Contents

Selected Recent Publications

The mosquito taste system and disease control

Proc Natl Acad Sci USA 29 Dec 2020

Although understanding of mosquito olfaction has progressed dramatically in recent years, mosquito taste remains greatly understudied. Since taste is essential to feeding, egg laying, and mating decisions in insects, improved understanding of taste in mosquitoes could provide new mechanistic insight into many aspects of their behavior. We provide a guide to current knowledge in the field, and we suggest a wealth of opportunities for research that are now enabled by recent scientific and technological advances. We also propose means by which taste might be exploited in new strategies for mosquito control, which maybe urgently needed as the geographical ranges of vector species increase with climate change.

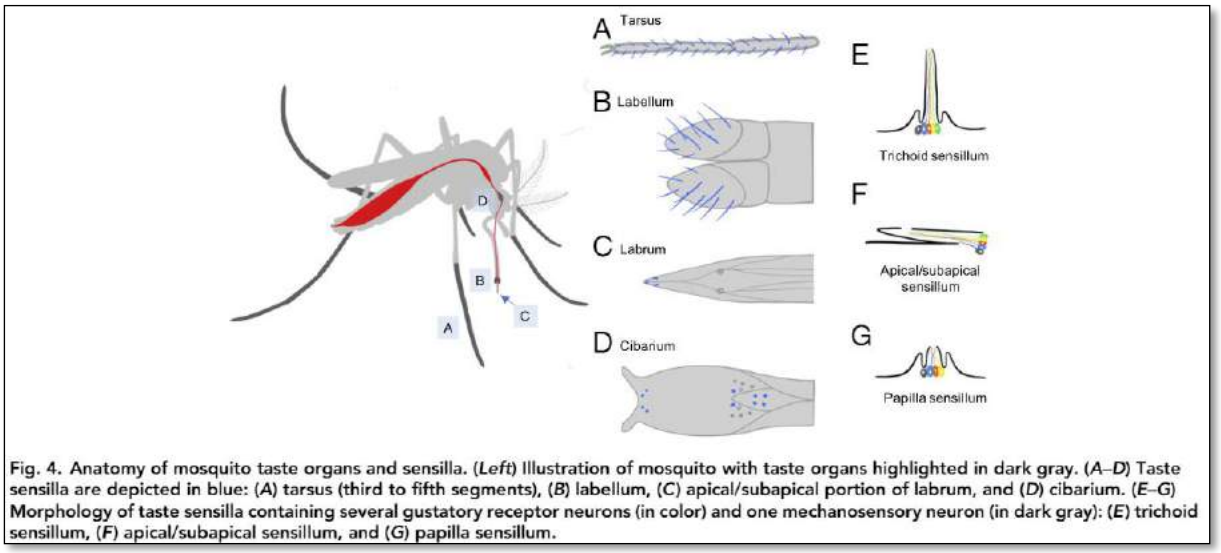


Fig. 4. Anatomy of mosquito taste organs and sensilla. (*Left*) Illustration of mosquito with taste organs highlighted in dark gray. (*A*–*D*) Taste sensilla are depicted in blue: (*A*) tarsus (third to fifth segments), (*B*) labellum, (*C*) apical/subapical portion of labrum, and (*D*) cibarium. (*E*–*G*) Morphology of taste sensilla containing several gustatory receptor neurons (in color) and one mechanosensory neuron (in dark gray): (*E*) trichoid sensillum, (*F*) apical/subapical sensillum, and (*G*) papilla sensillum.

Insecticide-treated house screening protects against Zika-infected Aedes aegypti in Merida, Mexico

PLoS Negl Trop Dis. January 2021

Author summary

We evaluated the efficacy of protecting houses with insecticide-treated nets permanently fixed with aluminium frames on external doors and windows on *Ae*. *aegypti* infestation and arbovirus infection during a Zika outbreak in Merida, Yucatan, Mexico. Houses protected with screens were ≈80% less infested with *Aedes* females and very importantly, had significantly less infected female *Ae*. *aegypti* during the peak of the epidemic. Communities strongly accepted the intervention, due to its perceived mode of action, the prevalent risk for *Aedes*-borne diseases in the area, and the positive feedback from neighbours. House screening provides a simple, affordable sustainable method to reduce human-vector contact inside houses and can protect against dengue, chikungunya and Zika.

Another dengue fever outbreak in Eastern Ethiopia-An emerging public health threat

PLoS Negl Trop Dis. January 2021

Author summary

Author summary

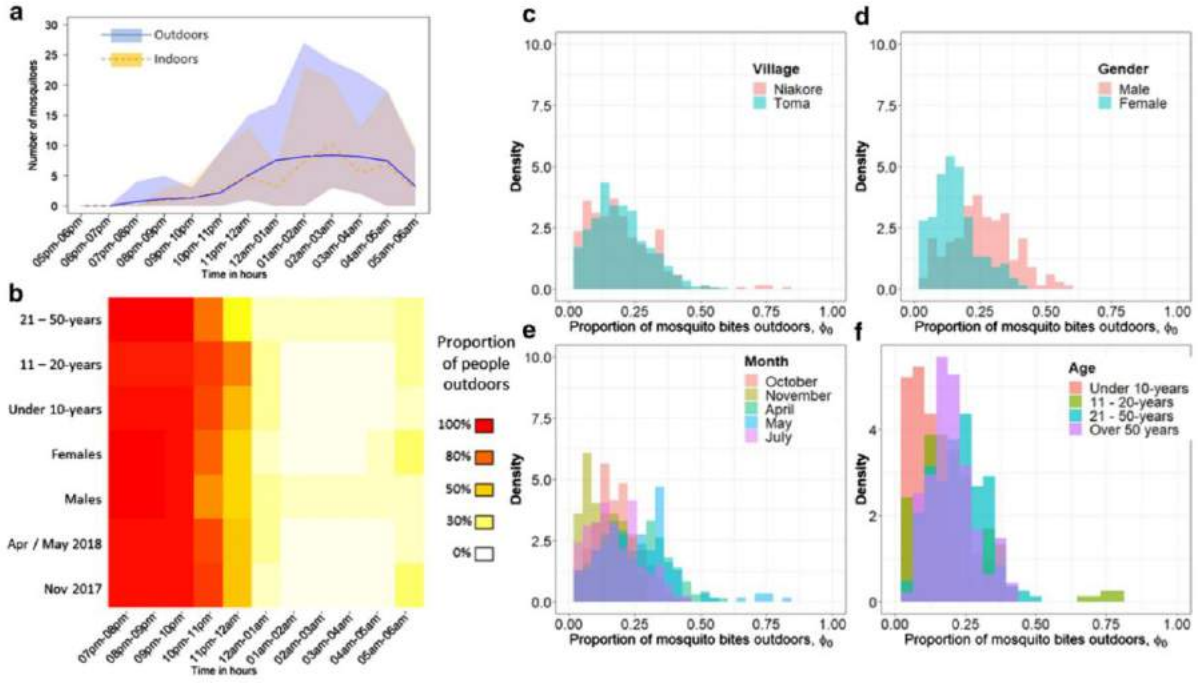
In 2017 an outbreak of Dengue fever (DF) was reported in Kabridahar Town, Ethiopia. This mosquito transmitted disease was recently detected in Ethiopia only four years prior, with this being the first time it was identified in the area. In response, our team was dispatched to confirm the presence of the disease, identify potential causes, and implement mitigation and control measures. We identified and compared suspected cases and suspected non-cases to identify the potential risk factors of infection. Laboratory confirmation of infection and disease-type was also performed. Due to the entomological nature of disease transmission, additional entomological investigations were conducted at the households of both groups to understand its influence at the household level. Through these measures, we were able to establish the presence of DF in

Kabridahar Town and identify risk factors leading to infection. Risk factors included a lack of formal education and open water containers near the home, while the presence of long-lasting insecticide-treated nets were found to be protective. Mitigation and control measures were implemented to combat or promote the identified risk and protective factors respectively. Cases counts began to reduce five days after the onset of these measures. Recommendations were made based on our findings to prevent future outbreaks. The last case was recorded ten days after implementation of the mitigation and control measures.

