RBM Partnership To End Malaria

Vector Control Working Group

Residual transmission and potential risks without adding (outdoor biting) innovation

Ellie Sherrard-Smith

30th October 2025











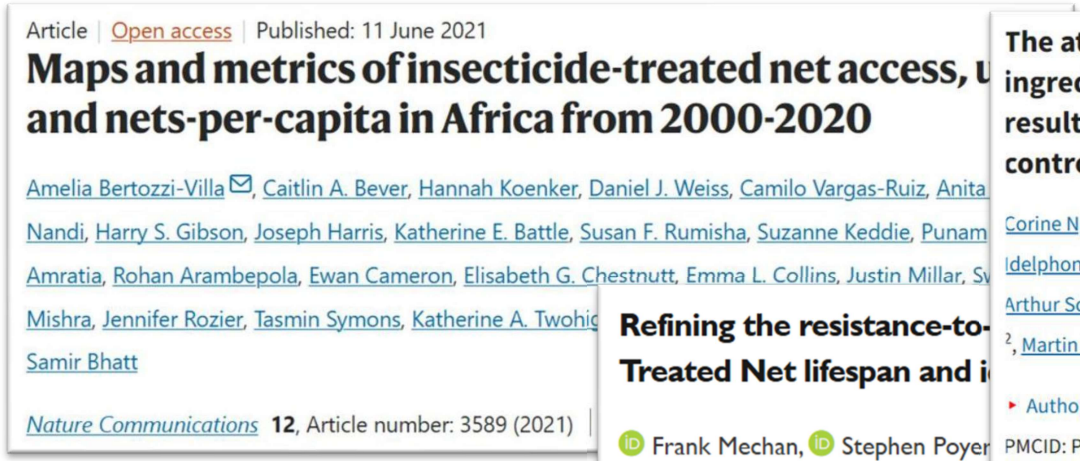
UNIVERSITE DE
FADA N'GOURMA

Residual transmission and potential risks without adding (outdoor biting) innovation

Ellie Sherrard-Smith



Ga


Article | Open access | Published: 11 June 2021

Maps and metrics of insecticide-treated net access, u and nets-per-capita in Africa from 2000-2020

Amelia Bertozzi-Villa, Caitlin A. Bever, Hannah Koenker, Daniel J. Weiss, Camilo Vargas-Ruiz, Anita Nandi, Harry S. Gibson, Joseph Harris, Katherine E. Battle, Susan F. Rumisha, Suzanne Keddie, Punam Amratia, Rohan Arambepola, Ewan Cameron, Elisabeth G. Chestnutt, Emma L. Collins, Justin Millar, Sv Mishra, Jennifer Rozier, Tasmin Symons, Katherine A. Twohig Samir Bhatt

Nature Communications **12**, Article number: 3589 (2021)

Refining the resistance-to- Treated Net lifespan and i

Frank Mechan, Stephen Poyer Albert Kilian, Hannah Koenker, Amy Wheldrake, Fadi Junaid, Christen Fornadel, Stephen J. Russell, Angus Spiers

doi: https://doi.org/10.1101/2025.03.02.641027


The attrition, physical and insecticidal durability of two dual active ingredient nets (Interceptor® G2 and Royal Guard®) in Benin, West Africa: results from a durability study embedded in a cluster randomised controlled trial

Corine Ngufor [1,2,3], Josias Fagbohoun [2,3], Augustin Fongnikin [2,3], Juniace Ahoga [2,3], Thomas Syme [1,2,3], Idelphonse Ahogni [2,3], Manfred Accrombessi [1,2], Natacha Protopopoff [1], Jackie Cook [1], Edouard Dangbenon [2], Arthur Sovi [1,2], Marie Baes [4], Olivier Pigeon [4], Damien Todjinou [2,3], Renaud Govoetchan [1,2,3], Germain Gil Padonou [2], Martin Akogbeto [2]

▸ Author information ▸ Article notes ▸ Copyright and License information

PMCID: PMC11459981 PMID: 39375740


The impact of pyrethroid resistance on the efficacy and effectiveness of bednets for malaria control in Africa

Thomas S Churcher, Natalie Lissenden, Jamie T Griffin, Eve Worrall, Hilary Ranson

mperial College London, United Kingdom; Liverpool School of Tropical Medicine, United Kingdom; Queen Mary's Jniversity, United Kingdom

ug 22, 2016 • https://doi.org/10.7554/eLife.16090

Context is key

ITN access: – does the community have enough nets?
physical integrity: (some nets will rip sooner which could c h
resistance: the phenotype of vectors drives efficacy (more r

community preferences: people may choose to stop using or discard the nets at different moments

activity: do people wake up throughout the night and leave the "safe space" beneath the ITN?

Gaps in Protection from Indoor Residual Spray

Context matters for estimating the efficacy of IRS.

Key information that does not depend on the product includes:

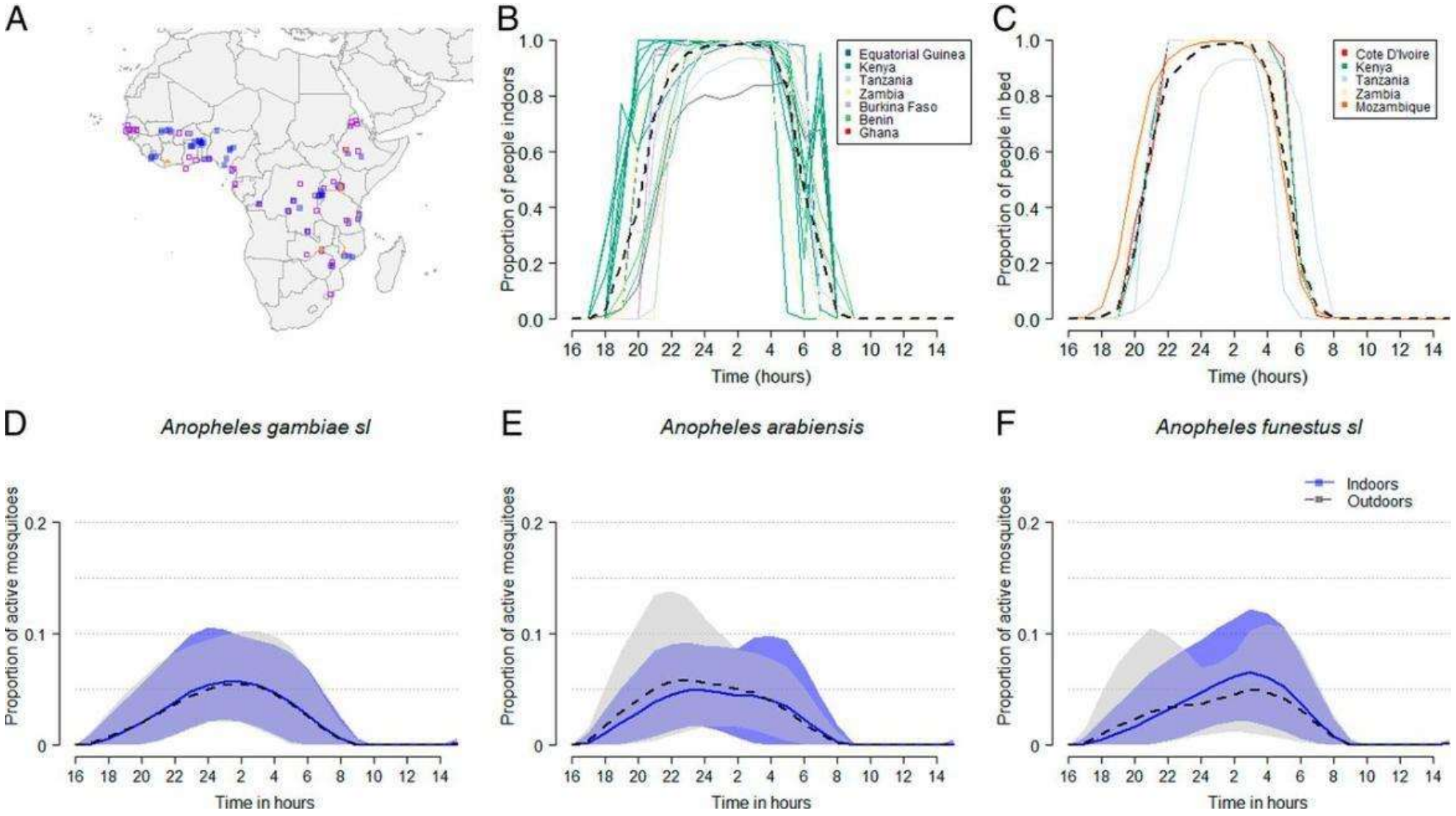
- **Location characteristics:** Local vector population characteristics and behaviour (species composition, phenotypic and genotypic resistance profiles, endophily versus exophily, biting time, and other behaviours). Human community nighttime outdoor exposure risks.
- **Environment:** Accessibility of indoor spaces for vectors due to house structure, use of pesticide in agriculture.
- **Climate and weather:** explicit weather patterns that may drive mosquito dynamics, year-on-year differences in risk, bioavailability of insecticide on sprayed surfaces.
- **Product delivery:** Spray quality, spray campaign timing, equipment quality, spray coverage, type of coverage (partial, full spraying of all spaces of just sleeping spaces), sufficient spray operators.

