OUTDOOR MALARIA TRANSMISSION IN AFRICA

Gerry Killeen, Nicodem Govella, Dan Msellemu, Isaac Namango, Neil Lobo, Ying Zhou, Alpha Malishee, Nabie Bayoh, Chadwick Sikaala, Aklilu Seyoum, Jenny Stevenson, Brandy St. Lawrent, Jon Cox, Chris Drakeley, Frank Collins, Tanya Russell, Tom Burkot, Bernie Huho, Salim Abdulla, Diadier Diallo, Olivier Briët, Tom Smith, John Gimnig, Sarah Moore, Silas Majambere, Katarina Kreppel & Heather Ferguson
An. gambiae s.l. 

An. funestus s.l.

Indoors Outdoors

Not present

Asembo Luangwa Rufiji Ulanga Oubritenga Kourweogo

BITING RATE (bites · person$^{-1}$ · hour$^{-1}$)

Time

Huho et al 2012 Int J Epidemiol (In press)
<table>
<thead>
<tr>
<th>Species</th>
<th>Location</th>
<th>Proportion caught indoors ($P_i$)</th>
<th>Proportion caught during sleeping hours ($P_{fl}$)</th>
<th>Proportion of human exposure occurring indoors for a non-user of LLINs ($\pi_i$)</th>
<th>Proportion of human exposure occurring indoors for an LLIN user ($\pi_{i,n}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>An. arabiensis</td>
<td>Rarieda, Kenya</td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
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</tr>
<tr>
<td>An. quadriannulatus</td>
<td>Luangwa, Zambia</td>
<td><img src="image" alt="Diagram" /></td>
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<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
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<tr>
<td>An. gambiae</td>
<td>Rufiji, Tanzania</td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>An. gambiae</td>
<td>Ulanga, Tanzania</td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>An. gambiae</td>
<td>Oubritenga, Burkina Faso</td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>An. gambiae</td>
<td>Korweogo, Burkina Faso</td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>An. gambiae</td>
<td>Bioko, Equatorial Guinea</td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
<td><img src="image" alt="Diagram" /></td>
</tr>
</tbody>
</table>

Reddy et al 2011 Malar J 10: 184
Huho et al 2012 Int J Epidemiol (In press)
An. funestus s.l.
Rarieda, Kenya

- Proportion caught indoors ($P_i$)
- Proportion caught during sleeping hours ($P_{fi}$)
- Proportion of human exposure occurring indoors for an LLIN non-user ($\pi_i$)
- Proportion of human exposure occurring indoors for an LLIN user ($\pi_{i,n}$)

An. funestus s.l.
Luangwa, Zambia

An. funestus s.l.
Oubritenga, Burkina Faso

An. funestus s.l.
Korweogo, Burkina Faso
Russell et al 2010 Malaria Journal 9: 187
$\beta = -0.0013, \text{se} = 4.19 \times 10^{-5}$

$p < 0.0001$

Proportion An. gambiae s.s.

Russell et al. Malaria Journal 2011, 10:80
Change in composition of the *Anopheles gambiae* complex and its possible implications for the transmission of malaria and lymphatic filariasis in north-eastern Tanzania

Yahya A Derua$^{1*}$, Michael Alifrangis$^2$, Kenneth M Hosea$^3$, Dan W Meyrowitsch$^4$, Stephen M Magesa$^{1,6}$, Erling M Pedersen$^5$ and Paul E Simonsen$^5$

Impact of insecticide-treated bed nets on malaria transmission indices on the south coast of Kenya

Francis M Mutuku$^{1*}$, Charles H King$^2$, Peter Mungai$^2$, Charles Mbogo$^3$, Joseph Mwangangi$^3$, Eric M Muchiri$^4$, Edward D Walker$^5$ and Uriel Kitron$^{1,6}$

Shifts in malaria vector species composition and transmission dynamics along the Kenyan coast over the past 20 years

Joseph M Mwangangi$^{12*}$, Charles M Mbogo$^{12}$, Benedict O Orindi$^2$, Ephantus J Muturi$^3$, Janet T Midega$^1$, Joseph Nzovu$^1$, Hellen Gatakaa$^2$, John Githure$^4$, Christian Borgemeister$^2$, Joseph Keating$^5$ and John C Beier$^6$
Outdoor host seeking behaviour of Anopheles gambiae mosquitoes following initiation of malaria vector control on Bioko Island, Equatorial Guinea