Quantifying individual variability in exposure risk to mosquito bites in the Cascades region, Burkina Faso

Malaria Journal 18 January 2021

Human and vector activities outside the hours when indoor interventions offer direct protection from infectious bites potentially increase exposure risk to bites from malaria-transmitting Anopheles mosquitoes. This work investigated the degree of variation in human behaviour both between individuals and through time (season) to quantify how it impacts exposure to malaria vectors. This work presents one of the first clear descriptions of the degree of heterogeneity in time spent outdoors between people and across the year. Appreciation of sociodemographic, cultural and entomological activities will help refine approaches to vector control.



House modifications for preventing malaria

Cochrane Database Syst Rev 20 Jan 2021

Objectives: To assess the effects of house modifications on malaria disease and transmission.
Authors' conclusions: Based on the two trials published to date, there is some evidence that screening may reduce malaria transmission and malaria infection in people living in the house. The four trials awaiting publication are likely to enrich the current evidence base, and we will add these to this review when they become available.

Predicting the impact of outdoor vector control interventions on malaria transmission intensity from semi-field studies

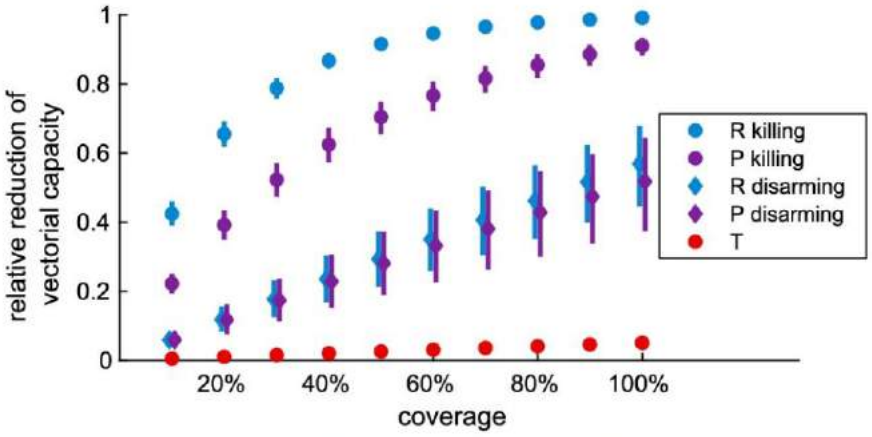
Parasites & Vectors 20 January 2021

Semi-field experiments with human landing catch (HLC) measure as the outcome are an important step in the development of novel vector control interventions against outdoor transmission of malaria since they provide good estimates of personal protection. However, it is often infeasible to determine whether the reduction in HLC counts is due to mosquito mortality or repellency, especially considering that spatial repellents based on

volatile pyrethroids might induce both. Due to the vastly different impact of repellency and mortality on transmission, the community-level impact of spatial repellents can not be estimated from such semi-field experiments. We present a new stochastic model that is able to estimate for any product inhibiting outdoor biting, its repelling effect versus its killing and disarming (preventing host-seeking until the next night) effects, based only on time-stratified HLC data from controlled semi-field experiments. With this methodology, we analysed data from recent semi-field studies in Kenya and Tanzania on the impact of transfluthrin-treated eave ribbons, the odour-baited Suna trap and their combination (push–pull system) on HLC of Anopheles arabiensis in the peridomestic area.

Fig. 12

From: Predicting the impact of outdoor vector control interventions on malaria transmission intensity from semi-field studies



Prediction for relative reduction of vectorial capacity of *An. arabiensis* under deployment of spatial repellents (R, blue), traps (T, red) and push–pull systems (P, purple) at coverage levels ranging from 10 to 100%, under two distinct assumptions on the effect of the transfluthrin-treated eave ribbons: repelling and killing (circle markers), or repelling and disarming (diamond markers). Indoor biting is assumed to be equally affected by the interventions as outdoor biting. Markers denote means and vertical bars denote 95% credible intervals from 2.5 percentile to 97.5 percentile

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Three papers have been published from the NgenIRS project's indoor residual spray trial in Mopeia, Mozambique. They detail the entomological and epidemiological results and the cost-effectiveness of IRS with pirimiphos-methyl in a highly endemic area with high ITN access and emerging pyrethroid resistance.

Reduced exposure to malaria vectors following indoor residual spraying of pirimiphos-methyl in a high-burden district of rural Mozambique with high ownership of long-lasting insecticidal nets: entomological surveillance results from a cluster-randomized trial.

Malaria Journal 21 January 2021

Conclusion—IRS with Actellic®300 CS (PM) used in addition to pyrethroid-only LLINs substantially reduced human exposures to malaria vectors during both years of the cluster-randomized controlled trial in Mopeia—a high-burden district where the primary vector, *An. funestus s.l.*, was equally likely to feed indoors or outdoors and demonstrated increasing resistance to pyrethroids. Findings suggest that IRS with PM can provide effective vector control, including in some settings where pyrethroid-only ITNs are widely used.

Incremental impact on malaria incidence following indoor residual spraying in a highly endemic area with high standard ITN access in Mozambique: results from a cluster-randomized study

Malaria Journal 10 February 2021

Conclusion—In a highly endemic area with high ITN access and emerging pyrethroid resistance, adding IRS with pirimiphos-methyl resulted in significant additional protection (18% lower incidence) for children under five years of age.

Cost and cost-effectiveness of indoor residual spraying with pirimiphos-methyl in a high malaria transmission district of Mozambique with high access to standard insecticide-treated nets

Malaria Journal 10 March 2021

The cost and cost-effectiveness of indoor residual spraying (IRS) with pirimiphos-methyl (Actellic®300 CS) were assessed in a high transmission district (Mopeia) with high access to pyrethroid insecticide-treated nets (ITNs), compared to ITNs alone. The major mosquito vectors in the area were susceptible to pirimiphos-methyl, but resistant to pyrethroids.

Conclusion

This study provides robust evidence that IRS with pirimiphos-methyl can be cost-effective in high transmission regions with high pyrethroid ITN coverage where the major vector is susceptible to pirimiphos-methyl but resistant to pyrethroids. The finding that insecticide cost is the main driver of IRS costs highlights the need to reduce the insecticide price without jeopardizing effectiveness.

The entomological impact of passive metofluthrin emanators against indoor Aedes aegypti: A randomized field trial

PLoS Negl Trop Dis 26 January 2021

Volatile pyrethroids, exhibiting both lethal and behavioural effects on mosquitoes are available in formulations that release insecticides passively to the air, at room temperature. These may be suitable for deployment in houses with the aim of creating “bite-free” spaces. By removing the need for conventional application methods, these devices might be rapidly deployed with minimum disruption to households. This is the first large-scale, randomized control trial to evaluate the entomological impacts of volatile pyrethroids in an urban environment. Using metofluthrin as an example, we confirm that some formulations have a significant impact on *Aedes aegypti* densities and landing behaviour indoors. These effects occur despite the presence of pyrethroid-resistance alleles associated with conventional insecticide resistance.

A 10% w/w metofluthrin "emanator" that passively disseminates insecticide from an impregnated net was evaluated in a randomized trial of 200 houses in Mexico. The devices were introduced at a rate of 1 per room and replaced at 3-week intervals. During each of 7 consecutive deployment cycles, indoor resting mosquitoes were sampled using aspirator collections. Assessments of mosquito landing behaviours were made in a subset of houses. Averaged across the trial, there were significant reductions in Abundance Rate Ratios for total *Ae. aegypti*, female abundance and females that contained blood meals. Average efficacy was 60.2% for total adults, 58.3% for females, and 57.2% for blood-fed females. The emanators also reduced mosquito landings by 90% from 12.5 to 1.2 per 10-minute sampling period (P<0.05).