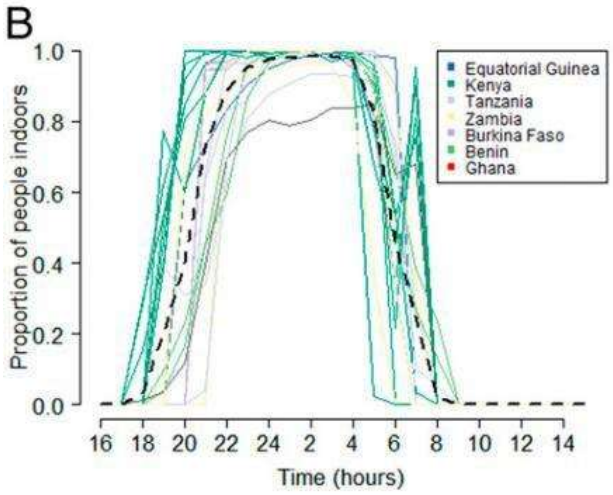
Key information that does depend on the product includes:

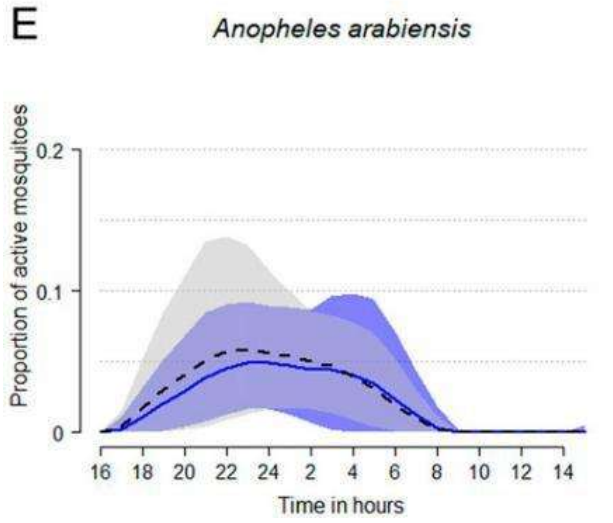
- **End user acceptance and actions:** refusal rates, wall modifications post application (this might depend on aspects of the product such as its smell).
- **Product quality:** insecticide use efficiency.
- **Climate and weather:** climatic factors affecting insecticide migration differently across products.
- **Insecticide durability:** phenotypic resistance profile of local mosquitoes will alter performance of products depending on the insecticide.
- **Insecticide batch quality:** variability over time and potentially between products.

Quantifying residual transmission

Sherrard-Smith et al. 2019 PNAS







$$\lambda_h(t) = \frac{Sum\ of\ Bites\ at\ hour(t) for\ location\ (inside\ or\ outside)}{Sum\ of\ bites\ for\ all\ hours\ for\ both\ locations}, \quad [1]$$

where subscript h indicates whether bites are taken indoors ($h = 1$) or outdoors ($h = 0$) (23).

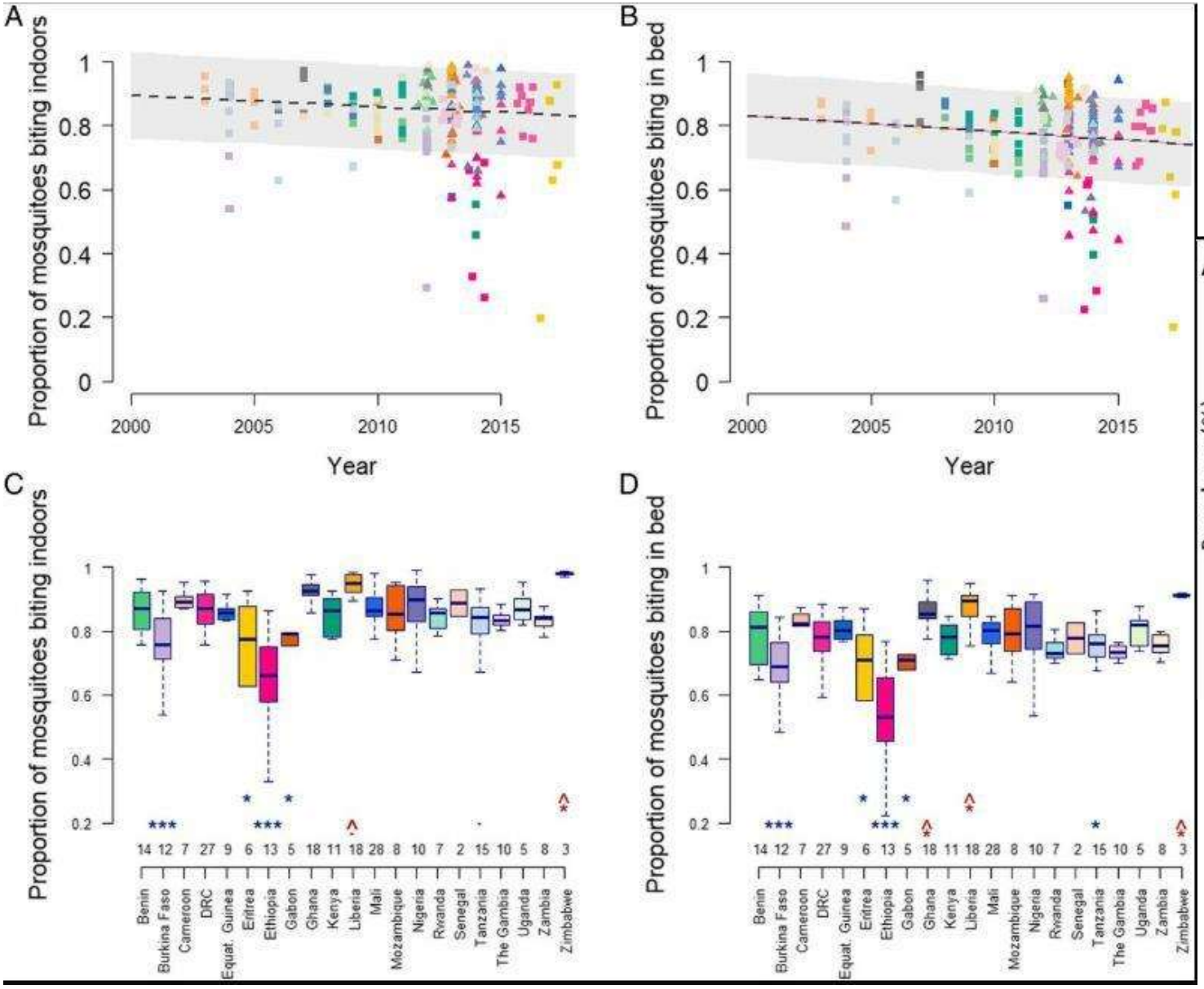
The proportion of mosquito bites taken on humans indoors (ϕ_I) and the proportion of mosquito bites taken on humans in bed (ϕ_B) are calculated as follows (23):

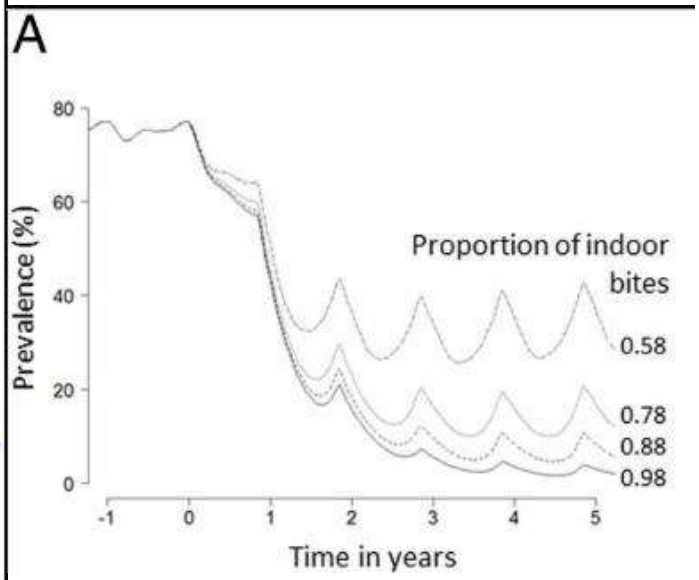
$$\Phi_I = \frac{\sum_t p_I(t)\lambda_I(t)}{\sum_t ((1-p_I(t))\lambda_o(t) + P_I(t)\lambda_I(t))}, \quad [2]$$

where, $p_I(t)$ is the proportion of people inside at hour (t), $\lambda_I(t)$ is the biting rate indoors at hour (t), and $\lambda_O(t)$ is the biting rate outdoors at hour (t). Similarly,

$$\Phi_B = \frac{\sum_t P_B(t)\lambda_I(t)}{\sum_t ((1-p_I(t))\lambda_o(t) + p_I(t)\lambda_I(t))}, \quad [3]$$

