Additional File: Supplementary Data Description and Analysis.

Incidence and consequences of damage to insecticide-treated mosquito nets in Kenya

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Supplementary data description

Table S 1 gives a breakdown of the recorded information on the causes of attrition and reasons why nets were absent at the time of survey.

Table S 1. Classification of nets by status at cross-sectional surveys

| Use Status     | Number of survey points |
|----------------|-------------------------|
| In use         |                         |
| In use last night | 15,851                 |
| Not in use last night | 2,350                |
| Not in use     |                         |
| Attrition      |                         |
| Destroyed-Burned by fire | 728                  |
| Discarded-Too torn¹ | 706                  |
| Discarded-Not killing mosquitoes | 25               |
| Other          |                         |
| Absent         |                         |
| Lost/Stolen    |                         |
| Given away or sold | 807                  |
| Household moved away | 2,637                |
| Total observations       | 29,959                |

¹Destructively sampled nets are listed under their status prior to being removed to the laboratory.

The analysis of reported reasons for attrition considers only nets classified as ‘Discarded-Too torn’ as reported damage.
Posterior densities and correlations from MCMC fitting

Figure S 1. Pairs plot of the Markov Chain Monte Carlo (MCMC) samples for ODE model parameters

The marginal distribution for each parameter is in the main diagonal. The entries above the main diagonal are scatters of paired samples from the posterior distributions. The entries below the main diagonal are the corresponding correlation coefficients. Correlation coefficients with magnitude greater than 0.3 are shown against a gray background.
Sensitivity analyses

Methods
The parameters of the ODE models were re-estimated with four distinct definitions of attrition (A1–A4), for different qualifying levels of damage (analysis A1_0), and for different assumptions about nets that were recorded as transitioning from damaged to undamaged (analysis A1_1) (Table S 2, Table S 3).

Table S 2. Sensitivity analyses

| Analysis  | Absent nets | Nets elsewhere | Damage cutoff | Coding of ‘repaired’ nets |
|-----------|-------------|----------------|---------------|---------------------------|
| A1 (Reference) | Attrition     | Censoring       | pHl=20        | Damaged                   |
| A2        | Censoring    | Censoring       | pHl=20        | Damaged                   |
| A3        | Censoring    | Attrition       | pHl=20        | Damaged                   |
| A4        | Attrition    | Attrition       | pHl=20        | Damaged                   |
| A1R       | Attrition    | Recycled        | pHl=20        | Damaged                   |
| A1_0      | Attrition    | Censoring       | pHl=0         | Damaged                   |
| A1_1      | Attrition    | Censoring       | pHl=20        | Undamaged                 |

A1 treats absent nets as attrition but nets elsewhere are not considered as attrition; rather they are treated as censored (i.e. having unknown status).

A2 considers as attrition only those nets that were reported as destroyed or repurposed (repurposed nets are included with destroyed nets for the purpose of this analysis). Intervals that ended with the net being sold, given away, or relocated were not included in this analysis (effectively treating such nets as remaining in the cohort. This model was used to estimate $P_1$, the proportion of destroyed nets that had been damaged before they were destroyed (see section Error! Reference source not found.). This gave the value:

$P_1 = 0.985$.

A3 considers as attrition nets that were recorded as elsewhere, in addition to those recorded as destroyed, where elsewhere encompasses sale, giving away, or relocation. This model was used to estimate $P_2$, the proportion of all these nets that had been damaged before attrition according to this broader definition:

$P_2 = 0.905$.

The questionnaire responses reported in Error! Reference source not found. provide an estimate of $P_3$, the proportion elsewhere among absent and destroyed nets,

$P_3 = 5687/(1750 + 5687) = 0.765$.

$P_4$ is defined as the proportion of nets elsewhere that were damaged before they were taken away, and can be obtained from simple probability calculations, since:

$P_2 = P_1(1 - P_3) + P_3P_4$,

which can be rearranged to give:

$P_4 = \frac{P_2 - P_1(1 - P_3)}{P_3} = 0.880$. 