Michael R Reddy¹*, Hans J Overgaard²,³, Simon Abaga⁴, Vamsi P Reddy⁵, Adalgisa Caccone⁶, Anthony E Kiszewski⁷ and Michel A Slotman⁵

In early 2004, 48.6% of An. gambiae s.l. in the Punta Europa area belonged to the M molecular form, 50.2% belonged to the S molecular form and 1% was An. melas (Slotman, unpublished). No S-form An. gambiae s.s. were observed in the current collections, meaning that only the M form of An. gambiae remains, at least in Mongola. This confirms previous observations that S-form populations declined following the initiation of anti-vector measures.

Reddy et al. Malaria Journal 2011, 10:184
http://www.malariajournal.com/content/10/1/184
Biologically meaningful coverage indicators for eliminating malaria transmission

Samson S. Kiware, Nakul Chitnis, Gregor J. Devine, Sarah J. Moore, Silas Majambere and Gerry F. Killeen


Attack related survival probability per feeding cycle:

\[ P_y = 1 - (\mu_{h,p} C_{A,p} + \mu_{h,u} (1-C_{A,p})) \]
πᵢ values derived from historical (2001-2004) data sets: An gambiae s.l (Huho et al, IHI, unpublished)

Recent estimates from Dar es Salaam (Govella et al, 2010)

Pooled July and August data from Zanzibar (ZMCP / IHI / BMGF 2010)

The proportion of bites received indoors given local patterns of human behaviour.

- Indoors (πᵢ).
- Outdoors.

Recent estimates from Dar es Salaam (Govella et al, 2010)

Pooled July and August data from Zanzibar (ZMCP / IHI / BMGF 2010)

Courtesy of Juma Mcha (ZMCP) and Greg Devine (IHI/LSTM)
Early biting rhythm in the afro-tropical vector of malaria, *Anopheles arabiensis*, and challenges for its control in Ethiopia

M. YOHANNE S¹ and E. BÖMLEE²

*Medical and Veterinary Entomology* (2012) **26**, 103–105

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**Fig. 1.** Numbers of *Anopheles arabiensis* assessed by hourly catches in light traps set near sleepers under untreated bednets over 4 nights in two houses in three villages in Tigray (24 trap nights; September 2008; *n* = 309 *An. arabiensis*). ◆, indoor catches, *n* = 248; ○, outdoor catches, *n* = 61.
Figure 4. Median catching time of *Anopheles funestus* before and after implementation of universal coverage of long-lasting insecticidal impregnated nets (LLINs) in Tokoli (A) and Lokohoué (B). Boxes indicate 1st-3rd quartile and median hours of biting activity. Whiskers indicate 2.5–97.5 percentiles. Boxes carrying the same letter were not significantly different \( (P<.05) \) when comparing median catching time using Mann–Whitney U tests. To compare all rounds to each other, only mosquitoes caught from 11 PM to 6 AM were taken into account in the statistical analysis.
Table 1 Species composition of *An. funestus* s.l. collected in the Gembe East area in western Kenya

<table>
<thead>
<tr>
<th>Species</th>
<th>Collection date - No. of females collected</th>
<th>2010</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>An. funestus</em> s.s.</td>
<td>74</td>
<td>686</td>
<td>732</td>
</tr>
<tr>
<td><em>An. rivulorum</em></td>
<td>0</td>
<td>58</td>
<td>373</td>
</tr>
<tr>
<td>(<em>An. rivulorum %</em></td>
<td>(0.0)</td>
<td>(7.8)</td>
<td>(33.8)</td>
</tr>
</tbody>
</table>