Sherrard-Smith et al. 2019 PNAS





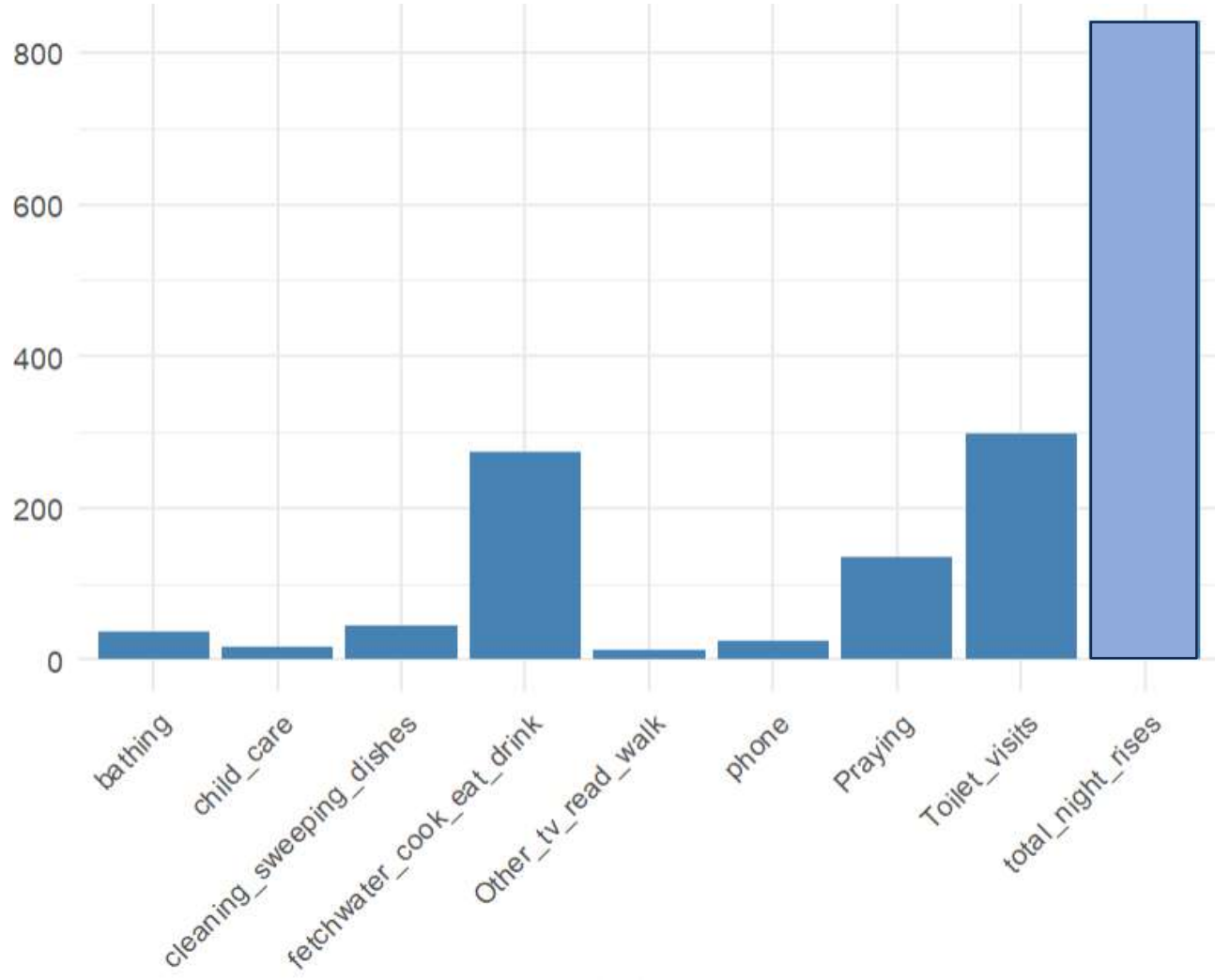
activity: do people wake up throughout the night and leave the “safe space” beneath the ITN?

New Nets Project Pilot data (Aug 2021)

Nigeria:

5 households
5 people per each household
7 nights
6 villages

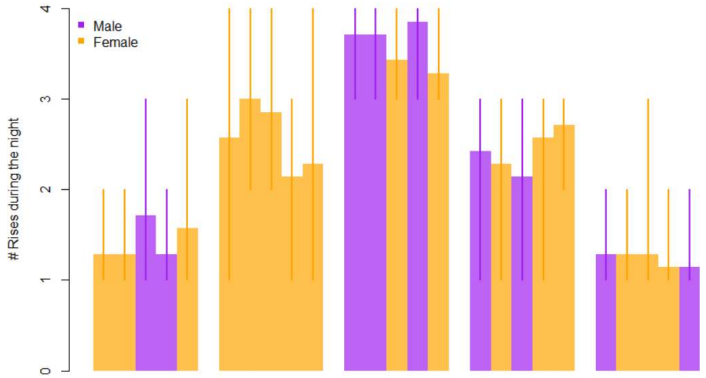
Total nights surveyed = **1,050**
Total rises reported 841



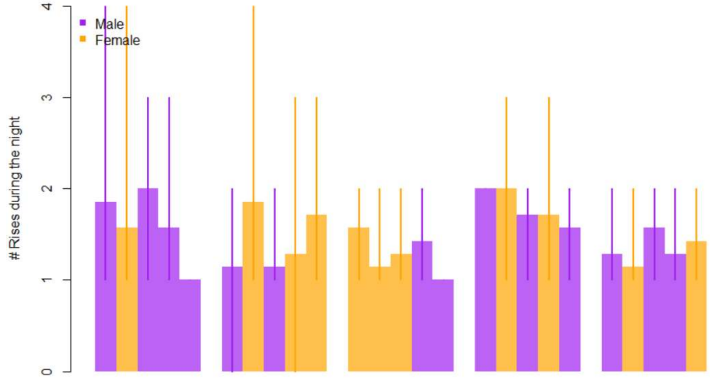
Visualising the raw data: Moro, Nigeria

Generating estimates of the proportion of bites received in bed using Nigerian data from the PNAS review (3 HLC studies) and the human data from the NNP pilot

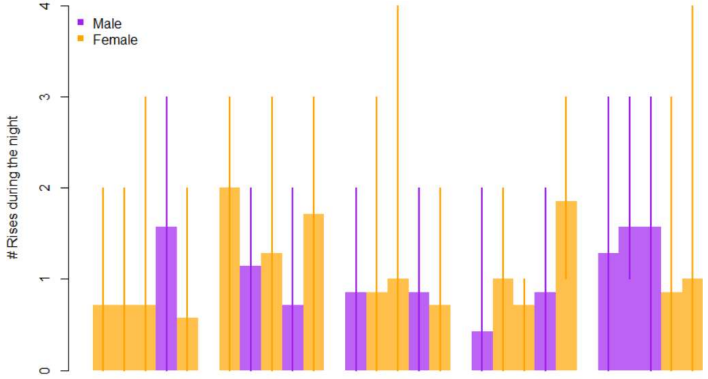
Village A



Village B



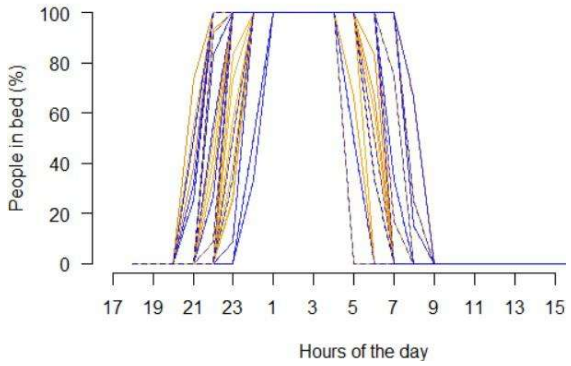
Village C



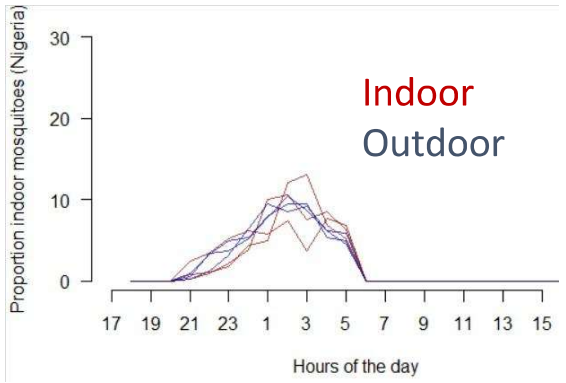
NNP Data (owned by PATH and IVCC)
Analysis: Ellie Sherrard-Smith