The impact of climate change on neglected tropical diseases: a systematic review

Trans R Soc Trop Med Hyg 28 January 2021

This review will interest those following the potential impacts of climate change on public health in tropical and subtropical areas. The authors discuss how an improved understanding of how climate change influences NTDs can help identify populations at risk to include in future public health interventions. Vector-borne NTDs addressed in the review include dengue/chikungunya viruses, Chagas disease, leishmaniasis, human African trypanosomiasis, LF and onchocerciasis.

Anopheles stephensi Mosquitoes as Vectors of Plasmodium vivax and falciparum, Horn of Africa, 2019

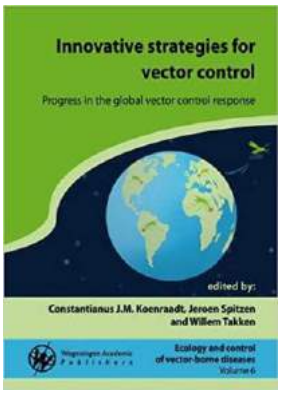
Emerg Infect Dis February 2021

Anopheles stephensi mosquitoes, efficient vectors in parts of Asia and Africa, have spread from Asia throughout the Horn of Africa, detected in Djibouti in 2012, Ethiopia in 2016, and Sudan in 2019. The authors detected widescale presence of *An. stephensi* larvae in artificial water bodies demonstrating that these mosquitoes are firmly established in an urban setting in Ethiopia. Larvae were found in 75.3% of water sources

surveyed and contributed to 80.9% of wild-caught *Anopheles* mosquitoes in Awash Sebat Kilo, Ethiopia. Detection of 4 haplotypes suggests independent arrival of different populations or heterogeneity arising after importation of the mosquito species. Mosquito feeding experiments predominantly included highly infective patients with clinical *P. vivax* infection. High susceptibility of these mosquitoes to *Plasmodium falciparum* and *vivax* infection presents a challenge for malaria control in the Horn of Africa.

Insecticides and malaria

Book chapter in Innovative strategies for vector control
Ecology and Control of Vector-borne Diseases 18 February 2021



This chapter charts the evolution of long-lasting insecticidal nets and indoor residual spraying into becoming the two principal malaria vector control classes and the innovation that has led to a new generation of these tools which aim to counter the growing threat of insecticide resistance. At the same time a need for new classes of vector control tools has been recognised to overcome not just the hazard of insecticide resistance but also the problems posed by outdoor vector biting, residual transmission and changes in human behaviour. The main developments in new vector control classes are described, including the role of non-insecticidal vector control. The chapter further outlines the type of evidence of efficacy that needs to be demonstrated for new classes of tools to achieve policy recommendation, and some of the challenges in generating the necessary evidence. For low transmission settings the potential of innovation in the deployment of vector control to accelerate the goal of malaria elimination is discussed. Finally, the chapter highlights the specific need for adapting vector control in conflict and humanitarian emergency situations to prevent the development of new foci of infection.

Creating long-term resilience against malaria vectors while addressing the immediate need to suppress pathogen transmission

Book chapter in Innovative strategies for vector control
Ecology and Control of Vector-borne Diseases 18 February 2021

This paper discusses a transitional approach for malaria prevention, involving judicious use of current tools while gradually building long-term resilience to sustain control of important vectors. The idea should be to carefully transition from insecticide-based to non-insecticidal approaches, without losing the gains made so far against malaria. In the short and medium-term, countries may deploy evidence-driven suites of current tools, e.g. insecticide treated nets (ITNs) and indoor residual spraying (IRS), while gradually introducing improved versions, such as nets with multiple chemical ingredients and long-lasting IRS formulations to suppress transmission. Depending on local evidence, these may be supplemented with niche technologies, such as spatial repellents, endectocides, odour-baited traps or mosquitocidal sugar baits to address gaps such as outdoor-biting and pyrethroid resistance. Once this is in place, countries should establish programmes to build long-term resilience to sustain the accrued gains and prevent transmission rebounds. Examples may include: incentivising the private sector to supply high-quality commodities e.g. locally-manufactured mosquito nets, providing subsidies to promote mosquito-free dwellings for low-income families, expanding community engagement in disease control and strengthening health systems to more effectively detect and manage cases. To secure these developments, endemic countries should also establish multi-sectorial initiatives prioritising disease control beyond malaria. Examples may include environmental sanitation to reduce vectors, institutionalised health education and capacity-building on biology and control of disease, appropriate legislation to improve compliance and protect vulnerable sub-populations and long-term domestic □nancing for malaria control. These programmes should be supported by a strong in-country research culture to constantly identify gaps, monitor progress and seek transformative approaches with potential to accelerate progress. If integrated in the wider public health context, this phased approach could contain ongoing malaria transmission, reduce over-reliance on insecticide-based tools and minimise transmission rebounds even in poor communities.

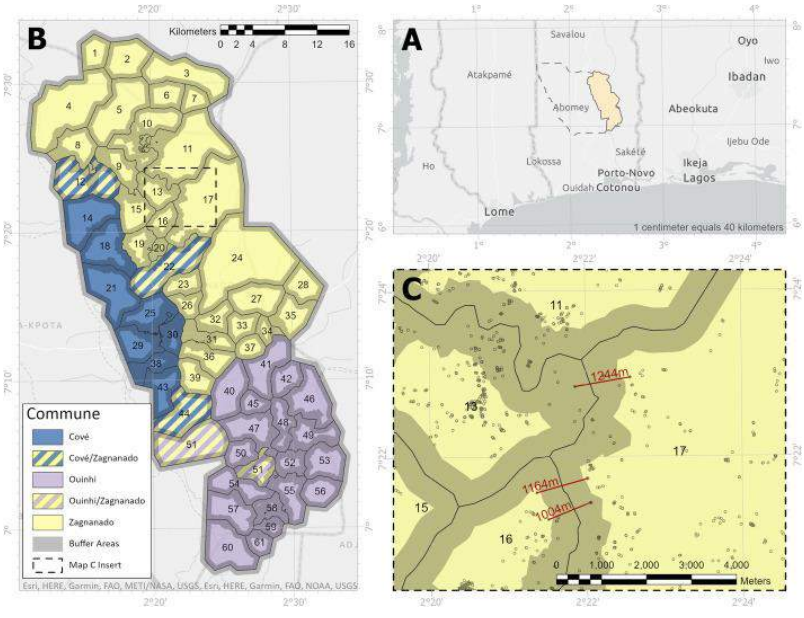
Larval source management for malaria control: prospects for new technologies and community involvement

Book chapter in Innovative strategies for vector control
Ecology and Control of Vector-borne Diseases 18 February 2021

In this chapter, progress in answering fundamental questions on larval ecology is reviewed and recent examples that specifically aimed to assess the feasibility of involving communities in IVM programs for malaria control are discussed.

Assessing the efficacy of two dual-active ingredients long-lasting insecticidal nets for the control of malaria transmitted by pyrethroid-resistant vectors in Benin: study protocol for a three-arm, single-blinded, parallel, cluster-randomized controlled trial

BMC Infect Dis 19 Feb 2021



This protocol presents a three-arm superiority, single-blinded, cluster randomized controlled trial to evaluate the impact of 2 novel dual-active ingredient LLINs on epidemiological and entomological outcomes in Benin, a malaria-endemic area with highly pyrethroid-resistant vector populations. The study arms consist of (i) Royal Guard® LLIN, a net combining a pyrethroid (alpha-cypermethrin) plus an insect growth regulator (pyriproxyfen), which in the adult female is known to disrupt reproduction and egg fertility; (ii) Interceptor G2® LLIN, a net incorporating two adulticides (alpha-cypermethrin and chlorfenapyr) with different modes of action; and (iii) the control arm, Interceptor® LLIN, a pyrethroid (alpha-cypermethrin) only LLIN.

