Contents

Selected Recent Publications

Effects of insecticide resistance and exposure on Plasmodium development in Anopheles mosquitoes

Current Opinion in Insect Science 2020

The potential impact(s) of insecticide resistance or sublethal insecticide exposure on *Plasmodium-Anopheles* interactions are poorly understood. This short review provides an update on our understanding of the interactions between insecticide resistance and exposure and *Plasmodium* development, focusing on the mechanisms which might underpin any interactions, and identifying some key knowledge gaps.

Highlights

• Changes in *Anopheles* vector competence for *Plasmodium* parasites have been linked to insecticide resistance status.

• Insecticide exposure is detrimental for *Plasmodium* in the midgut lumen.

• Xenobiotic detoxification reactions in mosquito tissues can affect *Plasmodium* development.

• It is likely that other resistance mechanisms impact parasite development directly or indirectly.

• Research on this topic is lacking despite the crucial impact that it may have on malaria epidemiology in an era of widespread pyrethroid resistance.

Malaria-carrying mosquitoes get a leg up on insecticides

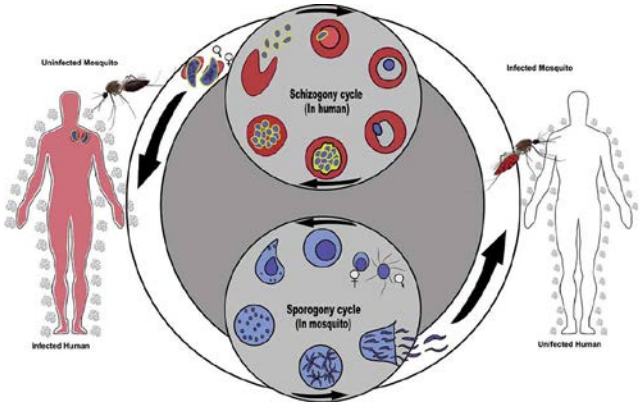
Nature News and Views Published 25 December 2019

This editorial is a follow up to a paper included in the January Tech Update *A sensory appendage protein protects malaria vectors from pyrethroids* in which the authors report that expression of a sensory appendage protein (SAP2), which is enriched in the legs, confers pyrethroid resistance in *Anopheles gambiae*. This editorial from Flaminia Catteruccia nicely summarizes the importance of these findings and concludes with a eye-opening statement—

"Whatever the eventual solution, the road to malaria elimination remains long. Mosquitoes are sending clear signals that they will fight for their survival."

Can Plasmodium's tricks for enhancing its transmission be turned against the parasite? New hopes for vector control

Pathog Glob Health Epub 7 January 2020



Abstract

Approximately 120 years ago the link between mosquito and the malaria transmission was discovered. However, even today it remains an open question whether the parasite is able to direct the blood-seeking and feeding behavior of its mosquito vector to maximize the probability of transmission. If the parasite has this ability, could it occur only through the alteration of the vertebrate host's volatile organic compounds (VOCs) and/or the parasite alteration of the behavior of the infected vector in a manner that favors its transmission? Although some recent empirical evidence supports the hypothesis regarding the parasite ability in alteration of the vertebrate host's VOCs, the role of parasite alteration and behavioral differences between infected and uninfected female mosquitoes toward infected and uninfected hosts has not yet been considered in the implementation of control measures. This review will discuss the current evidence, which shows 1. *Plasmodium* can direct uninfected mosquito blood-seeking and feeding behavior via alteration of vertebrate-host odor profiles and production of phagostimulants and 2. *Plasmodium* also manipulates its vector during the sporogony cycle to increase transmission. Briefly, we also consider the next generation of methods for moving the empirical laboratory evidence to potential application in future integrated malaria control programs.

Anopheles gambiae populations from Burkina Faso show minimal delayed mortality after exposure to insecticide-treated nets

Parasit Vectors. Published 10 Jan 2020

The efficacy of long-lasting insecticidal nets (LLINs) in preventing malaria in Africa is threatened by insecticide resistance. Bioassays assessing 24-hour mortality post-LLIN exposure have established that resistance to the concentration of pyrethroids used in LLINs is widespread. However, although mosquitoes may no longer be rapidly killed by LLIN exposure, a delayed mortality effect has been shown to reduce the transmission potential of mosquitoes exposed to nets. This has been postulated to partially explain the continued efficacy of LLINs against pyrethroid-resistant populations. Burkina Faso is one of a number of countries with very high malaria burdens and pyrethroid-resistant vectors, where progress in controlling this disease has stagnated. We measured the impact of LLIN exposure on mosquito longevity in an area of the country with intense pyrethroid resistance to establish whether pyrethroid exposure was still shortening mosquito lifespan in this setting.

Following single and multiple exposures to a PermaNet 2.0 LLIN only one of the four mosquito populations tested showed evidence of delayed mortality. No delayed mortality was seen in experimental hut studies using LLINs.
CONCLUSIONS: As mosquito pyrethroid-resistance increases in intensity, delayed effects from LLIN exposure are substantially reduced or absent. Given the rapid increase in resistance occurring in malaria vectors across Africa it is important to determine whether the failure of LLINs to shorten mosquito lifespan is now a widespread phenomenon as this will have important implications for the future of this pivotal malaria control tool.

Ivermectin as a novel complementary malaria control tool to reduce incidence and prevalence: a modelling study

Lancet Infect Dis. EPublished 13 Jan 2020

Abstract
Ivermectin is a potential new vector control tool to reduce malaria transmission. Mosquitoes feeding on a bloodmeal containing ivermectin have a reduced lifespan, meaning they are less likely to live long enough to complete sporogony and become infectious. We aimed to estimate the effect of ivermectin on malaria transmission in various scenarios of use.
We estimate that MDA with ivermectin will reduce prevalence and incidence and is most effective in areas with highly seasonal transmission. In a highly seasonal moderate transmission setting, three rounds of ivermectin only MDA at 3 × 300 μg/kg (rounds spaced 1 month apart) and 70% coverage is predicted to reduce clinical incidence by 71% and prevalence by 34%. We predict that adding ivermectin MDA to seasonal malaria chemoprevention in this setting would reduce clinical incidence by an additional 77% in children younger than 5 years compared with seasonal malaria chemoprevention alone; adding ivermectin MDA to MDA with dihydroartemisinin–piperaquine in this setting would reduce incidence by an additional 75% and prevalence by an additional 64% (all ages) compared with MDA with dihydroartemisinin–piperaquine alone.
Interpretation
Our modelling predictions suggest that ivermectin could be a valuable addition to the malaria control toolbox, both in areas with persistently high transmission where existing interventions are insufficient and in areas approaching elimination to prevent resurgence.

For more recent information on Ivermectin and its potential role in malaria prevention check out the ASTMH Journal's Ivermectin Supplement titled *A Roadmap for the Development of Ivermectin as a Complementary Malaria Vector Control Tool*

Preferred resting surfaces of dominant malaria vectors inside different house types in rural south-eastern Tanzania

