRS implementation with pirimiphos-methyl (Actellic) showing peaks of biting rate in the months of May and June. The association between house type, the incidence of malaria and diarrhoeal disease revealed that modern houses were associated with 53% reduction in human biting rate and 24% reduction in gastrointestinal illness compared to traditional houses. Musiime's work was funded by the NIH and conducted by the PRISM study and the Infectious Disease Research Collaboration (IDRC) teams.

Parallel session 2: Vector surveillance, entomological capacity and National Malaria Program support

Emily Dantzer (University of California San Francisco - UCSF, USA) presented "*Key findings of a global landscape analysis on entomological surveillance best practices"* which highlighted five main themes that could be summarized from outcomes of Key Informant Interview of 30 individuals. These themes

included: 1. Need for inherent and internal advocacy for malaria. 2. Good funding meant good entomological surveillance as countries prioritized best practices. 3. There was a difference in priorities between donors and the country. The main difference between donors and countries was the thought about what were the key important tools required for best practices in vector surveillance. 4. Human resources – all agreed on training with the main concern being the impact of the age gap between retiring entomologists and the early career researchers. 5. Need for collaborations with clearly defined roles of responsibilities and priorities. The problem arose in funding these collaborations as each party had their own expectations. The donor had the last say in most important matters.

Rosemary Susan Lees (Liverpool School of Tropical Medicine - LSTM, UK) talked on *"Validating entomological methods for evaluation of vector control tools"* which captures the essence of developing a process of validating bioassays, methods and standard operating procedures (SOPs) used for the evaluation of vector control tools (VCTs). She discussed four main stages of method validation, which include: defining design outcomes and refining the methods; quantifying inherent error in the methods; evaluating the ability of the methods to accurately characterize VC products; and affirming results by two external laboratories. The goal of this work is to help in developing a "consensus SOP" of methods for the monitoring of next-gen ITNs.

Parallel session 3: LLINS, IRS and Insecticide Resistance Management

Chris Clarkson (Anopheles gambiae 1000 genomes consortium - Ag1000G Consortium) started his talk on "*Insecticide resistance in the Anopheles gambiae complex - analysis of whole genome sequence data from 19 countries and three mosquito species*'' by explaining the Ag1000G project. This dataset consists of 2784 wild-caught samples, and Illumina whole-genome deep sequencing from 19 countries and 26 partner's studies. This data set is open and can be analysed in the cloud for free. Clarkson explained the results of the analysis of different insecticide resistance mechanisms. First was target-site resistance to pyrethroids. They discovered previously unknown mutations of the Vgsc genes. However, these unknown mutations were present in mosquitoes already with *kdr* mutations. These double and triple mutants can show much stronger pyrethroid resistance. They found 7 double mutants with high frequency in West and Central Africa. Another type of resistance they investigated was metabolic. They identified metabolic resistance using gene copy number variants as markers. They found geographical heterogeneity prevalence of pyrethroid resistance between West, Central and East Africa. Most samples had kdr mutations and *P450* amplifications in the West and East but in Central Africa, kdr was more prevalent. Organophosphate resistance was present in the form of *Ace1* in the West and *Gste* in the East. Finally, using genome-wide scans, they detected 3 novel genome loci possibly linked to insecticide resistance. One of them, *Keap1*, activates multiple metabolic insecticide resistant genes.

Iddrisu Alidu (Vestergaard - NMIMR Vector Labs Accra, Ghana) started his presentation on "*Maintaining Anopheles gambiae s.l mosquitoes using an artificial membrane feeding technique at Vetergaard-NMIMR Vector Labs, Ghana*" by mentioning the importance of blood-feeding in mosquito mass-rearing. Females mosquitoes require animal access to blood-feeding but animal access, especially live ones, can be challenging to handle. Therefore, artificial membrane feeders are an option to provide blood meals to female mosquitoes. They used a Hemotek feeding machine with parafilm to hold sheep blood. Then, the feeder was set to 33 ℃ before putting it in the cage. After that, they compared feeding rate and hatch rate between membrane feeding and direct feeding during 5 months (October - February). They found no difference in feeding rate or hatching rate between direct and membrane feeding. Direct feeding showed slightly higher percentages across the five months except in November and February. These results show no apparent negative effects from membrane feeding

in *Anopheles gambiae* strains. Moreover, this technique is easier to manipulate, has fewer risks associated and improves the quality of research.

Francesco Baldini (University of Glasgow) began his talk "*Transgenerational effects in life history traits and malaria susceptibility induced by insecticide sub-lethal exposure in the mosquito Anopheles gambiae*" addressing the impact of insecticide resistance on vector control effectiveness. The aim of the study was to understand the fitness cost of exposure to insecticide in susceptible *Anopheles* mosquitoes. They designed an experiment where mosquitoes were blood-fed and one group was exposed to a sublethal dose of permethrin (0.3%) with the other being the control group. Both groups layed eggs and their offspring were reared until adulthood. The offspring were blood-fed with infected blood and exposed to insecticide. Adult survival and fecundity, larval survival and development time, adult body size and malaria prevalence, and specifically intensity of infection, were then measured. Results showed that insecticide exposure affected survival by reducing it, although larger mosquitoes tended to have higher survival. Moreover, the number of eggs produced also reduced. Larvae survival was reduced from mothers exposed to insecticide but larvae developed into pupae in a shorter time compared to the control. Finally, there was no difference in larvae size between the two groups. Generally, maternal exposure to the insecticide did not affect the survival of their offspring. Another interesting observation was that at day 12, maternal exposure made offspring tolerate the insecticide better than in the control but they layed fewer eggs. In terms of malaria infection, there was no difference between the two groups in malaria prevalence but the intensity of infection was lower in mosquitoes exposed to insecticide. However, this effect was not seen when the mothers were exposed to insecticide. These results showed the impact of maternal exposure to insecticide and how it affects the offspring's life history traits.

Priscille Barreaux (Liverpool School of Tropical Medicine - LSTM, UK) started her talk on *"Exposure to pyrethroid nets reduces blood feeding efficiency and longevity in resistant mosquitoes"* explaining how insecticides affect the mosquito's life. Insecticides prevent the mosquito from entering the house, decreases biting, and kills mosquitoes before or after blood meal. However, resistant mosquitoes do not die and they can finish the gonotrophic cycle and transmit the malaria parasite. The aim of the project was to explore if insecticide treated nets (ITNs) alter mosquito's host searching and blood feeding behaviour, the amount of blood ingested and its longevity. They tested blood feeding and mosquito survival by exposing resistant mosquitoes to permanet 2.0 and 3.0. Results showed that ITN reduced feeding success by reducing the time spent feeding with a feeding success of 9% when exposed to ITN + PBO. Longevity was also reduced by ITN with 20 days for fed females and 12 days for unfed females. They also tested blood seeking efficiency with ITN with Olyset, Permanet 2 and untreated using a baited box method. Mosquitoes spent more time flying avoiding the ITN compared to the control. Also, mosquitoes had a higher number of landings in the net and finally the proportion of mosquitoes flying away was higher with ITN. Moreover, there was a reduced proportion of blood fed mosquitoes and the blood volume also was reduced. This trend was also found in blood feeding duration, defecation time and proportion of defecating mosquitoes, suggesting that ITN decreased blood meal quality. Overall, ITN decreases blood feeding success, longevity and blood meal sizes in resistant mosquitoes.

This report is brought to you by the MESA Correspondents Stella Riunguh, Amelie Wamba, Eggrey Aisha Kambewa, Mauro Pazmino Betancourth, Udoka Nwangwu, Thoan Ho Dac, Faith Hungwe and Jackson Nyarko, with mentoring and editorial support from Charles Quaye.