Visualising the raw data: Moro, Nigeria

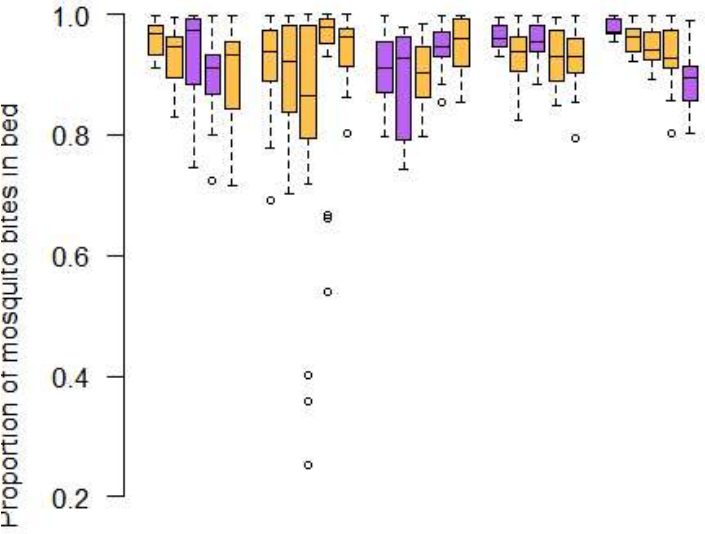
Generating estimates of the proportion of bites received in bed using Nigerian data from the PNAS review (3 HLC studies) and the human data from the NNP pilot



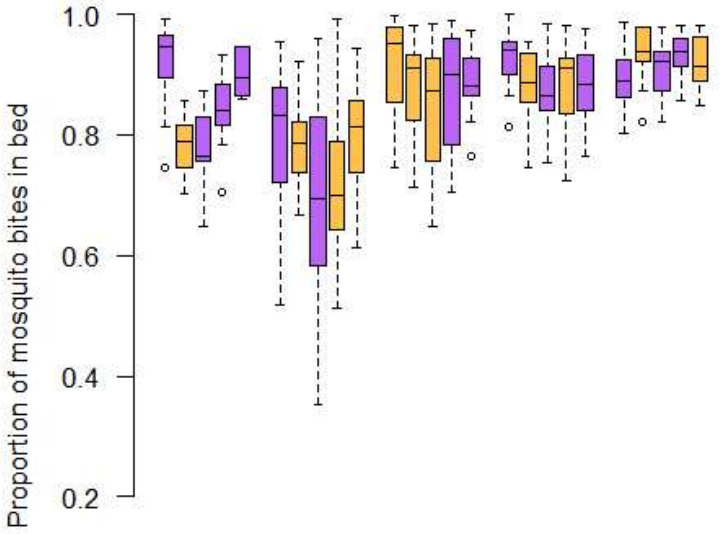
For each person, each nightly pattern is summed with the mosquito nightly pattern of activity



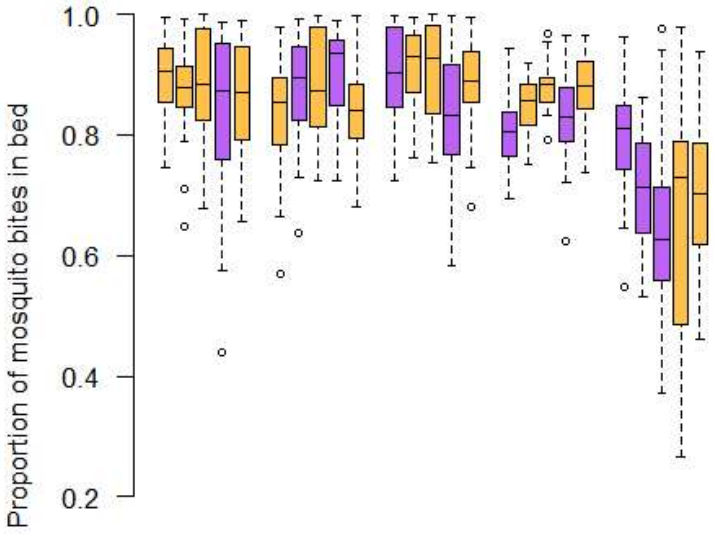
Village A



Village B

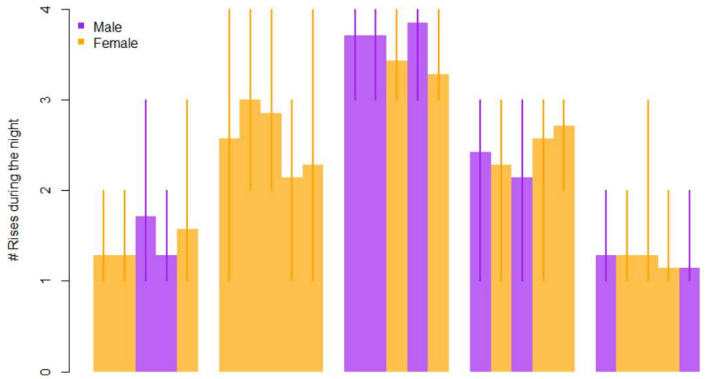


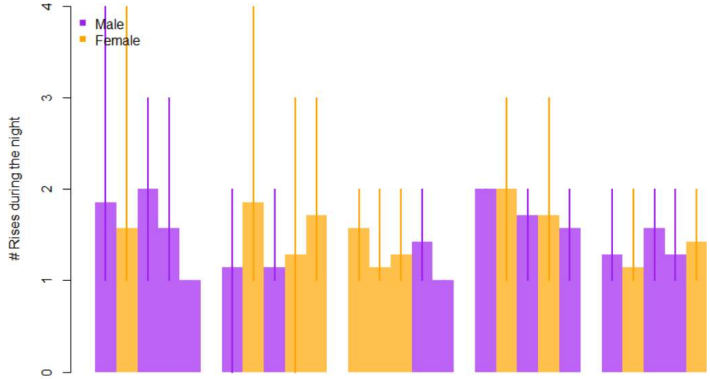
Village C

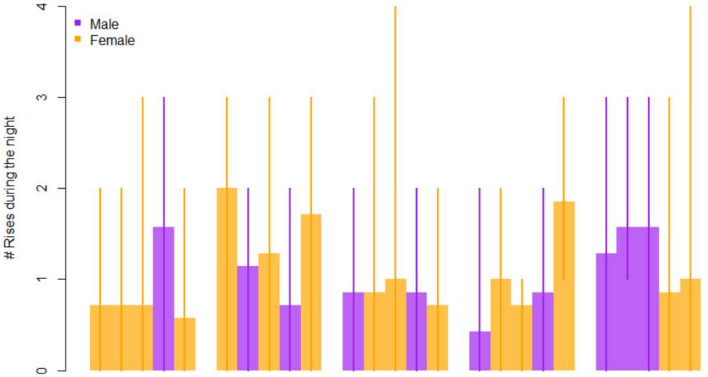


Visualising the raw data: Moro, Nigeria

Generating estimates of the proportion of bites received in bed as previous but now accounting for the possible effects of getting up multiple times in the night (bootstrapping)