Malaria Journal Published 15 January 2020

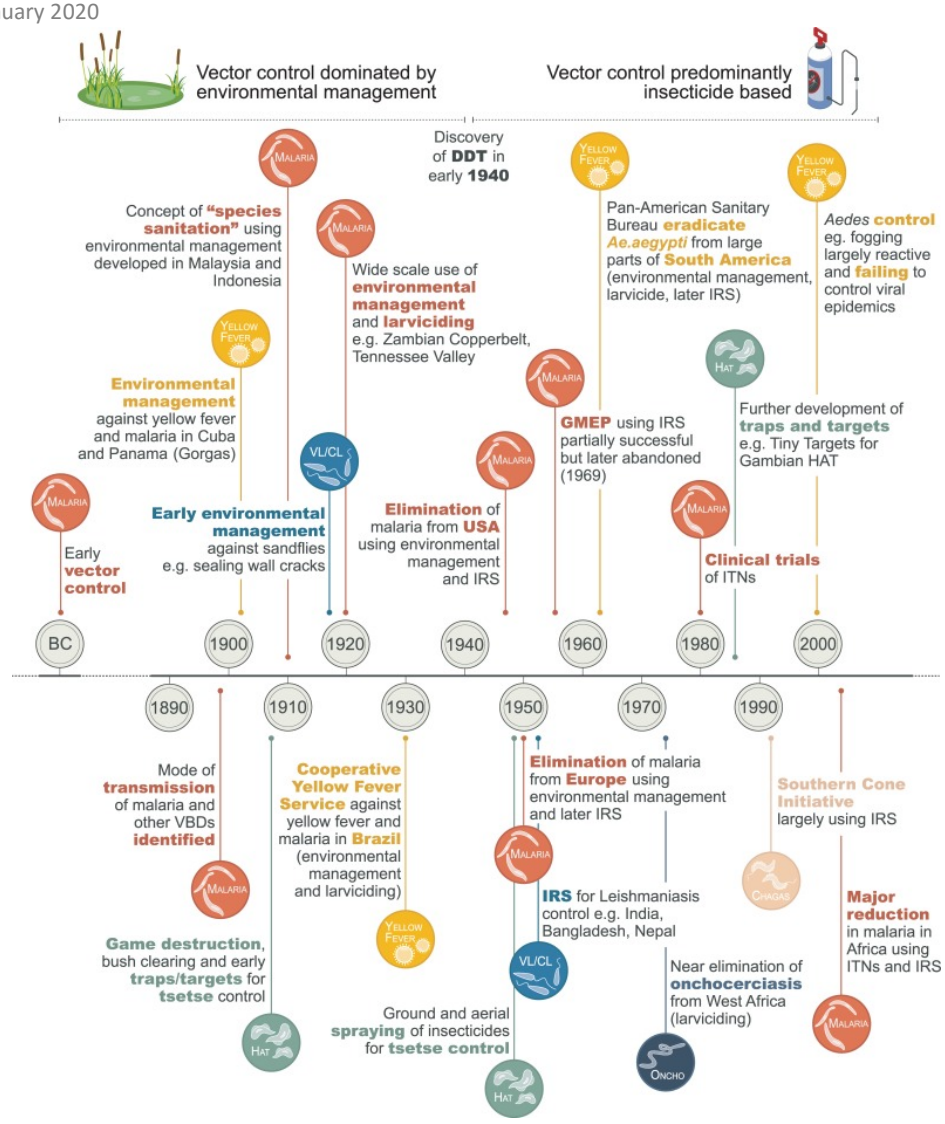
Malaria control in Africa relies extensively on indoor residual spraying (IRS) and insecticide-treated nets (ITNs). IRS typically targets mosquitoes resting on walls, and in few cases, roofs and ceilings, using contact insecticides. Unfortunately, little attention is paid to where malaria vectors actually rest indoors, and how such knowledge could be used to improve IRS. This study investigated preferred resting surfaces of two major

malaria vectors, *Anopheles funestus* and *Anopheles arabiensis*, inside four common house types in rural south-eastern Tanzania. Overall, only 26% of *An. funestus* and 18% of An. arabiensis were found on walls. Considering all data together, approximately 40% of mosquitoes rested on surfaces not typically targeted by IRS, i.e. floors, furniture, utensils, clothing and bed nets. This gap exceeds one-third of malaria mosquitoes in grass-thatched houses and can reach two-thirds in metal-roofed houses. Where field operations exclude roofs during IRS, the gaps can be much greater. In conclusion, there is need for locally-obtained data on mosquito resting behaviours and how these influence the overall impact and costs of IRS.

The importance of vector control for the control and elimination of vector-borne diseases

PLoS Negl Trop Dis. 16 January 2020

This is an excellent historical review which concludes stating that, ***"We cannot afford to wait until new tools and strategies, such as Wolbachia and genetically modified mosquitoes, are available. Instead, we should revisit successful programs from the past and adopt a problem-solving approach that implements tailored vector control solutions drawing upon our entire toolbox of available interventions, including insecticide and non–insecticide-based control methods."***



The authors chart the history of vector control through time from elucidation of the transmission route of VBDs to the present day. Pre-1940 vector control relied heavily on environmental management and larval control based on a thorough understanding of pathogen transmission but was replaced by insecticide-based vector control, often deployed as a monotherapy. The authors call for increased political will and investment in vector control and **a return to locally tailored vector control that draws on the entire toolbox of interventions available.**

We spray and walk away': wall modifications decrease the impact of indoor residual spray campaigns through reductions in post-spray coverage

Malaria Journal Published 17 January 2020

Whilst human attitude and behaviour towards LLINs are well-documented both during and after distribution, only initial coverage is monitored for IRS and in a few geographic settings the residual efficacy of the used product. IRS coverage can decrease rapidly over time as a result of wall modifications post-spraying. Here, the

historical evidence on end-users modifying their wall surfaces post-spraying is presented, a behaviour that has the potential to reduce actual IRS coverage, effectiveness and impact, as fewer people are truly protected. These data underscore the importance of post spray monitoring, public education and IRS products with favourable community acceptance profiles.

Heterodissemination: precision targeting container Aedes mosquitoes with a cohabiting midge species carrying insect growth regulator

Pest Manag Sci. Published: 17 January 2020

Abstract

Management of *Aedes albopictus* and *Ae. aegypti* is challenging in large part due to the cryptic nature of their larval habitats. Autodissemination, using conspecific species to transfer pesticide, is unable to provide proactive control. Here we report results from a new hypothesis, heterodissemination, wherein females of the cohabiting non-biting midge, *Chironomus decorus*, reared in the laboratory, treated with pyriproxyfen, and released to transfer lethal concentrations to shared mosquito larval habitats.

Pyriproxyfen-impregnated oil and powder formulations were developed. The average payload for each female midge treated with oil followed by powder formulations was 5.07 ± 0.92 µg of active ingredient or 1660 times the median lethal concentration (LC50) for *Ae. albopictus* or *Ae. aegypti* in 200 mL of water. Subsequent residue analysis showed pyriproxyfen transference from chironomids, treated with oil formulation only, into water-holding containers up to 2.06 ppb or 171.7 times the LC50. Releasing 20 laboratory reared and contaminated *Chironomus decorus* into a small room resulted in 80.42 ± 0.67% and 75.67 ± 3.14% *Ae. albopictus* pupal mortality in open and cryptic sentinel ovicups, respectively. Container water volumes ranging up to 4 L did not affect efficacy. In a large field cage, 90.3 ± 2.5% *Ae. albopictus* mortality was

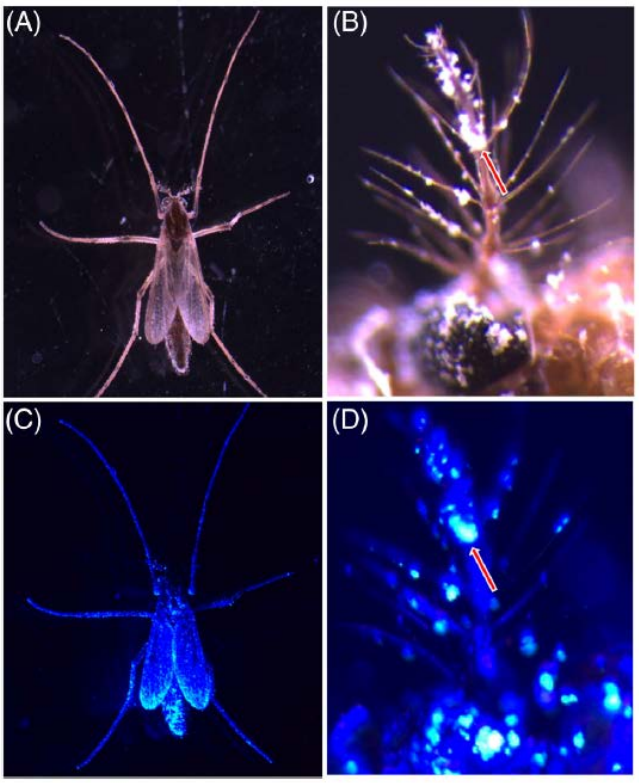


Figure 3 Female chironomid treated with oil-and-powder pyriproxyfen formulations and ultraviolet (UV)-florescent dye. (A) Treated chironomid under normal light. (B) Enlargement of antenna showing attached particles (arrow) under normal light. (C) Treated chironomid under UV light. (D) Enlargement of antenna showing attached particles (arrow) under UV light. More than 94% of particles were in the range of 0.732 to 3.75 µm and, therefore, too small to be visible under stereomicroscopy.

