Package: ExpBites (via r-universe)

November 21, 2026

Title Analyzing Human Exposure to Mosquito Biting

Version 0.1.4

Description Tools to analyse human and mosquito behavioral interactions and to compute exposure to mosquito bites estimates. Using behavioral data for human individuals and biting patterns for mosquitoes, you will be able to compute hourly exposure for bed net users and non-users, and summarize (e.g. proportion indoors and outdoors, proportion per time periods, and proportion prevented by bed nets) or visualize these dynamics across a 24-hour cycle.

License GPL-3

Encoding UTF-8

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Imports dplyr, tidyr, ggplot2, Rdpack (>= 0.7)

RdMacros Rdpack

Suggests knitr, rmarkdown, testthat (>= 3.0.0)

Depends R (>= 4.1.0)

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URL https://github.com/Nmoiroux/ExpBites

BugReports https://github.com/Nmoiroux/ExpBites/issues

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Repository https://nmoiroux.r-universe.dev

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`calculate_Exp` *Calculate Hourly Mosquito Biting Exposure for Bednet Users and Non-Users*

Description

Using a model of behavioral interactions, computes the hourly exposure to mosquito bites for both bednet users and non-users, based on their location (indoors, outdoors, under a net) and mosquito biting rates. For users, exposure is adjusted for the protective effect of bednets.

Usage

```
calculate_Exp(df, df_bites, protection = 0.92)
```

Arguments

`df`	A dataframe with individual-level data, including columns: • `individual` – individual ID, • `hour` – hour of the day (0–23), • `state` – activity/location state (1 = outdoors, 2 = indoors awake, 3 = indoors asleep, 4 = indoors asleep under bed net), • `bednet_user` – logical indicator of bed net use (TRUE/FALSE).
`df_bites`	A dataframe of biting rates by hour, with columns: • `hour` – hour of the day (0–23), • `indoor_bites` – number of bites indoors, • `outdoor_bites` – number of bites outdoors.
`protection`	A numeric value (default = 0.92, according to Corbel et al. (2010) for Permanet 2 ITNs) indicating the proportion of bites prevented by bednet use.

Details

The mathematical model of behavioral interactions is an extension of the Killeen et al. (2006) model as previously described in Geissbühler et al. (2007) and Moiroux et al. (2014)

Value

A dataframe with one row per hour (0–23) and the following columns:

- `Bi_t` – indoor biting rate,
- `Bo_t` – outdoor biting rate,
- `N` – number of human individuals,
- `Np` – number of human individuals that are net users,
- `It` – proportion of people indoors (users and non-users),
- `Eui` – mean exposure of non-users indoors,
- `Euo` – mean exposure of non-users outdoors,
- `Eu` – total mean exposure of non-users,
- `p_in` – proportion of people (users) being indoors,
- `p_net` – proportion of people (users) being asleep (under net),
- `Epi` – mean exposure of users indoors (not under net),
- `Epn` – mean exposure of users indoors under bed net (adjusted by protection),
- `Epo` – mean exposure of users outdoors,
- `Epp` – mean exposure prevented by bed net use,
- `Ep` – total mean exposure of users.

References

Corbel V, Chabi J, Dabiré RK, Etang J, Nwane P, Pigeon O, Akogbeto M, Hougard J (2010). "Field Efficacy of a New Mosaic Long-Lasting Mosquito Net (PermaNet 3.0) against Pyrethroid-Resistant Malaria Vectors: A Multi Centre Study in Western and Central Africa." *Malaria Journal*, **9**, 113. ISSN 1475-2875. doi:10.1186/147528759113.

Geissbühler Y, Chaki P, Emidi B, Govella NJ, Shirima R, Mayagaya V, Mtasiwa D, Mshinda H, Fillinger U, Lindsay SW, Kannady K, de Castro MC, Tanner M, Killeen GF (2007). "Interdependence of Domestic Malaria Prevention Measures and Mosquito-Human Interactions in Urban Dar Es Salaam, Tanzania." *Malaria Journal*, **6**, 126. ISSN 1475-2875. doi:10.1186/147528756126.

Killeen GF, Kihonda J, Lyimo E, Oketch FR, Kotas ME, Mathenge E, Schellenberg JA, Lengeler C, Smith TA, Drakeley CJ (2006). "Quantifying Behavioural Interactions between Humans and Mosquitoes: Evaluating the Protective Efficacy of Insecticidal Nets against Malaria Transmission in Rural Tanzania." *BMC infectious diseases*, **6**, 161. ISSN 1471-2334. doi:10.1186/147123346-161.