This study is the second cluster randomised controlled trial to evaluate the efficacy of these next-generation LLINs to control malaria transmitted by insecticide-resistant mosquitoes.

Impact and cost-effectiveness of a lethal house lure against malaria transmission in central Côte d'Ivoire: a two-arm, cluster-randomised controlled trial

The Lancet 27 February 2021

Figure 1: **A house in Côte d'Ivoire with screening plus Eave Tubes**
The inset shows the Eave Tube insert placed within the tube.

Methods -We did a two-arm, cluster-randomised controlled trial with 40 village-level clusters in central Côte d'Ivoire between Sept 26, 2016, and April 10, 2019. All households received new insecticide-treated nets at universal coverage (one bednet per two people). Suitable households within the clusters assigned to the treatment group were offered screening plus Eave Tubes, with Eave Tubes treated using a 10% wettable powder formulation of the pyrethroid β-cyfluthrin. Because of the nature of the intervention, treatment could not be masked for households and field teams, but all analyses were blinded. The primary endpoint was clinical malaria incidence recorded by active case detection over 2 years in cohorts of children aged 6 months to 10 years.

Findings - 3022 houses received screening plus Eave Tubes, with an average coverage of 70% across the intervention clusters. 1300 eligible children were recruited for active case detection in the control group and 1260 in the intervention group. During the 2-year follow-up period, malaria case incidence was 2·29 per child-year (95% CI 1·97–2·61) in the control group and 1·43 per child-year (1·21–1·65) in the intervention group (hazard ratio 0·62, 95% CI 0·51–0·76; p<0·0001). Cost-effectiveness simulations suggested that screening plus Eave Tubes has a 74·0% chance of representing a cost-effective intervention, compared with existing healthcare activities in Côte d'Ivoire, and is similarly cost-effective to other core vector control interventions across sub-Saharan Africa. No serious adverse events associated with the intervention were reported during follow-up.
Interpretation - Screening plus Eave Tubes can provide protection against malaria in addition to the effects of insecticide-treated nets, offering potential for a new, cost-effective strategy to supplement existing vector control tools. Additional trials are needed to confirm these initial results and further optimise Eave Tubes and the lethal house lure concept to facilitate adoption.

Effectiveness and cost-effectiveness of reactive, targeted indoor residual spraying for malaria control in low-transmission settings: a cluster-randomised, non-inferiority trial in South Africa

The Lancet 27 February 2021

We investigated the effectiveness and cost-effectiveness of a reactive, targeted IRS strategy…in northeastern South Africa over two malaria seasons (2015–17). Targeted IRS was non-inferior, safe, less costly, and cost-effective compared with standard IRS in this very-low-transmission setting. Saved resources could be reallocated to other malaria control and elimination activities.

Implications of all the available evidence

Together with previous evidence, this study suggests that targeted IRS could be cautiously implemented as an alternative to annual IRS campaigns in areas with very low malaria transmission and strong surveillance systems. Doing so would enable scarce resources available for malaria control to be more effectively used for other life-saving activities, such as enhanced case detection or increased disease surveillance.

Addressing key gaps in implementation of mosquito larviciding to accelerate malaria vector control in southern Tanzania: results of a stakeholder engagement process in local district councils

Malaria Journal 2 March 2021

This study investigated key obstacles and opportunities relevant to effective rollout of larviciding for malaria control, with a focus on the meso-endemic region of Morogoro, southern Tanzania.

Conclusions

The larviciding programme was widely supported by both communities and malaria control officials, but there were gaps in technical knowledge, implementation and public engagement. To improve overall impact, it is important to: (i) intensify training efforts, particularly for identifying habitats of important vectors, (ii) adopt standard technical principles for applying larvicides or larval source management, (iii) improve financing for local implementation and (iv) improve public engagement to boost community awareness and participation. These lessons could also be valuable for other malaria endemic areas wishing to deploy larviciding for malaria control or elimination.

Efficacy of indoor residual spraying with broflanilide (TENEBENAL), a novel meta-diamide insecticide, against pyrethroid-resistant anopheline vectors in northern Tanzania: An experimental hut trial

PLoS One 3 March 2021

Abstract

Novel chemistry for vector control is urgently needed to counter insecticide resistance in mosquitoes. Here a new meta-diamide insecticide, broflanilide (TENEBENAL™), was evaluated in East African experimental huts in Moshi, northern Tanzania. Two consecutive experimental hut trials with broflanilide 50WP were conducted; the first evaluating the efficacy of three concentrations, 50 mg/m^2, 100 mg/m^2, and 200 mg/m^2 using a prototype formulation, and the second trial evaluating an improved formulation. The IRS treatments were applied on both mud and concrete surfaces and efficacy was monitored over time. The mortality, blood-feeding inhibition and exiting behaviour of free-flying wild mosquitoes was compared between treatment

arms. Additionally, cone assays with pyrethroid-susceptible and resistant mosquito strains were conducted in the huts to determine residual efficacy. The first trial showed a dosage-mortality response of the prototype formulation and 3–8 months of residual activity, with longer activity on concrete than mud. The second trial with an improved formulation showed prolonged residual efficacy of the 100 mg/m^2 concentration to 5–6 months on mud, and mosquito mortality on the concrete surface ranged between 94–100% for the full duration of the trial. In both trials, results with free-flying, wild *Anopheles arabiensis* echoed the mortality trend shown in cone assays, with the highest dose inducing the highest mortality and the improved formulation showing increased mortality rates. No blood-feeding inhibition or insecticide-induced exiting effects were observed with broflanilide. Broflanilide 50WP was effective against both susceptible and pyrethroid-resistant mosquito strains, demonstrating an absence of cross resistance between broflanilide and pyrethroids. The improved formulation, which has now been branded VECTRON™ T500, resulted in a prolonged residual efficacy. These results indicate the potential of this insecticide as an addition to the arsenal of IRS products needed to maintain both control of malaria and resistance management of malaria-transmitting mosquitoes.

Real-time dispersal of malaria vectors in rural Africa monitored with lidar

PLoS One 4 March 2021

Abstract

Lack of tools for detailed, real-time observation of mosquito behavior with high spatio-temporal resolution limits progress towards improved malaria vector control. We deployed a high-resolution entomological lidar to monitor a half-kilometer static transect positioned over rice fields outside a Tanzanian village. A quarter of a million in situ insect observations were classified, and several insect taxa were identified based on their modulation signatures. We observed distinct range distributions of male and female mosquitoes in relation to the village periphery, and spatio-temporal behavioral features, such as swarming. Furthermore, we observed that the spatial distributions of males and females change independently of each other during the day, and were able to estimate the daily dispersal of mosquitoes towards and away from the village. The findings of this study demonstrate how lidar-based monitoring could dramatically improve our understanding of malaria vector ecology and control options.

Personal protection with PBO-pyrethroid synergist-treated nets after 2 years of household use against pyrethroid-resistant Anopheles in Tanzania

Parasites & Vectors 10 March 2021

Our project assessed personal protection of the World Health Organization first-in-class PBO-Py LLIN (Olyset Plus) versus the standard LLIN (Olyset net) against pyrethroid-resistant *Anopheles gambiae sensu lato (s.l.)* and *An. funestus* in North-West Tanzania after 20 months of household use.