resulted from releasing 100 treated female midges. Releasing 400 contaminated midges into a residential backyard resulted in 74.3% pupal mortality in sentinel ovicups.
CONCLUSIONS: Room, large field cage and field release trials demonstrated that adult midges reared and treated in the laboratory transfer highly lethal concentrations of pyriproxyfen to *Ae. albopictus* container habitats. Heterodissemination provides a potential approach for precision, proactive mosquito control, which may draw attention for further studies.

Geographical distribution of Anopheles stephensi in eastern Ethiopia

Parasites & Vectors Published: 20 January 2020

The recent detection of the South Asian malaria vector *Anopheles stephensi* in Ethiopia and other regions in the Horn of Africa has raised concerns about its potential impact on malaria transmission. We report here the findings of a survey for this species in eastern Ethiopia using both morphological and molecular methods for species identification. Our findings show that *An. stephensi* is widely distributed in eastern Ethiopia and highlight the need for further surveillance in the southern, western and northern parts of the country and throughout the Horn of Africa. Studies are ongoing to evaluate the distribution in the rest of the country and the potential risk for *An. stephensi* to change the malaria transmission landscape in the country and the rest of the African continent. Cross country cooperation and collaborations are needed to effectively address this potential global health concern.

Taking the 'I' out of LLINs: using insecticides in vector control tools other than long-lasting nets to fight malaria.

Malar Journal Published 14 Feb 2020

In the spirit of innovation, this potentially contentious opinion paper is included to stimulate thought and encourage us to think critically about current norms. The authors whether there is a value in nets without insecticide as part of the IVM toolset. They argue that developing long-lasting nets without insecticide(s) can still reduce vector populations and provide both personal and community protection, if combined with other approaches or technologies. Taking the insecticide out of the equation (i) allows for a faster response to the current pyrethroid resistance crisis, (ii) avoids an LLIN-treadmill aimed at replacing failing bed nets due to insecticide resistance, and (iii) permits the utilization of our current and future insecticidal arsenal for other vector control tools to target persistent malaria transmission.

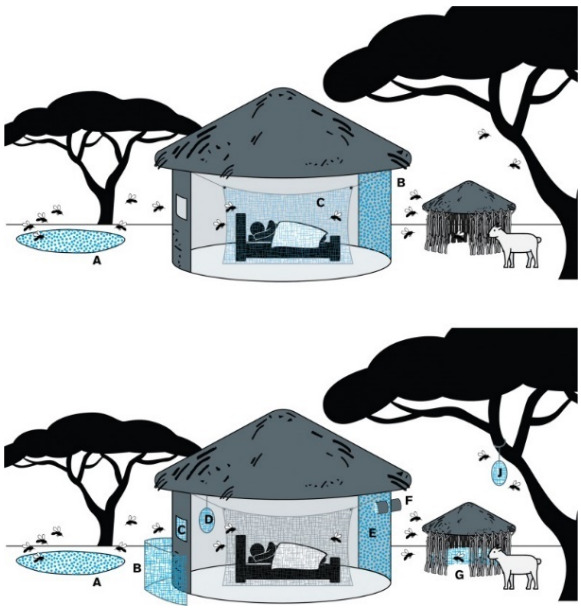


Figure: Top panel: Areas that are currently being targeted with insecticides, which include breeding sites (larvicides a) and inside houses (adulticides on walls b and/or in bed nets c). Bottom panel: Tools that may require insecticides in the future to have an impact. These include, but are not limited to, larvicides (a), barrier screens (b), window/eave screening (c), attractive targeted sugar baits (d, j), IRS (e, g), eave tubes (f), and/or wall liners (e, g)

Large-scale field trial of attractive toxic sugar baits (ATSB) for the control of malaria vector mosquitoes in Mali, West Africa

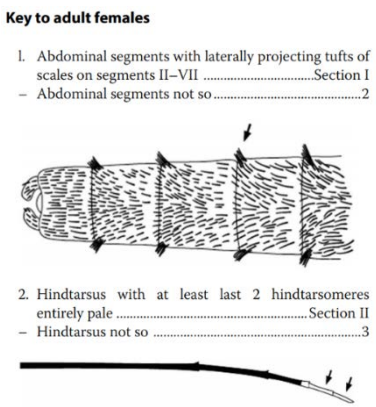
Malaria Journal | Published: 14 February 2020

The aim of this field trial was to evaluate the efficacy of attractive toxic sugar baits (ATSB) in Mali, where sustained malaria transmission occurs despite the use of long-lasting insecticidal nets (LLINs). ATSB bait stations were deployed in seven of 14 similar study villages, where LLINs were already in widespread use. The combined use of ATSB and LLINs was tested to see if it would substantially reduce parasite transmission by *Anopheles gambiae sensu lato* beyond use of LLINs alone. Refer to the paper for the detailed results which, in general, showed that ATSB used against *Anopheles* mosquitoes in Mali drastically reduced the density of

mosquitoes, the number of older females, the number of sporozoite infected females and the EIR demonstrating how ATSB significantly reduces malaria parasite transmission.

Key to the females of Afrotropical Anopheles mosquitoes (Diptera: Culicidae)

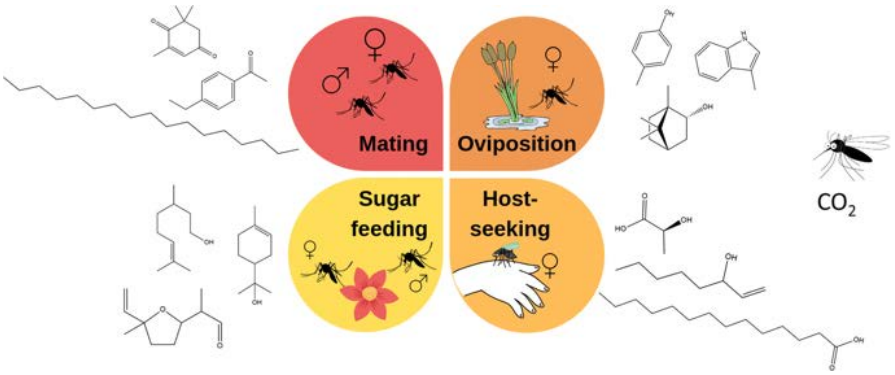
Malaria Journal Published: 13 February 2020



A revised key to adult female *Anopheles* in Africa has been published and can be downloaded from the Malaria Journal.
In 1987, Gillies and Coetzee published a pictorial key for the morphological identification of adult
female mosquitoes of Africa South of the Sahara. Since then, several new species of anopheline mosquitoes have been described and new species described in the literature over the past 32 years have been included. A list of all currently known Afrotropical species is provided. *Anopheles stephensi* is included for the first time as occurring on the African continent.

