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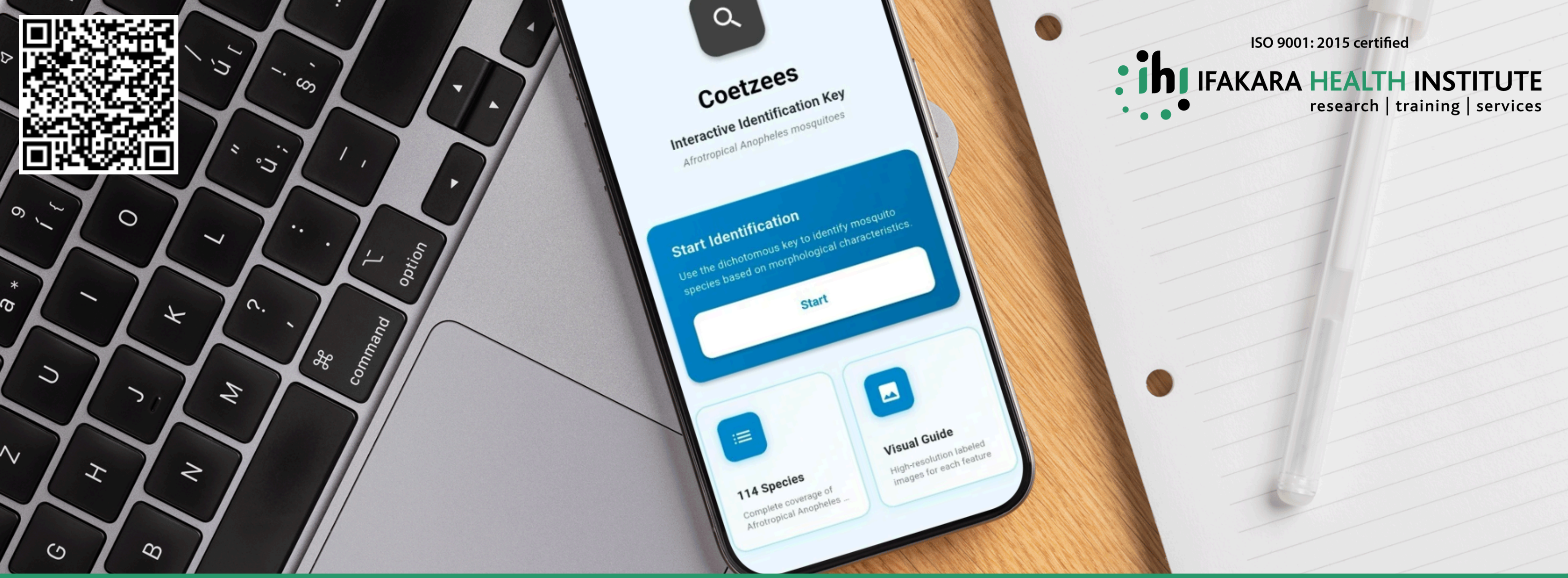
A SNAPSHOT OF MALARIA INNOVATIONS AT IFAKARA HEALTH INSTITUTE



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AN INTERACTIVE MOBILE APPLICATION FOR ANOPHELES IDENTIFICATION USING THE COETZEE (2020) KEY

DICKSON MSAKY

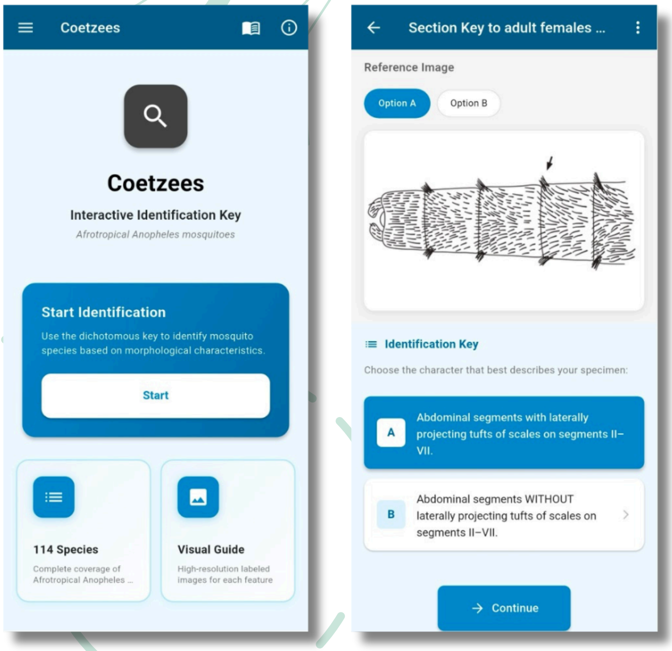
PROBLEM

Accurate mosquito species identification is fundamental to malaria vector surveillance and control, however the primary reference for this work in sub-Saharan Africa, the Coetzee (2020) dichotomous key to female Afrotropical Anopheles mosquitoes exists only in paper-based format. Despite growing mobile adoption across the region (GSMA, 2024), no digital implementation of the Coetzee (2020) key existed for field use. This project addressed that gap by digitising the key and deploying it as an interactive mobile application with offline support for use in field settings.