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A4 considers as attrition all nets that were eligible to be followed up but were not present. In addition to destroyed and nets that were elsewhere, this includes nets that were absent for which there was no data, in those cases where the net did not reappear at a subsequent survey. This model was used to estimate \( P_5 \), the proportion of all nets that had been damaged before the survey where they did not appear. This gave the value:

\[ P_5 = 0.834. \]

**Table S 3. Classification of intervals analyzed by use status.**

| Initial status | Final status | Analysis |
|----------------|--------------|----------|
|                |              | A1 | A2 | A3 | A4 |
| New            | Last Night   | 2614 |   |    |    |
| Last Night     | Last Night   | 9981 |   |    |    |
| Not Last Night | Last Night   | 736  |   |    |    |
| Not Use        | Last Night   | 1705 |   |    |    |
| New            | Not Last Night | 349  |   |    |    |
| Last Night     | Not Last Night | 714  |   |    |    |
| Not Last Night | Not Last Night | 259  |   |    |    |
| Not Use        | Not Last Night | 284  |   |    |    |
| New            | Not Use      | 1106 |   |    |    |
| Last Night     | Not Use      | 1745 |   |    |    |
| Not Last Night | Not Use      | 327  |   |    |    |
| Not Use        | Not Use      | 1887 |   |    |    |
| New            | Attrition    | 36   | 36 | 314| 314|
| Last Night     | Attrition    | 1267 | 293| 1281| 2255|
| Not Last Night | Attrition    | 151  | 44 | 196 | 303|
| Not Use        | Attrition    | 485  | 177| 796 | 1104|

**Recycling of nets**

Treating absent nets as a mixture of destroyed and nets that were elsewhere, the mixing proportion was estimated by assuming the association between holes and the outcome (destruction or removal) to be the same in the absent nets as for those with explicit information about the outcome, and that this can be quantified by the odds ratio:

\[ \Psi = \frac{P_4(1-P_3)}{P_1(1-P_4)} = 0.112. \]

The Markov property of the transition model justifies simulating nets that are elsewhere as returning either to compartment \( S_1 \) (if they are undamaged), or to compartment \( S_2 \) (if they are damaged). Recycling of absent nets was simulated using the A1 primary definition of attrition, but at each time, \( t \), returning a proportion \( P_3 \) of attrition to the forward simulations, where the allocation between compartments \( S_1 \) and \( S_2 \) was determined from the proportion of attrition arising from damaged nets, \( P_H(t) \), and the odds ratio, \( \Psi \), where:
\[ P_H(t) = \frac{a_2S_2(t) + a_4S_4(t)}{a_1S_1(t) + a_2S_2(t) + a_3S_3(t) + a_4S_4(t)} \]

The allocation between \( S_1 \) and \( S_2 \) was determined from the 2 x 2 table classifying the attrition at any given time (Table S 4). Defining \( x \) as the (time dependent) proportion of attrition that both have holes and will be recycled (to \( S_2 \)):

**Table S 4. Classification of attrition for simulating recycling**

|                | Damaged   | Not damaged |
|----------------|-----------|-------------|
| Recycled       | \( x \)   | \( P_3 - x \) |
| Destroyed      | \( P_H - x \) | \( 1 - P_3 - P_H + x \) |

Where \( x \) is obtained as the solution of a quadratic equation, from:

\[ \Psi = \frac{x(1 - P_3 - P_H + x)}{(P_3 - x)(P_H - x)} \]

So that the model equations (model A1R) become:

\[
\begin{align*}
\frac{dA}{dt} &= (a_1S_1 + a_2S_2 + a_3S_3 + a_4S_4)(1 - P_3) \\
\frac{dS_1}{dt} &= v_3S_3 - (u_1 + h_1 + a_1)S_1 + \left( \frac{P_3 - x}{1 - P_3} \right) \frac{dA}{dt} \\
\frac{dS_2}{dt} &= h_1S_1 + v_4S_4 - (u_2 + a_2)S_2 + \left( \frac{x}{1 - P_3} \right) \frac{dA}{dt} \\
\frac{dS_3}{dt} &= u_1S_1 - (v_3 + h_3 + a_3)S_3 \\
\frac{dS_4}{dt} &= h_3S_3 + u_2S_2 - (v_4 + a_4)S_4
\end{align*}
\]

Where the parameter vector \( \{ h_1, h_3, u_1, u_2, v_3, v_4, a_1, a_2, a_3, a_4 \} \) is that estimated with the A1 definition of attrition.