Controlling mosquitoes with semiochemicals: a review

Parasites & Vectors Published: 17 February 2020



The use of semiochemicals in odour-based traps for surveillance and control of vector mosquitoes is deemed a new and viable component for integrated vector management programmes. Over 114 semiochemicals have been identified, yet implementation of these for management of infectious diseases such as malaria, dengue, chikungunya and Rift Valley fever is still a major challenge. The difficulties arise due to variation in how different mosquito species respond to not only single chemical compounds but also complex chemical blends. Additionally, mosquitoes respond to different volatile blends when they are looking for a mating partner, oviposition sites or a meal. Analytically the challenge lies not only in correctly identifying these semiochemical signals and cues but also in developing formulations that effectively mimic blend ratios that different mosquito species respond to. An overview of the current studies of these chemical messages and the chemical ecology involved in complex behavioural patterns is given. This includes an updated list of the semiochemicals which can be used for integrated vector control management programmes.

Anopheles stephensi as an emerging malaria vector in the Horn of Africa with high susceptibility to Ethiopian Plasmodium vivax and Plasmodium falciparum isolates

bioRxiv Preprint Posted 25 February 2020

Anopheles stephensi, an efficient Asian malaria vector, recently spread into the Horn of Africa and may increase malaria receptivity in African urban areas. We assessed occurrence, genetic complexity, blood meal source and infection status of *An. stephensi* in Awash Sebat Kilo town, Ethiopia. We used membrane feeding assays to assess competence of local *An. stephensi* to *P. vivax* and P. falciparum isolates from clinical patients. 75.3% of the examined waterbodies were infested with *An. stephensi* developmental stages that were genetically closely related to isolates from Djibouti and Pakistan. Both *P. vivax* and *P. falciparum* were detected in wild-caught adult *An. stephensi*. Local *An. stephensi* was more receptive to *P. vivax* compared to a colony of *An. arabiensis*. We conclude that *An. stephensi* is an established vector in this part of Ethiopia, highly

permissive for local *P. vivax* and *P. falciparum* isolates and presents an important new challenge for malaria control.

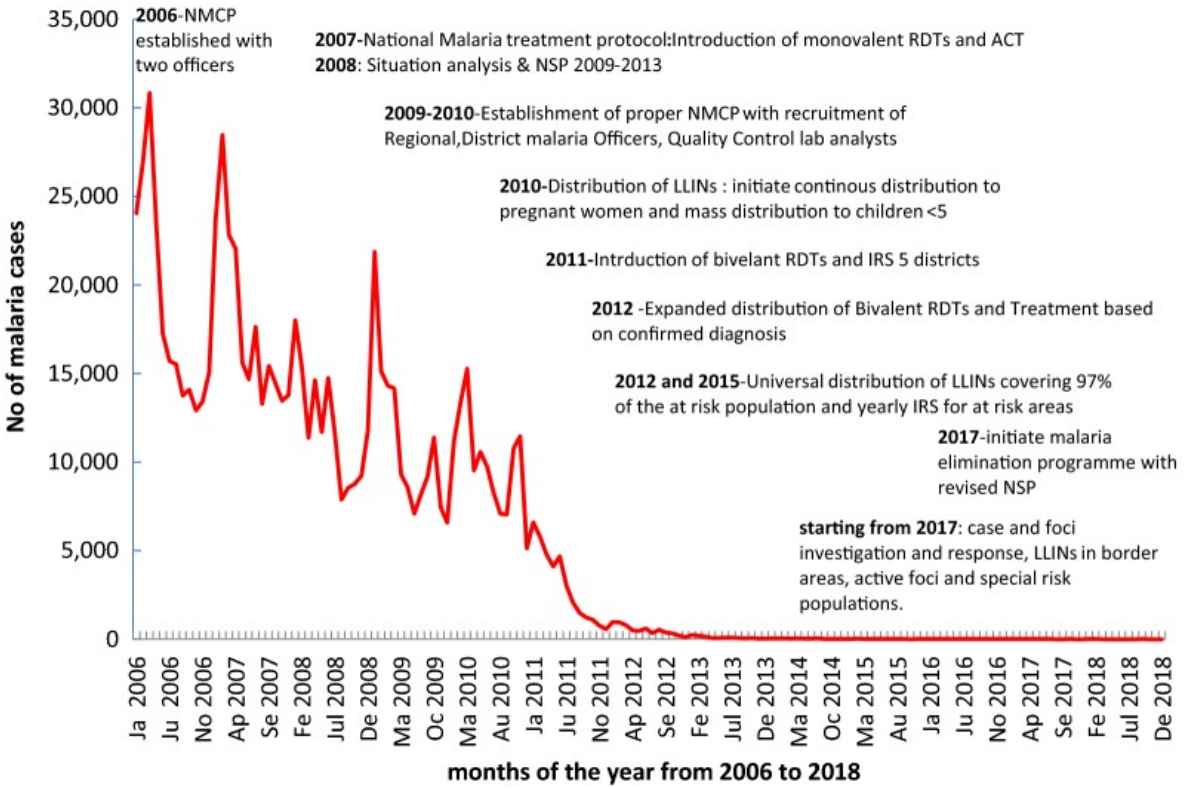
From malaria control to elimination within a decade: lessons learned from Timor Leste, a newly independent country

Malaria Journal Published: 4 March 2020

BACKGROUND: Timor Leste has made remarkable progress from malaria control to malaria elimination in a span of 10 years during which organized malaria control efforts were instituted. The good practices and possible factors that have contributed to the remarkable transition from malaria control to elimination in a newly independent country devastated by civil unrest which left the entire administrative structure including the health sector in a disrupted non-functional state are highlighted.

RESULTS: With the setting up of the NMCP just after independence in 2003 with two officers, the programme expanded over the years and strategic malaria control activities in an organized manner commenced in 2009 with funding from the Global Fund. The incidence of malaria declined dramatically from 223,002 cases in 2006 with the last indigenous case being reported in June 2017. The decline in malaria was associated with strategic application of key evidence-based interventions taking into account the burden of disease, characteristics of vectors, and stratification of risk areas ensuring universal access to malaria prevention, and quality assured diagnostic tools and effective anti-malarial medicines at point of care, intensified surveillance, monitoring and evaluation, and capacity building, including training of staff, with adequate programme funding. The incorporation of the malaria control programme within an evolving health system helped the transition from malaria control to malaria elimination.

CONCLUSION: Universal access to quality assured malaria diagnosis and treatment and focussed vector control, implemented throughout the country in an organized manner with adequate funding and political commitment were key to the successful interruption of malaria transmission in the country. All the practices or factors listed did not work in isolation but rather synergistically in an integrated manner. Malaria elimination is possible even in tropical areas of South and Southeast Asia.



Updated list of Anopheles species (Diptera: Culicidae) by country in the Afrotropical Region and associated islands