WORK

To address this gap, the key was digitised and deployed as an interactive mobile application:

- **Content Digitisation.** The reference was structured into a database containing 114 Anopheles species and a library of over 370 diagnostic illustrations drawn from the source publication.
- **Application Development.** The interface was explicitly designed around the workflow of a researcher or field technician using a microscope. It displays each identification couplet alongside the official illustration, enabling direct comparison between the standard and the physical specimen.
- **Offline Functionality.** Full offline support was implemented so the application remains completely operational in remote field settings without network access.



CONTRIBUTION

- **Digitisation.** The Coetzee (2020) dichotomous key was digitised and structured into an interactive digital format, converting a previously paper-based identification reference into a field-accessible mobile application with full offline support.

SCALABILITY

- **Broader Application.** The application consolidates the complete key and 370 diagnostic illustrations onto a single mobile device, enabling faster and more direct navigation of the identification reference in field settings.

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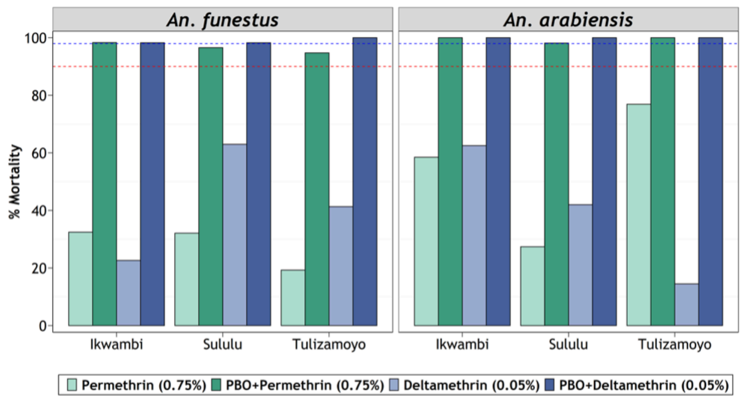
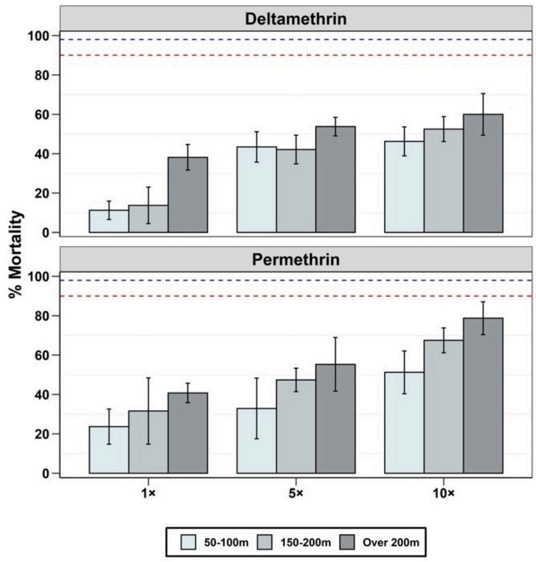
WHY MALARIA PERSISTS IN SOUTH-EASTERN TANZANIA: THE ROLE OF INSECTICIDE RESISTANCE AND MOSQUITO ECOLOGY

BACKGROUND

Studies in south-eastern Tanzania by P. G. Pinda and colleagues show that malaria transmission is largely driven by Anopheles funestus, a mosquito highly resistant to commonly used pyrethroid insecticides. This resistance, mainly due to enhanced detoxification mechanisms, allows the mosquitoes to survive even high doses of insecticides, which helps them continue spreading malaria despite widespread use of treated bed nets. Previous work has shown that An. funestus is much more resistant than species like Anopheles arabiensis, although using synergists such as piperonyl butoxide (PBO) can restore some effectiveness of these insecticides P. G. Pinda et al. 2020