Day 2: 21st September 2021

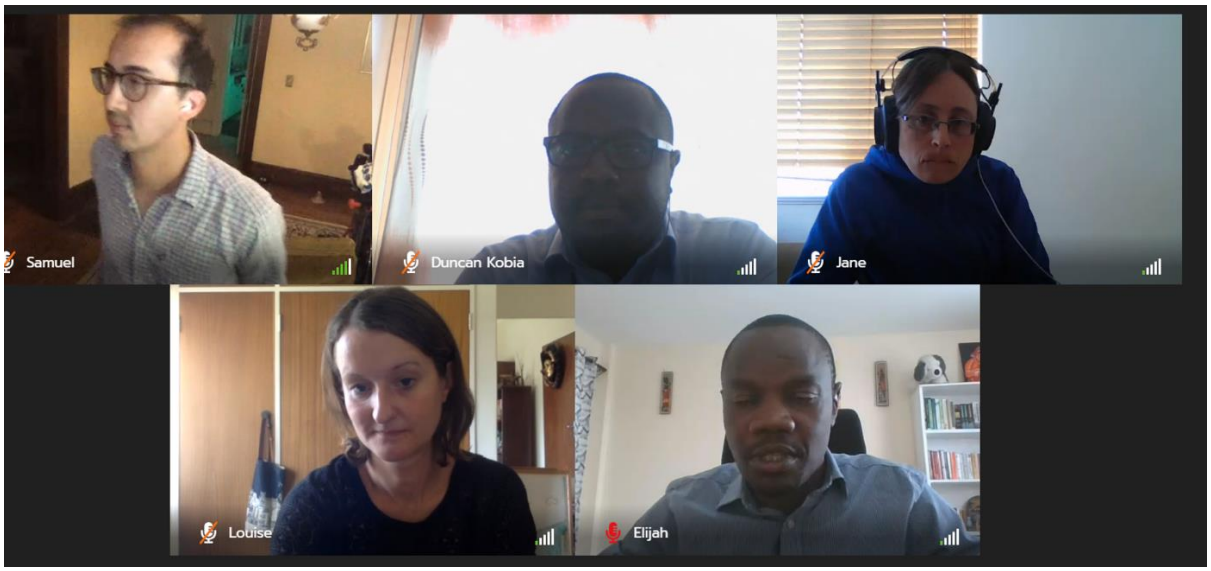
Plenary Session 2: Challenges of vector control in the wake of COVID-19 pandemic in Africa: innovating new solutions for vector-borne disease elimination

Audrey Lenhart (Centers for Disease Control and Prevention - CDC, USA) challenged the idea of technological innovation as the main focus for malaria elimination and the need to explore new solutions after COVID-19. The challenges vector control programs faced during the pre-COVID-19 era were mainly limited funding, stagnation, limited vector control toolbox, how the agenda was run by external funders, and the rampant widespread of insecticide resistance. During the pandemic, various research projects were delayed or paused and countries faced competing public health priorities with extra demand on already stressed systems. Overall, countries tried not to lose the gains achieved in vector control before the pandemic. Lenhart shared how we can reimagine vector control surveillance in the post COVID-19 era by innovations and new areas. These areas are innovation in engagement by strengthening connections between countries and regional networks to exchange expertise and knowledge. There should also be innovation in research practices that tackle inequality faced by African scientists and acknowledge the imbalance in power dynamics between external and local institutions. She then spoke of innovations in partnerships that broaden the scope of which expertise is most valued, innovations that remove the dichotomy between international and local organizations or lead versus local organizations and innovations that increase investment in non-western organizations. This would then form a platform where structural and institutional innovations can take place empowering and recognising non-western institutions and experts as leaders. Consequently, they would become direct recipients of funding for training and equipping institutions in endemic areas. She acknowledged how corruption needed to be mitigated and not be used as an excuse to not fund institutions. Finally, resilient innovations are necessary to create strong local leadership, cultivate expertise and alleviate poverty. Lenhart concluded with how technological innovations are important but not sufficient to achieve malaria elimination.

Symposium Session 2:

Parallel symposium 3 - Data Sharing in the African Context - Opportunities to Reshape the Conversation

This session was moderated by **Elijah Juma** (Programme Manager, PAMCA). He gave a brief overview of the session as activities and opportunities in data sharing on the African continent.



The first speaker, **Duncan Athinya** (Vestergaad, Kenya), talked on the topic "*Africa-led entomological aggregation and visualization efforts and advances in entomological sharing: are we making progress*". He explained how strategic information can impact the 'high burden to high impact strategy' of the WHO and the relevance of quality entomological data in malaria control, using the Insecticide Resistance (IR) Mapper. Duncan identified IR as a major threat to malaria vector control. Hence, the need for the IR Mapper, an African-led initiative that aggregates and visualizes insecticide resistance data to aid planning and implementation of insecticidal vector control approaches. The platform can be used to identify IR data gaps and strategically use quality data to help countries deploy the most effective control tools and predict risks and spread of diseases.

The second speaker, **Samuel Rund** (University of Notre Dame, USA) talked about the collection and public dissemination of US mosquito surveillance data. He highlighted the large number of institutions involved in mosquito surveillance and the way they collect and disseminate data. Using the National Association of County and City Health Officials (NACCHO) study as an example, he described how needs assessment for core competencies was carried out in the United States (US) as a way of filling the gap in the quality of data generated. He hinted that data is made available through diverse methods including annual reports, datasheets, weekly trap results, statewide reports, vector surveillance maps and charts, among others. Rund concluded by pointing out some open data sharing concerns.

Jane Wyngaard (University of Cape Town, South Africa) talked about the value of open scientific data. Her talk hinged on examples of the value of open data sharing and technical challenges to open data sharing. She used examples of several projects which help in the correct forecast of natural disasters, drought and issues relating to wetlands. Also highlighted were technology, standards, regulatory and ethical requirements, data practices and infrastructure, as the main challenges to open data sharing. Wyngaard suggested solutions to these challenges as, making data findable, accessible, interoperable and reusable (FAIR); digitized and automated, with the requisite community collaboration.

Louise Bezuidenhout (University of Cape Town, South Africa) spoke on hidden challenges to openness in African research. She discussed effective data sharing in the context of support from the environment, motivations of individual researchers and characteristics of the data. Bezuidenhout pointed out that underreporting of Low/Middle-Income countries (LMICs) in Open Data (OD) discussions and use of binaries when distinguishing LMICs from high-income countries (HICs), are reasons for the unfavourable scientific research environment in LMICs. Ways of addressing binaries, motivations, concerns in sharing data and practices, were pointed out as building trust and facilitating openness through proper networking.

Scientific Sessions:

Parallel session 4: LLINS, IRS and Insecticide Resistance Management

Fotso Toguem Yvan Gaétan (University of Yaounde 1, Cameroon) presented *"Polymorphism analysis of CYP6M2, a main metabolic resistance gene in Anopheles gambiae from Yaoundé, Cameroon."* Malaria incidence is still high in Cameroon, accounting for 3,263 deaths in health facilities, with 68.7% deaths occurring in children under 5. There has been an equally rapid evolution of insecticide resistance which has extended to all classes of insecticides in Cameron. Nonetheless, the role of allelic variation and information on polymorphism is lacking. Thus this study assessed the genetic diversity of the enzyme CYP6M2, to detect potential resistance markers of resistance, in *An. gambiae*. Bioassays were used to assess the resistance profile of both field and lab-bred hybrid *An.*

gambiae while cone assays were used to assess bed net efficacy. Results showed higher resistance to DDT, permethrin and deltamethrin. There was partial recovery (~46%) after exposure suggesting the implication of P450s genes. There was a loss of efficacy (<20%) against Olyset® Net compared to Olyset Plus ® Net (>80%); which was attributed to insecticide selection pressure due to the massive use of LLINs and selection of resistance from breeding sites due to agricultural pesticide use. Finally, CYP6P4, CYP6Z2 and CYP6M2 were significantly upregulated in wild *An. gambiae*. CYP6M2 was found to be upregulated up to 8.3 folds in the wild and 12 folds in hybrid F4 generation.

Delia Doreen Djuicy (Centre for Research in Infectious Diseases - CRID, Cameroon) presented on *"CYP6P9-Driven Signatures of Selective Sweep of Metabolic Resistance to Pyrethroids in the Malaria Vector Anopheles funestus Reveal Contemporary Barriers to Gene Flow."* Pyrethroid resistance in *An. funestus* is a major constraint to malaria control in Africa, with a rapid expansion rate across southern Africa, and its main mechanism being: P450-based metabolic resistance (CYP6P9 genes). This study was to determine whether the resistance mechanism is confined to this part of the continent or whether it faces some barriers preventing its spread into other countries. Researchers tracked contemporary gene flow in *An. funestus* mosquitoes in 9 locations across 7 countries covering southern and east-central Africa. Preliminary results showed 45 haplotypes of the CYP6P9a gene were found to be guttered into 3 groups across the study locations: Group A was made up of samples from Mozambique, Malawi, Zambia and Tanzania; Group B from the Democratic Republic of the Congo (DRC) and Cameroon; and Group C from Uganda. Further genetic diversity analyses of CYP6P9a gene showed low polymorphism, low haplotype and low nucleotide diversity in the mosquito population sampled from southern Africa. There was a strong selection at CYP6P9a particularly in the coding region (1st exon); a clear geographic divergence between southern Africa (Mozambique, Malawi, Zambia and Tanzania) and eastern-central Africa (Uganda, DRC, and Cameroon); and only a single major haplotype (freq. = 118): from southern Africa were found to form a defined clade from east-central populations dominated by this nucleotide from southern Africa. They concluded that there was very low genetic differentiation but high gene flow within southern Africa, which is contrary to what is observed globally.