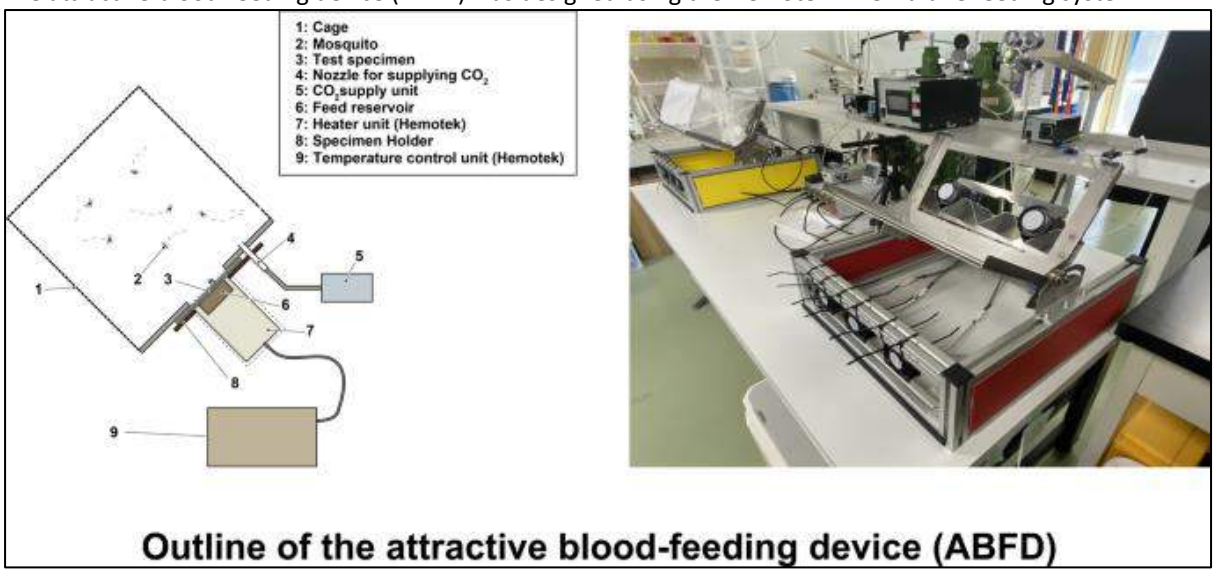
Conclusion: The PBO-Py LLINs provided improved protection after 20 months of household use, as demonstrated by the higher bioassay mortality and absence of pyrethroid-resistant *An. gambiae* s.s. and *An. funestus* collected from inside Olyset Plus nets, irrespective of HI category, as compared to Olyset nets.

New mosquito repellency bioassay for evaluation of repellents and pyrethroids using an attractive blood-feeding device

Parasites & Vectors 10 March 2021

Here we report a textile testing method using an artificial blood-feeding system that does not involve human volunteers or live animals, which aligns with the policy of protecting human and animal welfare.

The attractive blood-feeding device (ABFD) was designed using the Hemotek® membrane feeding system.



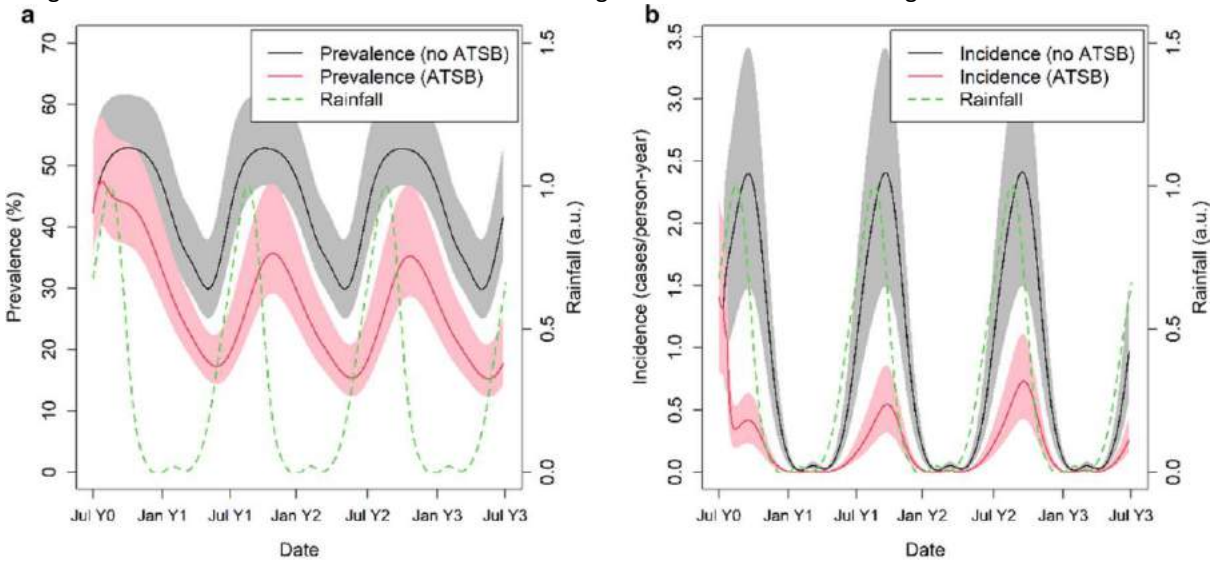
Outline of the attractive blood-feeding device (ABFD)

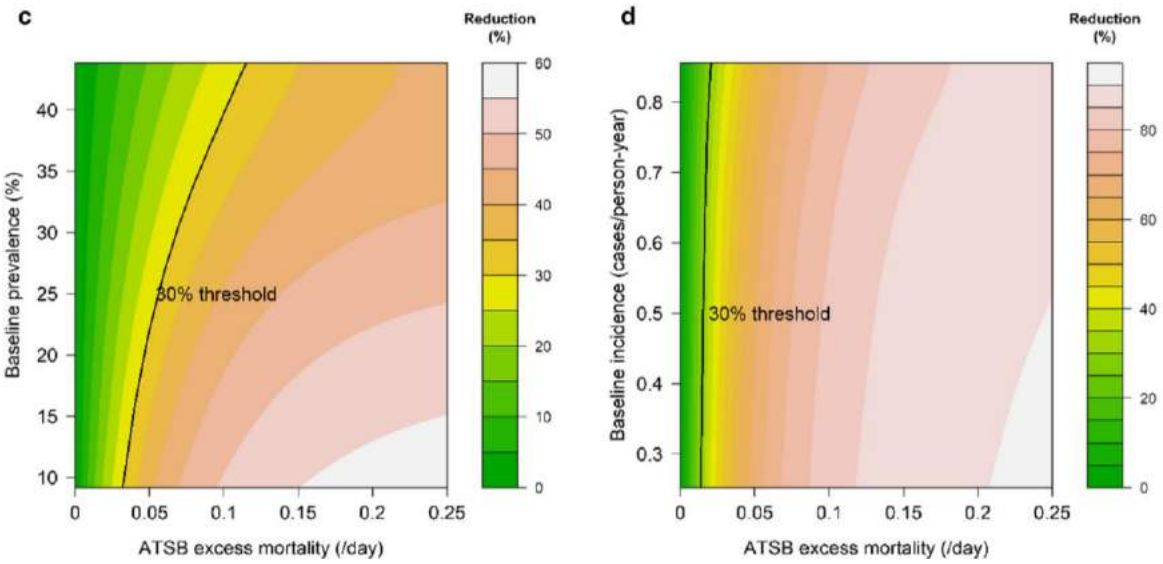
Estimating the potential impact of Attractive Targeted Sugar Baits (ATSBs) as a new vector control tool for Plasmodium falciparum malaria

Malaria Journal 17 March 2021

Conclusions

From epidemiological modelling, it was predicted that ATSBs could result in large reductions (> 30% annually) in prevalence and clinical incidence of malaria, even in regions with an existing high malaria burden. These results suggest that this new tool could provide a promising addition to existing vector control tools and result in significant reductions in malaria burden across a range of malaria-endemic settings.