Interestingly, not all mosquitoes behave the same way. Resistance changes depending on how old the mosquito is and how far it flew from the aquatic habitat. Younger mosquitoes, especially those close to breeding sites, tend to be the most resistant. But older mosquitoes the ones that are more likely to have bitten people multiple times and are therefore more important for spreading malaria are usually found farther away, in the village center, and are actually easier to kill with insecticides. This means that, even in places with high resistance, current tools can still have an impact by targeting these older, more infectious mosquitoes P. G. Pinda et al. 2022



A collaborative work by N. H. Urio et al. 2022 and colleagues adds another layer, showing that farming practices also play a role. The use of pesticides in agriculture exposes mosquito larvae to chemicals early in life, which reduce how well insecticides work later on. Even when the effects are not immediate, this exposure can gradually influence mosquito development and potentially contribute to resistance over time.

Overall, these findings highlight that malaria control is more complex than it might appear, involving not just the mosquitoes themselves, but also their environment and human activities. But good news is that we can still make progress with smarter strategies: using PBO-treated nets, rotating or combining alternative insecticides, tailoring interventions to local context, and improving coordination between agriculture and public health. By taking these steps, we can stay ahead of resistance and reduce malaria transmission more effectively.

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CLIMATE-INFORMED MALARIA MODELING IN TANZANIA AND MOZAMBIQUE

This project aims to develop a **data-driven modeling framework** to improve how malaria programs anticipate and respond to climate variability and extreme weather events in Tanzania and Mozambique. Malaria transmission is strongly influenced by environmental factors such as rainfall, temperature, and flooding, yet these data are rarely integrated into routine decision-making.

By combining climate, epidemiological, entomological, and health system data, the project will generate **sub-national forecasts and risk maps** to support more timely and targeted malaria interventions.

THE PROBLEM

Malaria control efforts are increasingly challenged by:

- Climate variability and extreme weather events (e.g., floods, cyclones) that alter transmission patterns and disrupt health services
- Fragmented and underutilized data systems are limiting the ability to predict outbreaks
- Limited local capacity to analyze and apply climate-health data

In Tanzania and Mozambique, these factors contribute to persistent malaria burden and reduce the effectiveness of existing interventions.

SOLUTION

The project will implement an integrated approach with three core components:

1. Data Integration
   - Compile and harmonize climate, malaria, vector, and health system datasets
   - Digitize historical climate records to improve data quality
2. Modeling and Decision Support
   - Develop statistical and mechanistic models linking climate and malaria transmission
   - Produce sub-national forecasts and early warning indicators
   - Strengthen existing tools (e.g., MapRoom) for program use
3. Capacity Strengthening
   - Train local researchers and program staff in modeling and data use
   - Support integration of model outputs into national malaria control systems

IMPACT

The project is expected to:

- Improve **timing and targeting of malaria interventions**
- Strengthen **preparedness for climate-related outbreaks**
- Enhance **the use of data in national malaria programs**
- Build **sustainable in-country expertise** in climate-health modeling

SCALABILITY

The approach is designed for expansion:

- Uses **standardized and adaptable methods** that can be applied in other settings
- Builds on **existing national systems and platforms**
- Generates tools and evidence relevant across malaria-endemic regions

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DEEP ONCHO

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BACKGROUND

Onchocerciasis remains a persistent public health challenge in Tanzania despite decades of mass drug administration (MDA) with ivermectin. The disease, caused by the filarial nematode Onchocerca volvulus and transmitted by Simulium blackflies, causes blindness and chronic skin disease (Figure 1).

Figure 1: Onchocerciasis morbidity, severe skin disease and blindness

Although progress has been made towards elimination, residual transmission persists in several regions, including eastern and southern Tanzania (Figure 2). In these areas, annual ivermectin MDA (with albendazole co-administration where lymphatic-filariasis is co-endemic) has greatly reduced morbidity, yet surveys still detect infections in humans with prevalence >20% in several districts, indicating ongoing transmission (Figure 2).

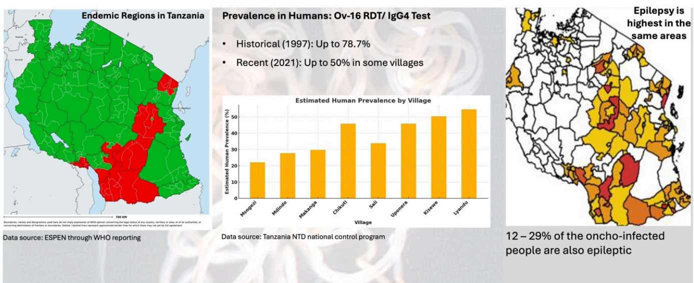
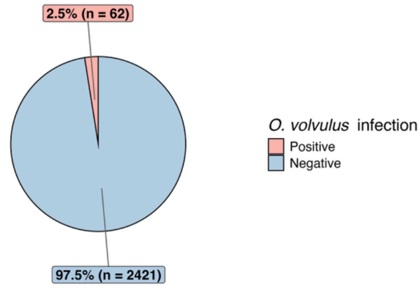


Figure 2: Onchocerciasis endemicity in Tanzania

Moreover, PCR-positive flies and sporadic L3 larvae are still detected in recent surveys (our preliminary surveys show high infection rate of 2.5%), confirming ongoing transmission (Figure 3).



