

When is it safe for malaria control and elimination programs to scale back vector control?

Yukich, Chitnis and Mnzava

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# When is it safe for malaria control and elimination programs to scale back vector control?

## Literature Review and Simulation Study

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- Universal coverage with vector control a costly (but effective) activity.
- Can transmission and burden reductions be maintained, even in the absence, or reduction, of vector control?
- Consultations during Global Technical Strategy development made clear the need for guidance to countries.



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- 1 Are there situations in which reduction in coverage of vector control activities will *not* result in resurgent transmission?
- 2 What set of indicators is necessary to identify locations and times this might be safely undertaken?
- 3 What is the impact of the precision and bias associated with these measurements on estimates of the risk of resurgence?
- 4 What sets of measurements of these indicators would indicate that reductions in malaria vector control could be safely undertaken?



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Overarching Literature Review  
Precision and Bias Monte Carlo Simulation  
Malaria Transmission OpenMalaria  
Emulation Logistic Regression



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- Searched Published and gray literature electronically for vector control “graduation” — “withdraw”, “consolidation phase”, “resurgence” and other related topics.
- Many observational studies on “resurgence”
- Few controlled studies
- No randomized control trials completed but one currently underway, in South Africa (*Pers. com.*, Immo Kleinschmidt).



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- Resurgence reviewed in Cohen *et al.* systematic review of the published and gray literature to identify events of malaria resurgence.
- Reductions in funding most common cited reason for weakening of control program in question (49%). They state that:

*Reasons for funding reductions or cessation were not clear for all events, but in several, donors appear to have reallocated funding specifically **because** successful reductions in malaria burden had occurred (Emphasis Ours)*

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- Other studies *e.g.*, Zambia and Benin shown that withdraw or relaxation of vector control efforts can lead, over short time periods, to resurgences in malaria prevalence, clinical incidence and transmission.
- Cohen *et al.* review is basically a case series
- Unfortunately few "controls" were found
- Best examples come from elimination settings



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- One controlled study of withdrawal of vector control.
- Low transmission area – zoophilic vectors,
- Indoor residual spraying (IRS) with deltamethrin for 3 years at high intensity
- Withdrawn after annual parasite index (API) fell by nearly 90% to below one per 10,000 per year and follow-up studies were conducted over a period of 10 years.
- API & sporozoite positive rate (SPR) returned to levels comparable to an unsprayed control area by the end of study
- Nearly ten years of follow up.

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- During the Global Malaria Eradication Program (GMEP), transition from the “attack” to “consolidation” program phases.
- Initially, local API  $< 5$  per 10,000 per annum and human (annual) blood examination rate (H(A)BER)  $> 10\%$
- Later revised to  $< 1$  per 10,000 per annum.



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- Infection Importation Rate
- Annual Blood Examination Rate
- EIR (pre-intervention)
- Annual Parasite Incidence

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- Infection Importation Rate (IIR)
  - Number of importations weekly:  $N \sim \text{Poisson}(\text{True IIR})$
  - Observation  $\sim \text{Binomial}(N, p)$
  - One year period (52 weeks) for 10,000 iterations



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- Varied true IIRs (from 1 per 1,000 persons per annum to 5 per 1,000 persons per annum) and detection rates (from 20% to 80%).
- Tested a threshold of 2 per 1,000 per annum exact Poisson test with  $\geq 90\%$  confidence.
- Applied logistic regression to estimate the predicted probability of concluding that IIR (based on the measurement) was below the threshold.



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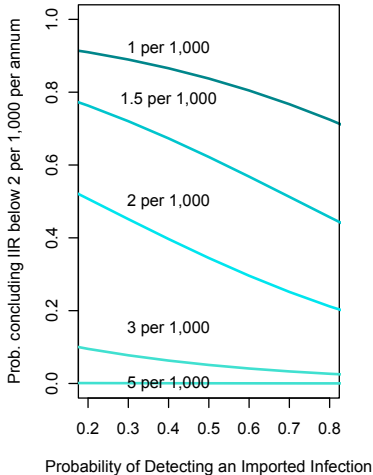
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- Better detection implies that bias in determining IIR is low will be very conservative
- Danger of concluding this is low due to a poor surveillance system and misclassification



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- Annual Blood Examination Rate

- Divergence between ABER and the total proportion of a population tested
- Simulated a cohort with either independent probabilities of being tested in each round or without independence
- Non-independent probability:  $p_i \sim \text{Beta}(\alpha, \beta)$
- Testing in one round:  $p_{ij} \sim \text{Bernoulli}(p_i)$