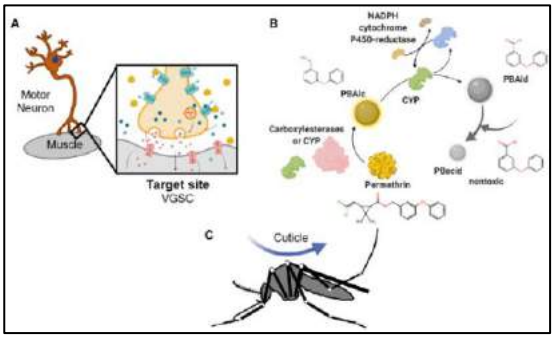




a, **b** Model-predicted all-ages parasite prevalence (**a**) and clinical incidence (**b**) over the course of 3 years after introduction of ATSBs (red line) and without ATSBs during the same period (black line). The green dotted line shows the assumed rainfall pattern (in arbitrary units). For these runs the excess mortality μ_{ATSB} is set to the average value estimated from field trial results (0.09/day). Shaded areas represent range of values obtained using model parameters in 95% credible interval. **c**, **d** Model-predicted reduction in all-age year-round parasite prevalence (**c**) and clinical incidence (**d**) in first year of ATSB use as a function of prevalence/incidence under non-ATSB conditions and ATSB excess mortality μ_{ATSB}. All simulations use the seasonal Mali rainfall profile shown in **a** and **b**

From Global to Local-New Insights into Features of Pyrethroid Detoxification in Vector Mosquitoes

Insects 24 March 2021



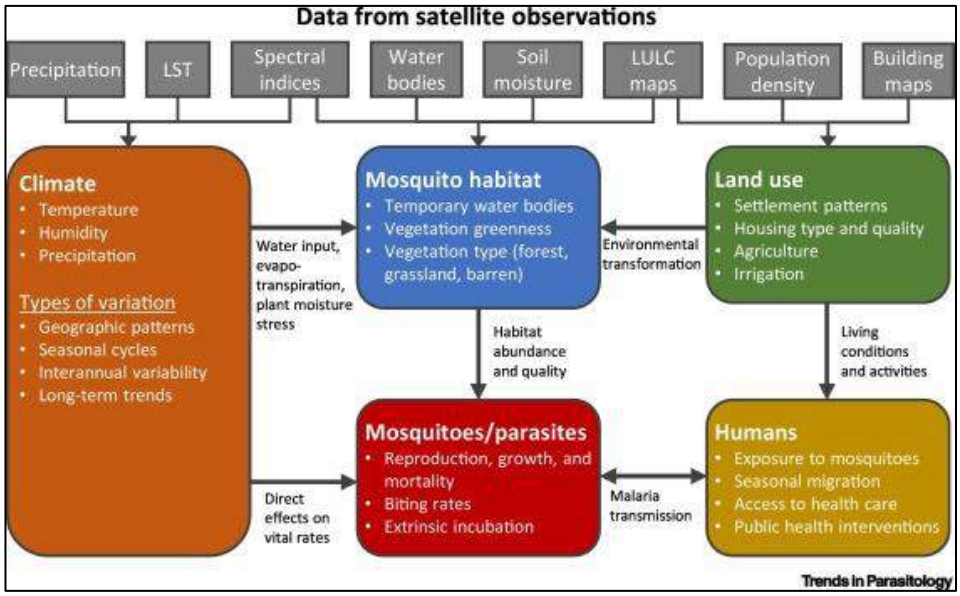
This review describes new insights into the ways in which mosquitoes have evolved resistance to pyrethroids. For example, before pyrethroids bind to their targets on motoneurons to paralyze mosquitoes, they must first pass through the outer exoskeleton to inner tissues.
Resistant mosquitoes have evolved the ability to break down pyrethroids into nontoxic products that are then excreted. This metabolism prevents toxic build-up of the insecticide, which would otherwise be lethal to the mosquitoes. Scientists have identified a variety of changes to mosquito genes that are responsible for insecticide degradation and excretion. In this review, we outline the genes and pathways involved in the breakdown of pyrethroids and the key gene categories that are involved.

Satellite Observations and Malaria: New Opportunities for Research and Applications

Trends Parasitol. 25 March 2021

New technologies, including innovations in the field of malaria informatics, are needed to facilitate more effective data-driven management of malaria interventions. Satellite remote sensing is now routinely used in malaria research to measure environmental conditions that influence mosquito populations, human vulnerability, and malaria transmission cycles. These relationships provide the basis for risk maps that highlight locations with the highest malaria risk and early warning systems that forecast malaria outbreaks based on lagged responses to environmental variation. Satellite data can also be used to map buildings, estimate human population density, and identify land use practices that affect human exposure to mosquitoes. An important

goal is to incorporate this information into spatial decision support systems that target malaria interventions at the locations and times when they will be most effective.



Efficacy of interceptor® G2, a long-lasting insecticide mixture net treated with chlorfenapyr and alpha-cypermethrin against Anopheles funestus: experimental hut trials in north-eastern Tanzania

Malaria Journal 9 April 2021

Chlorfenapyr is a pyrrole insecticide that disrupts mitochrondrial function and confers no cross-resistance to neurotoxic insecticides. Interceptor® G2 LN (IG2) is an insecticide-mixture LLIN, which combines wash-resistant formulations of chlorfenapyr and the pyrethroid alpha-cypermethrin. The objective was to determine IG2 efficacy under controlled household-like conditions for personal protection and control of wild, pyrethroid-resistant *Anopheles funestus* mosquitoes.

Results: In the two trials held in NE Tanzania, *An. funestus* mortality was 2.27 (risk ratio 95% CI 1.13–4.56) times greater with unwashed Interceptor G2 than with unwashed Interceptor LN (p = 0.012). There was no significant loss in mortality with IG2 between 0 and 20 washes (1.04, 95% CI 0.83–1.30, p = 0.73). Comparison with chlorfenapyr treated net indicated that most mortality was induced by the chlorfenapyr component of IG2 (0.96, CI 0.74–1.23), while comparison with Interceptor LN indicated blood-feeding was inhibited by the pyrethroid component of IG2 (IG2: 0.70, CI 0.44–1.11 vs IG1: 0.61, CI 0.39–0.97). Both insecticide components contributed to exiting from the huts but the contributions were heterogeneous between trials (heterogeneity Q = 36, P = 0.02). WHO susceptibility tests with pyrethroid papers recorded 44% survival in *An. funestus*.

Conclusions: The high mortality recorded by IG2 against pyrethroid-resistant *An. funestus* provides first field evidence of high efficacy against this primary, anthropophilic, malaria vector.

Efficacy of broflanilide (VECTRON T500), a new meta-diamide insecticide, for indoor residual spraying against pyrethroid-resistant malaria vectors

Sci Rep 12 April 2021

Broflanilide is a newly discovered insecticide under consideration. We investigated the efficacy of a wettable powder (WP) formulation of broflanilide (VECTRON T500) for IRS on mud and cement wall substrates in laboratory and experimental hut studies against pyrethroid-resistant malaria vectors in Benin, in comparison with pirimiphos-methyl CS (Actellic 300CS). There was no evidence of cross-resistance to pyrethroids and broflanilide in CDC bottle bioassays. In laboratory cone bioassays, broflanilide WP-treated substrates killed > 80% of susceptible and pyrethroid-resistant *An. gambiae* sl for 6–14 months. At application rates of 100 mg/m^2 and 150 mg/m^2, mortality of wild pyrethroid-resistant *An. gambiae* sl entering experimental huts in Covè, Benin treated with VECTRON T500 was similar to pirimiphos-methyl CS (57–66% vs. 56%, P > 0.05). Throughout the 6-month hut trial, monthly wall cone bioassay mortality on VECTRON T500 treated hut walls remained > 80%. IRS with broflanilide shows potential to significantly improve the control of malaria

transmitted by pyrethroid-resistant mosquito vectors and could thus be a crucial addition to the current portfolio of IRS insecticides.