Since onchocerciasis is chronic, verifying whether transmission persists requires detecting Onchocerca volvulus nematodes in field-collected blackflies. As Onchocerca prevalence declines, costs to confirm elimination rise, threatening Tanzania's ability to meet WHO elimination targets. Current surveillance, including skin snips, serology, and molecular screening of blackfly vectors, are sensitive but invasive, costly, and logistically challenging.

HYPOTHESIS

The persistent onchocerciasis transmission in Southern Tanzania is sustained by poorly characterised vector-parasite associations and by surveillance tools unsuited to highly fragmented transmission landscapes. To address both gaps, we are aiming to develop an AI-powered mid-infrared spectroscopy (MIRS) method to detect O. volvulus in Simulium blackflies. This approach allows high-throughput, reagent-free, low-cost diagnostics and surveillance for resource-limited settings. Building on our previous malaria work, where I used MIRS and AI to detect malaria parasites, identify mosquito species, and determine blood-meal sources, we will adapt this methodology to onchocerciasis (i.e., Simulium surveillance).

METHOD

We will train AI models to detect O. volvulus in Simulium vectors and assess model accuracy, speed, sample-preservation needs, and field feasibility in Tanzanian transmission hotspots. Our preliminary findings already demonstrate the potential to detect spectral signatures distinguishing infective O. ochengi L3 in field-collected Simulium (Figure 4A & B, achieving training accuracy of 92%), demonstrating feasibility for detecting O. volvulus infections.

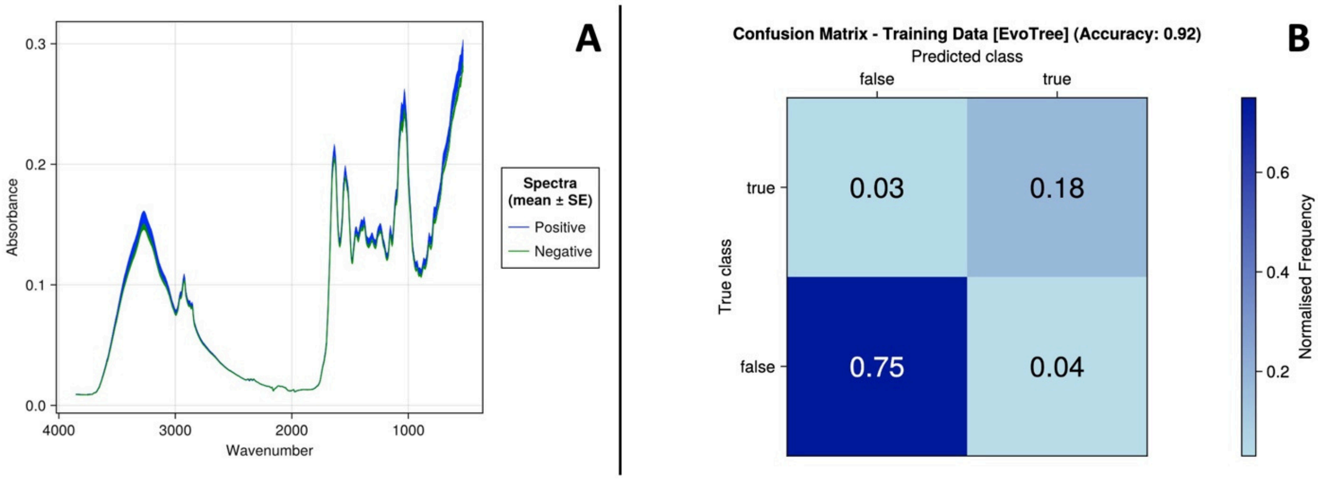


Figure 4: Preliminary results: (A) Mean spectra of Simulium positive (infected) and negative (uninfected) with infective O. ochengi L3 larvae; (B) Preliminary machine-learning training results showing the model detecting signals that distinguish between Simulium from Cameroon infected and uninfected with infective O. ochengi L3 larvae.