Moiroux N, Damien GB, Egrot M, Djenontin A, Chandre F, Corbel V, Killeen GF, Pennetier C (2014). "Human Exposure to Early Morning Anopheles Funestus Biting Behavior and Personal Protection Provided by Long-Lasting Insecticidal Nets." *PloS One*, **9**(8), e104967. ISSN 1932-6203. doi:10.1371/journal.pone.0104967.

Examples

```
# generate fake data
df <- gen_df_human(n_individuals = 100, hours = c(0:9,17:23))
df_bites <- gen_df_mosquito()
# calculate mean hourly exposure to bites
exposure_results <- calculate_Exp(df, df_bites)
```

`gen_df_human` *Generate a Simulated Dataset of Human Behavioral States Over 24 Hours*

Description

Simulates the hourly state of a set of individuals (either bednet users or non-users) over a 24-hour period. Each individual's state is assigned probabilistically based on the hour of the day and whether they use a bednet.

Usage

```
gen_df_human(n_individuals = 100, hours = c(0:23), prob_use = 0.5)
```

Arguments

`n_individuals`	Integer. Number of individuals to simulate. Default is 100.
`hours`	Integer vector. The hours of the day to simulate, typically `0:23`. Default is `0:23`.
`prob_use`	Numeric. Probability of being a bednet user vs non-user. Default is 0.5.

Value

A data.frame with the following columns:

individual Individual ID.

hour Hour of the day (0–23).

bednet_user Logical, indicating whether the individual is a bednet user.

state Integer representing the individual's state at that hour: `1` = outdoors, `2` = indoors and awake, `3` = indoors asleep (non-user), `4` = indoors asleep under bednet (user).

state_label Factor version of `state` with descriptive labels.

Examples

```
df <- gen_df_human(n_individuals = 50)
df <- gen_df_human(n_individuals = 100, hours = c(0:9,17:23))
head(df)
```

gen_df_mosquito *Generate a Simulated Dataset of Hourly Mosquito Biting Rates*

Description

Simulates the number of Anopheles mosquito bites occurring indoors and outdoors for each hour of the day. Biting rates follow predefined lambda patterns that reflect typical mosquito activity (e.g., low during the day, peaking at night).

Usage

```
gen_df_mosquito()
```

Value

A data.frame with the following columns:

hour Hour of the day (0–23).

indoor_bites Simulated number of mosquito bites occurring indoors for each hour.

outdoor_bites Simulated number of mosquito bites occurring outdoors for each hour.

Examples

```
df_bites <- gen_df_mosquito()
head(df_bites)
```

plot_behaviors *Plot Human and Mosquito Behaviors by Hour*

Description

Generates a dual-axis plot showing the hourly variation in human behavior (proportion of individuals indoors and under bednets) and mosquito biting behavior (biting rates indoors and outdoors). Human behavior is shown as a stacked area plot on the primary Y-axis, while mosquito biting rates are shown as lines on the secondary Y-axis. Hours are centered on midnight.

Usage

```
plot_behaviors(data)
```

Arguments

data	A dataframe (typically the output of calculate_Exp) containing the following columns: • hour – hour of the day (0–23), • p_in – proportion of users indoors (not under a net), • p_net – proportion of users under a net, • Bi_t – indoor mosquito biting rate, • Bo_t – outdoor mosquito biting rate.

Value

A ggplot2 plot object with a stacked area chart for human behavior (on the primary Y-axis) and line plots for mosquito biting rates (on the secondary Y-axis), with hours centered on midnight.

Examples

```
# generate fake data
df <- gen_df_human(n_individuals = 100, hours = c(0:9,17:23))
df_bites <- gen_df_mosquito()
# calculate mean hourly exposure to bites
exposure_results <- calculate_Exp(df, df_bites)
# plot
plot_behaviors(exposure_results)
```

---

plot_exposure *Plot Exposure to Mosquito Bites by Hour for Bednet Users*

Description

Creates a stacked area chart showing the hourly distribution of exposure to mosquito bites among bednet users, broken down by exposure type: outdoors, indoors (no net), indoors (under net), and prevented exposure due to bednet use. The hours are centered on midnight for better visualization.