Amélie N.R. Wamba (University of Yaounde 1, Cameroon) presented *"The Cytochrome P450 CYP325A is a major driver of pyrethroid resistance in the major malaria vector Anopheles funestus in Central Africa."* There are no target-site linked to pyrethroid resistance in *Anopheles funestus*. Although it is known that metabolic resistance is the main mechanism that involves major detoxification enzymes especially cytochrome P450. CYP325A is one of the overexpressed P450s in central Africa. Thus, the need to understand how this biochemical resistance is acquired and spread in the field. The process involved characterization and implication of CYP325A; *In silico* prediction of homology modeling then *in vitro* validation sub-cloned into pCW and co-expressed with CPR in *E.coli*. Data analyses were made using polymorphism analysis PoolSeq readings from pooled population data aligned to the *An. funestus* chromosomal assembly, and gene ontology and transcript detection and amino acid sequence characterization. Results on the susceptibility profile of *An. funestus* mosquitoes to insecticide showed that there is high resistance to pyrethroids (permethrin and deltamethrin) in Mibellon, Cameroon. Piperonyl butoxide (PBO) synergist assays pointed to the major role of P450 in pyrethroid-based resistance in Cameroon. It was concluded that CYP325A is present in all resistant species of *An. funestus* from Cameroon.

Parallel session 5: LLINS, IRS and Insecticide Resistance Management

Duncan Kobia Athinya (Vestergaard Frandsen Limited, Kenya) began his talk by introducing his study which aimed at understanding the long-term efficacy of PermaNet®3.0, pyrethroid-based piperonyl butoxide (PBO) long lasting-insecticide net (LLIN). Pyrethroid-PBO is now becoming the new standard of care in countries where confirmed or conferred pyrethroid resistance has been detected in

mosquito vectors. This is because pyrethroid-PBO nets have been demonstrated to be more effective than the conventional non-PBO LLINs. However, due to the physicochemical properties of PBO, little information exists on the long-term durability and efficacy of PBO LLINs. He highlighted studies they performed on PBO nets collected from Nigeria, Sudan, Ethiopia, Uganda and Bioko (Equatorial Guinea). The team conducted chemical content analyses and bioefficacy tests according to WHO standards. The results were thereafter compared to those obtained from three former World Health Organization Pesticide Evaluation Scheme (WHOPES) Phase III countries; Ghana, Kenya and India. They found that the durability of the PermaNet®3.0 varies, as it is dependent on usage and environmental conditions. Chemical analyses showed that post-market surveillance data fell within WHOPES Phase III observed ranges, whilst bioefficacy results revealed that used PermaNet®3.0 nets were more efficacious than new ones. Lastly, PBO was detected on all PermaNet®3.0 samples consistent with the expected useful life of three years. Athinya concluded with an appeal to expand the current WHO guidelines to include testing with well characterised pyrethroid-resistant strains as well as post-market surveillance. This is in addition to routine, long-term monitoring of PBO nets in order to better understand their efficacy.

Thomas Syme (London School of Hygiene and Tropical Medicine – LSHTM, UK) began his talk by explaining that pyrethroid-PBO nets are a new class of insecticide treated net (ITN) that have demonstrated improved vector control. Syme went on to explain that most households combine ITN and indoor residual spraying (IRS) to prevent malaria transmission thus the combined use of PBO ITNs and IRS is an operational possibility. The aim of the study was to assess whether pyrethroid-PBO nets would reduce the efficacy of IRS when used in combination. To test this hypothesis, Syme used a pyrethroid ITN and two different pyrethroid-PBO nets in IRS applied households. The results obtained from these experiments demonstrated that the toxicity of IRS was more reduced in pyrethroid-PBO nets but not with the pyrethroid nets. Syme thus recommended the combined use of ITNs and IRS as this increases protection against blood-feeding mosquitoes. As the study was conducted on a small scale, the epidemiological impact is uncertain and much work needs to be done to better understand this as it may influence decision-making strategies. He concluded his talk by stating that the purpose of his presentation is not to discourage the combined use of ITNs and IRS but there are circumstances where it is suboptimal and these factors must be put into consideration when implementing vector control measures.

Barnabas Zogo (Sumitomo Chemical, UK) started with an overview of insecticide resistance in Africa, pointing out its increasing usage. It is based on this that Sumitomo Chemical formulated the SumiShield 50WG (clothianidin-based insecticide) for malaria vector control through indoor residual spraying (IRS). He explained that the product, which was prequalified by the World Health Organization (WHO) in 2017, has been tested extensively in about 13 African countries, with good results. In this study, they carried out tests using susceptible and resistant malaria vectors, comparing the novel product to other pyrethroid-based products that are also used for IRS. The results show that, unlike pyrethroid-based insecticides, SumiShield 50WG treated surfaces allowed for significantly longer contact time, thereby reducing the chances of development of resistance. This is in addition to its excellent durability and killing effect. Zogo concluded by stressing that SumiShield 50WG is a valuable tool for use alongside other vector control interventions.

Borel Djiappi Tchamen (University of Dschang, Cameroon) gave an overview of arboviruses and their vectors, narrowing it down to the situation in Cameroon. He pointed out that vector control, an effective measure against arbovirus transmission, is threatened by an increase in insecticide resistance. Hence, the aim of the study was to understand the molecular mechanisms mediating insecticide resistance in *Ae. Aegypti* and *Ae. Albopictus* populations found in Yaoundé, Douala and Dschang. Through larval sampling, immature stages of the mosquitoes were collected and reared to adults. Adults were morphologically identified, subjected to insecticide resistance bioassays and

molecular analyses for *kdr* and metabolic resistance. Findings revealed that genetic mutations and metabolic based mechanisms were associated with insecticide resistance in the *Aedes* populations, though the mosquitoes were still susceptible to some insecticides. Tchamen concluded with an urgent call to control arbovirus vectors so as to forestall outbreaks of arboviruses.

Parallel session 6: Larval source management, IVM, Global Health, and public engagement

Doumbe Belisse Patricia (University of Yaounde, Cameroon) started her talk on "*Assessing malaria transmission and vector dynamics in a context of larviciding trial in the city of Yaoundé, Cameroon*" with an overview of the situation of malaria in urban areas. Although the consensus is that urban areas reduce malaria transmission this has not generally been the case. Unplanned urbanization and agricultural urbanization create breeding sites and malaria cases are on the rise. Therefore, the aim of the project was to assess the impact of larvicide on mosquito density, malaria transmission and parasite prevalence. The trial was conducted in 26 study sites in the city. Most of the sites were crossed by a river or surrounded by swamps. Pre intervention and post intervention lasted from 2017 to 2020. Larvicide intervention achieved a rate reduction of 53.3% in anopheline mosquitoes with no impact on species composition. There was a steady decrease in mosquito density measured by CDC traps and human landing catches. Entomological inoculation rate was very high before intervention (90 infective bites per month per year) and was reduced by 79% after the intervention. Malaria prevalence experienced a decrease in the second and third years after the intervention compared to the control, however, this difference was not significant. This trial presented evidence of high efficacy of larviciding in reducing adult population numbers and malaria transmission, therefore this tool can be used to control vector population in urban areas as part of an integrated control approach.

Mark Lwakatare (FHI 360, USA) started his talk on "*Achieving improvements in malaria behaviours and behavioural determinants through integrated social and behaviour change activities in Tanzania Mainland*" by explaining that this program was offering support to the Government of Tanzania towards social and behavioral changes and programming in behavior change. The USAID Tulonge Afya project is implemented using two platforms: Naweza and FHI 360, categorized according to age and cohorts of the beneficiaries. Lwakatare emphasized that the USAID Tulonge Afya project under the Naweza platform focuses on the pregnancy and birth behaviors in women, which involves different health changes including malaria. It also focuses on caregiving and parenting of children up to five years of age, with a concentration on sleeping under insecticide treated nets and seeking care at health facilities. Therefore, Lwakatare's team focused on national and community level media like public announcements and cultural theatre performances. He reported that the USAID Tulonge Afya project has been successful, with an increase in knowledge on risks of malaria during pregnancy, an improved attitude of women towards insecticide treated mosquitoes and IPTP usage during pregnancy. Thus, Lwakatare highlighted that the project illuminated the importance of resonance and integration in addressing people related issues.