Results of sensitivity analyses

With the exception of the parameters measuring attrition rates, the fitted values for the parameter vector were similar for each of the analyses A1–A4, and for A1_0 and A1_1 (Table S 5). This was reflected in the derived values given in **Table S 6**, where substantial differences are seen only in the projected lifetimes of the nets. Simulation A1_0, in which the reference model (A1) was re-fitted, classifying nets with any holes as damaged (rather than requiring a PHI>20) gave very similar results to the original (A1). Similarly, the alternative coding of apparently repaired nets (A1_1), in which these were coded as undamaged at both start and end of the interval, made little difference to the projections from the model (Figure S 2).
The alternative definitions of attrition made considerable differences to the model predictions (Figure S 3). Analysis A2, which considers only explicitly destruction or repurposing as attrition, suggests a median net lifetime of 9.3 years (Table S 2); conversely, A3 and A4, which have more inclusive definitions of attrition, give rise to simulations with shorter lifetimes.

The simulation with recycling (A1R) gives similar results to A2. The definition of attrition made little difference to the simulated proportion of nets in the undamaged states (Figure S 3), and in all simulations by the age of three years almost all nets are classified as damaged, so the differences between simulations mainly relate to the question of how often damaged nets that are absent, or which are stated to have been moved elsewhere, remain in use.
| Analysis | $h_1$ ($h_3$) | $u_1$ | $u_2$ | $v_3$ | $v_4$ | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $P_o$ |
|----------|--------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| A1       | 1.18 (0.98, 1.42) | 0.87 (0.76, 0.98) | 1.67 (1.40, 2.01) | 1.30 (1.13, 1.47) | 2.77 (2.45, 3.22) | 0.44 (0.39, 0.51) | 0.04 (0.01, 0.09) | 0.37 (0.29, 0.47) | 0.26 (0.20, 0.33) | 0.26 (0.23, 0.30) | 0.60 (0.59, 0.61) |
| A1_0     | 1.01 (0.81, 1.26) | 0.79 (0.67, 0.90) | 1.59 (1.32, 1.90) | 1.33 (1.17, 1.51) | 2.55 (2.25, 2.96) | 0.44 (0.39, 0.49) | 0.04 (0.01, 0.10) | 0.36 (0.28, 0.44) | 0.33 (0.25, 0.39) | 0.24 (0.21, 0.27) | 0.65 (0.63, 0.66) |
| A1_L     | 1.39 (1.13, 1.68) | 1.09 (0.95, 1.25) | 2.30 (1.86, 3.06) | 1.21 (1.06, 1.37) | 4.14 (3.47, 5.33) | 0.42 (0.37, 0.48) | 0.03 (0.00, 0.08) | 0.35 (0.27, 0.43) | 0.33 (0.26, 0.41) | 0.25 (0.22, 0.28) | 0.60 (0.59, 0.62) |