VECTOR CONTROL PRODUCT TESTING UNIT (VCPTU)

BACKGROUND

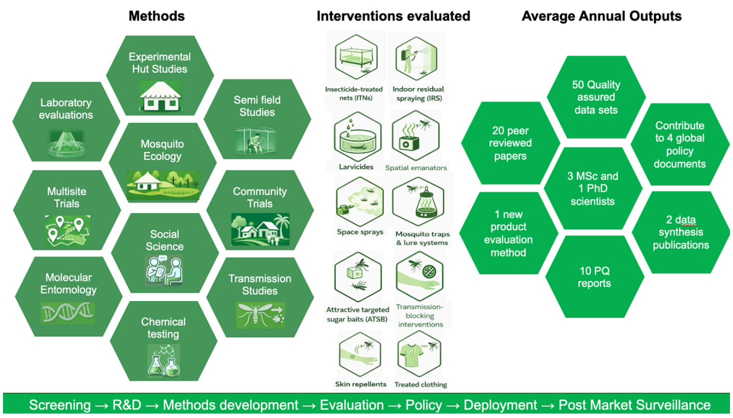
Vector control interventions—particularly insecticide-treated nets (ITNs)—remain the cornerstone of malaria prevention in Africa. However, their effectiveness is increasingly undermined by widespread insecticide resistance and poor product durability, underscoring the need for new insecticide classes, improved product quality, and a diversified vector control innovation strategy that includes technologies beyond ITNs to address malaria and other mosquito-borne diseases such as dengue. At the same time, the vector control community faces a significant financing gap and must maximise the impact of every dollar spent.

One of the most effective ways to improve value for money is to increase competition in the vector control product market. When more high-quality products reach the market, procurers have greater choice, prices decrease, and programmes can deploy the most cost-effective tools. However, vector control technologies cannot enter the market without rigorous independent evaluation demonstrating safety, efficacy, and operational performance under realistic use conditions. Testing platforms that meets global standards while remaining embedded in malaria-endemic settings remain limited. The VCPTU was established in 2017 and obtained Good Laboratory Practice (GLP) certification in 2021 to address this gap. The unit provides a comprehensive platform for independent evaluation of vector control products, helping accelerate the pathway from product conceptualisation to policy recommendation and market entry.

ACTION/WORK

The VCPTU serves the vector control community through excellence in product evaluation, methodological innovation, and the training of the next generation of scientists. As a not-for-profit platform embedded in malaria-endemic Africa, the unit accelerates the transition of new vector control technologies from research and development to policy recommendation and global procurement.

By generating the independent evidence required for regulatory approval and World Health Organisation (WHO) policy guidance, and by developing new evaluation methods that remove bottlenecks in the innovation pipeline, the VCPTU helps ensure that promising technologies can reach vector control programmes rapidly and efficiently.



The platform supports the vector control innovation pipeline from early research and development (R&D) through to post-market surveillance. The unit conducts independent studies using both established WHO methods and new methodologies tailored to novel interventions. These include laboratory assays, experimental hut trials, and community studies of the full spectrum of vector control technologies designed to measure entomological efficacy, durability, and operational performance under conditions representative of malaria and dengue transmission settings where pyrethroid resistance is widespread. The unit also operates a chemical analysis laboratory that investigates insecticide content, chemical ageing, and degradation of vector control products such as ITNs and spatial emanators, generating critical evidence on chemical durability and product longevity. Complementary social science research examines user experience and product acceptability, enabling evidence-based feedback to manufacturers for product design and performance optimisation.

VCPTU scientists collaborate with partner laboratories to validate and harmonise new evaluation assays, and train visiting researchers in their application, helping ensure that innovative chemistries and technologies can be reliably evaluated across multiple geographies. Unit members also contribute to vector control policy development through participation in national technical working groups in Tanzania and international guideline development processes at WHO.

IMPACT

The VCPTU has become one of the leading African platforms for vector control product evaluation. Despite entering the product testing sphere relatively late, the unit has generated data used for one third of all vector control products that are currently WHO prequalified.

By generating the independent data required for new products to achieve regulatory approval and policy recommendation, the unit expands the range of products available to vector control programmes. When additional manufacturers are able to enter the market with WHO-recommended products, procurement agencies can leverage competition to negotiate lower prices. Even modest reductions in the price of widely deployed tools such as ITNs can translate into tens to hundreds of millions of dollars in savings, enabling vector control programmes to reach more households with available resources.

