**Global Relative R0 Model for Dengue based on *Aedes aegypti* vector**

**Goal:**

Construct a Worldwide Relative Basic Reproductive Number (R0) model for Dengue at 5 x 5 km grid resolution based on work of Ndeffo & Pandey (2020) which accounts for:

* Distribution of *Aedes aegypti* mosquito vectors
* Interaction between socio-economic factors (including prosperity, housing conditions, etc.) and human-mosquito contact = Risk of Exposure
* Rainfall & temperature effects on transmission dynamics
* Carrying capacity informed by empirical data
* Human density informed by empirical data

**Constructing the R0 model**

Basic Reproductive Number (R0) Model for *Aedes aegypti* derived from Ngonghala et al., 2021. This is an extended version of the Ross-Macdonald formulation with a function of Temperature T (°C):

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\* Parameter Condition: >

**Table 1. Dengue R0 model parameter settings using Ngonghala et al. (2021) and *Aedes aegypti* mosquitoes**. R0 is the average number of secondary cases arising from a typical primary infection in an otherwise fully susceptible population.

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| **Parameter** | **Description** | **Function** | **Constant/Formula** |
| T | Temperature °C | ---- | Monthly min, max, and average temperature (°C)and rainfall (mm) at various resolutions from 1970-2000  (use 2.5 min spatial resolution data for 5 km)  <https://www.worldclim.org/> |
| b | Mosquito biting rate | Brière | 2.02E-04\*T\*(T-13.35)\*(40.08-T)^0.5 |
| Beta\_vh  βvh | Probability that an infectious mosquito successfully transmits the virus while taking a blood meal from a susceptible human (i.e., transmission rate) | Brière | 8.49E-04\*T\*(T-17.05)\*(35.83-T)^0.5 Ϯ  Ϯ Value is taken from Mordecai et al., 2017 |
| Beta\_hv  βhv | Probability that an infectious human successfully transmits the virus to a biting susceptible mosquito (i.e., infection rate) | Quad | -3.54E-03\*(T-38.38)\*(T-22.72) |
| Sigma\_v  σv | Rate at which vectors become infectious (extrinsic incubation period) | Brière | 1.74E-04\*T\*(T-18.27)\*(42.31-T)^0.5 |
| Sigma\_h  σh | Rate at which humans become infectious (intrinsic incubation period) | Constant | 1/5.9 (days) |
| Gamma\_h  ϒv | Per capita human recovery rate | Constant | 1/5 (days)  Ϯ Value is taken from Mordecai et al., paper |
| Theta  ϴ | # of eggs a female mosquito produces per day | Brière | 8.56E-03\*T\*(T-14.58)\*(34.61-T)^0.5 |
| Nu  ν | Probability of surviving from egg to adult | Quad | -5.99E-03\*(T-38.29)\*(T-13.56) |
| Phi  φ | Rate at which an egg develops into an adult mosquito | Brière | 7.86E-05\*T\*(T-11.36)\*(39.17-T)^0.5 |
| Mu  μ | Natural Mosquito Death Rate | Quad | 1/(-3.02E-01\*(T-11.25)\*(T-37.22)) |
| ƒ(R) | Modeling Precipitation | ƒ(RBrière)  ƒ(RQuadratic)  ƒ (RInverse) | Text, letter  Description automatically generated  \*\*See values in Table 2 below |
| Kappa  κ | Carrying Capacity (Maximum # of mosquitos a site can support) | ---- | Constant Habitat per Unit Area  9.34x10^8/492.84 = 1.985x10^6  Rain Filled Habitat per Unit Area  3.72x10^8/492.84 - 7.548x10^5  Adjusted from 1°x 1° to 5 km x 5 km units at latitude of San Juan, Puerto Rico (Soda et al., 2018; Perkins et al, 2018) |
| Rse | Risk of exposure | ---- | Risk of exposure (factor of socioeconomic variables)  Estimated using Geolocalized economic data from Nordhuas, 2006 as cited in the Zhang et al., 2017  \*\*See values in Table 3 below |
| Pae | Probability of aegypti occurrence | ---- | Probability of Aedes aegypti occurrence derived from Kraemer et al., 2005 study (R data file)  \*\*See values in Table 3 below |
| Nh | Human Population Density | ---- | Population density from WorldPop Hub:  <https://hub.worldpop.org/project/categories?id=18> |

The temperature dependent parameters were based on both the quadratic c(T-Tm)(T-T0) and Brière (cT(T-T0)(Tm-T)1/2 functional forms. Here *T* is the temperature (Celsius), *c* is the rate (or scaling constant), *T0* is the critical thermal minimum temperature and *Tm* is the critical thermal maximum temperature.

**Table 2. Values for carrying capacity as a function of precipitation (Caldwell et al., (2021)**

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| --- | --- | --- | --- | --- |
| **Function** | **Rate Constant (c) value** | **Minimum Rainfall (Rmin) value (m)** | **Maximum Rainfall (Rmax) value (m)** | **Scaling Factor (z) value** |
| ƒ(RBrière) = c \* R \* (R-Rmin)\* √(Rmax-R) \* z | 7.86e-5 | 0.001 | 0.123 | 0.28 |
| ƒ(RQuadratic) = c \* (R-Rmin)\* (R- Rmax) \* z | -5.99E-3 | 0.001 | 0.123 | 0.025 |
| ƒ(RInverse)= 1/R \* z | --- | --- | --- | 0.60 |

**Table 3. Risk of Exposure Function.** Fraction of the exposed population that can be associated with the geographically based version of the per capital Gross Domestic Product based on Purchasing Power Parity (GDP per capita, PPP) (Zhang et al., 2017).

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| --- | --- |
| Risk of Exposure Function | Range of Values |
| 1.67 -0.34\*log(PPP\*exp(0.47)) | 1.97>log(PPP\*exp(0.47))<4.911 |
| 1 | log(PPP\*exp(0.47))<1.97 |
| 0 | log(PPP\*exp(0.47))>4.911 |

**Table 3. Databases with high spatial resolution used to parameterize the model**

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| --- | --- |
| **Parameter** | **Description & Source** |
| Global Aedes Distribution (Pae) | Uncertainty estimates for mosquito distribution at 5 km x 5 km resolution  <https://www.dropbox.com/sh/bpxcmzmmpiiav8u/AAAl3CBKnBYwXb0n1s1C4-K-a?dl=0>  (R datafiles and *Aedes* maps)  (Kraemer et al., 2015) |
| Global Climate Database (R & T) | Monthly min, max, and average temperature (°C)and rainfall (mm) at various resolutions from 1970-2000  (Use 2.5 min spatial resolution data for 5 km)  <https://www.worldclim.org/>  (Fick & Hijmans, 2017) |
| Geolocalized Economic Data (G-econ) | Geophysically scaled dataset linking per capita gross product (GDP) at purchasing power parity (PPP) rates (recomputed to change 1 km x 1 km to match 5 km x 5 km resolution of other data)  Excel File: <http://gecon.yale.edu/sites/default/files/files/Gecon40_post_final.xls>  (Zhang et al., 2017) |
| Human Population Density | Population density from WorldPop Hub:  <https://hub.worldpop.org/project/categories?id=18>  We will use the Unconstrained individual countries 2000-2020 UN adjusted (1 km resolution). This will need to be changed to match the 5 km x 5 km resolution of the other data sets. |