Sandra Ngadjeu (University of Yaoundé, Cameroon) started the talk on "*Perceptions and practices of communities during a larviciding trial in the city of Yaounde, Cameroon*" by highlighting that malaria still remains a major public health problem in Cameroon. She however explained that anti larval control measures were used to reduce the vector densities and transmission of malaria. She stated that one of the control measures that has been instrumental in Cameroon is the free distribution of mosquito nets. However, the knowledge and perception of malaria among the larval control population are expected to either increase or reduce. From her study, she found out that the knowledge of mosquito breeding sites increased in the intervention areas with larviciding treatment than in the control areas. Furthermore, Long Lasting Insecticidal Nets (LLINs) were the main methods used to fight mosquitoes, through regular usage of the LLINs decreased in the non-intervention and intervention areas with time. Moreover, people in the treated sites also have good knowledge of

malaria transmission. Finally, Ngadjeu concluded that the high knowledge of people in the treated areas was due to adequate knowledge on malaria symptoms and mosquito breeding sites in treated areas as compared to the control sites.

Symposium Session 3:

Parallel symposium 5: Using entomological surveillance data and programmatic tools for evidence-based planning and selection of vector control interventions

The session was moderated by **Sheila Ogoma** (Ifakara Health Institute - IHI, Tanzania). She introduced the speakers and invited them to present.

Elodie Vadja (University of San Francisco, USA) introduced the Entomological Surveillance Planning Tool (ESPT) as a decision-support tool designed to empower local programmes and institutions to formulate priority programme questions. It also enables programmes to utilize available capacity and funding to formulate an achievable, adaptable and sustainable surveillance framework. Vadja stressed how driving entomological surveillance optimises use of funds, capacity and data towards evidence-based decision-making. She showed an example of how the tool can enable decision-makers to identify human-vector contact points that are not targeted by current interventions (gaps in protection). Vadja concluded that LLINs are appropriate and effective intervention but are not sufficient as sole intervention and should be complemented with other interventions that could address some gaps in protection such as outdoor biting.

Charles Ntege (National Malaria Control Division - Ministry of Health - NMCD-MOH, and Malaria Consortium, Uganda) presented on the use of entomological surveillance data to inform vector control decisions in Uganda. Entomological data has been used in Uganda to enhance community participation in vector control, to help in deployment of LLINs for insecticide resistance management, and to guide in the rotation of indoor residual spraying (IRS) chemicals. Currently, the insecticide resistance data shows that there is moderate resistance in *An. gambie* due to partial or full involvement of mixed functional oxidates. Ntege reported that the delivery of Malaria control interventions in this project was based on entomological data. Some of these interventions included decision making on the net types to use, the geographical distribution of nets, and net funding. Thus, he emphasized the use of entomological data in malaria control decision making.

Stark Katokele (Ministry of Health and Social Services, Namibia) highlighted the components of good quality entomological data for making data-driven decisions which include the right interventions as well as the management and sustainability of limited resources. According to him, the endemicity of malaria did not improve in the country, despite decades of using dichlorodiphenyltrichloroethane (DDT) and deltamethrin in IRS. Hence, insecticide resistance monitoring and vector surveillance were carried out between 2018 and 2020. Results show very little indoor biting and resting activities. Pyrethroid resistance moved from suspected resistance in 2018 to resistance across all districts in 2020, while the mosquitoes were susceptible to Actellic. Residual efficacy tests also showed effectiveness of Actellic on metallic surfaces. Stark concluded his talk by sharing the successes of how the National Malaria Control Programme had to switch to Actellic for IRS and from standard pyrethroid-only nets to Piperonyl Butoxide (PBO) nets.

Bernard Kouassi (PMI VectorLink, Ivory Coast) talked about the standard entomological data collection methods they deployed across well-selected entomological monitoring sites in the country. From his results, there was pyrethroid resistance across all sites, while insecticides (chlorfenapyr, pirimiphos-methyl and clothianidin) from other classes revealed that the local population of mosquitoes were either susceptible, suspected resistant or outright resistant from one district to the

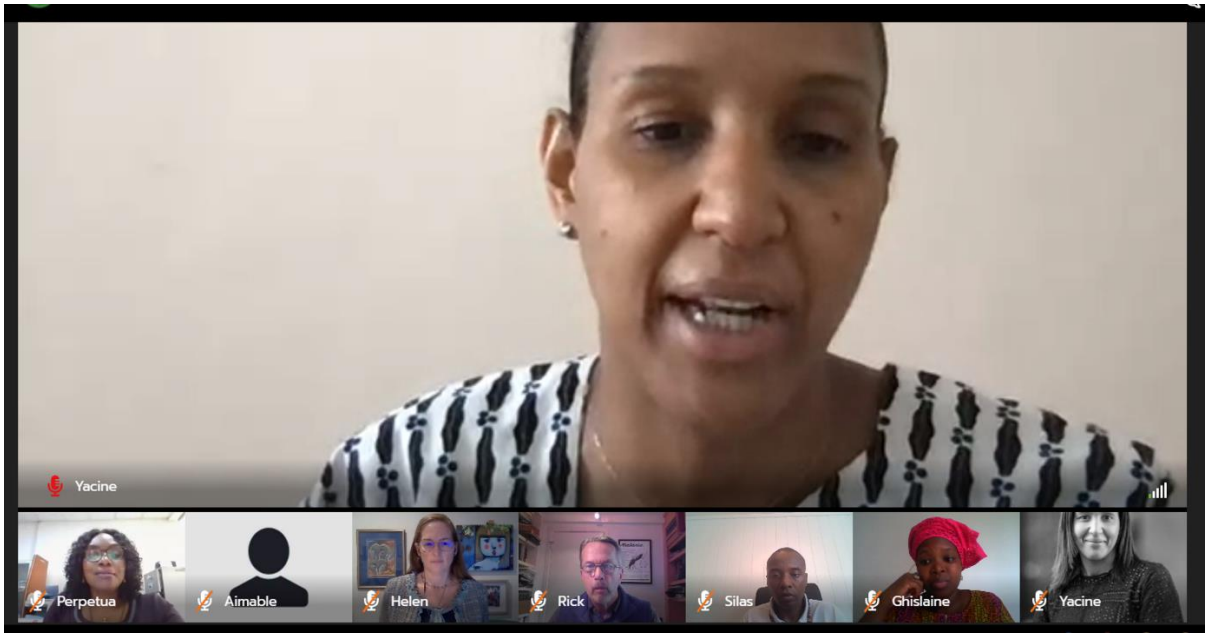
other. Biting and infectivity rates were also found to be high in several sites, leading to relatively high entomological inoculation rates. Based on these findings, there was stratification of Insecticide Treated Nets (ITNs) in the 2020 mass campaign. Piperonyl Butoxide (PBO) nets were distributed to districts where the mosquitoes showed susceptibility to it, while Interceptor G2 (IG2) nets were distributed to districts where chlorfenapyr susceptibility was recorded. The same evidence-based decision-making methods were applied to sites chosen for IRS.

Tom Burkot (Institute of Tropical Health and Medicine, Australia) presented the findings of a global analysis of the capacity of the National Malaria Control Programme (NMCP) to implement vector surveillance and control, a research that was conducted together with Tanya Russel. The study was conducted in 35 countries: 18 from Africa, 14 from Asia-Pacific, and 3 from the Americas. The findings revealed that capacity for vector surveillance, ITN, IRS and larval source management was insufficient in most of the countries. Burkot pointed out that the huge limitations in the capacity to implement activities are due to inadequate governance, funding, human resources, information systems, logistics and infrastructure. He emphasized that governance and human resources were by far the greatest limitations. Acknowledging that insecticide resistance monitoring and laboratory analyses are strengths in Africa, Burkot suggested that using data collected for decision-making, adequate training for available human resources and tracking progress in vector surveillance will improve the capacity for National Malaria Control Programmes to implement vector surveillance and control.

Roundtable discussion: A conversation between funders and implementers of malaria control and elimination in Africa

This discussion was hosted by **Silas Majambere** (Pan African Mosquito Control Association - PAMCA, Kenya) and **Ghislaine Aquedeogo-Ametchie** (Pan African Mosquito Association - PAMCA, Ivory Coast). The funders were represented by **Helen Jamet** (Bill and Melinda Gates Foundation - BMGF, USA) and **Rick Steketee** (President's Malaria Initiative - PMI, USA). The implementers were represented by **Aimable Mbituyumuremy** (National Malaria Control Programme - NMCP, Rwanda), **Perpetua Uhomoibhi** (National Malaria Elimination Programme - NMCP, Nigeria) and **Yacine Djimbo** (Speak Up Africa, Senegal). The discussion covered three topics: 1. The role of the funders and implementers in

malaria control. 2. How funders and implementers each set their agendas. 3. How the funders and implementers set their priorities.