Figure 2 WHO product evaluators visiting the facility to learn more about how products are evaluated

The unit also plays a key enabling role in vector control innovation by developing and validating new evaluation assays. These methods help ensure that novel insecticides and emerging vector control technologies can be reliably assessed, reducing bottlenecks in the product development pipeline. The IHI has recently signed a Memorandum of Understanding with the WHO to develop the VCPTU as a Centre of Excellence in Vector Control Product Testing, further strengthening its role in supporting global malaria control efforts.

As a not-for-profit platform, the VCPTU reinvests revenue and data generated from product testing into scientific training and capacity strengthening. Since its establishment in 2017, the unit has supported the training of 12 PhD and 14 MSc graduates, with a further 5 PhD and 8 MSc students currently in training. Approximately 30% of trainees are women and 80% are from sub-Saharan Africa, contributing to the development of a regional workforce with expertise in vector control product evaluation. The unit also contributes significantly to the global evidence base on malaria vector control, producing approximately 20 peer-reviewed scientific publications annually on topics including product efficacy, insecticide resistance, durability, and evaluation methodologies. These are mainly authored by the unit's students supported by 7 PhD level mentors (5 based in Tanzania and 2 in Europe).

By providing independent testing capacity embedded in malaria and dengue-endemic settings, the VCPTU helps remove critical bottlenecks in the vector control innovation pipeline. Through strengthening African research capacity, developing new evaluation methodologies, and enabling new products to enter global markets, the VCPTU contributes to a vector control ecosystem that is more competitive, more innovative, and better able to deliver effective vector control within constrained global health budgets.

SCALABILITY

The VCPTU provides large-scale research infrastructure capable of supporting the rapidly evolving pipeline of vector control and transmission-blocking innovations. Its integrated platform - combining laboratory testing, semi-field systems, experimental hut trials, and community studies - enables rigorous, independent evaluation of emerging technologies and generates evidence required for WHO policy recommendations and large-scale procurement decisions. The unit also partners with leading experts and institutions to strengthen capacity in statistics, trial design, mathematical modelling and social science.

Infrastructure includes 60 experimental huts, 6 semi-field systems, 4 product testing laboratories, an ITN wash facility, an ITN ageing facility, a chemical analysis laboratory, a transmission laboratory with gametocyte culture, a spatial emanator testing suite and 15 mosquito colonies producing 5,000,000 mosquitoes used annually for testing. At current capacity, the VCPTU conducts approximately 30 product evaluations annually across the full spectrum of vector control technologies. The unit employs 50 staff, 60% of whom hold a at least a BSc. This scale and diversity of this infrastructure allow multiple technologies to be assessed simultaneously at high quality, accelerating the pathway from discovery to policy recommendation and deployment.

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DEEP SURVEILLANCE

Doreen J. Siria[1,2], Emmanuel Mwanga[1,2], Issa Mshani[1,2], Halfan Ngowo[1,2], Jacqueline Mgaya[1], Naomi Urio[1,2], Sophia Mwinyi[1,2], Idrisa Mchola[1], Mauro Pazmino-Betancourth[2], Mario Gonzalez Jimenez[2], Simon Babayan[2], Heather Ferguson[1,2], Francesco Baldini[1,2], Fredros Okumu[1,2]

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2. School of Biodiversity, One Health and Veterinary Medicine, University of Glasgow, Glasgow G12 8QQ, UK.

BACKGROUND

Malaria transmission by Anopheles mosquitoes is age-dependent, as females must survive about 11 (±1) days to become infectious. The age structure of mosquito populations, particularly the proportion of older females, is therefore a key indicator of transmission risk and intervention effectiveness. However, mosquito age-grading is rarely included in routine surveillance because traditional ovarian dissection methods and methods used in identification of species are technically demanding and difficult to apply at large scale Siria et al. (2026, preprint), Figure 1.

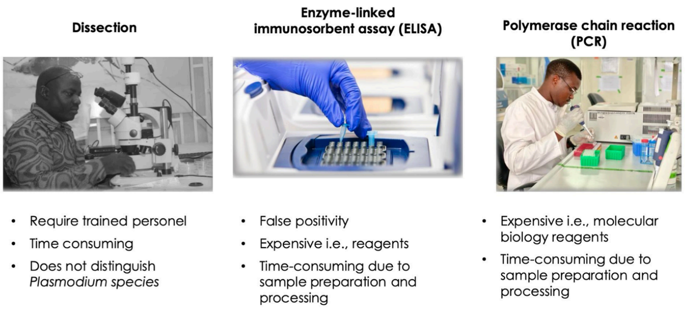

Figure 1. Limitations of existing mosquito surveillance methods. Traditional approaches including microscopic ovarian dissection, ELISA, and PCR

Near-infrared (NIR) and mid-infrared (MIR) spectroscopy provide a rapid and scalable alternative to traditional mosquito age-grading methods and specie identification. These techniques require minimal sample preparation and enable high-throughput analysis of thousands of mosquitoes per day.