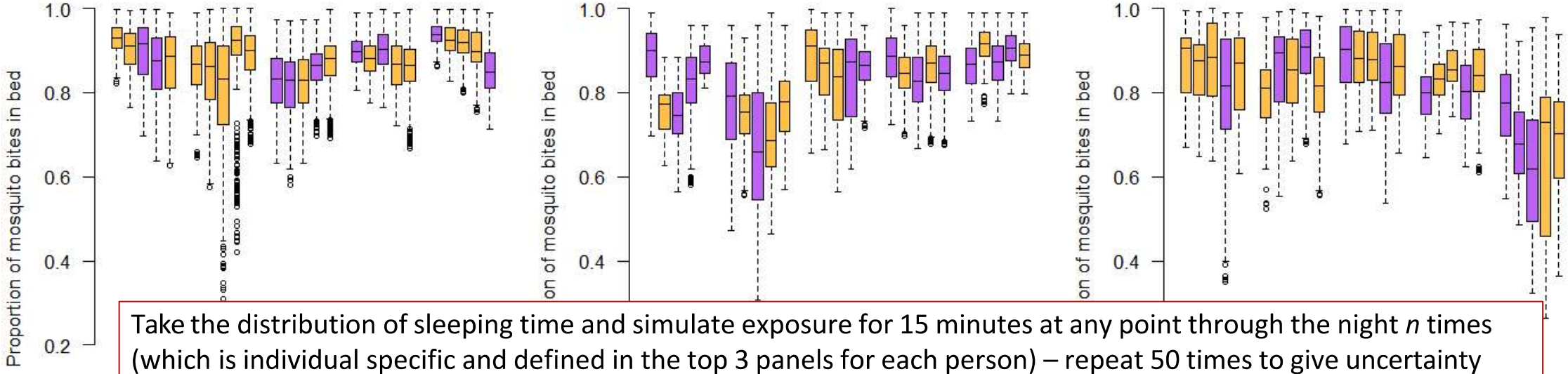




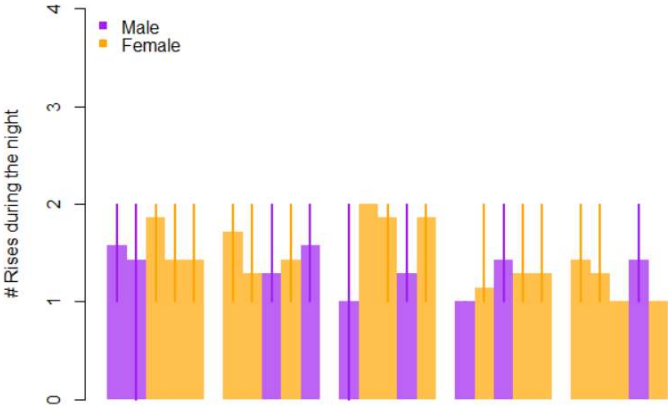
Village A

Village B

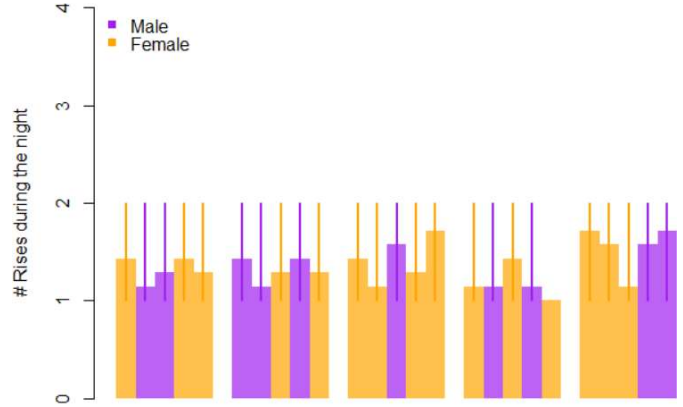
Village C



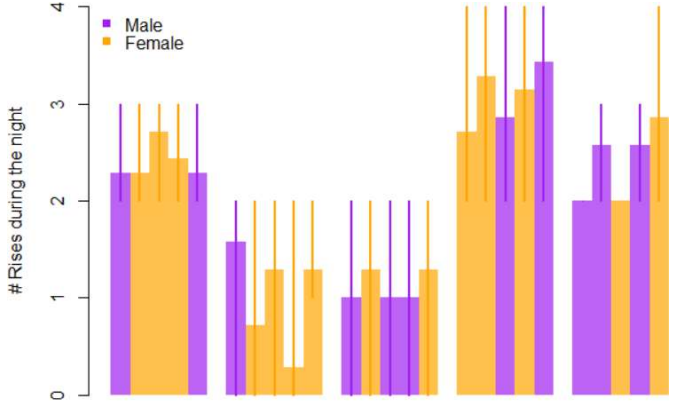
Take the distribution of sleeping time and simulate exposure for 15 minutes at any point through the night *n* times (which is individual specific and defined in the top 3 panels for each person) – repeat 50 times to give uncertainty