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- The annual blood examination rate was calculated as

$$ABER = \frac{\text{Number of Tests Conducted}}{\text{Person-Years}} \quad (1)$$

- The proportion of the population actually tested was calculated as

$$PT = \frac{\text{Number of Individuals Tested}}{\text{Person-Years}} \quad (2)$$



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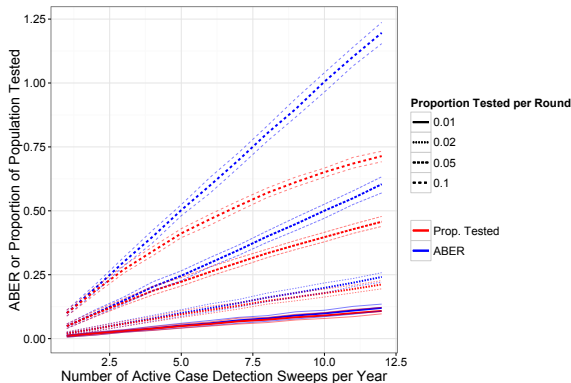


Figure: Simulation Results for Measurement of the Annual Blood Examination Rate

- ABER and the proportion tested by a surveillance system diverge at high values
- At low levels ABER is likely to be a reliable metric for the monitoring surveillance system coverage

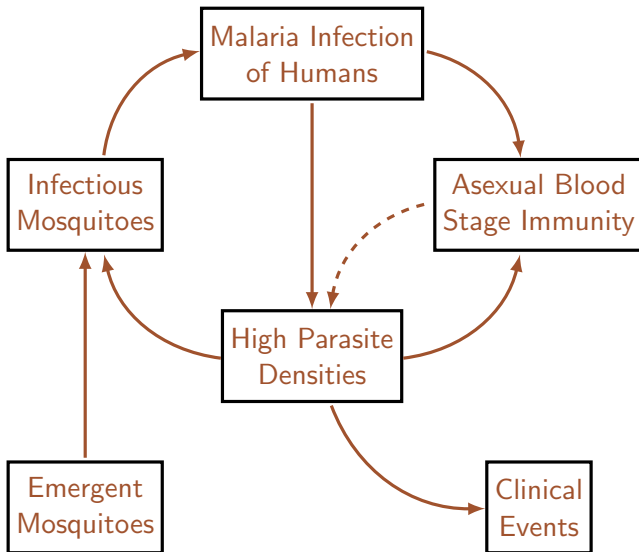


Figure: Schematic of the malaria transmission model

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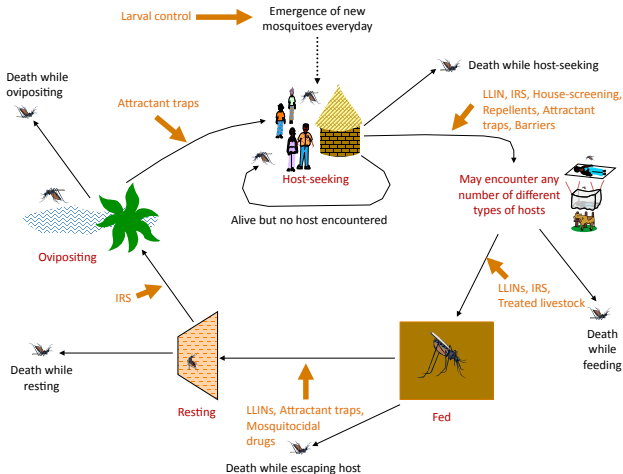
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**Figure:** Schematic of mosquito feeding cycle dynamics including the effects of interventions.



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VC: Vector control

AS: Active surveillance

Baseline parameterizations for Western Kenya and Solomon Islands

- Human demographic profile
- Health systems settings
- Vector bionomics
- Seasonality
- Human population size of 10 000.



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VC: Vector control

AS: Active surveillance

- Pre-intervention annual EIR of  $\{0.1, 0.5, 1, 2, 5\}$ .
- Coverage (proportion of population sleeping under) of LLINs of  $\{0, 0.2, 0.5, 0.8\}$ .
- IIR of  $\{0.1, 1, 10\}$  per 1000 people per annum  
 $\sim \text{Poisson}(\text{IIR})$



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VC: Vector control

AS: Active surveillance

- Effective case management coverage of  $\{0.2, 0.5, 0.8\}$ .
- AS coverage of  $\{0, 0.025, 0.1, 0.2\}$  4 times a year using rapid diagnostic tests (RDTs).
- 14 model variants
- 10 random seeds