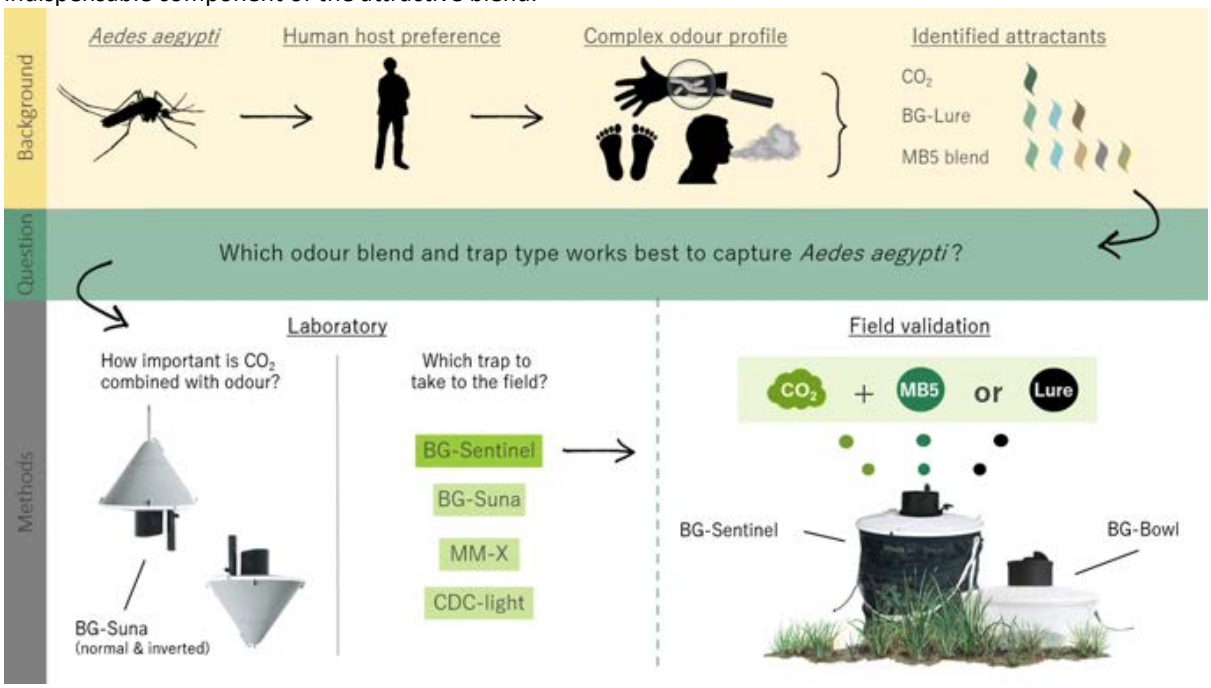
Zootaxa Published: 4 March 2020

The distributions of the Afrotropical *Anopheles* mosquitoes were first summarized in 1938. In 2017, an extensive geo-coded inventory was published for 48 sub-Saharan African countries, including information such as sampling methods, collection dates, geographic co-ordinates and the literature consulted to produce the database. Using the information from the 2017 inventory, earlier distribution lists, museum collections and publications since 2016, this paper presents an updated, simplified list of *Anopheles* species by mainland countries and associated Afrotropical islands, with comments where applicable. It is intended as a supplement to the 2017 geo-coded inventory.

Optimisation and field validation of odour-baited traps for surveillance of Aedes aegypti adults in Paramaribo, Suriname

Parasites & Vectors Published: 6 March 2020

Blends of human-like synthetic chemical attractants can be used to attract host-seeking mosquitoes. The aim of this study was to test new combinations of traps and odour baits in the laboratory, followed by testing the best candidates in the field to improve *Ae. aegypti* monitoring and surveillance. First, the BG-Suna trap was evaluated for capturing laboratory-reared Ae. aegypti by testing normal and inverted positions in screen cage tests. Secondly, the attractiveness of the MB5 blend, CO2, and their combination was tested. Thirdly, we tested the attractiveness of different trap types (BG-Suna, BG-Sentinel, MM-X and CDC light trap). Finally, we confirmed laboratory results in the field in Paramaribo, Suriname, using the MB5 and BG-Lure odour blends, CO2 and the BG-Sentinel and BG-Bowl trap using a Latin Square design. Our study demonstrated that the BG-Sentinel trap baited with the MB5 blend and CO2 outperforms the current golden standard (BG-Sentinel trap with BG-Lure) for monitoring Ae. aegypti females and males, in both laboratory and field experiments. The BG-Bowl baited with the MB5 blend is a good candidate for home use. Finally, the results show that CO2 is an indispensable component of the attractive blend.



Creating mosquito-free outdoor spaces using transfluthrin-treated chairs and ribbons

Malaria Journal Published: 11 March 2020

This study characterized common peri-domestic spaces in rural south-eastern Tanzania, and assessed protective efficacy against mosquitoes of hessian fabric mats and ribbons treated with the spatial repellent, transfluthrin, and fitted to chairs and outdoor kitchens, respectively. Approximately half (52%) of houses had verandas. Aside from these verandas, most houses also had peri-domestic spaces where residents stayed most times. The outdoor structures were usually makeshift kitchens having roofs and partial walls. Transfluthrin-

treated chairs reduced outdoor-biting *An. arabiensis* densities by 70–85%, while transfluthrin-treated hessian ribbons fitted to the outdoor kitchens caused 77–81% reduction in the general peri-domestic area. Almost all the field-collected *An. arabiensis* (99.4%) and *An. funestus* (100%) exposed under transfluthrin-treated chairs died. The *An. arabiensis* were susceptible to non-pyrethroids (pirimiphos methyl and bendiocarb), but resistant to pyrethroids commonly used on LLINs (deltamethrin and permethrin).

Cytochrome P450 metabolic resistance (CYP6P9a) to pyrethroids imposes a fitness cost in the major African malaria vector Anopheles funestus

Heredity Epub available: 10 March 2020

IRM strategies such as rotation of insecticide classes, rely on resistance alleles having a fitness cost inducing a selection against resistance alleles in the absence of insecticide selection pressure. Therefore, understanding the fitness cost that selection can act against mosquitoes is a key pre-requisite to effective IRM. This study has investigated the fitness cost of P450-based metabolic resistance to pyrethroids in a major malaria vector revealing significant fitness cost for fecundity, fertility and the larval development of resistant mosquitoes. This fitness cost was further supported by the observation of a return to susceptibility in the absence of insecticide over ten generations (around 1 year) showing that if suitable resistance management strategies such as rotation was implemented, P450-based resistance could be managed. This should encourage future strategies using non-pyrethroid-based LLINs to reduce the selection pressure and allow such rotation to slow the spread of pyrethroid resistance.

Impact of indoor residual spraying with pirimiphos-methyl (Actellic 300CS) on entomological indicators of transmission and malaria case burden in Migori County, western Kenya

Sci Rep. Published 11 March 2020

Indoor residual spraying (IRS) of insecticides is a major vector control strategy for malaria prevention. We evaluated the impact of a single round of IRS with the organophosphate, pirimiphos-methyl (Actellic 300CS), on entomological and parasitological parameters of malaria in Migori County, western Kenya in 2017, in an area where primary vectors are resistant to pyrethroids but susceptible to the IRS compound. Malaria case burden data were extracted from laboratory records of four health facilities within the sprayed area and two adjacent unsprayed areas. IRS was associated with reductions in *An. funestus* numbers in the intervention areas compared to non-intervention areas by 88% with light traps (risk ratio [RR] 0.12, 95% CI 0.07-0.21, $p < 0.001$) and 93% with PSC collections (RR = 0.07, 0.03-0.17, $p < 0.001$). The corresponding reductions in the numbers of *An. arabiensis* collected by PSC were 69% in the intervention compared to the non-intervention areas (RR = 0.31, 0.14-0.68, $p = 0.006$), but there was no significant difference with light traps (RR = 0.45, 0.21-0.96, $p = 0.05$). Before IRS, *An. funestus* accounted for over 80% of *Anopheles* mosquitoes collected by light trap and PSC in all sites. After IRS, *An. arabiensis* accounted for 86% of *Anopheles* collected by PSC and 66% by CDC light trap in the sprayed sites while the proportion in non-intervention sites remained unchanged. No sporozoite infections were detected in intervention areas after IRS and biting rates by *An. funestus* were reduced to near zero. *Anopheles funestus* and *An. arabiensis* were fully susceptible to pirimiphos-methyl and resistant to pyrethroids. The residual effect of Actellic 300CS lasted ten months on mud and concrete walls. Malaria case counts among febrile patients within IRS areas was lower post- compared to pre-IRS by 44%, 65% and 47% in Rongo, Uriri and Nyatike health facilities respectively. A single application of IRS with Actellic 300CS in Migori County provided ten months protection and resulted in the near elimination of the primary malaria vector *An. funestus* and a corresponding reduction of malaria case count among out-patients. The impact was less on *An. arabiensis*, most likely due to their exophilic nature.