Q) How do funders and implementers set their priorities?

Funders set their agenda based on the strategies of funding organizations. They evaluate the success of existing programs to determine the continuation of support. Implementers on the other hand try to align their strategies to global and national strategies based on epidemiological and ecological data and funding availability. Thereon existing and new programs are assessed to determine how community health systems are supported.

Q) Silas Majambere took the chance to bring on the table and ask the speakers a concerning point that arose during the previous plenary session by Audrey Lenhart on the friction that can arise between local implementers and funders resulting from different priorities and/or implementation strategies. **How do funders and implementers deal with these situations when they arise?**

It is complicated but funders acknowledge the power imbalance and disproportionate allocation of funds particularly in northern countries. Funders are accountable to their local authorities and it is in their best interest to fund global strategies which may not align with a recipient country's strategies. There is a need for funders to align their strategies to local strategies.

Q) Is there an equitable relationship between funders and implementers?

There is no equitable relationship and striking a balance between both parties is a challenge, however, "funders are committed to changing the power imbalance". It is imperative that host countries are given more leeway in decision-making strategies so as not to always align their decisions with those of the funders.

Q) Are there any problems with directly funding local organisations?

Funders need help in identifying local organisations that are transparent in their management of resources. Unfortunately, some local organisations lack the expertise and experience. There is

therefore a need to build capacity and technology transfer in organisations that lack experience in managing resources. Partnerships at national levels are required and the phenomenon is not malaria specific.

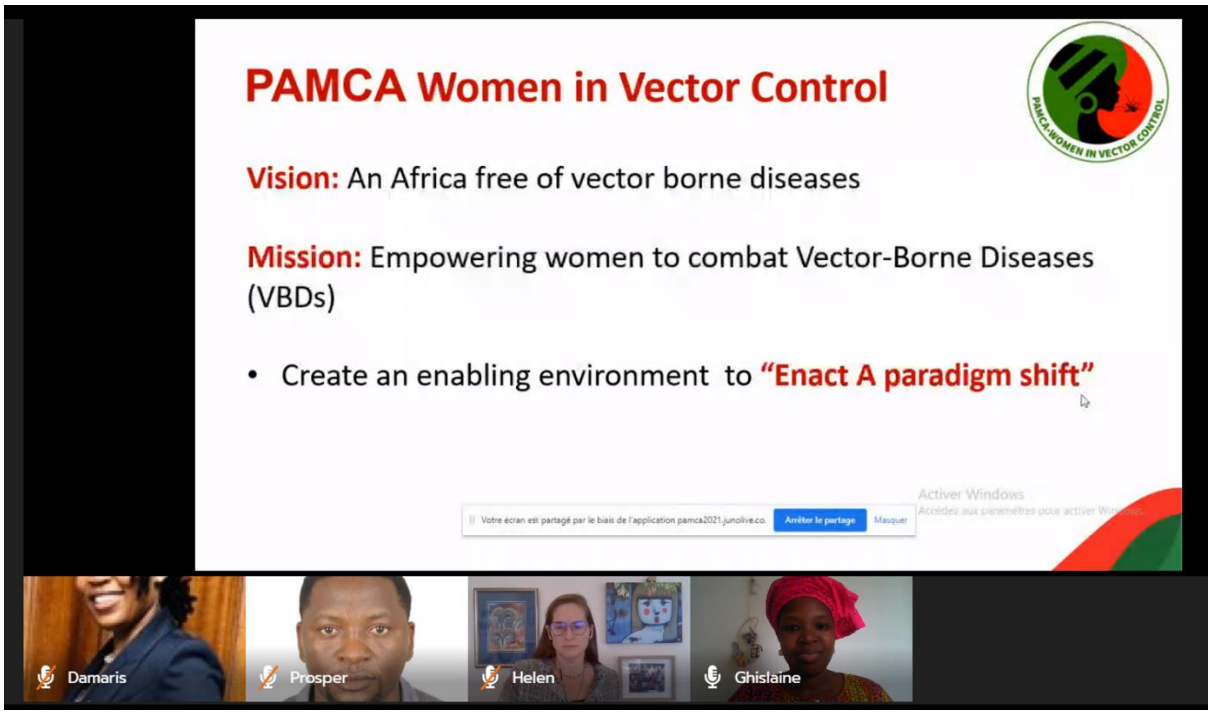
Q) When does the decision from a country supersede the funder's decision? Do funders feel like they have the responsibility to pull out in such a scenario especially if the country's vision does not align with theirs?

Donors decisions are data driven and are trying to meet country specific needs. It is difficult for them to fund novel tools that are not WHO recommended unless the new tools demonstrate to work better than the current ones. It is a trade off and public safety becomes a priority.

Symposium Session 2:

Parallel symposium 4 - PAMCA WIVC professional development

Emma Orefuwa (Pan-African Mosquito Control Association - PAMCA) started the session with an overview of the PAMCA Women in Vector Control (WIVC) program whose vision is an Africa free of vector-borne diseases and a mission to empower women by creating an enabling environment to enact a paradigm shift. She underlined the fact that out of 394 medical entomologists in Africa, only 28% are women (UNESCO, 2015) and the complexity of global health problems demands leadership that is representative of the pluralism of our society. To increase the representation of women in vector control, priority areas for the WIVC program are mentorship, capacity building, networking, gender policy advocacy and non-professional empowerment.



Helen Jamet (Bill Melinda Gates Foundation - BMGF, USA) shared her experience as a woman working in vector control in different fields such as industry with Vestergaard and now with the BMGF. During her work experience, she worked usually under the leadership of men. In addition, having a baby made it difficult to enroll for an MBA like others in the field. Consequently, she had to learn on the job and was able to have much lateral growth. However, it wasn't easy to grow up the promotional ladder

which was frustrating and dispiriting sometimes. She had to persevere and was fortunate to have someone in leadership who believed in her, as well as a very supportive partner. Jamet believes it is important to know your worth, build self-confidence, help others grow professionally and establish dialogue to identify any issues team members may have and help them build capacity by delegating. Fostering a safe space in the workplace can be done internally and externally through the Human Resource by creating a support system to detect predatory behaviours.

Prosper Chaki (Pan African Mosquito Control Association - PAMCA) used his experience to talk about three things he believed when available in the workspace will not only help bridge the gender gap but also help develop women. First, having strong supervision, which challenges both genders in the workspace to improve and be equally competent, so opportunities and roles could be rightly distributed. Secondly, having team members who are very cooperative in the work done. Thirdly, having a mix of men and women in the workspace helps the team to see things from different perspectives and get a broader and objective picture of goals and targets to be achieved. He affirmed that having a number of women, who encouraged him, in his workspace during his early career contributed greatly to his ability to believe in himself and push forward to where he is now. Chaki concluded that the major constraint to the gender equity/equality gap is the feeling of not being valued and not being heard, which is mostly among women. Thus, the challenge is for us all, men especially, to ensure that whenever we find women who demonstrate management and leadership abilities, we should give them leading roles. So that other women will use those that they see as springboards to overcome their fears.