Testing configurations of attractive toxic sugar bait (ATSB) stations in Mali, West Africa, for improving the control of malaria parasite transmission by vector mosquitoes and minimizing their effect on non-target insects

Malaria Journal 14 April 2021

Abstract

Application methods of Attractive Toxic Sugar Baits (ATSB) need to be improved for wide-scale use, and effects on non-target organisms (NTOs) must be assessed. The goals of this study were to determine, at the village level, the effect of different configurations of bait stations to (1) achieve < 25% *Anopheles* mosquito vector daily feeding rate for both males and females and (2) minimize the effect on non-target organisms.

Use of two and three stations per house gave feeding rates above the 25% goal.

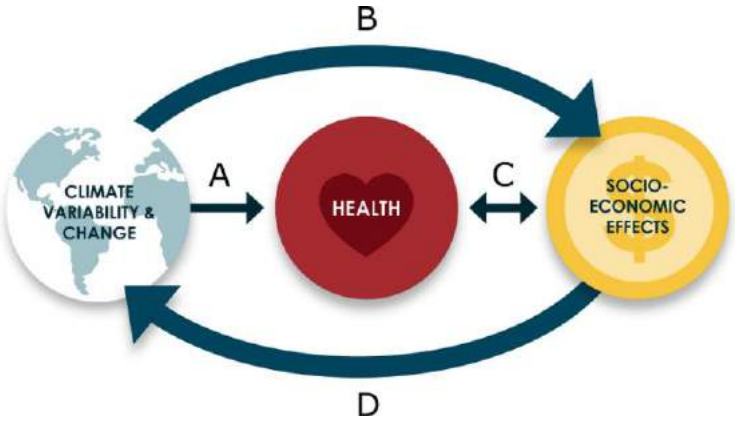
Using one or two stations significantly reduced percentage of bait-fed NTOs compared to three stations which had the highest feeding rates. Percentages were as follows: 6.84 ± 2.03% Brachycera followed by wasps (Hymenoptera: Vespidae) 5.32 ± 2.27%, and Rhopalocera 2.22 ± 1.79%. Hanging the optimal number of stations per house for catching mosquitoes (two) at 1.8 m above ground, limited the groups of non-targets to Brachycera, Chironomidae, Noctuoidea, Rhopalocera, parasitic wasps and wasps (Hymenoptera). Feeding at 1.8 m only occurred when stations were damaged.

Climate-proofing a malaria eradication strategy

Malaria Journal 17 April 2021

Abstract

Two recent initiatives, the World Health Organization (WHO) Strategic Advisory Group on Malaria Eradication and the Lancet Commission on Malaria Eradication, have assessed the feasibility of achieving global malaria eradication and proposed strategies to achieve it. Both reports rely on a climate-driven model of malaria transmission to conclude that long-term trends in climate will assist eradication efforts overall and, consequently, neither prioritize strategies to manage the effects of climate variability and change on malaria programming. This review discusses the pathways via which climate affects malaria and reviews the suitability of climate-driven models of malaria transmission to inform long-term strategies such as an eradication programme. Climate can influence malaria directly, through transmission dynamics, or indirectly, through myriad pathways including the many socioeconomic factors that underpin malaria risk. These indirect effects are largely unpredictable and so are not included in climate-driven disease models. Such models have been effective at predicting transmission from weeks to months ahead. However, due to several well-documented limitations, climate projections cannot accurately predict the medium- or long-term effects of climate change on malaria, especially on local scales. Long-term climate trends are shifting disease patterns, but climate shocks (extreme weather and climate events) and variability from sub-seasonal to decadal timeframes have a much greater influence than trends and are also more easily integrated into control programmes. In light of these conclusions, a pragmatic approach is proposed to assessing and managing the effects of climate variability and change on long-term malaria risk and on programmes to control, eliminate and ultimately eradicate the disease. A range of practical measures are proposed to climate-proof a malaria eradication strategy, which can be implemented today and will ensure that climate variability and change do not derail progress towards eradication.



WHO News and Publications

Updating WHO's global strategy for malaria

1 February 2021

Representatives from malaria-affected countries and partner organizations gathered on 28 January in a WHO virtual forum to share feedback and perspectives on the Global technical strategy for malaria 2016-2030. Inputs from a diverse group of stakeholders will be reflected in an updated strategy, which will be published in June 2021.

WHO launches consolidated guidelines for malaria

16 February 2021

The WHO Guidelines for malaria, launched today, bring together the Organization's most up-to-date recommendations for malaria in one user-friendly and easy-to-navigate online platform. They are designed to support malaria-affected countries in their efforts to reduce and, ultimately, eliminate a disease that continues to claim more than 400 000 lives each year.

Through the new platform, MAGICapp, users will find:

- All official WHO recommendations for malaria prevention (vector control and preventive chemotherapies) and case management (diagnosis and treatment). Recommendations for elimination settings are in development.
- Links to other resources, such as guidance on the strategic use of information to drive impact; surveillance, monitoring and evaluation; operational manuals, handbooks, and frameworks; and a glossary of key terms and definitions.

Users can access the evidence that underpins each WHO recommendation through the new web-based platform. There is a feedback tab to help identify recommendations that may need an update or further clarification, and inputs from stakeholders are also welcome by email (gmpfeedback@who.int).

WHO Vector Control Advisory Group update

Note the new VCAG website ***https://www.who.int/groups/vector-control-advisory-group***

Thirteenth meeting of the WHO Vector Control Advisory Group 7-10 Dec 2020

Report available 8 March 2021

This report details the proceedings and outcomes of the meeting, including advice provided to the following applicants: bait stations; lethal house lures; reduced pathogen transmission induced by Wolbachia; spatial repellents; and treatment of humans and/or livestock with an endectocide.

The Vector Control Advisory Group met for its 14th session on 19–21 April 2021 to discuss eave tubes, gene drive, ATSBs, spatial repellents, and PBO nets.

WHO has published two preferred product characteristics and three more are expected this year

Insecticide-treated nets for malaria transmission control in areas with insecticide-resistant mosquito populations - Preferred product characteristics

12 February 2021 | Technical document

"Preferred product characteristics" (PPCs) are key tools to incentivize and guide the development of urgently needed health products. The PPC published here describes the characteristics of new types of insecticide-treated nets (ITNs) to control malaria transmission in areas with insecticide-resistant mosquito populations. The document was developed to address the public health need caused by the evolution and spread of insecticide resistance, particularly to pyrethroids. Such resistance threatens the effectiveness of the current standard of malaria vector control in many countries, namely pyrethroid-only long-lasting insecticidal nets (LLINs).

Vector control interventions designed to control malaria in complex humanitarian emergencies and in response to natural disasters - Preferred product characteristics

12 February 2021 | Technical document

Some of the vector control interventions deployed in complex emergencies and in response to natural disasters – namely insecticide-treated nets (ITNs) and indoor residual spraying (IRS) – have already met identified public health needs in more stable settings; other tools such as insecticide-treated tarpaulins have been specifically designed for this use case. Given the diverse mix of existing and potential new interventions and the considerable gaps in the associated evidence base, this PPC aims to clearly articulate the unmet public health needs for tools designed to control malaria transmission in complex emergencies and in response to natural disasters.

Other PPCs planned for later in 2021:

- ❑ Indoor residual spraying/indoor wall treatments
- ❑ Interventions to combat outdoor biting of mosquitoes
- ❑ Revision of PPC on endectocides

Norms, standards and processes underpinning WHO vector control policy recommendations

For WHO to recommend a novel tool or strategy for use by governments and public health agencies, WHO must be certain that these interventions demonstrate public health value against their target disease(s). Furthermore, the interventions need to be safe, of high quality in their production and/or manufacturing, and efficacious against the target vectors.

This document outlines the evaluation process that WHO undertakes to assess novel tools and strategies targeted at VBDs. Its aim is to articulate the linkage between the generation of evidence that demonstrates public health impact of novel interventions, and the development of policy recommendations based on the generated data. The document defines standards for the evaluation process, as well as the steps that an applicant needs to undertake, along with some guiding principles that aim to support applicants in the development of submissions with WHO.