Ability of near-infrared spectroscopy and chemometrics to predict the age of mosquitoes reared under different conditions

Parasites & Vectors Published: 30 March 2020

Practical, field-ready age-grading tools for mosquito vectors of disease are urgently needed because of the impact that daily survival has on vectorial capacity. Previous studies have shown that near-infrared spectroscopy (NIRS), in combination with chemometrics and predictive modeling, can forecast the age of laboratory-reared mosquitoes with moderate to high accuracy. It remains unclear whether the technique has utility for identifying shifts in the age structure of wild-caught mosquitoes. Here we investigate whether models derived from the laboratory strain of mosquitoes can be used to predict the age of mosquitoes grown

from pupae collected in the field. **Models derived with laboratory mosquitoes could not differentiate between field-derived age groups, with age predictions relatively indistinguishable for day 1–14**. Principal components analysis confirms substantial spectral variations between laboratory and field-derived mosquitoes despite both originating from the same island population. This study suggests that laboratory-reared mosquitoes do not capture enough environmental variation to accurately predict the age of the same species reared under different conditions.

District-level Approach for Tailoring and Targeting Interventions: A New Path for Malaria Control and Elimination

Malaria Journal Published: 30 March 2020

Despite huge investments and implementation of effective interventions for malaria, progress has stalled, with transmission being increasingly localized among difficult-to-reach populations and outdoor-biting vectors. Targeting difficult pockets of transmission will require the development of tailored and targeted approaches suited to local context, drawing from insights close to the frontlines. Districts are best placed to develop tailored, locally appropriate approaches. We propose a reorganization of how malaria services are delivered. Firstly, enabling district health officers to serve as conduits between technical experts in national malaria control programmes and local community leaders with knowledge specific to local, at-risk populations; secondly, empowering district health teams to make malaria control decisions. This is a radical shift that requires the national programme to cede some control. Shifting towards a district or provincial level approach will necessitate deliberate planning, and repeated, careful assessment, starting with piloting and learning through experience. Donors will need to alter current practice, allowing for flexible funding to be controlled at sub-national levels, and to mix finances between case management, vector control and surveillance, monitoring and evaluation. System-wide changes proposed are challenging but may be necessary to overcome stalled progress in malaria control and elimination and introduce targeted interventions tailored to the needs of diverse malaria affected populations.

Note: The authors' thesis is nicely alingned with the WHO's *Global Vector Control Response 2017-2030* which emphasizes the need for "*effective **locally adapted** sustainable vector control.*"

Wide Area Spray of Bacterial Larvicide, Bacillus Thuringiensis Israelensis Strain AM65-52, Integrated in the National Vector Control Program Impacts Dengue Transmission in an Urban Township in Sibu District, Sarawak, Malaysia

PLoS One Published: 1 April 2020

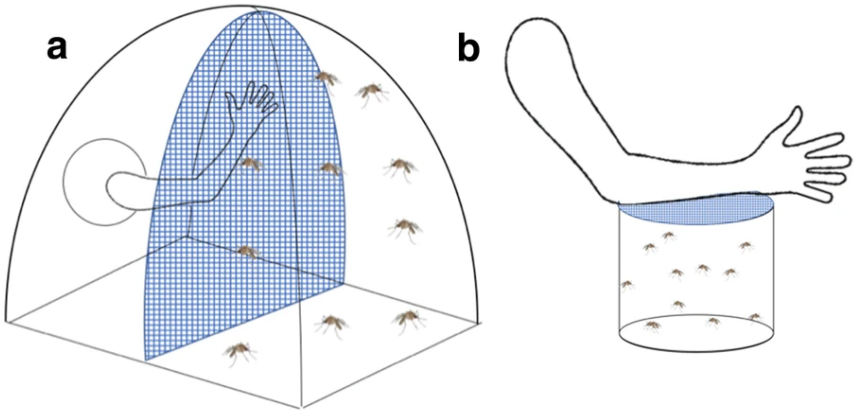
Several sites in Sibu district, Sarawak, Malaysia, experienced intense dengue transmission in 2014 that continued into 2015. This paper reports on an operational pilot study conducted in 2015 in an area with high density of dengue paper and also reports the integration of wide area spray application of VectoBac WG into routine operational dengue control program activities in 2016 and its impact on dengue transmission.

Use of alternative bioassays to explore the impact of pyrethroid resistance on LLIN efficacy

Parasites & Vectors Published: 7 April 2020

Current understanding of the distribution of resistance derives from extensive use of the standardized WHO discriminating dose assay. This standard assay exposes young, unfed female mosquitoes to a diagnostic insecticide dose in a single, forced exposure, whereas in the field, mosquitoes vary in their age, blood-feeding status, and the frequency or intensity of LLIN exposure. These more realistic conditions could ultimately impact the capacity of "resistant" mosquitoes to transmit malaria. The authors present results using two different assays that allow female mosquitoes to contact a LLIN as they host-seek and blood-feed. They quantified mortality after both single and multiple exposures, using seven different strains of *Anopheles* ranging in pyrethroid resistance intensity. They found that strains classified as 1×-resistant to the pyrethroid insecticide deltamethrin in the standard WHO assay exhibited > 90% mortality over 24 h following more realistic LLIN contact. Mosquitoes that were able to blood-feed had increased survival compared to their unfed counterparts, but none of the 1×-resistant strains survived for 12 days post-exposure (the typical period for malaria parasite development within the mosquito). Mosquitoes that were 5×- and 10×-resistant (i.e. moderate or high intensity resistance based on the WHO assays) survived a single LLIN exposure well. However, only about 2–3% of these mosquitoes survived multiple exposures over the course of 12 days and

successfully blood-fed during the last exposure. These results suggest that the standard assays provide limited insight into how resistance might impact LLIN efficacy.



Experimental setup. **a** Experiment 1, the "tent" assay: a Permanet 2.0 divided a BugDorm2120 Insect Rearing Tent into two sections. A human host placed her arm inside of the tent and pressed it against the net, allowing mosquitoes on the other side of the net to obtain a bloodmeal through the net. **b** Experiment 2, the "cup" assay: a 16oz paper cup was covered with a Permanet 2.0. Mosquitoes were released into the cup through a small hole in the net, and the human host placed her arm on top of the net, allowing mosquitoes to obtain a blood meal through the net

Control of malaria vectors and management of insecticide resistance through universal coverage with next-generation insecticide-treated nets

Lancet 15 April 2020

In this *Viewpoint,* Gerry Killeen presents a number of arguments regarding development and deployment of next generation ITNs. Among them, he argues a case for prioritising durability over affordability; product diversity over efficacy; vector lethality over coverage and timely recommendations for new products over evidence-based certainty. Throughout the paper he emphasizes the importance of proactive resistance prevention and suggests that deploying diversified product groups for the pre-emptive management of insecticide resistance over the long term might be more important than maximising the coverage or effect immediately achievable with any single product.

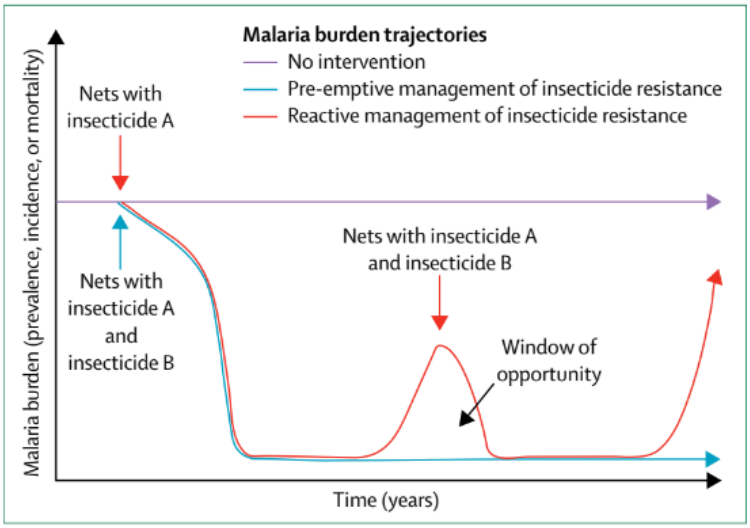
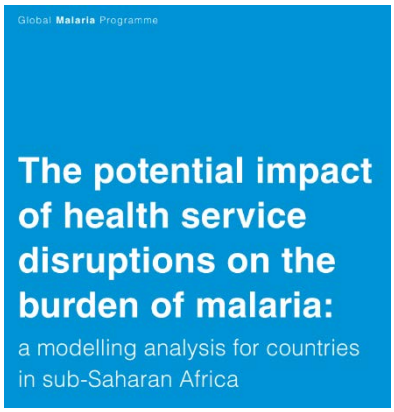


Figure 4: **An illustration of the trajectories of malaria burden expected in an experimentally controlled study comparing no intervention, pre-emptive management of insecticide resistance, and reactive management of insecticide resistance**

The black arrow represents a window of opportunity to show the superiority of pre-emptive management of insecticide resistance, but only after resistance has emerged in the study group randomly assigned to reactive management.