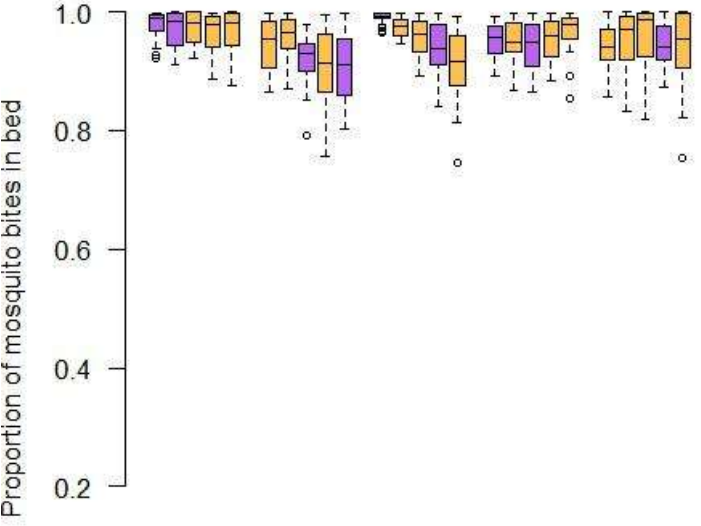
Village D

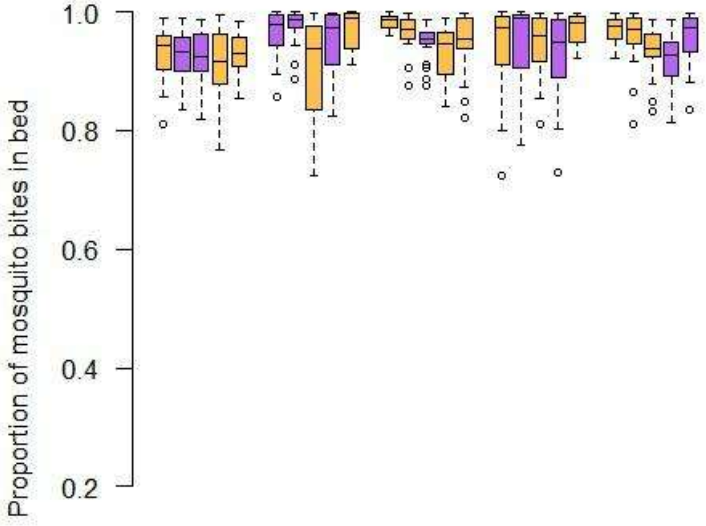


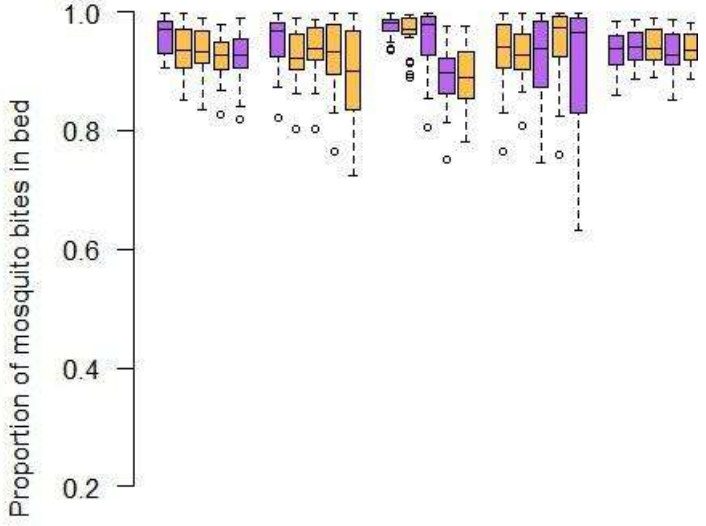
Village E



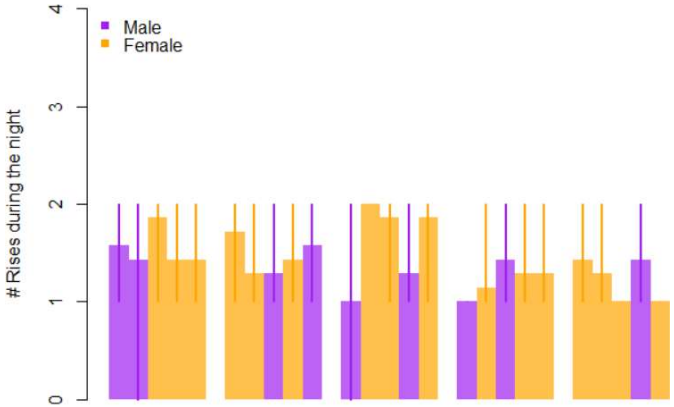
Village F



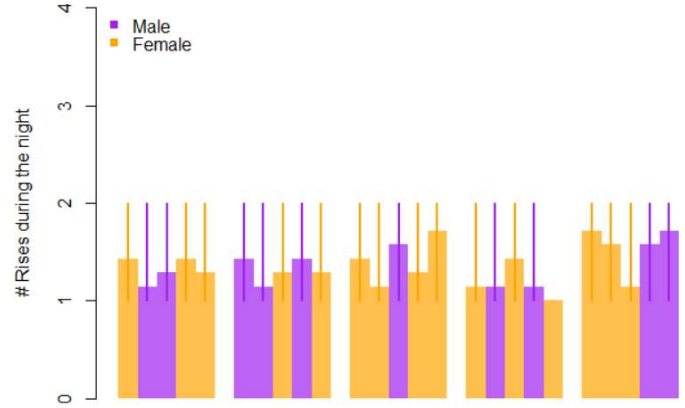




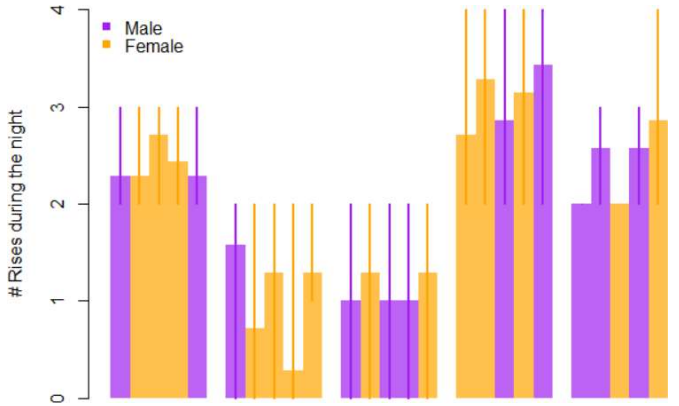
Repeating for Asa:
Without accounting for rises through the night



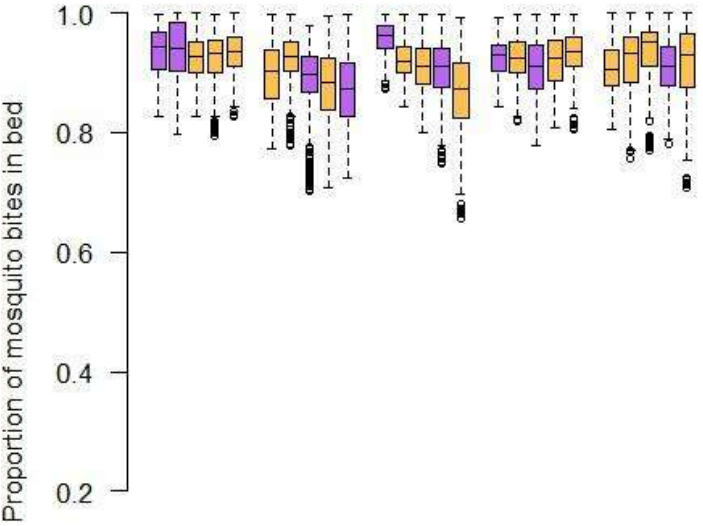
Village D

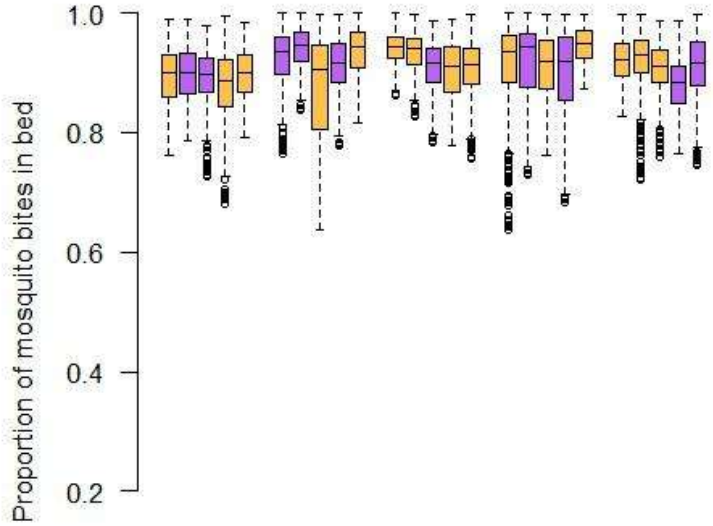


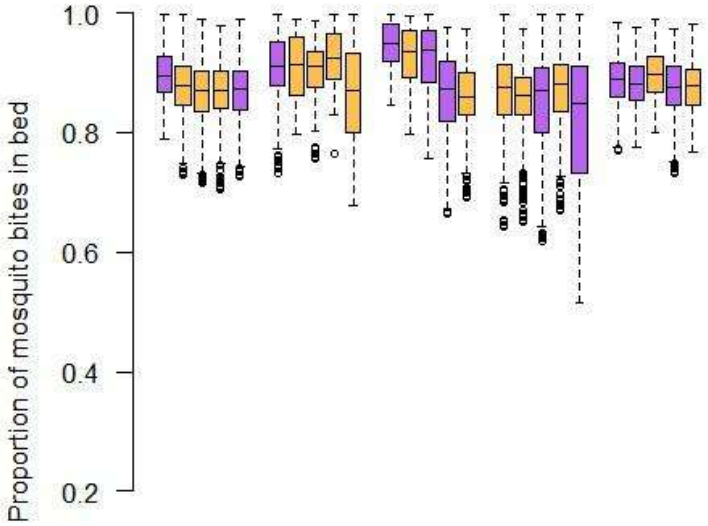
Village E



Village F







Repeating for Asa:
With accounting for rises through the night

Analysis

Fitted a hierarchical model to the individual data (nested in households, nested in villages)

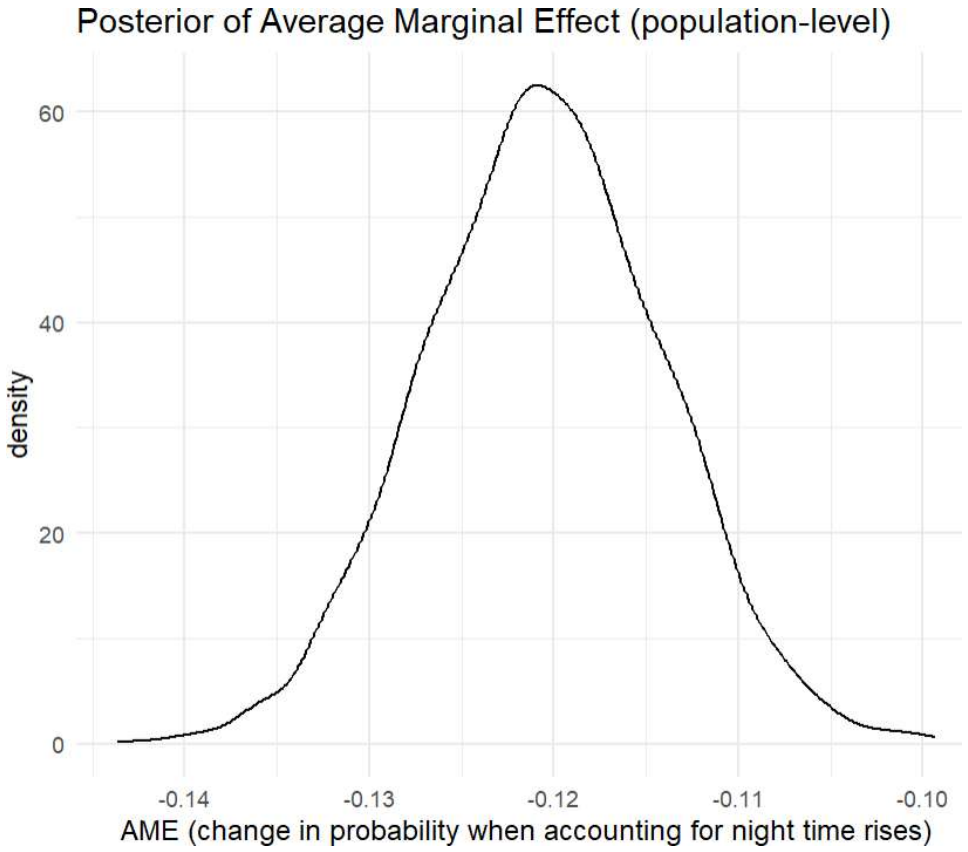
Covariates: Sex and Age and whether the data were adjusted for rises or not (the data were repeated to include this logical covariate)

The coefficients for terms with rises included give us an indication in the shift in probability of mosquitoes biting while a person is in bed.