Table 3 Blood meal composition in female *An. funestus* s.l. collected

<table>
<thead>
<tr>
<th>Species</th>
<th>Detection method</th>
<th>No. examined</th>
<th>Human blood (%)</th>
<th>Cow blood (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>An. funestus</em> s.s.</td>
<td>Direct sequencing</td>
<td>25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12 (48.0)</td>
<td>16 (64.0)</td>
</tr>
<tr>
<td></td>
<td>PCR</td>
<td>69&lt;sup&gt;b&lt;/sup&gt;</td>
<td>35 (50.7)</td>
<td>4 (5.8)</td>
</tr>
<tr>
<td><em>An. rivulorum</em></td>
<td>Direct sequencing</td>
<td>148&lt;sup&gt;a&lt;/sup&gt;</td>
<td>24 (16.0)</td>
<td>145 (98.0)</td>
</tr>
<tr>
<td></td>
<td>PCR</td>
<td>89&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6 (6.7)</td>
<td>33 (37.1)</td>
</tr>
</tbody>
</table>

Table 2 *Plasmodium falciparum* sporozoite rate in *An. funestus* s.l. collected in the Gembe East area in western Kenya, Sept–Oct 2010

<table>
<thead>
<tr>
<th>Species</th>
<th>No. of females used</th>
<th>No. of <em>P. falciparum</em> positive (ELISA)</th>
<th>No. of <em>P. falciparum</em> positive (PCR)</th>
<th>% positive</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>An. funestus</em> s.s.</td>
<td>250</td>
<td>5</td>
<td>2</td>
<td>0.80</td>
</tr>
<tr>
<td><em>An. rivulorum</em></td>
<td>284</td>
<td>5</td>
<td>2</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Kawada et al. *Parasites & Vectors* 2012, 5:230
http://www.parasitesandvectors.com/content/5/1/230

<table>
<thead>
<tr>
<th>Line</th>
<th>ITN coverage ($C_h$)</th>
<th>Proportional of exposure occurring indoors ($\pi_i$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>Not relevant</td>
</tr>
<tr>
<td></td>
<td>0.8</td>
<td>0.9</td>
</tr>
</tbody>
</table>

**Main Vectors**

<table>
<thead>
<tr>
<th>GENERAL</th>
<th>LOCALIZED</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>gambiae</em> (species A and B)</td>
<td><em>nili</em> <em>moucheti</em> <em>melas</em> <em>merus</em></td>
</tr>
<tr>
<td><em>funestus</em></td>
<td></td>
</tr>
</tbody>
</table>

**Secondary or Incidental Vectors**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>cousiani</em></td>
<td><em>hargreavesi</em></td>
</tr>
<tr>
<td><em>paludis</em></td>
<td><em>wellcomei</em></td>
</tr>
<tr>
<td><em>ziemannii</em></td>
<td><em>pretoriensis</em></td>
</tr>
<tr>
<td><em>brunnipes</em></td>
<td><em>rufipes</em></td>
</tr>
<tr>
<td><em>flavicosta</em></td>
<td><em>pharoensis</em></td>
</tr>
<tr>
<td><em>gibbinsi</em></td>
<td><em>squamoussis</em></td>
</tr>
<tr>
<td><em>hancocki</em></td>
<td></td>
</tr>
</tbody>
</table>
However, 216 (62.1%) could not be matched (<90% identity) to any of the 224 ITS2 or 164 CO1 published sequences of anopheline vectors or nonvectors. These 216 specimens could be grouped into several separate clades, distinct from known vectors in the area (Figure). Specimens were grouped by ITS2 sequence. These groups were ranked by abundance and arbitrarily named species A-J. Of the 348 sequenced DNA specimens, the most abundant group having identical but novel ITS2 and CO1 sequences (species A, n = 147, 42.2%) could not be matched definitively to a single species by using the morphologic key. The mosquitoes in this group were most frequently caught outdoors (132, 89.8%). For 64 of a total of 192 traps, collections were made every 2 hours between 6:30 PM and 6:30 AM for 64 nights. Of 30 specimens of species A from these collections, 22 (73.3%) were caught outdoors before 10:30 PM. Data we have collected on human sleeping patterns from this area suggest that a significant proportion of the population is still outdoors before 10:30 PM and therefore exposed to these vectors.

Five of 293 mosquitoes tested had ELISA results positive for *Plasmodium falciparum* sporozoites. All 5 had no previously published ITS2 or CO1 sequences, nor could they be identified by morphologic features. All were collected outdoors.

Figure. Phylogenetic tree of sequence group consensuses with National Center of Biotechnology Information reference sequences for *Anopheles* spp. mosquitoes caught in 2010 in Kisii District, Nyanza Highlands, western Kenya. Sequence groups of caught specimens arbitrarily named species A to J are ranked by abundance. Gray highlighting indicates study samples with sporozoites; dashed circles around text indicate study samples that match known African vectors. Scale bar represents nucleotide substitutions per 100 residues.