Usage

```
plot_exposure(data, cPalette = c("#000000", "#E69F00", "#56B4E9", "#009E73"))
```

Arguments

data	A dataframe resulting from the calculate_Exp function, containing columns: • hour – hour of the day (0–23), • Epo – exposure outdoors, • Epi – exposure indoors (not under a net), • Epn – exposure indoors under a net, • Epp – exposure prevented by net use.

cPalette — A character vector of color values (hex codes or color names) used to fill each exposure category. Must be of length 4 and will be applied in the following order: Prevented, Indoor (under net), Indoor (no net), Outdoor. Defaults to c("#000000", "#E69F00", "#56B4E9", "#009E73").

Value

A ggplot2 stacked area chart object showing the distribution of exposure types across centered hours.

Examples

```
# generate fake data
df <- gen_df_human(n_individuals = 100, hours = c(0:9,17:23))
df_bites <- gen_df_mosquito()
# calculate mean hourly exposure to bites
exposure_results <- calculate_Exp(df, df_bites)
# plot
plot_exposure(exposure_results)
```

---

summarise_exposure *Summarize Exposure to Mosquito Bites Over 24h and a Time Interval*

Description

Computes daily (24h) and interval-specific exposure statistics for both non-users and bednet users, based on the output of calculate_Exp. Protective efficacy of bednets and proportion of exposure indoors or during the specified interval are computed.

Usage

```
summarise_exposure(data, interval = c(22, 5))
```

Arguments

data — A dataframe returned by calculate_Exp(), including columns:

- Eui, Euo, Eu – indoor, outdoor, and total exposure for non-users,
- Epi, Epn, Epo, Epp, Ep – indoor, indoor under net, outdoor, prevented, and total exposure for users,
- hour – hour of the day (0–23).

interval — A numeric vector of length 2 giving the start and end hour (inclusive) of the time interval, e.g., c(22, 5) for 10pm to 5am. Wraps over midnight if needed.

Details

The mathematical model of behavioral interactions is an extension of the Killeen et al. (2006) model as previously described in Geissbühler et al. (2007) and Moiroux et al. (2014)

Value

A tibble with three columns:

type Character string indicating the category of summary:

- `"non_user_daily"` – metric for non-users of nets (daily),
- `"user_daily"` – metric for users of nets (daily),
- `"non_user_interval"` – metric for non-users of nets (specified time interval),
- `"user_interval"` – metric for users of nets (specified time interval),
- `"interval_vs_daily"` – metric comparing exposure in the specified time interval to the daily exposure,
- `"net_efficacy"` – metric related to net protective efficacy

.

output Name of the exposure component or metric:

- `"Eui"` – average exposure of an unprotected individual (non-user) indoors (in bites),
- `"Euo"` – average exposure of an unprotected individual (non-user) outdoors (in bites),
- `"Eu"` – average exposure of an unprotected individual (non-user) (in bites),
- `"Epi"` – average exposure of a net-protected individual (user) indoors but not under the net (in bites),
- `"Epo"` – average exposure of a net-protected individual (user) outdoors (in bites),
- `"Epn"` – average exposure of a net-protected individual (user) indoors under the net (in bites),
- `"Epp"` – average exposure prevented by the use of a net (in bites),
- `"Ep"` – average exposure of net-protected individual (user)(in bites),
- `"prop_indoor"` – proportion of exposure to bites occurring indoors (in %),
- `"prop_interval_non_user"` – proportion of exposure to bites occurring during the specified time interval, for unprotected non-users (in %),
- `"prop_interval_user"` – proportion of exposure to bites occurring during the specified time interval, for net-protected users (in %),
- `"prop_prevented"` – proportion of exposure to bites prevented by the use of a net (in %)

.

value Numeric value corresponding to the output for the given type.

References

Geissbühler Y, Chaki P, Emidi B, Govella NJ, Shirima R, Mayagaya V, Mtasiwa D, Mshinda H, Fillinger U, Lindsay SW, Kannady K, de Castro MC, Tanner M, Killeen GF (2007). "Interdependence of Domestic Malaria Prevention Measures and Mosquito-Human Interactions in Urban Dar Es Salaam, Tanzania." *Malaria Journal*, **6**, 126. ISSN 1475-2875. doi:10.1186/147528756126.

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Examples

```
# generate fake data
df <- gen_df_human(n_individuals = 100, hours = c(0:9,17:23))
df_bites <- gen_df_mosquito()
# calculate mean hourly exposure to bites
exposure_results <- calculate_Exp(df, df_bites)
# summarise exposure estimates
summarise_exposure(exposure_results, interval = c(22, 5))
```

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