| A2       | 1.11 (0.89, 1.38) | 0.87 (0.75, 1.00) | 1.63 (1.35, 1.97) | 1.30 (1.13, 1.50) | 2.83 (2.49, 3.32) | 0.44 (0.38, 0.51) | 0.01 (0.00, 0.03) | 0.14 (0.09, 0.20) | 0.02 (0.00, 0.05) | 0.06 (0.04, 0.08) | 0.60 (0.59, 0.62) |
| A3       | 1.24 (0.98, 1.52) | 0.88 (0.75, 1.00) | 1.64 (1.36, 2.00) | 1.25 (1.08, 1.43) | 2.86 (2.50, 3.36) | 0.46 (0.39, 0.52) | 0.12 (0.04, 0.19) | 0.55 (0.44, 0.66) | 0.12 (0.05, 0.19) | 0.22 (0.18, 0.26) | 0.60 (0.59, 0.62) |
| A4       | 1.25 (1.01, 1.51) | 0.88 (0.77, 1.00) | 1.67 (1.41, 2.01) | 1.25 (1.10, 1.43) | 2.80 (2.47, 3.23) | 0.46 (0.40, 0.52) | 0.17 (0.08, 0.26) | 0.71 (0.60, 0.83) | 0.36 (0.27, 0.45) | 0.41 (0.37, 0.46) | 0.60 (0.59, 0.61) |
| Dawplus 2.0 | 0.62 (0.30, 1.07) | 1.24 (0.93, 1.63) | 0.91 (0.61, 1.28) | 1.41 (0.93, 2.09) | 1.70 (1.24, 2.28) | 0.62 (0.44, 0.88) | 0.03 (0.00, 0.11) | 0.69 (0.41, 1.07) | 0.42 (0.25, 0.61) | 0.23 (0.12, 0.34) | 0.65 (0.62, 0.68) |
| DuraNet  | 0.53 (0.15, 1.28) | 0.56 (0.40, 0.77) | 2.60 (1.55, 6.79) | 0.46 (0.25, 0.79) | 4.77 (3.17, 11.56) | 0.30 (0.21, 0.42) | 0.04 (0.00, 0.16) | 0.22 (0.09, 0.45) | 0.26 (0.11, 0.40) | 0.22 (0.15, 0.31) | 0.49 (0.46, 0.52) |
| Interceptor | 0.61 (0.12, 1.20) | 0.66 (0.44, 0.91) | 0.58 (0.23, 1.07) | 3.58 (2.37, 6.31) | 1.91 (1.51, 2.40) | 0.31 (0.18, 0.63) | 0.07 (0.01, 0.17) | 0.11 (0.01, 0.50) | 0.21 (0.10, 0.33) | 0.33 (0.25, 0.42) | 0.59 (0.56, 0.63) |
| NetProtect | 2.14 (1.26, 3.42) | 0.85 (0.43, 1.20) | 2.11 (1.08, 11.66) | 1.63 (1.17, 2.27) | 3.27 (2.24, 12.06) | 0.76 (0.55, 1.05) | 0.10 (0.01, 0.28) | 0.36 (0.15, 0.60) | 0.10 (0.01, 0.26) | 0.26 (0.15, 0.38) | 0.59 (0.55, 0.62) |
| Olyset   | 0.92 (0.53, 1.40) | 1.41 (0.93, 1.95) | 1.69 (1.17, 2.66) | 0.77 (0.56, 1.04) | 2.48 (1.62, 4.17) | 0.80 (0.62, 1.04) | 0.13 (0.02, 0.27) | 0.35 (0.22, 0.52) | 0.17 (0.02, 0.41) | 0.27 (0.16, 0.38) | 0.65 (0.62, 0.68) |
| PermaNet 2.0 | 0.45 (0.04, 1.06) | 1.79 (1.26, 2.34) | 2.08 (1.45, 5.01) | 1.40 (0.81, 2.50) | 1.83 (1.14, 5.73) | 0.58 (0.36, 0.94) | 0.12 (0.01, 0.29) | 0.88 (0.50, 1.45) | 0.22 (0.05, 0.44) | 0.40 (0.23, 0.55) | 0.61 (0.57, 0.64) |
| PermaNet 3.0 | 1.37 (0.86, 2.15) | 0.71 (0.38, 1.02) | 1.95 (1.08, 7.37) | 2.06 (1.53, 2.73) | 3.25 (2.24, 11.11) | 0.29 (0.19, 0.43) | 0.05 (0.01, 0.20) | 0.15 (0.02, 0.38) | 0.33 (0.15, 0.49) | 0.19 (0.12, 0.26) | 0.64 (0.61, 0.67) |
Table S 6. Estimates of derived quantities for sensitivity analyses and net-type specific analyses.