Infrared spectroscopy (IRS) detects biochemical signatures in mosquito tissues, including chitin, proteins, and lipids, which vary with mosquito age, species, and physiological status, Figure 2. When combined with machine learning, these spectral patterns can be used to predict mosquito characteristics such as species identity, age class, sporozoite infection, and insecticide resistance, supporting faster and more efficient vector surveillance.

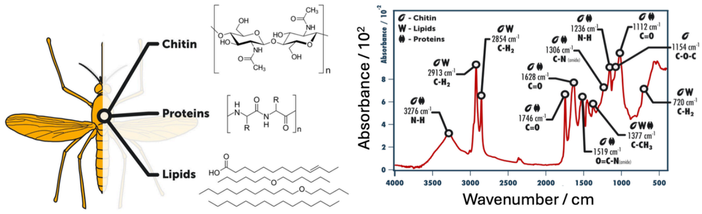

Figure 2. Infrared spectroscopy provides biochemical information

EVIDENCE FROM OUR RESEARCH

Our group has led several key studies from optimizing to validating this approach in African settings; Siria et al 2022 [PMID: 35314683]: Using mid-infrared spectra from over 40,000 ecologically and genetically diverse mosquitoes, a deep transfer learning model simultaneously identified the species and age class of three major malaria vectors (An. gambiae, An. arabiensis, and An. coluzzii) in natural populations across Tanzania and Burkina Faso, achieving up to 95% accuracy, Figure 3.

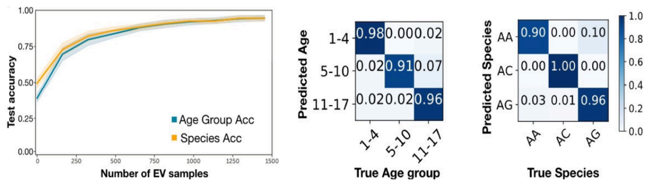

Figure 3. Confusion matrix showing age-grading and species classification accuracy for *An. gambiae*, *An. arabiensis*, and *An. coluzzii*. Adapted from Siria et al., *Nature Communications*, 2022

Mwanga et al. (2023) [PMID: 36624386]: Demonstrated that applying transfer learning (TL) and dimensionality reduction to MIRS data substantially improves model generalisability across different mosquito populations, with minimal re-training data required from new field sites a key step toward practical deployment, Figure 4.

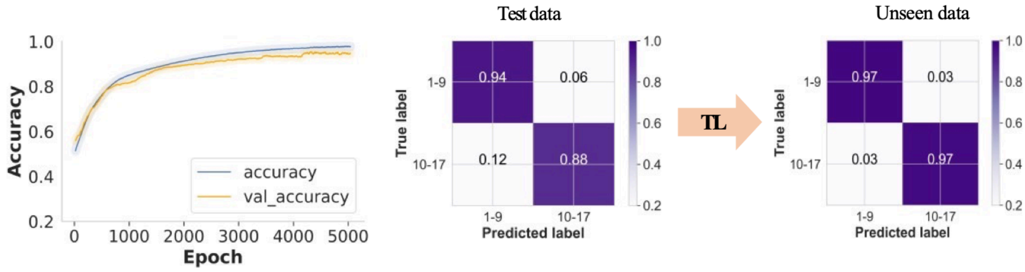

Figure 4. Improved model generalisability across mosquito populations using transfer learning and dimensionality reduction. Adapted from Mwanga et al.,2023

Mwanga, Siria, Mshani et al. (2024) [PMID: 38500231]: Extended using the mid spectroscopy + machine learning (ML) pipeline to Anopheles funestus, classifying mosquitoes into epidemiologically meaningful age groups (young: 1-9 days; old: ≥10 days, potentially infectious), with 95% accuracy demonstrating applicability across all major Afrotropical malaria vectors, Figure 5.