When we include estimates for rising in the night, there is a probable change in the estimate of proportion of mosquitoes biting at night of about -0.**12 (95% CrI: 0.135 – 0.109)**

i.e. if we were assuming the proportion of bites at night was **0.9,** including the probable rises throughout the night shifts this estimate to 0.9 x (1 – 0.12) = **0.792 (0.78 – 0.80)**

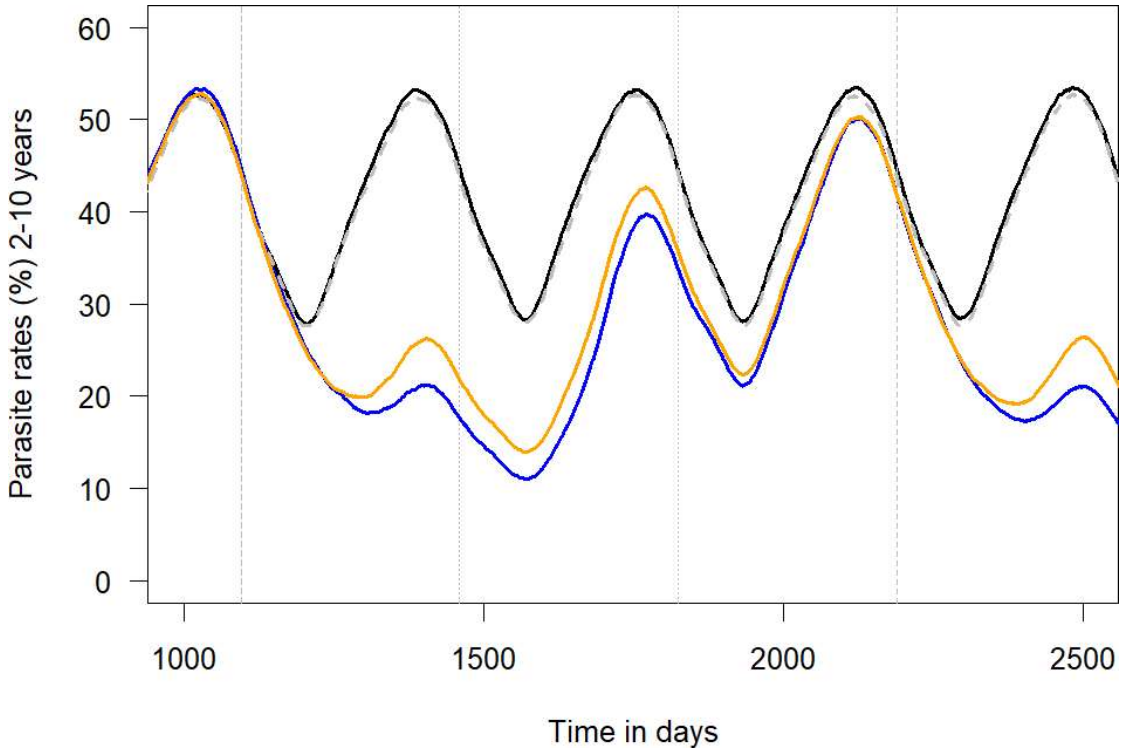
Posterior mean change: -0.12
95% CrI: -0.135 -0.109



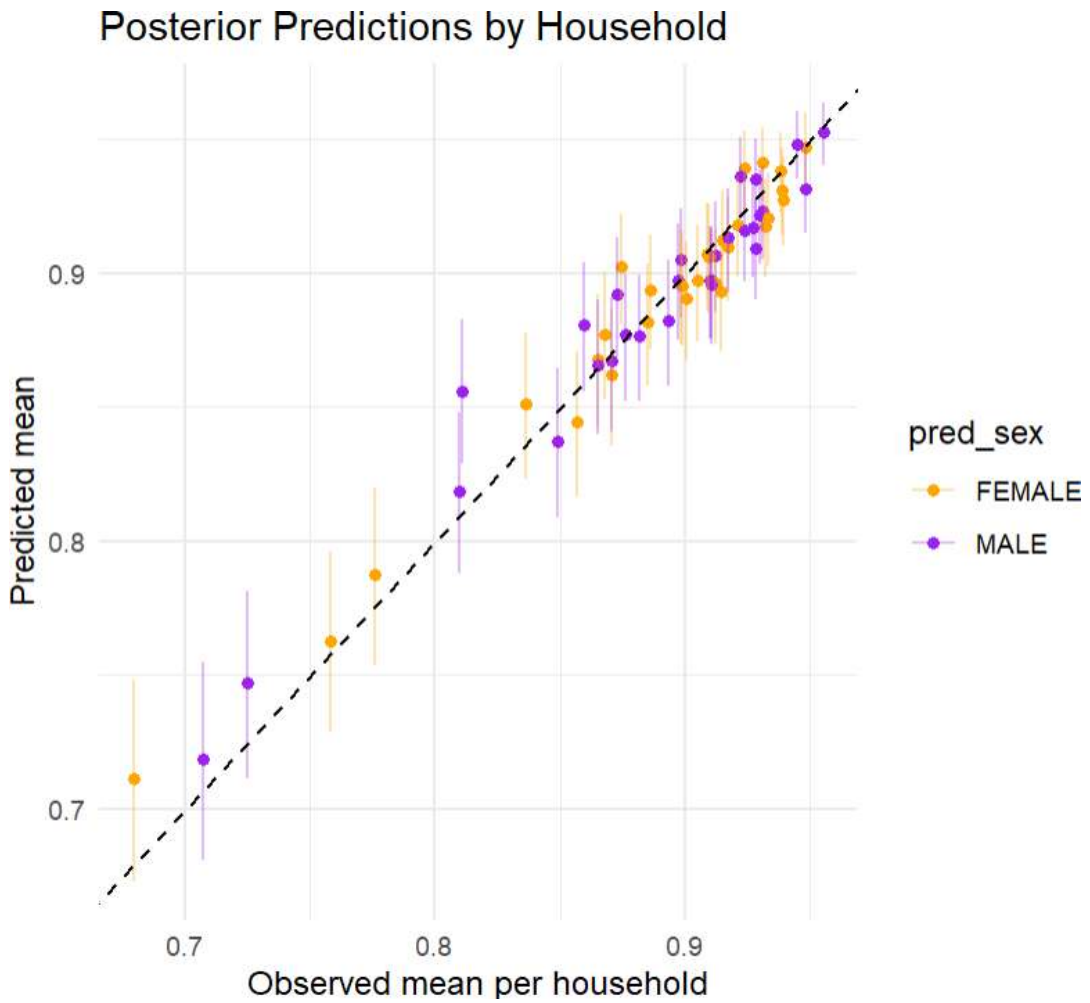
No interventions simulated

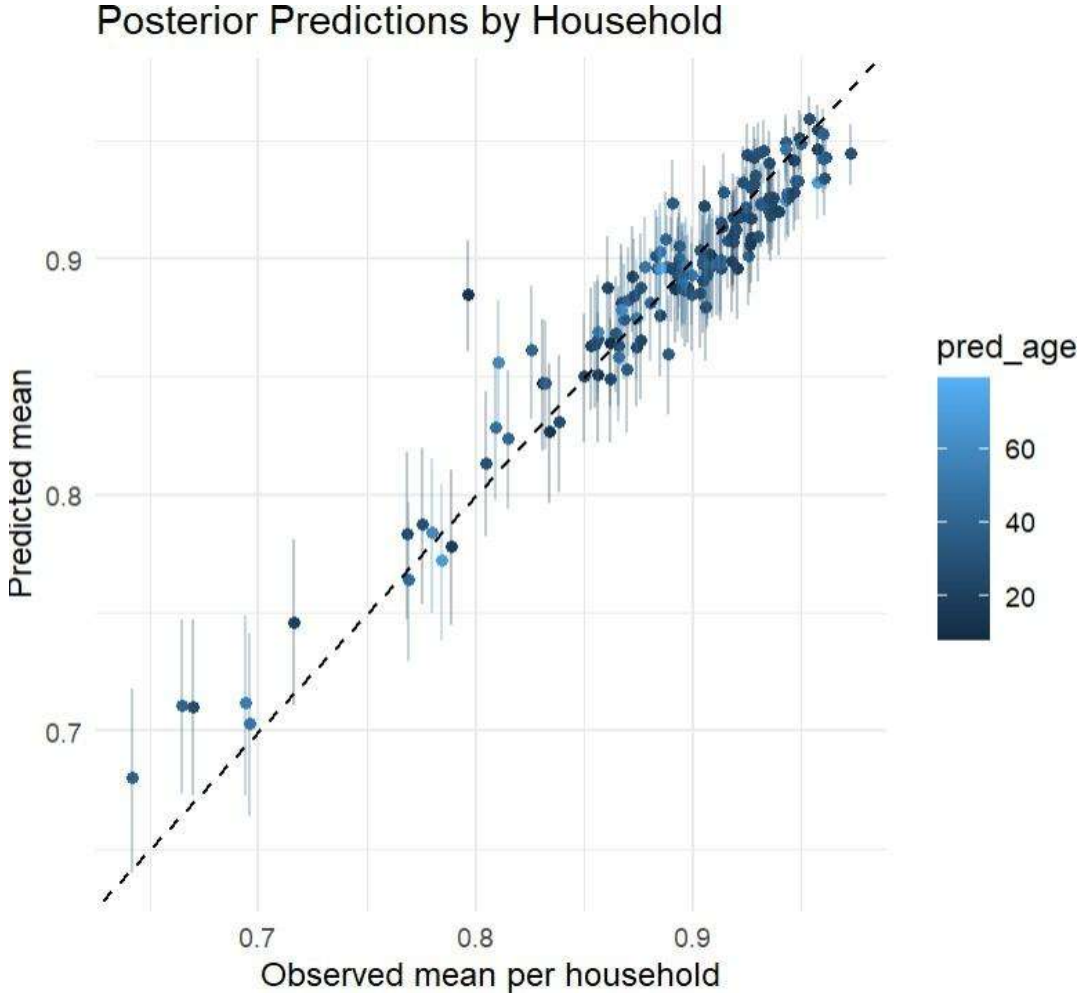
3-yearly ITN campaign with
Assumption of 0.9 bites indoors