Stevenson et al. 2012 Emerg Infect Dis 18: 1547
PARASITE RATES OF INFANTS UP TO ONE YEAR OLD

before dieldrin

after dieldrin

Apr.-June 1954
July-June 1955
March-Oct. 1955
Nov.-Dec. 1955
Jan.-March 1956
Apr.-June 1956
July-Oct. 1956
Nov.-Dec. 1956
Jan.-March 1957
Apr.-June 1957
July-Oct. 1957
Nov.-Dec. 1957
Jan.-March 1958
Apr.-June 1958
July-Oct. 1958
Nov.-Dec. 1958
Jan.-March 1959
Draper & Smith 1960 TRSTMH 54: 342

Fig. 1. Numbers of *A. gambiae* and *A. funestus* in spray catches in huts.
Fig. 43. Crude proportion positive for *P. falciparum* and *P. malariae* in the unprotected population (area C) and in the population protected in 1972-73 by propoxur and high-frequency MDA (area A1)\(^a\)

INTERVENTION PHASE

<table>
<thead>
<tr>
<th>Paras.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serol.</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seasons</td>
<td></td>
<td>dry</td>
<td>wet</td>
<td>dry</td>
<td>wet</td>
<td>dry</td>
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<td>dry</td>
<td>wet</td>
<td>dry</td>
<td>wet</td>
</tr>
</tbody>
</table>

\(^a\) Molineaux & Gramiccia (1980) The Garki Project WHO Monograph
Fig. 4. The prespraying median biting hour (NBC, IN + OUT) of *A. gambiae* s.l. and its residual NBC (IN + OUT) under propoxur, by village.
Fig. 2. The prespraying NBC (IN)/(PSC.HBI) ratio of *A. gambiae* s.l. and its residual NBC (IN) under propoxur, by village.
THE INFLUENCE OF VECTOR BEHAVIOR ON MALARIA TRANSMISSION

R. ELLIOTT

Scientist, Pan American Health Organization, Guatemala, Guatemala

SUMMARY

Delays in malaria eradication programs are caused more by non-response of fully susceptible vectors to attack measures than by physiological resistance, though the latter receives more attention.

The present slowing down of progress toward eradication since 1966\(^1\) has mainly been caused by lack of response to attack measures by vector species which remain susceptible to the insecticide in use; physiological resistance has been critical in only a few programs,\(^2\) affecting only 1% of the treated areas.\(^3\)
THE INFLUENCE OF VECTOR BEHAVIOR ON MALARIA TRANSMISSION

R. ELLIOTT

Figure 3. Man-vector contact in A. darlingi, El Pescado, Colombia.

Figure 4. Man-vector contact in A. nucleotovari, Pto. Reyes, Colombia.
Table 1: Relative risk of malaria infection estimated by generalised linear models, for age and proportion of indoor exposure ($\pi_i$) for LLIN users and non-users in Dar es Salaam.

<table>
<thead>
<tr>
<th>Test variables</th>
<th>Non-users of LLINs</th>
<th>Users of LLINs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR(95% CI)</td>
<td>P</td>
</tr>
<tr>
<td><strong>Age categories</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-4 years</td>
<td>1.00\textsuperscript{a}</td>
<td>NA</td>
</tr>
<tr>
<td>5-17 years</td>
<td>0.35 (0.15, 0.80)</td>
<td>0.013</td>
</tr>
<tr>
<td>18-30 years</td>
<td>0.35 (0.15, 0.81)</td>
<td>0.013</td>
</tr>
<tr>
<td>&gt;30 years</td>
<td>0.30 (0.13, 0.70)</td>
<td>0.005</td>
</tr>
<tr>
<td><strong>$\pi_i$ terciles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper tercile</td>
<td>1.00\textsuperscript{a}</td>
<td>NA</td>
</tr>
<tr>
<td>Middle tercile</td>
<td>2.49 (1.04, 5.95)</td>
<td>0.041</td>
</tr>
<tr>
<td>Lower tercile</td>
<td>3.70 (1.90, 7.22)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

\textsuperscript{a}: Reference; CI: Confidence Interval; OR: Odds Ratio; NA: Not Applicable; $\pi_i$: Proportion of exposure to vectors occurring indoors
Reported house entry and exit times of individuals interviewed during cross-sectional household surveys in Dar es Salaam, Tanzania, stratified by derived estimates for the proportion of their exposure to humans that occurs indoors ($\pi_i$).