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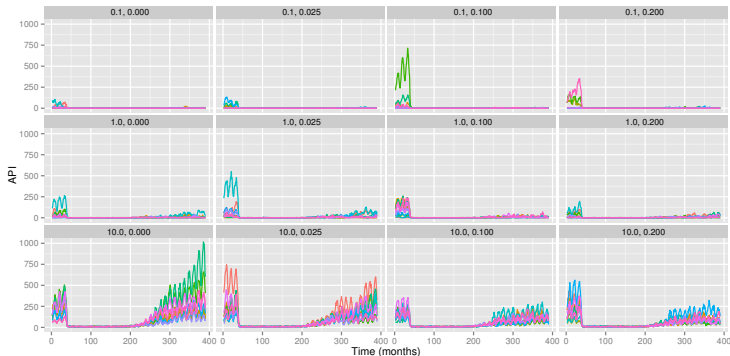
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**Figure:** OpenMalaria simulation results for API per 1,000 per annum with an annual input EIR of 0.1, case management coverage of 80%, and ITN coverage of 80% during the period of Vector Control implementation. Each chart shows simulations results for varied levels of Infection Importations Rate and Active Surveillance (Quarterly Mass Screening and Treatment (MSAT) coverage)

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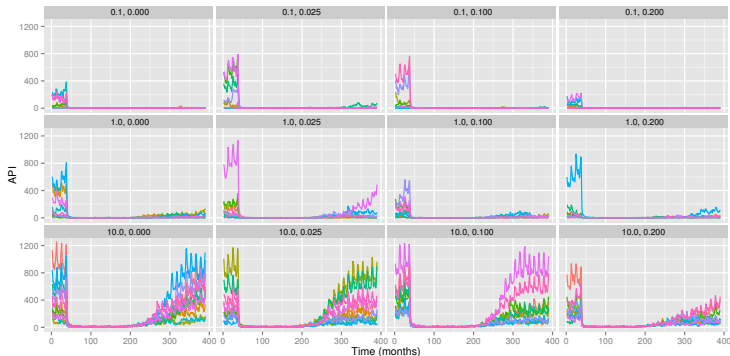
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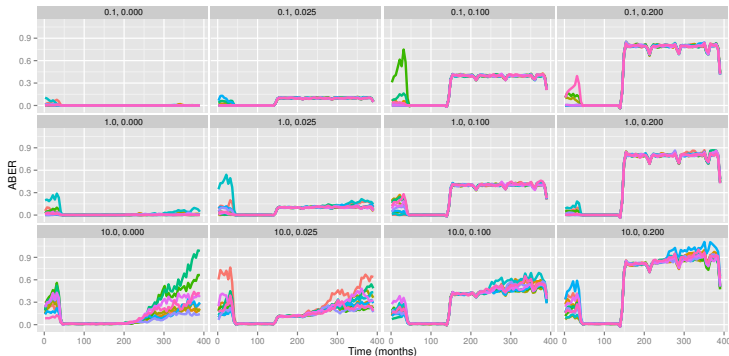
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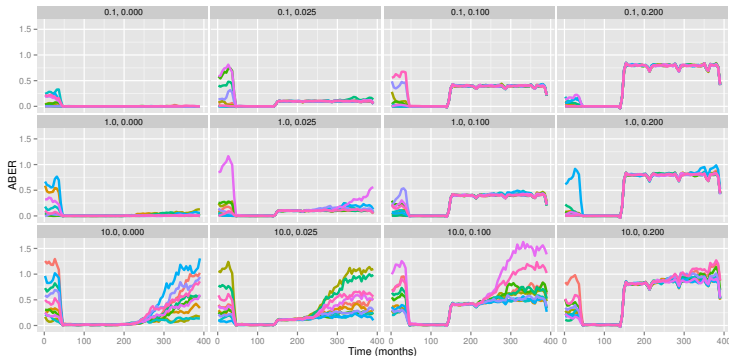
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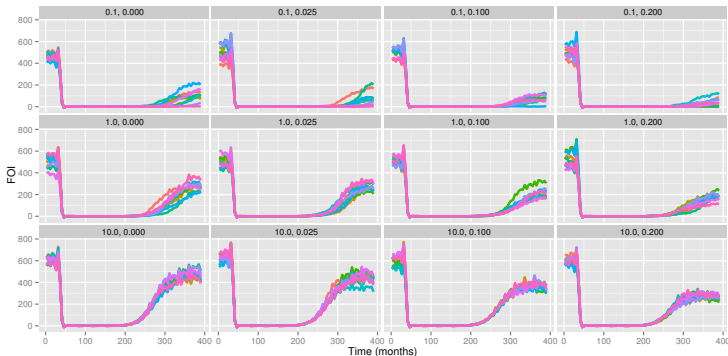
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**Figure:** OpenMalaria simulation results for force of infection (FOI) per 1,000 per annum with an annual input EIR of 1, case management coverage of 80%, and ITN coverage of 80% during the period of Vector Control implementation. Each chart shows simulations results for varied levels of Infection Importations Rate and Active Surveillance (Quarterly Mass Screening and Treatment (MSAT) coverage).