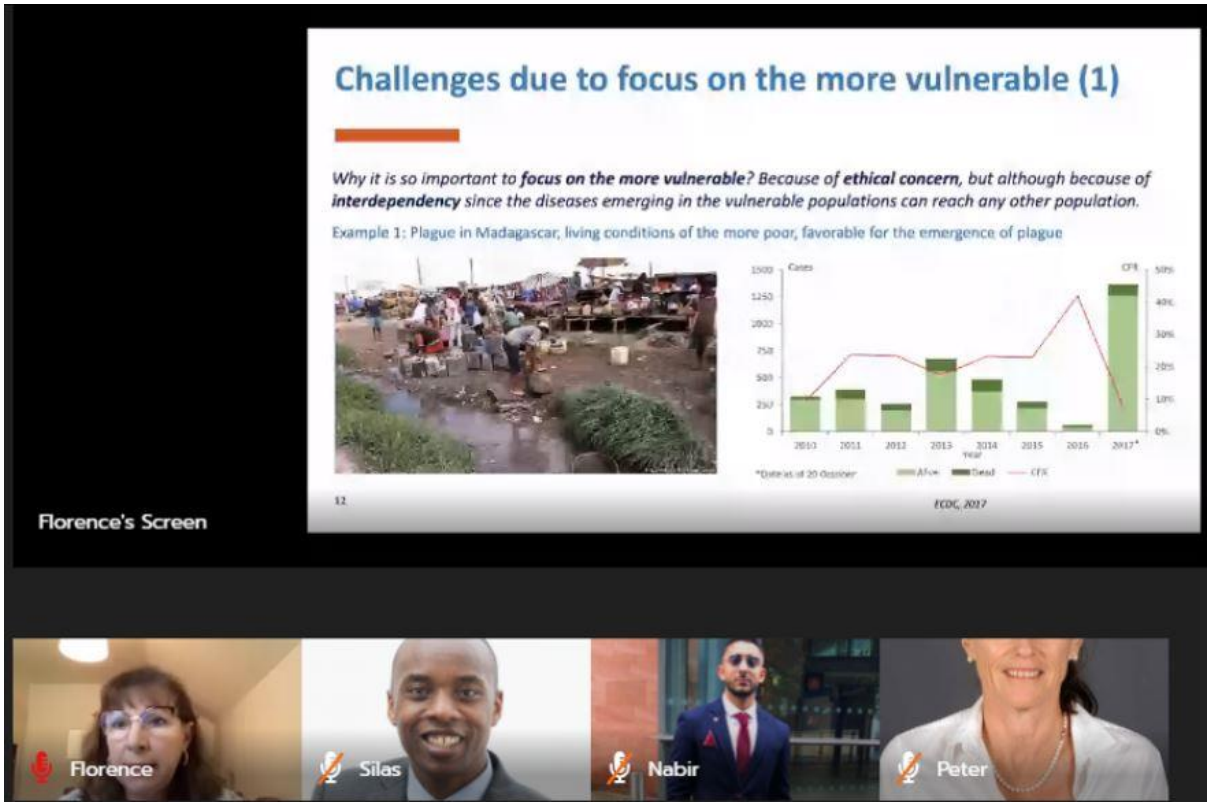
Pamela Mbabazi (World Health Organization - WHO, Africa) pointed out that in her career experience, she has been working and interacting with pregnant women and nursing mothers. She argued that vaccinations are not the only solution to reducing child mortality, since there were cases of children contracting malaria and other vector-borne diseases. Thus, she emphasized the need for an integrated intervention approach in health care. Further, she reiterated that the burden of children suffering from malaria and other vector diseases was her drive in her career. Mbabazi highlighted that there were fewer women up the career ladder in her sector, thus, there is a need to empower women in vector control, since the challenges cut across all cultural situations and usually involve striking a balance between life and work, especially among African women. Mbabazi stressed the importance of being professionally inclusive in the workplace by creating a safe workplace for women. Where a safe place is defined as an articulated and defined area that identifies and punishes inappropriate behaviors. In conclusion, she advised women to comprehend their vulnerabilities and to create a plan to mitigate and/or eliminate them.

This report is brought to you by the MESA Correspondents Stella Riunguh, Amelie Wamba, Eggrey Aisha Kambewa, Mauro Pazmino Betancourth, Udoka Nwangwu, Thoan Ho Dac, Faith Hungwe and Jackson Nyarko, with mentoring and editorial support from Charles Quaye.

Day 3: 22th September 2021

Plenary Session 3: Global health and the emerging challenges of arthropod-borne diseases in Africa

Florence Fouque (Institute Pasteur, France) started her presentation by introducing the concept of global health as population-based, with a focus on the most vulnerable, prevention-oriented, multidisciplinary and multisectorial (Koplan et al. 2009). Fouque summarized the overall challenges with arthropod-borne diseases, such as malaria, to be linked to the vector, the host and the environment. She also mentioned the challenges with arboviral borne diseases in global health including the distribution and adaptability of the vectors, rapidity of spread of the disease and preparedness to unpredictable emerging diseases laying a great emphasis on poverty. Next, she highlighted the challenges due to population-centered global health such as socio-economic conditions, housing, occupation, age distribution and behaviour, making a point of adopting recommendations to target populations. Fouque also mentioned other concerning challenges linked to basic knowledge on detection, prevention and response. Emphasis was made on ethical concerns since interdependencies like the case of the Plague in Madagascar (ECDC, 2017) and Zika virus in pregnant women and children (Kelly et al. 2020). Fouque explained the multidisciplinary approach of global health based on human, animal and environmental health (Suer et al. 2018) laying emphasis on enabling factors including leadership advocacy, resource mobilization to reduce the burden and threat. To conclude her presentation, she shared a multisectorial approach in the special programme for research and training in tropical diseases (TDR), mentioning coordinated pathways and incentives as well as other activities such as training, communications and data sharing.

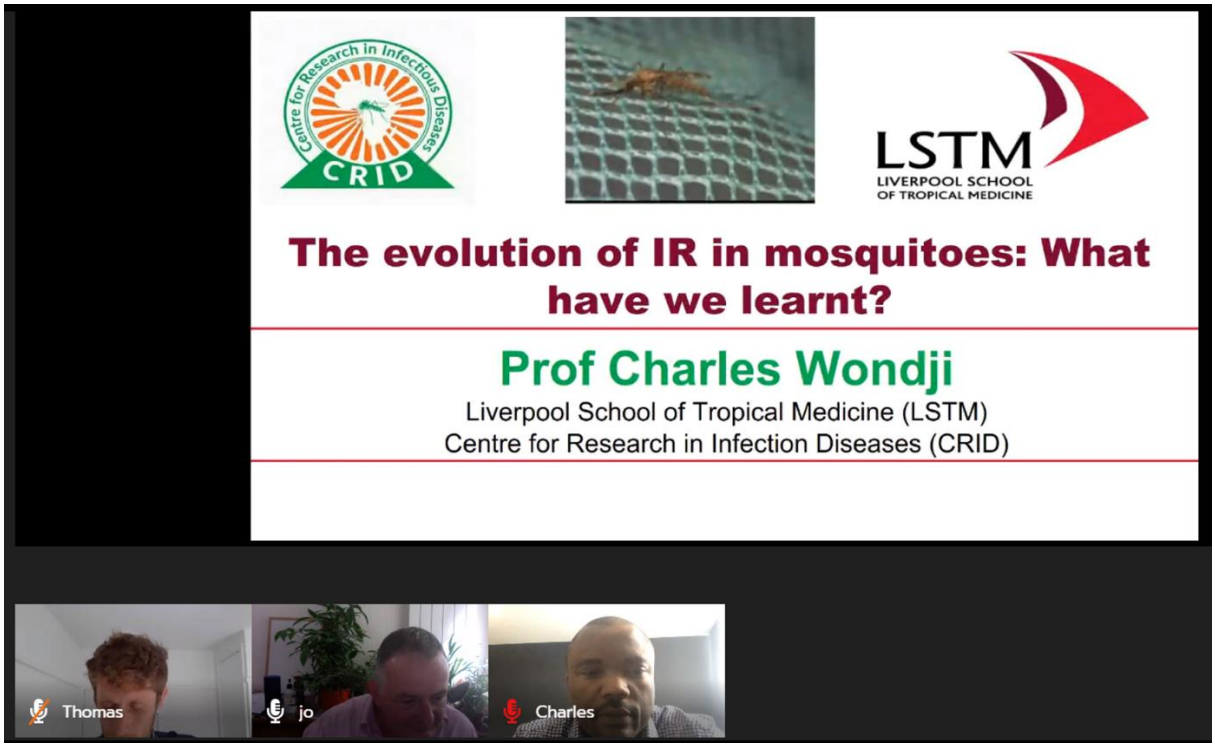


Symposium Session 4:

Parallel symposium 6 - How is GPIRM going? Generating the evidence to inform insecticide resistance management

Jo Lines (London School of Hygiene and Tropical Medicine – LSHTM, UK) started the session with the talk "*The Global Plan for Insecticide Resistance Management (GPIRM): A window of opportunity to improve sustainability and impact of vector control*". He began by stating that insecticide-treated nets have always been known to work effectively against vectors. However, mosquitoes that spread malaria are developing resistance to pyrethroids and thus the insecticide-treated nets are less effective than in the past. Insecticide resistance has had a significant impact on vector control implementation strategies whereby conventional long-lasting insecticide nets (LLIN) and indoor residual spraying (IRS) are not as efficacious as they used to be. It was therefore important for Lines and his team to understand resistance management by evaluating various LLIN products from a supply perspective and then conducting genetic analysis to identify DNA markers associated with insecticide resistance. The Resilience Against Future Threats (RAFTs) project was established to evaluate and compare the efficacy of LLIN and IRS products using data collected from field and laboratory research to determine which tools (LLINs and IRS) to use after a cost analysis has been done. The project aims to ensure that finite resources are used conservatively. Additionally, genetic analysis of resistance characteristics (genes and phenotypes) will enable Lines and his team to evaluate which product was able to overcome which set of resistant genes. Lines concluded his talk by stating that economic analysis of the expected effect of a product will aid programmes and countries to plan their vector control strategies more efficiently.