Nicodem J. Govella,* Fredros O. Okumu, and Gerry F. Killeen

Best practice for holoendemic sub-Saharan Africa in 2013 or 1963

Adapted from Smith et al. 2007 PLoS Biol 5: e42
P. guajava

C. melo

P. reticulatum

F. thonningii

Muller et al. Malar J 9: 262
Target product profiles for protecting against outdoor malaria transmission

Gerry F Killeen\textsuperscript{1,2,*} and Sarah J Moore\textsuperscript{1,3}
Killeen and Moore Malaria Journal 2012, 11:17
http://www.malariajournal.com/content/1/1/17

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**Figure 3** Progressive impact upon a completely outdoor transmission system ($r_i = 0$) of products with increasing efficacy of personal protection ($p_o$) achieved by either repelling ($\theta_{D,o}$) or killing ($\theta_{\mu,pre,o}$) attacking mosquitoes before they feed upon human users. The grey arrows represent interpolation of the efficacy thresholds at which the toxic mode of action achieves equivalent transmission control to the theoretical limit at complete protective efficacy ($\theta_{D,o} = 1.0$ so $p_o = 1.0$) for spatial repellents at high coverage ($C_r = 0.8$). Impact is expressed in terms of the mean relative risk of exposure experienced by the average community member ($\psi_{fe,\Omega}$). Further details of the model and symbol definitions are available online (See Additional file 4).
**Figure 2** Additional incremental impact of outdoor contact toxins ($\theta_{\text{pre},0} = 0.5$) or repellents that are exclusively used outdoors ($\theta_{\Delta,0} = 0.5$) or used both indoors and outdoors ($\theta_{\Delta,H} = 0.5$) when combined with indoor LLINs with contact toxins ($\theta_{\mu,\text{pre},1} = 0.5$), compared with their direct impact as stand-alone intervention strategies. Impact is expressed in terms of the mean relative risk of exposure to residual transmission for the average community member where LLINs are combined with additional products with the above profiles ($\psi_{\text{combination}}$) compared with when they are applied as a stand-alone measure ($\psi_{\text{LLIN alone}}$). All products are assumed to confer 50% personal protection ($p_{\mu} = 0.5$ or $p_{\Delta,H} = 0.5$) by either repelling or killing half of all mosquitoes that attack them ($\theta = 0.5$). Further details of the model and symbol definitions are available online (See Additional file 4).
BASELINE PROPORTION OF BLOODMEALS TAKEN FROM HUMANS ($Q_{h,0}$)

BASELINE PROPORTION OF HUMAN EXPOSURE OCCURRINGindoors ($\pi_{i,0}$)

ADVANTAGE OF OUTDOOR APPLICABILITY

ADVANTAGE OF TOXICITY OVER REPELLENCY

ATTENUATION OF INDOOR CONTACT INSECTICIDE

IMPACT BY CO-APPLICATION WITH REPELLENTS

Kiware et al. 2012 Biol Lett 8: 874
ADVANTAGE OF TOXICITY OVER REPELLENCY

BASELINE PROPORTION OF BLOODMEALS TAKEN FROM HUMANS ($Q_{h,0}$)

BASELINE PROPORTION OF HUMAN EXPOSURE OCCURING INDOORS ($\pi_{i,0}$)

ADVANTAGE OF OUTDOOR APPLICABILITY

ATTENUATION OF INDOOR CONTACT INSECTICIDE

IMPACT BY CO-APPLICATION WITH REPELLENTS

An. arabiensis

An. rivulorum etc?

Kiware et al. 2012 Biol Lett 8: 874
ADVANTAGE OF TOXICITY OVER REPELLENcy

BASELINE PROPORTION OF BLOODMEALS TAKEN FROM HUMANS ($Q_{h,0}$)

BASELINE PROPORTION OF HUMAN EXPOSURE OCCURRING INDOORS ($\pi_{i,0}$)

ATTENUATION OF CONTACT

IMPACT BY CO-APPLICATION WITH REPELLENTS

An. gambiae

An. funestus

An. arabiensis

An. rivulorum etc?