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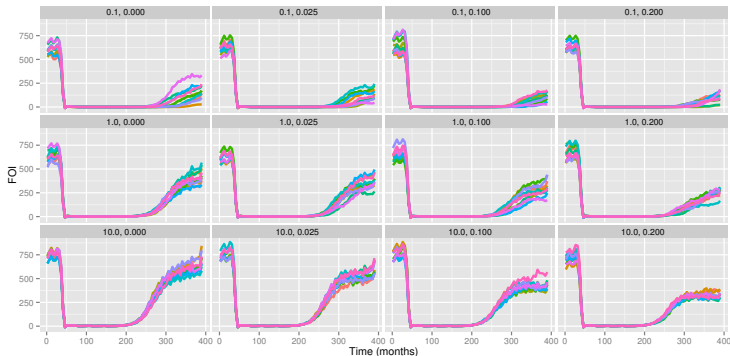
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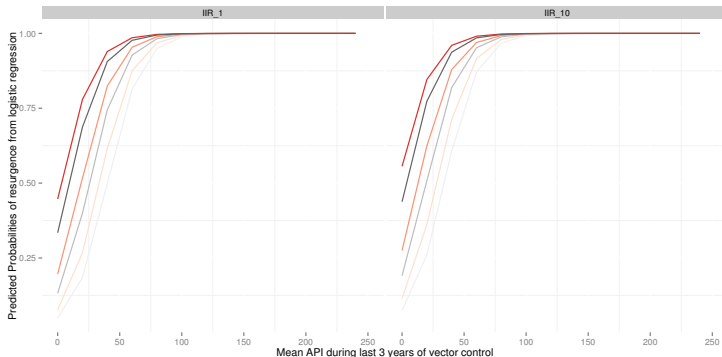
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**Figure:** Predicted probabilities of resurgence based on logistic regression results. Darker lines represent increasing EIR (0.1, 1, 2), while grey lines represent Active surveillance coverage of 1% per quarter and red lines represent Active surveillance coverage of 10% per quarter. All slopes here are for ITN coverage of 80%.



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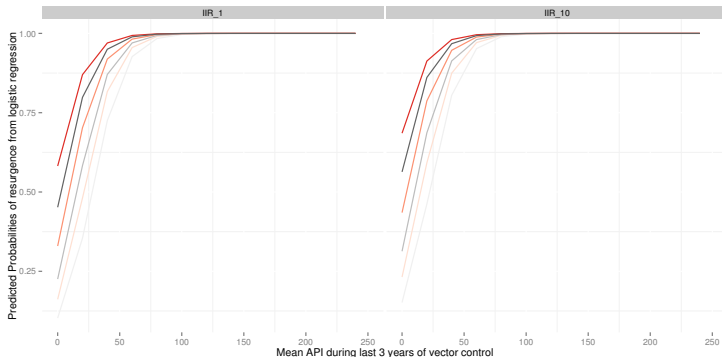
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- Did not include vivax malaria
- Did not model spatially or temporally responsive strategies.
- Assumed stable receptivity

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On the basis of this evidence, WHO recommends the following:

*In areas<sup>1</sup> with ongoing local malaria transmission (irrespective of both the pre-intervention and the current level of transmission), the scale-back of vector control is not recommended. Universal coverage with effective malaria vector control of all persons at risk of malaria in such areas should therefore be pursued and maintained.*

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<sup>1</sup>The minimum size of an area is determined by availability of reliable disaggregated disease surveillance data and feasibility for decisions on vector-control implementation.

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On the basis of this evidence, WHO recommends the following:

*In areas<sup>2</sup> where transmission has been interrupted, the scale-back of vector control should be based on a detailed analysis that includes assessment of receptivity<sup>3</sup>, vulnerability and disease surveillance coverage, and capacity for case management and vector-control response.*

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<sup>2</sup>The minimum size of an area is determined by availability of reliable disaggregated disease surveillance data and feasibility for decisions on vector-control implementation.

<sup>3</sup>The abundant presence of human-biting competent anopheline vectors and the existence of other ecological factors favouring malaria transmission



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On the basis of this evidence, WHO recommends the following:

*Countries and partners are therefore requested to invest in health systems particularly in the strengthening of disease and entomological surveillance, as identification of such areas and the subsequent response, depends on the availability of this capacity.*