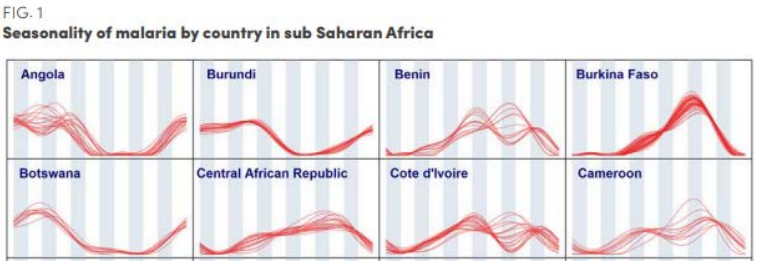
WHO News and Publications

News



The potential impact of health service disruptions on the burden of malaria: a modelling analysis for countries in sub-Saharan Africa

This document has some very interesting information based on work from the Malaria Atlas Project and PATH including country specific predications and a graphic of modelled seasonality of malaria by country in Africa.



Malaria-Related Deaths Could Double In Africa This Year Amid COVID-19 Pandemic, WHO Warns Ahead Of World Malaria Day

The Guardian: Pandemic could 'turn back the clock' 20 years on malaria deaths, warns WHO
"Deaths from malaria could double across sub-Saharan Africa this year if work to prevent the disease is disrupted by Covid-19, the World Health Organization has warned. The U.N.'s global health agency said that if countries failed to maintain delivery of insecticide-treated nets and access to antimalarial medicines, up to 769,000 people could die of malaria this year. That figure, which would be more than double the number of deaths in 2018, would mark a return to mortality levels last seen 20 years ago..."

Notice of intent to modify the classification of ITN products and associated evaluation procedures

In case you missed it, the WHO is planning to revise the classification of insecticide-treated nets (ITNs) communicated in 2017, with a view of providing a clear link between the currently known entomological effects of ITNs and their evaluation. Interested parties were invited to provide their comments in February 2020. All related information is available on the website at the following link:
https://www.who.int/malaria/news/2020/notice-of-intent-classification-of-itn-products/en/

New version of Malaria Threats Map released with new maps to guide the deployment of pyrethroid-PBO nets

Malaria Threats Map has bene revamped. The latest release, launched in January 2020 includes maps highlighting sites were local vector populations meet the WHO-recommended criteria for the deployment of pyrethroid-PBO nets. These maps are based on data from the WHO global database on insecticide resistance in malaria vectors, which collates data for 89 countries and more than 4400 geographical locations worldwide.

VCAG membership

The Vector Control Advisory Group (VCAG) has two new members: Alfred B. Tiono and Mamadou B. Coulibaly and is issued a recent call for epidemiologists, with experience in study design and statistics.

WHO PUBLICATIONS

Malaria eradication: benefits, future scenarios & feasibility

A report of the Strategic Advisory Group on Malaria Eradication
20 April 2020

After a 3-year study of trends and future projects, WHO's Strategic Advisory Group on Malaria Eradication has released a detailed report of its key findings and recommendations. The report builds on an executive summary published in August 2019. Members of the advisory group highlight 6 areas in the report that would underpin a successful malaria eradication effort:

1. reinforcing the Global technical strategy for malaria 2016-2030;
2. research & development for new tools;
3. access to affordable, high quality, people-centered health care and services;
4. adequate and sustained financing;
5. strengthened surveillance and response; and
6. engaging communities.

Q&A on new types of insecticide-treated nets

Over the last few years, colleagues in GMP's entomology and vector control unit have received a number of queries from country-based stakeholders on new types of insecticide-treated nets. They have compiled responses to the following questions in a Q&A document on the website:

- Which types of insecticide-treated nets (ITNs) does WHO consider to be 'new types'?
- Why do WHO guidelines use both the terms long-lasting insecticidal nets (LLINs) and insecticide-treated nets (ITNs)?
- How do these new types of ITNs differ from the traditional pyrethroid-only LLINs?
- Are new types of ITNs more effective than pyrethroid-only LLINs?
- Are all pyrethroid-PBO nets the same?
- Are new types of ITNs more expensive than pyrethroid-only LLINs?
- In the context of new types of ITNs, what is the difference between a net being prequalified by WHO and a net having an associated specific WHO policy recommendation?
- Interceptor® G2 and Royal Guard® are not covered by a specific WHO policy recommendation – what does this mean in practice?
- When should a country consider purchasing a new type of ITN?
- Is there a specific threshold at which pyrethroid-only LLINs fail to work? Is there a specific pyrethroid-resistance threshold at which a switch to a new type of ITN is recommended by WHO?
- What is the scale-back strategy in the event that new types of ITNs not currently covered by WHO policy recommendations fail to demonstrate public health value?
- What messages should the national malaria control programme communicate with respect to new types of ITNs to communities and authorities in malaria-endemic areas?
- What is the Unitaid/Global Fund 'New Nets Project'?

This Q&A is intended as a "living" document that will be updated periodically in the coming months and years, and that will inform updates to WHO's *Guidelines on malaria vector control*. Please send your feedback and questions to vcguidelines@who.int.

Generic risk assessment models for insecticide-treated clothing, skin-applied repellents and household insecticides

Global situation of pesticide management in agriculture and public health. Report of a 2018 WHO–FAO survey

Guidelines for personal protection when handling and applying pesticides

Detoxifying agriculture and health from highly hazardous pesticides A call for action

11th VCAG meeting report

This report details the proceedings and outcomes of the meeting, including advice provided to the following applicants: endectocides, lethal house lures, piperonyl butoxide-impregnated nets, spatial repellents and *Wolbachia* suppression.

The safety and applicability of synthetic pyrethroid insecticides for aircraft disinsection: A systematic review. Travel Medicine and Infectious Disease

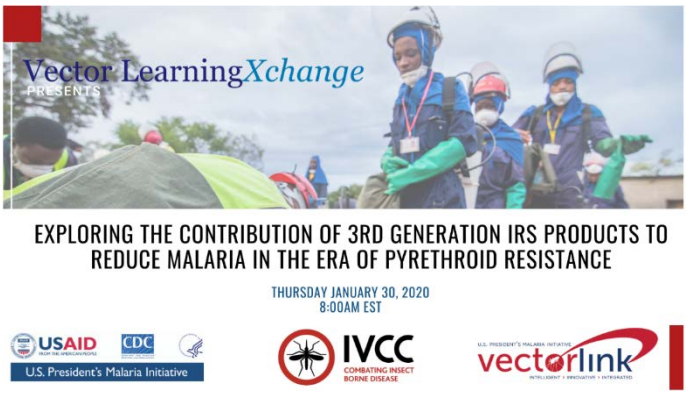
Useful websites and resources

Key to the females of Afrotropical Anopheles mosquitoes (Diptera: Culicidae)

Malaria Journal Published: 13 February 2020

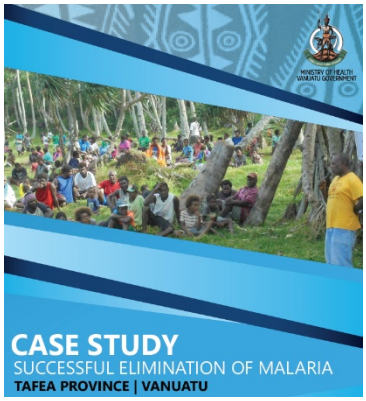
A revised key to adult female *Anopheles* in Africa has been published and can be downloaded from the Malaria Journal.