ADVANTAGE OF OUTDOOR APPLICABILITY

Kiware et al. 2012 Biol Lett 8: 874
PARTICIPANTS IN HUMAN LANDING CATCHES PROVIDED WITH CHEMOPROPHYLAXIS ARE SAFER FROM MALARIA THAN THEIR NEIGHBOURS

Gimnig et al. 2013 AJTMH In press
QUANTIFYING THE HUMAN FACTOR

Geissbühler et al. 2007 Malar J 6: 126
Table 2
Mean resting times of three vectors, according to nutritional state (time of day by which 50% of resting completed, from Figures 1 and 2)

Data from five localities in Colombia, 1966–1968

<table>
<thead>
<tr>
<th>Species</th>
<th>Locality*</th>
<th>Number observed</th>
<th>Time of day to 50%</th>
<th>Difference (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Unfed</td>
<td>Fed</td>
<td>Unfed</td>
</tr>
<tr>
<td>A. darlingi</td>
<td>1</td>
<td>147</td>
<td>207</td>
<td>2054</td>
</tr>
<tr>
<td>A. darlingi</td>
<td>2</td>
<td>318</td>
<td>421</td>
<td>2200</td>
</tr>
<tr>
<td>A. nuneztovari</td>
<td>3</td>
<td>77</td>
<td>504</td>
<td>2206</td>
</tr>
<tr>
<td>A. nuneztovari</td>
<td>4</td>
<td>196</td>
<td>497</td>
<td>2136</td>
</tr>
<tr>
<td>A. nuneztovari</td>
<td>2</td>
<td>93</td>
<td>110</td>
<td>2306</td>
</tr>
<tr>
<td>A. punctimacula</td>
<td>5</td>
<td>533</td>
<td>179</td>
<td>2306</td>
</tr>
</tbody>
</table>

* 1, El Pescado, unsprayed house; 2, Caseri, sprayed house; 3, Pto. Reyes, sprayed house; 4, Rio Leon, sprayed house; 5, Veleva,

The longest mean duration, over 12 minutes, was seen in A. darlingi in unsprayed houses; at the same place (Caseri) the mean for sprayed surfaces was nearly 6 minutes, but in both the medians were under 2.5 minutes. In A. nuneztovari and A. punctimacula, mean durations were shorter, 2.5 to 5.5 minutes, and medians were not more than 2 minutes.

Figure 8. Entry and exit times of A. darlingi.
CONCLUSIONS:
1. Stable outdoor malaria transmission always has been ubiquitous in Africa
2. Outdoor transmission doesn’t cause LLIN/IRS failure—it just defines the limit of what they can realistically achieve
3. Expect surprising vectors to become more obvious with LLIN/IRS scale up
4. **Dead mosquitoes tell no tales:** Recent reports of increased proportions of outdoor transmission, particularly by *An. arabiensis*, predominantly reflect success of LLINs/IRS for controlling indoor transmission and pre-existing phenotypic plasticity

RECOMMENDATIONS:
1. Don’t panic and carefully communicate the overwhelming success of indoor control measures—manage the sensationalist-prone media.
2. Standardized entomological measurement of the proportions of human exposure occurring indoors ($\pi_i$) with HLC and questionnaires.
3. Develop equivalent measures for resting site ($\pi_r$) and sugar resources ($\pi_\sigma$)
4. Extract pre-intervention estimates from historical literature to understand impact on missing/modified vector taxa post IRS/LLINs
5. Develop prototype products for preventing outdoor transmission by repelling or killing mosquitoes (host or sugar feeding).
6. Ensure these new products don’t undermine LLINs/IRS impact on endophilic/endophagic *An. gambiae* and *An. funestus* by repelling mosquitoes from houses through co-application
Rise in cases of malaria in Africa linked to insecticide-treated bed nets

Insecticide-treated bed nets, whose use is being widely promoted in Africa to combat malaria, may be linked to local resurgence of the disease, a study has found.

The finding raises doubts about the worldwide strategy, led by Bill Gates, to wipe out malaria by distributing insecticide-treated bed nets Photo: ALAMY