Charles Wondji (Liverpool School of Tropical Medicine, LSTM, UK and Centre for Research in Infectious Diseases - CRID, Cameroon) talked about: "*The evolution of Insecticide Resistance in mosquitoes: what have we learnt?*". He mentioned that the Global Plan for Insecticide Resistance Management (GPIRM) was set up as a consequence of insecticide resistance rise in recent years. Thus, there is an urgent need to understand the genetic basis of resistance and its evolution across vectors. He then highlighted briefly the genetic basis of metabolic. Approximately, 200 enzymes are involved in metabolic resistance and CYP6P9a and CYP6P9b were identified as the main pyrethroid resistance genes in vector populations from Mozambique and Malawi. No resistance marker was identified for metabolic resistance until the first *An. funestus* DNA-based metabolic resistance markers were mapped. A similar mutation was also found in *An. gambiae* (L114T strain). It was thereafter found that directionally selected cytochrome P450 alleles were driving the spread of pyrethroid resistance in the major malaria vector *An. funestus* RNAseq transcription profiling revealed that over-expression of key detoxification genes varied across African countries. With this knowledge, Wondji and his colleagues designed the first P450 mediated DNA-based diagnostic tool for metabolic resistance, 20 years after the first kdr assay was established. Furthermore, they designed a simple PCR assay to detect the 6.5 kb structural variant. Wondji concluded with the key benefits of elucidating the genetic basis of resistance, and detection and monitoring of insecticide resistance spread.



Thomas Churhcer (Imperial College, UK) began his talk titled "*MINT (Malaria Intervention Tool): A decision support tool for insecticide resistance management*" by stating that novel tools are being developed and these will be more advantageous in our efforts to eliminate malaria. However, there is a cost effect that these new tools pose resulting in a financial conflict of choosing between the more expensive and better tools or cheap suboptimal tools. With regards to vector control methods, Churcher explained the importance of epidemiological and ecological surveillance data to determine what strategies and tools to implement. He thereafter shared how he and Ellie Sherrard-Smith built the Malaria Intervention Tool (MINT); an online mathematical model (https://mint.dide.ic.ac.uk) meant to support insecticide resistance management decisions. The tool recommends what vector control methods to implement based on the user's input parameters (budget, region among other options). To finalize, he demonstrated how the model works so as to familiarise users' with the model.

Parallel symposium 7 & Launch of African Gene Drive Network & Outreach - Who keeps gene drive research safe? Engaging African researchers and experts in governance of gene drive research

The moderator, **Charles Mugoya** (Target Malaria, Uganda) introduced the symposium by giving an overview of the topics and the need for a robust discussion. He then invited the speakers to present.

Tony Nolan (Liverpool School of Tropical Medicine - LSTM, UK) with his talk "*Gene drive landscape*", started the symposium. He gave an overview of the landscape of gene drive. Gene drive helps genetic modifications persist and expand in a mosquito population with the objective of suppressing it or replacing it. It is species-specific and non-toxic. It can make mosquitoes susceptible to insecticides, resistance to malaria parasites, sterile or change behaviour. This technique is not only being researched in mosquitoes but also in other disease vectors/reservoirs such as snails for schistosomiasis and rodents for Lyme disease. Gene drive has also been tested to control invasive rodent species to stop the decimation of bird populations and in the control of insect pests in agriculture.

Zaira Lana (Outreach Network for Gene Drive Research) with her talk *"Why policy matters?"*, invited attendees to think about why policy matters and how scientists can be more involved in policy making. Policy shapes the actions of governments and institutions and directly affects how research is conducted due to regulations or funding availability. Gene drive was discussed in the Convention of Biological Diversity, specifically in the Cartagena protocol; Nagoya-Kuala Lumpur Supplementary Protocol; Post 2020 Global Biodiversity framework; World Health Organization and the International Union for the Conservation of Nature (IUCN). The main topics discussed about gene drive are the value of gene drive, safety, engagement and decision making and responsibility. Lana concluded her talk by giving tips to scientists on how to get involved in policymaking: addressing technology misinformation, learning how to deliver information to policymakers, participating in national level dialogues and joining international discussion.

Laura Norris (Bill and Melinda Gates Foundation - BMGF, USA), represented by **Prosper Chaki** (PMACA), talked on "*BMGF Malaria Strategy Overview*". He gave an overview of BMGF and the organization's drive to chart an eradication pathway that minimizes deaths. He also gave an insight into the BMGF's malaria eradication strategy as well as its vector control research and development portfolio. Chaki concluded by listing BMGF's current grant areas in genetically-based vector control and asked some rhetorical questions on the challenges for gene drive.

Emma Orefuwa (Pan African Mosquito Control Association - PAMCA) as part of the launch of the African Network for Gene Drive, talked about "*African Gene Drive for Vector Control Network*". She highlighted the mission, vision and strategic pillars of PAMCA, which is centered on supporting African institutions and giving the African researcher a strong voice. She also talked about the potential

benefits of gene drive amidst the risk concerns. As a way of improving knowledge and awareness on gene drive, Orefuwa informed that PAMCA has trained 76 individuals from 17 countries, in 3 yearly cohorts, since 2017. She encouraged those interested to join the African Gene Drive for Vector Control Network; a platform that will promote networking, knowledge sharing, regional collaboration and cooperation. Orefuwa concluded by pointing out that there is strong evidence of the interest of many early-mid career scientists in gene drive and gave insights into some new initiatives to bolster gene drive awareness in Africa.

Scientific Sessions:

Parallel session 7: Innovation and new tools for mosquito surveillance and control

Yacouba Poumachu (International Atomic Energy Agency- IAEA, Vienna) started his presentation by introducing malaria and current malaria control methods stressing the absence of an effective vaccine that makes vector control interventions (ITNs, IRS and larval control) frontline in the fight against malaria. However, these control methods present some limitations, especially the rapid rise of insecticide resistance, hence the need to integrate new and innovative strategies such as the Sterile Insect Technique (SIT) to control malaria vectors (WHO, 2008). Poumachu continued by explaining briefly the concept of SIT where irradiated mosquitoes are rendered sterile and liberated in the wild where they competitively mate with wild females producing no offsprings. This method presents the advantage of being effective in insect management, eco-friendly, sustainable and complementary to other control tools. However, one major challenge involved is the prerequisite to remove hematophagous and Plasmodium-transmitting females before releasing the mosquitoes and using temperature discrimination to develop a male-biased sex ratio strain. Poumachu also explained the steps involved in establishing the thermosensitive strain through mutagenesis and heat-shocking. Among their findings, he presented the mortality between the control and mutants from which candidate families were chosen. Next was the development and isolation of a male-biased distortion strain by irradiation with gamma rays, crossing and selection of the progenies that respond to the physical treatment resulting in a final male-biased ratio of 4:3 for the irradiated families compared to 1:0 for the control confirming the success of irradiation. Poumachu concluded with the success of their experiment to establish a sex-ratio distortion of up to 80% in favour of males and the establishment of the heat-tolerant strain.

Simon Péguédwindé Sawadogo (Partnership for increasing the impact of Vector Control - PIIVeC, UK) introduced the rationale for their work about microbiomes shaping the physiology of insects, which in turn shapes their behaviour in terms of reproduction and susceptibility to pathogens. Thus, they characterized the microbiome of males that have successfully mated versus single males within the natural swarm. They collected mated and unmated male mosquitoes from swarms in 2 localities in Ivory Coast. DNA extraction (using QIAGEN Kit) was followed by mosquito species identification and 16S genes sequencing. Relative abundance analyses of mated and unmated groups of male microbial communities identified 41 different bacteria phyla. Four dominant phyla which altogether made up 95% of the communities of bacteria were Proteobacteria (74.4%), Firmicutes (12.0%), Bacteriodetes (4.64%) and Actinobacteria (3.6%). The remaining 5% were made up of another 38 phyla including *E. coli*. Further, relative abundance at the family level revealed 14 families with the dominant ones being Acetobacteraceae, Enterobacteriaceae, Flavobacteriaceae, Moraxellaceae and Lactobacillaceae. Dominant genera among the 18 that were revealed were: Providencia, Acetobacter, Thorsellia, Acinetobacter, Lactobacillus among others. There was however a non-significant difference in the relative abundance between mated and unmated male groups from the 2 localities. Finally, 10 major genera were found which could interact with plasmodium and the top 5 included; Thorsellia, Asaia, Spiroplasma, Rickettsia and Wolbachia. Sawadogo concluded that this assessment provides a panel of

core and endosymbiotic bacteria that can be potentially exploited to interfere with the transmission of malaria parasites by the Anopheles mosquito vectors.