|                | Median life of LLIN (years) | Reduction in net lifetime attributable to holes (years) | Proportion of lifetime of LLIN for which it is damaged | Proportion loss in net lifetime attributable to holes | Proportion of lifetime of LLIN for which it is in use$^1$ | Proportion of lifetime of LLIN for which it is in use$^2$ | Proportion of lack of use attributable to holes |
|----------------|-----------------------------|--------------------------------------------------------|--------------------------------------------------------|----------------------------------------------------|--------------------------------------------------------|--------------------------------------------------------|--------------------------------------------------------|
| A1             | 2.86 (2.68, 3.08)           | 2.88 (1.77, 4.34)                                       | 0.78 (0.75, 0.81)                                       | 0.49 (0.38, 0.58)                                   | 0.60 (0.58, 0.62)                                       | 0.56 (0.54, 0.58)                                       | 0.13 (-0.08, 0.30) |
| A1_0           | 3.03 (2.82, 3.26)           | 1.83 (1.04, 2.82)                                       | 0.77 (0.74, 0.80)                                       | 0.37 (0.26, 0.47)                                   | 0.61 (0.59, 0.63)                                       | 0.57 (0.55, 0.59)                                       | -0.09 (-0.28, 0.11) |
| A1_I           | 2.90 (2.69, 3.13)           | 2.35 (1.40, 3.61)                                       | 0.82 (0.80, 0.84)                                       | 0.43 (0.32, 0.53)                                   | 0.61 (0.59, 0.63)                                       | 0.57 (0.55, 0.59)                                       | -0.03 (-0.25, 0.17) |
| A2             | 9.34 (7.91, 11.40)          | 8.59 *                                                 | 0.91 (0.89, 0.92)                                       | 0.40 (0.29, 0.48)                                   | 0.69 (0.66, 0.71)                                       | 0.64 (0.62, 0.67)                                       | -0.15 (-0.40, 0.03) |
| A3             | 2.60 (2.41, 2.82)           | 3.24 (1.77, 5.98)                                       | 0.78 (0.74, 0.81)                                       | 0.53 (0.40, 0.65)                                   | 0.60 (0.57, 0.62)                                       | 0.56 (0.53, 0.58)                                       | 0.20 (-0.04, 0.42) |
| A4             | 1.74 (1.64, 1.85)           | 1.23 (0.77, 1.96)                                       | 0.69 (0.66, 0.72)                                       | 0.44 (0.34, 0.55)                                   | 0.54 (0.51, 0.56)                                       | 0.50 (0.48, 0.52)                                       | 0.13 (-0.06, 0.30) |
| Dawaplus 2.0   | 2.64 (2.21, 3.12)           | 2.19 (0.72, 4.94)                                       | 0.67 (0.57, 0.76)                                       | 0.49 (0.38, 0.58)                                   | 0.52 (0.46, 0.59)                                       | 0.49 (0.43, 0.55)                                       | 0.13 (-0.06, 0.29) |
| DuraNet        | 3.90 (3.03, 4.99)           | 1.62 (-0.01, 4.44)                                      | 0.70 (0.53, 0.83)                                       | 0.46 (0.21, 0.63)                                   | 0.48 (0.39, 0.55)                                       | 0.44 (0.36, 0.51)                                       | 0.05 (-0.47, 0.40) |
| Interceptor    | 3.40 (2.80, 4.25)           | 3.32 (1.00, 9.42)                                       | 0.67 (0.47, 0.80)                                       | 0.29 (-0.02, 0.53)                                   | 0.63 (0.53, 0.70)                                       | 0.59 (0.49, 0.66)                                       | 0.01 (-0.52, 0.41) |
| NetProtect     | 2.73 (2.25, 3.30)           | 3.57 (0.63, 13.23)                                      | 0.85 (0.79, 0.90)                                       | 0.49 (0.27, 0.67)                                   | 0.59 (0.53, 0.64)                                       | 0.55 (0.50, 0.60)                                       | -0.49 (-2.20, 0.05) |
| Olyset         | 2.73 (2.31, 3.26)           | 1.85 (0.38, 5.56)                                       | 0.77 (0.71, 0.83)                                       | 0.49 (0.38, 0.58)                                   | 0.44 (0.39, 0.50)                                       | 0.41 (0.36, 0.46)                                       | 0.31 (-0.45, 0.64) |
| PermaNet 2.0   | 2.01 (1.74, 2.31)           | 2.06 (0.69, 5.79)                                       | 0.64 (0.55, 0.72)                                       | 0.37 (0.26, 0.47)                                   | 0.60 (0.55, 0.66)                                       | 0.56 (0.51, 0.61)                                       | 0.34 (-0.08, 0.62) |
| PermaNet 3.0   | 4.00 (3.26, 5.12)           | 0.47 (-1.29, 2.71)                                      | 0.86 (0.80, 0.90)                                       | 0.43 (0.32, 0.53)                                   | 0.75 (0.70, 0.79)                                       | 0.70 (0.65, 0.74)                                       | 0.45 (0.14, 0.70) |

$^1$As defined by ‘net in use’; $^2$As defined by ‘net in use last night’; *interval estimates outside the simulated range.