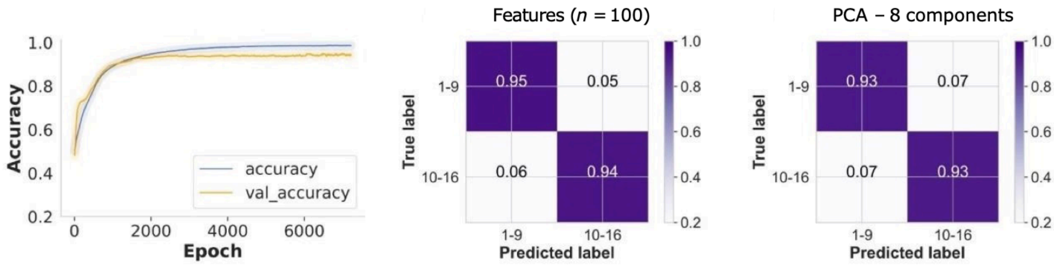

Figure 5. Age classification of *Anopheles funestus* into epidemiologically relevant groups using mid-infrared spectroscopy. Adapted from Mwanga, Mshani et al.,2024

RESEARCH FOCUS

Currently, our research focuses on optimizing infrared spectroscopy (NIR and MIR) combined with artificial intelligence (AI) to enable rapid and scalable mosquito surveillance. Using data from laboratory, semi-field, and field setting, we are improving algorithms for mosquito age-grading and species identification, reducing the need for local calibration. The long-term goal is to develop an integrated, field-ready IR-AI system that allows researchers and National Malaria Control Programmes (NMCPs) to collect spectral data and generate real-time predictions of key mosquito indicators, supporting routine monitoring of malaria vectors and evaluation of vector control interventions.

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INVESTIGATING OPPORTUNITIES FOR TARGETED LARVAL SOURCE MANAGEMENT IN RURAL COMMUNITIES WHERE MALARIA TRANSMISSION IS DOMINATED BY ANOPHELES FUNESTUS

OVERVIEW

AcThis study investigated the feasibility and impact of targeted larval source management (LSM) as a complementary malaria control strategy in rural sub-Saharan Africa, particularly in areas where Anopheles funestus is the dominant vector. Using a combination of regional analysis, field entomological surveys, experimental larvicide trials, and mathematical modelling, the research provides robust evidence that malaria transmission in these settings can be substantially reduced by targeting a limited number of high-productivity larval habitats. The findings demonstrate that LSM is both operationally feasible and epidemiologically impactful when tailored to vector ecology in rural environments.

PROBLEM

Malaria control in sub-Saharan Africa has relied predominantly on insecticide-treated nets (ITNs) and indoor residual spraying (IRS), which target adult mosquitoes. While these interventions have reduced malaria burden, their effectiveness has declined due to insecticide resistance, behavioural adaptations of mosquitoes (including outdoor biting), and gaps in coverage. As a result, residual transmission persists, particularly in rural areas. Larval source management has historically been underutilized in these settings due to assumptions that breeding habitats are too numerous, diffuse, and difficult to target effectively.

SOLUTION (WHAT THE STUDY OBSERVED)

This study shows that in areas where Anopheles funestus dominates transmission, larval habitats are not uniformly distributed but are concentrated in a relatively small proportion of available water bodies (approximately 15–17%). These habitats are typically permanent, large, and vegetated, making them stable and identifiable. Field and semi-field experiments demonstrated that biological larvicides (Bti and Bti-based combinations) achieve over 98% reduction in larval densities, with effectiveness lasting up to one to two weeks depending on habitat conditions. Furthermore, the slower larval development of An. funestus supports less frequent (biweekly) application schedules, enhancing operational feasibility. Together, these findings confirm that targeted larviciding is practical in rural settings when focused on ecologically relevant habitats.

IMPACT

The study provides strong empirical and modelled evidence of impact. Mathematical simulations indicate that integrating targeted larviciding with existing ITN coverage can reduce malaria transmission intensity by 70–77% when focusing on An. funestus alone, and up to 85–90% when additional vector species are included. Significant reductions are also observed in lower ITN coverage scenarios, demonstrating that LSM can meaningfully enhance malaria control even where existing interventions are suboptimal. By targeting mosquitoes at the larval stage, this approach also addresses key limitations of adult-focused interventions, including insecticide resistance and behavioural avoidance, contributing to more sustained control.

SCALABILITY

The findings indicate that targeted LSM is scalable in rural African settings. Its feasibility is driven by the concentration of vector breeding in a limited number of identifiable habitats, which reduces the need for extensive resource deployment. The use of WHO-recommended biological larvicides supports environmental safety and community acceptability. The approach can be integrated into existing malaria control frameworks as part of integrated vector management without replacing current interventions. Scaling would involve expanding implementation in areas with demonstrated An. funestus dominance, supported by habitat mapping, local capacity for larvicide application, and alignment with national malaria programs. Overall, this study provides a strong evidence base for incorporating targeted LSM into broader malaria control strategies in rural settings.

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