3-yearly ITN campaign with
Assumption of 0.79 bites indoors



Assuming 0.9 bites indoors corresponds to a **46.3%** reduction in U5 clinical cases over 3 years
Assuming 0.79 bites indoors corresponds to a **39.9%** reduction in U5 clinical cases over 3 years
In this entirely theoretical simulation this corresponds to about 3000 cases


Posterior Predictions by Household
Predicted mean
0.9
0.8
0.7
0.7
0.8
0.9
Observed mean per household
pred_sex
FEMALE
MALE

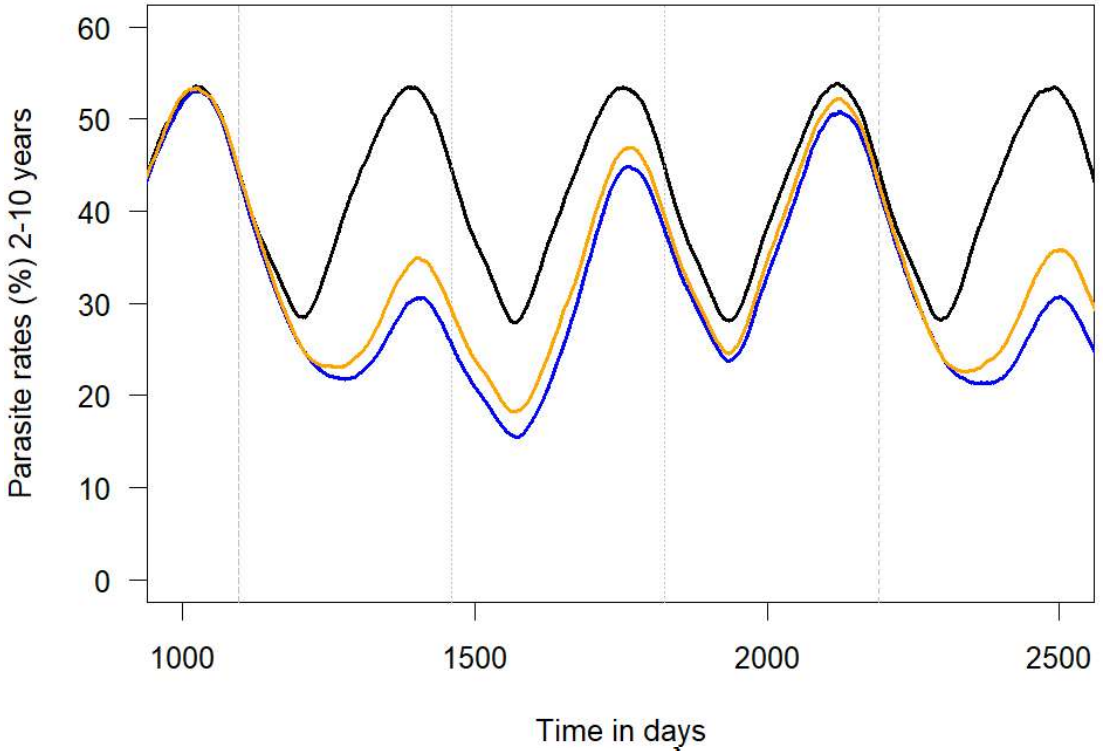

Posterior Predictions by Household
Predicted mean
0.9
0.8
0.7
0.7
0.8
0.9
Observed mean per household
pred_age
60
40
20

ITN access:
Assume 80% use → 60% use

Physical integrity/Community choice:
Assume 2.1 years → 1.5 years

Resistance:
Assume susceptible 100% mortality → 10% mortality

Activity: **No rises** → **some nighttime rises**



Glover et al 2025 Subnational tailoring of ITN distributions to maximise malaria control | medRxiv

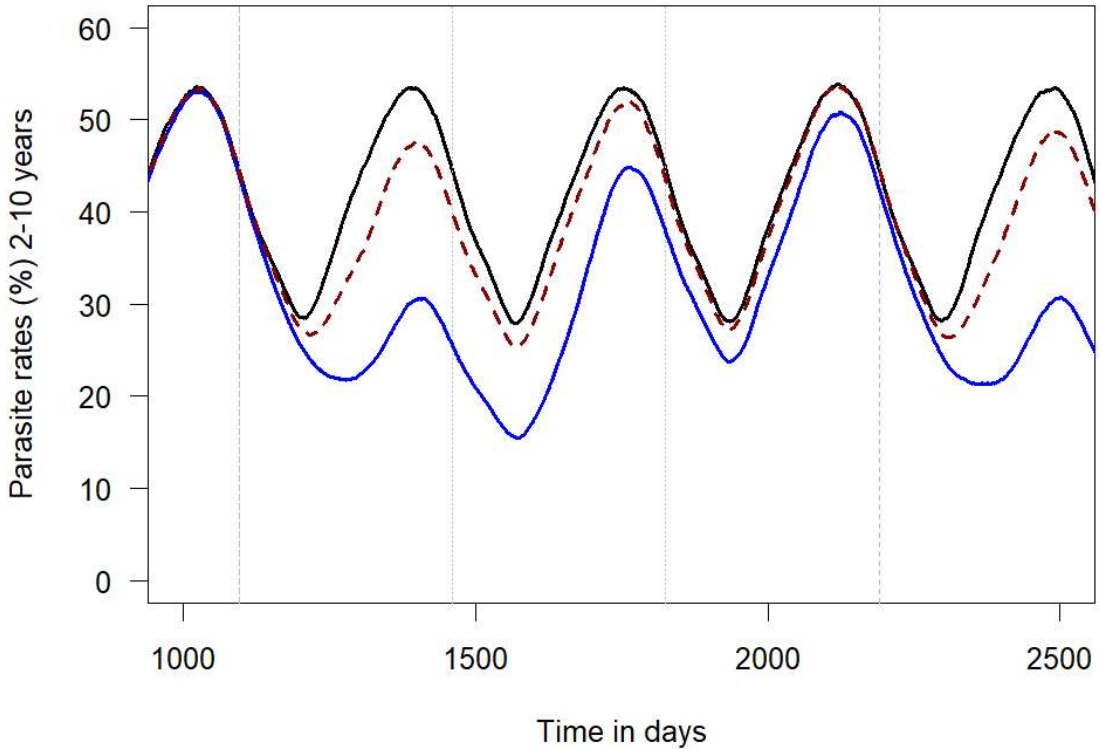
ITN access:
Assume 80% use → 60% use

Physical integrity/Community choice:
Assume 2.1 years → 1.5 years

Resistance:
Assume susceptible 100% mortality → 10% mortality

Activity: No rises → **some nighttime rises**

If all these effects are simulated….



Gaps in protection from Insecticide Treated Nets (and Indoor residual spraying)

Conclusion: ….context is key

ITN access: – does the community have enough nets?
physical integrity: higher durability could avert more cases over the course of a 3- year campaign?
resistance: the phenotype of vectors drives efficacy (more resistance = less efficacy)

community preferences: people may choose to stop using or discard the nets at different moments

activities: we need interventions can continue to protect people when rising throughout the night…

- ✓ Interventions that protect the whole space?

Thank you & questions welcome!

Janetta E. Skarp

Andrew D. Beale

Christen Fornadel

Laura C. Norris

Sarah J. Moore

Selam Mihreteab

Jacques Derek Charlwood

Samir Bhatt

Peter Winskill

Jamie T. Griffin

Thomas S. Churcher

All those generating data

IVCC Vector Control Saving Lives

Dave Malone, Christen Fornadel, Kyra Arnett, Joseph Wagman, Kenzie Tynuv, Julia Mwesigwa, Molly Robertson, Christelle Gogue, and Peder Digre



NATIONAL MALARIA ELIMINATION PROGRAMME
Federal Ministry of Health, Abuja

Unitaid SAVE LIVES FASTER

amp The Alliance for Malaria Prevention

UKRI MRC Centre for Global Infectious Disease Analysis Imperial College London

LSTM LIVERPOOL SCHOOL OF TROPICAL MEDICINE

LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

PATH