In 1987, Gillies and Coetzee published a pictorial key for the morphological identification of adult female mosquitoes of Africa South of the Sahara. Since then, several new species of anopheline mosquitoes have been described and new species described in the literature over the past 32 years have been included. A list of all currently known Afrotropical species is provided. *Anopheles stephensi* is included for the first time as occurring on the African continent.



NgenIRS webinar

The NgenIRS partnership has completed four years of work to improve access to the most effective, long-lasting IRS products. The Vector LearningXchange hosted a recent webinar during which representatives from the NgenIRS partnership discussed the role of 3rd generation IRS products in reducing malaria in light of increasing pyrethroid resistance. ***The recorded webinar can be accessed here***



CASE STUDY SUCCESSFUL ELIMINATION OF MALARIA: TAFEA PROVINCE | VANUATU

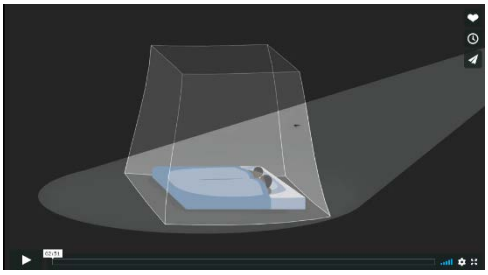
Key Messages

- A malaria-free Vanuatu is within reach
- Malaria plummeted in Vanuatu from over 15,000 cases in 2003 to 644 cases in 2018.
- The southern province of Tafea was declared malaria-free in November 2017. This was achieved through the distribution of treated nets, indoor residual spraying, rapid diagnosis and appropriate treatment of confirmed malaria cases, and community engagement and support.

- Due to good progress, national elimination goals will be shifted two years earlier.
- The aim is for zero monthly reported local malaria cases by December 2023.
- Certification of malaria-free status is anticipated three years later, by the end of 2026.

Inside and Out: Building Advice for Vector-Borne Disease Prevention

Here is a nice video from the *BOVA network* showing how to protect houses from mosquitoes that carry both malaria and dengue and remove potential breeding sites from the surroundings.



PIIVeC
Partnership for Increasing the Impact of Vector Control
Partenariat pour accroitre l'impact de la lutte antivectorielle

The PIIVec partnership has published a document titled *Evidence to inform how new bed nets can be used to prevent malaria in Malawi*. The purpose of the policy brief was to:

1. Contextualise the evidence to the malaria situation in Malawi
2. Raise the profile of a hut study measuring the entomological impact of IG2 nets in Malawi.

Vector Control in Humanitarian Emergencies

Forcibly displaced persons now total more than 70.8 million; many at increased risk for vector-borne diseases: malaria throughout much of Africa, leishmaniasis in Syria, dengue in Yemen. The RBM VCWG hosts an initiative to facilitate innovative but practical steps to address vector control in these populations of such great need. The group has published a list of recommended action points under these two topics:

1. Improve use of existing vector and surveillance tools
2. Facilitate the development, approval and deployment of new vector control tools

Recent and upcoming events of note

The *15th RBM Vector Control Working Group (VCWG)* meeting was held in February. The *final report* is now available and the following presentations are now available online.

Plenary session
IRS IRM Priorities
LLIN Priorities
Larval Source Management
New Tools, New Challenges in Vector Control
IVM, Evidence and Capacity
VBDs and Built Environment

Following the 2020 RBM VCWG annual meeting, MESA has updated the MESA Track database to reflect the new research presented at the meeting. Presenters are kindly asked to check the information is correct at http://www.mesamalaria.org/mesa-track?researchInstitution=8626

VCWG members who did not present at the annual meeting can make sure that the malaria research they are leading is in the MESA Track database by searching for their name here https://mesamalaria.org/index.php/mesa-track

Contact Maria about any missing projects or information at maria.tusell@isglobal.org

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The following are all pending, subject to COVID-19 related changes:

- ***Science of Eradication: Malaria*** 21-26 Jun 2020, Basel Switzerland
- ***Kigali Summit on Malaria & NTDs*** A high-level Global Summit on Malaria and NTDs, hosted by the Government of Rwanda, on the eve of the Commonwealth Heads of Government Meeting 2020 25 June 2020
- ***3rd BOVA Open Network Meeting/*** UN-Habitat IG-UTP symposium; 14-17 September 2020, Mohammed VI Polytechnic University, Benguerir, Morroco
- ***The 20th International Congress for Tropical Medicine and Malaria (ICTMM)*** 20-24 Sep 2020, Bangkok, Thailand
- ***The 69th American Society of Tropical Medicine and Hygiene (ASTMH) Annual Meeting*** Toronto, Canada on November 15 - 19
- Note that the 7th Pan - African Mosquito Control Association (PAMCA) Annual Conference has been postponed until a date in 2021

A special issue of the Journal Insects in tribute to Professor William (Bill) Black

In honor of our respected colleague, Bill Black, a special collection has been organized through the Journal, *Insects*. Bill has significantly impacted the field of medical entomology over the years through his extensive research on ticks and mosquitoes, as well as his dedication to teaching and mentoring. Click here for a complete description of the collection and scope of articles sought. The deadline for submission is Dec 31, 2020.
Questions or ideas regarding a potential submission can be directed to Rebekah C. Kading, PhD at Rebekah.Kading@colostate.edu

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In the news and social media

Although outside the scope of vector control and malaria, I included this news headline as a follow from the last issue *Africa threatened with severe food crisis as locust 'mega-swarms' devour crops* 26 Jan 2020

Coronavirus in Africa: Locusts add to food security concerns
BBC 23 Apr 2020

At a time when the world is fighting the coronavirus pandemic, a number of countries in Africa are also battling locust swarms which are destroying crops. The president of the African Development Bank, Akinwumi Adesina, says that financial grants aim to help those countries in their two-fold fight against food insecurity.
"We can't afford that Covid-19 leads to another food crisis caused by Locust-19", the ADB president says. Qu Dongyu, FAO director-general, said that desert locust storms were growing exponentially, warning: "Without rapid action, we will be facing a rapidly expanding humanitarian crisis."

You can listen to *the BBC Radio Forum programme 'Man vs Mosquito'* broadcasted on 20 February 2020. This general broadcast is very interesting and covers numerous topics which will appeal to a wide range of people including those of you who are not entomologists. Joining Bridget Kendall to discuss the history of man and the mosquito are Dr. Erica McAlister, Senior Curator of Diptera - Flies - at the Natural History Museum in London; Dr. Timothy Winegard, historian and author of The Mosquito: A Human History of our Deadliest Predator; and Dr. Clifford Mutero of the International Centre for Insect Physiology and Ecology (ICIPE) in Nairobi, Kenya, and author of Mosquito Hunter: Chronicles of an African Insect Scientist.

Is the insect apocalypse really upon us? It's complicated, say researchers

Several recent reports have warned of a crushing decline in insect populations that could have a catastrophic effect on our environment and food supply. However, a new study that's been described as the largest and most comprehensive assessment to date of insect and arachnid populations paints a much more nuanced picture. It suggested that while some might be in peril, an insect apocalypse isn't upon us quite yet.

Note this issue covers the January through March 2020 although a few topics from early April have been included in this update.