WHO issues new guidance for research on genetically modified mosquitoes to fight malaria and other vector-borne diseases

19 May 2021

For more than 2 decades, scientists have been working to harness the promise of molecular biology to develop genetically modified mosquitoes (GMMs) for use as public health tools to prevent the transmission of vector-borne diseases. Responding to a need for additional standards and guidance, the WHO Special Programme for Research and Training in Tropical Diseases (WHO-TDR) and the Foundation for the National Institutes of Health (FNIH) published in 2014 the first WHO Guidance framework for testing genetically modified mosquitoes.

This revised version takes into account the technical progress made and lessons learned in this rapidly advancing field of research. Like the original guidance framework, it is intended to provide standards that foster quality and consistency in the processes for developing, testing and regulating these new genetic technologies. Best practices recommended in the 2021 guidance framework will further contribute to the comparability of results and credibility of conclusions in order to facilitate decision-making by countries interested in the potential use of GMMs as public health tools for the control of vector-borne diseases.

El Salvador certified as malaria-free by WHO

25 February 2021 News release

El Salvador is first Central American country to achieve this status, third in all of the Americas in recent years following Argentina in 2019 and Paraguay in 2018.

Webinars, websites and other resources

Ifakara Master Classes in Public Health & Medical Entomology

Hosted by Fredros Okumu (Ifakara Health Institute) and Sheila Ogoma (Clinton Health Access Initiative), the recorded Q and A sessions around various topics are available on YouTube. Recent topics include:

- 12 May - ***Malaria Delenda Est***: a MasterClass with Drs. Phillip Welkhoff, Helen Jamet & Meera Venkatesan
- 5 May - ***Fixed, Few & Findable:*** a MasterClass with Profs. H Kafy, P Dambach, P Dechant & S Majambere
- 21 April - ***Aedes & Stephensi***: a Master Class with Profs. Peter Ryan, Basile Kamgang & Fitsum G. Tadesse
- 8 April - **A Thousand Lives a Day**: a Master Class with Profs. Pedro Alonso, Patrick Kachur & Elizabeth Juma
- 31 March - **The Mosquitoes Must Die**: a Master Class with Profs. Hilary Ranson & Corine Ngufor
- 24 March - **There's a Gene in my Mosquitoes**: a MasterClass with Profs. Austin Burt, Tony Nolan & A. Diabate
- 10 March - **The Elegant Math of Malaria Transmission & Its Control**: a MasterClass with Prof. David L Smith
- 3 March - **The Long Road to Malaria Elimination**: a MasterClass with Prof. Brian M Greenwood

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APMEN TechTalks archive

If you missed the latest APMEN TechTalks you can access the recorded events *here*.

MESA Webinars: Science for Malaria Impact

For the first time, MESA will virtually celebrate a series of monthly discussions, the MESA Webinars: Science for Malaria Impact. These webinars bring together the malaria community of innovators and showcase the work of malaria-endemic researchers. Starting in May, the virtual events will be held on the first Wednesday of each month and will feature two researchers. These one-hour sessions will cover a range of topics, from social sciences to entomology, through insecticide drug resistance, stratification and genomics.

When: First Wednesday of each month until December
Time: 8:00 am EDT - 2:00 pm CEST/CAT - 8:00 pm SGT

The next session is scheduled for Wednesday June 2.
MESA Webinars 2 - Techniques to Improve Malaria Mosquito Surveillance and Control to Accelerate Efforts Toward Elimination
Speakers:
Fredros Okumu (Ifakara Health Institute - IHI, Tanzania)
Mercy Opiyo (Barcelona Institute for Global Health - ISGlobal, Spain and Manhiça Health Research Centre - CISM, Mozambique)

The Entomological Surveillance Planning Tool (ESPT)

To reduce malaria burden and achieve elimination, a shift in mindset is needed toward local problem-solving. To support this shift, and in response to malaria program demand, the UCSF Malaria Elimination Initiative and the University of Notre Dame led the development of an Entomological Surveillance Planning Tool (ESPT) with guidance from a technical working group. The ESPT is for national malaria program managers, vector control officers, program entomologists, surveillance officers, and M&E officers to use in collaboration with their implementing, technical, and research partners. The ESPT aligns with and aims to distil WHO guidance (and other technical partners and resources such as PMI) into an operational and iterative decision-support tool for national malaria programs to support question-driven, cost effective, locally tailored, and evidence-based vector control. The ESPT supports programs to reorient and plan routine entomological surveillance activities, foci and outbreak investigations, and receptivity monitoring based on priority programmatic questions. The tool also helps to identify gaps in protection, or limitations with current prevention measures, by collecting and integrating priority entomological data with other data, such as climatic, epidemiological, and human behavioral data. This data in turn can support decisions on targeting and tailoring vector control to address the human-vector contact point (i.e., where transmission occurs).

The ESPT was translated into French, Spanish, Portuguese, and Farsi. All versions are available on the *MEI website*. Any questions can be directed to *mei@ucsf.edu*

In the news and social media

In2Care® EaveTubes reduce malaria up to 47%, in a large-scale trial in Ivory Coast

February 2021

Results of a large randomized controlled trial in Ivory Coast with In2Care® EaveTubes are published in The Lancet. On top of bednets, EaveTubes reduce malaria on average with 38% and up to 47% in villages where 70% of the houses were treated with EaveTubes and window screening. The results of the trial demonstrates that In2Care® EaveTubes can be a big step towards eradication of malaria in African countries.

Genetically Modified Mosquitoes Have Come to the U.S. Will They Work?

Time 9 May 2021

"Our Mosquito Project Takes Flight," reads a baby-blue billboard off US-1 in the Florida Keys, alongside an image of an insect tracing a path in the shape of a heart. Sponsored by the local mosquito control board and U.K.-based biotech firm Oxitec, the ad promotes a contentious plan to release millions of genetically modified Aedes aegypti mosquitoes here to test a new method of bioengineered pest control. It's the first-ever such experiment in the United States, and one that has turned this chain of sun-soaked island communities into a battleground over scientific truth, government authority, and humanity's right to modify nature.

PMI Welcomes Dr. Raj Panjabi as the New U.S. Global Malaria Coordinator

The U.S. President's Malaria Initiative (PMI) is honored to officially welcome Raj Panjabi, MD, MPH as the new U.S. Global Malaria Coordinator. Dr. Panjabi was appointed by President Joe Biden and sworn in on February 1, 2021. Dr. Panjabi brings a wealth of expertise in global health and social entrepreneurship, as well as extensive on-the-ground experience working to reshape inequitable health systems in rural communities in many parts of the world. He also has first-hand experience with malaria having had it as a child and, alongside community and other frontline health workers, having cared for patients with severe malaria in rural Africa.

Dr. Panjabi grew up in Liberia and fled Liberia's civil war with his family when he was nine years old, becoming a refugee in the United States. He returned to Liberia as a medical student and then in 2007 co-founded Last Mile Health, where he served as CEO until joining PMI. Prior to joining PMI, Dr. Panjabi was also Assistant Professor of Medicine at Harvard Medical School and advisor for the World Health Organization's Independent Panel for Pandemic Preparedness and Response.

New U.S. Malaria Czar: Why We Should Care About The Disease, Even In A Pandemic

NPR 4 March 2021

Read more about PMI's impact in its *15th Annual Report to Congress*

The Malaria Elimination Initiative annouces a new director

The Malaria Elimination Initiative (MEI) at the UCSF Institute of Global Health Sciences announces new leadership, strategy and toolkit updates, and a strengthened partnership model to accelerate malaria elimination efforts

- *Letter from Allison Tatarsky, Director of the MEI*
- *Sir Richard Feachem and Dr. Roly Gosling welcome the MEI's new leadership*
- *The MEI Malaria Elimination Toolkit*
- *Imagine a World Free from Malaria with the MEI [video]*

Note this issue covers the period from mid January 2021 through end of April 2021.