Parallel session 8: Innovation and new tools for mosquito surveillance and control

Michelle Stanton (Liverpool School of Tropical Medicine, UK) started the session by presenting her work on "*Using resolution drone imagery to understand the impact of human-made larval habitat on dry season malaria transmission in rural Malaria"*. Stanton is trying to understand the influence on spatial variability in malaria transmission risk and if it can help with planning and implementing targeted interventions. The group set out to understand dry season malaria dynamics to provide better information for implementers. This led to the MALADRONE project, which had two working terms; entomology for vector surveillance and using spatial technology to support vector surveillance, such as using drone imagery to identify larval habitats. They conducted a study during the dry season in an area surrounded by few fixed larval habitats. The hypothesis was that these reservoirs drove malaria transmission during the dry season. Entomological surveillance was conducted and drone imagery of larval habitats with high resolution to identify potential habitats was taken. Larval sampling was subsequently conducted manually in the potential habitats to confirm presence or lack of larvae. Manual sampling was able to confirm the presence of larvae in the large reservoirs and smaller habitats, with large numbers of larvae found in the larger habitats. Through the entomological surveillance, areas near reservoirs had the highest *Anopheles* mosquitoes, smaller larval habitats did not influence the number of mosquitoes found indoors. The study concluded that large reservoirs drive malaria transmission in the dry season due to a large number of larvae compared to smaller bodies through the use of entomological surveillance and spatial technology.

Laban Njoroge (National Museums, Kenya) presented his work titled "*A larval mosquito rearing robot inspired by the COVID -19 induced lockdowns".* COVID -19 brought along many challenges and one of those was the rearing and maintaining mosquito colonies. To adhere to COVID-19 restrictions and also not lose the mosquito colonies, as mosquito rearing is labor demanding, Njoroge and the team decided to explore an automated larval mosquito rearing robot. The robot was conceptualized, designed and a prototype was developed and started operating. The functions taken over by the robot included regulating photoperiod, mixing water pre-feed and feeding at preset intervals. The robot uses direct current power, meaning it can use batteries in case of power failure. The larvae reared maintained by this robot were very large and healthy, there was synchronized pupation, increased emergence rates and high survival rates for adults. This innovation has potential to revolutionize mosquito rearing in Africa due to the reduction in costs and labor intensity.

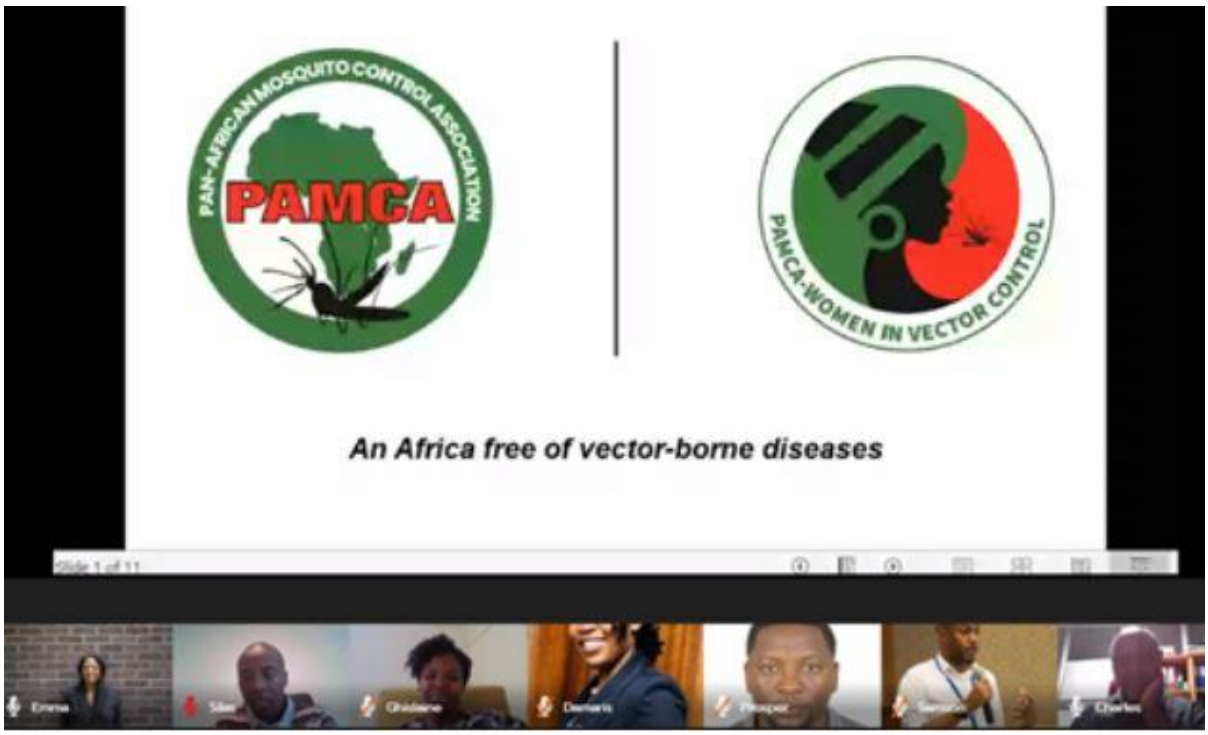
Bazoumana Bala Danouma Sow (Institute for Research in Health Sciences - IRSS, Burkina Faso) and **Neema Zephaniah** (Ifakara Health Institute - IHI, Tanzania) presented their work on "*An online platform for malaria vector surveillance in Africa using artificial Intelligence and mosquito infrared spectroscopy" to* identify vectors transmitting malaria as an important factor towards elimination. Nowadays, identifying malaria vectors is laborious and expensive. Sow and Zephaniah developed a mid-infrared spectroscopy in addition to artificial intelligence to predict vector age and species. This new method is considerably cheaper and has a 90% accuracy rate. Furthermore, anyone can use it, all it needs is an internet connection, a computer with any software (Windows, MAC, etc), then you input the information of the infrared mosquitoes results on the platform, which then makes its predictions. This innovation has proven to be accurate and most importantly can be applied to other vectors.

Frederik Seelig (London School of Hygiene and Tropical Medicine - LSHTM, UK) presented "*The Global Vector Hub - building entomological capacity worldwide and improving epidemic preparedness".* With this Hub, the intention is to bring together researchers and health workers on the largest scale from all disciplines, diseases and vectors. The Hub's main aim is to be the first port of call for researchers,

implementers, governments and policy workers. Some of the objectives of the Hub are to build capacity and maximize preparedness for outbreak situations, to build a community of training through hosting bespoke educational materials and learning packs for professionals and to connect vector control professionals. An early version of the platform was launched and plans to launch the full version is underway. The platform includes data, resources and networking features with a focus mostly on capacity building and systems strengthening for vector control globally. It includes a global directory of training courses in medical entomology, a place where registered users can share data and information. It also includes information on relevant academics, governments and institutions. The Hub is backed by many key partners within the vector control community.

Closing Ceremony

Silas Majembere ((Pan-African Mosquito Control Association - PAMCA, Kenya)) welcomed everyone to the closing ceremony and declared the success of the 7th PAMCA conference. He then handed over to Emma Orefuwa and Ghislaine Aquedeogo-Ametchie, the hosts of the Women in Vector Control (WIVC) Excellence awards ceremony. There were three categories: early career, mid-career and late-career/expert. The overall winner of the Early-career category was Jessy Goupeyou-Youmsi and the runner up Rosalia Joseph whilst Evelyn Olanga won the Mid-career category. Lastly**,** Chioma Amajoh was awarded the WIVC Senior-career/Expert category and the runner up was Léa Paré**.** The closing ceremony remarks were given by Samuel Dadzie (President of the Local Organising Committee, Ghana), Prosper Chaki (Executive Director of PAMCA) and Charles Mbogo (Chair of the Board of Directors of PAMCA) who all expressed their gratitude towards the PAMCA committee for selecting Ghana as the host for the 7th PAMCA conference, even though the conference was done fully online, as well as the sponsors, presenters and participants for the time they dedicated to making the PAMCA conference a success. At the end of the conference, Silas announced the 8th PAMCA conference will be hosted in Rwanda. PAMCA strives for an Africa free of vector-borne diseases. The take-home message of the conference was *"**Let us unite and work towards an Africa free of vector-borne diseases.**"*



This report is brought to you by the MESA Correspondents Stella Riunguh, Amelie Wamba, Eggrey Aisha Kambewa, Mauro Pazmino Betancourth, Udoka Nwangwu, Thoan Ho Dac, Faith Hungwe and Jackson Nyarko, with mentoring and editorial support from Charles Quaye.

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