# Understanding Epidemics: Malaria model instructions

## Malaria model

The model is driven by monthly data on temperature and rainfall. These data are displayed in the two graphs on the right hand side (temperature in red and rainfall in blue) and the output is the graph on the left (purple). This shows a malaria transmission potential (the risk of malaria being transmitted).

The parameters for the model (the factors considered) are shown in the top left of the spreadsheet. What follows is a brief description of these:

### 1. Human Blood Index

The human blood index is the proportion of mosquito bites on humans compared with animals. The biting rate is driven by the time it takes to complete a gonotrophic cycle (egg production / laying cycle of the female mosquito – see biology) as the female mosquito needs a blood meal for each batch of eggs she produces.

This is therefore closely linked to the gonotrophic, sporogonic and mosquito survival variables.

### 2. Mosquito survival

Mosquitoes are vulnerable to predations especially whilst they are resting after a blood meal. The survival probability is the proportion of mosquitoes which survive each blood meal and therefore complete each gonotrophic cycle.

The key issue here is that when the temperature gets almost as low as the sporogonic cycle threshold (18oC) the sporogonic cycle will take so long that it is unlikely that the mosquito will live long enough for it to be completed.

### 3. Sporogonic factors

The sporogonic cycle (the development of the parasite within the mosquito – see biology) is governed by temperature. This is a complex relationship which is strongly dependent on mosquito survival, which is in turn linked to temperature.

The sporogonic cycle requires a minimum temperature to occur, then it occurs more quickly if the temperature is consistently high, but must not be too high as that will mean that the mosquito will die before the cycle is complete.

The units used for the length of sporogonic cycle are degree days. This is a complex term, but an easy way to think about it is in terms of energy. A certain amount of energy is needed for the cycle to be completed. This energy comes from heat. So, if the heat for each day is added up and it is enough then the cycle is able to occur. This cannot however happen over an infinite time in the case of malaria as, if the required amount of heat isn't reached within the mosquito's lifetime, the sporogonic cycle will not occur.

**4. Gonotrophic factors**

The gonotrophic cycle (the egg production/laying cycle of the female mosquito) is controlled by temperature (see biology pages).

Like the sporogonic cycle, the length of the gonotrophic cycle is measured in degree days and the gonotrophic cycle is the minimum temperature required for mosquito reproduction.

**7. Rainfall threshold**

As described in the biology pages, mosquitoes require bodies of still water in order to reproduce. Rainfall is therefore needed in order to provide this water.

The rainfall threshold in the model means that the model only allows for malaria to develop in times when there is sustained rainfall. The units used are mm per month. The rules-based model provided by MARA which was described above used 80mm as the minimum. However, when this is put into this model this means that there is no malaria. Malaria can occur with lower rainfall, especially when there are other sources of water (e.g. rivers).

Most agricultural models use 10-20mm as the threshold and we suggest that 10mm is used a first starting point for this model.

**8. Temperature increment**

The temperature data is the average daily maximum. Because this is an average and a maximum, the actual values are likely to be less.

The temperature increment allows this difference to be factored into the model. We suggest that the daily temperature will be between 5 and 8 degrees less than the average daily maximum, and so the temperature increment is set at –5.

See next page for details on using the model.

## Exploring the model

To explore the model we suggest you leave the values for both gonotrophic and sporogonic cycles as originally set.

Original Value

Human blood index 0.8
Mosquito survival probability per gonotrophic cycle 0.5
Length of sporogonic cycle 111
Sporogonic threshold 18
Length of gonotrophic cycle 37
Gonotrophic threshold 9
Rainfall threshold (sustained for 4 months) 10
Temperature increment (-/+) -5

The figures in bold and highlighted - human blood index, mosquito survival, rainfall threshold and temperature increment - can all be changed.

We suggest that you look at the sensitivity of the model by changing each value in turn. Change the values a little at a time (the model may crash if you go too far) and start by just varying one parameter.

Look at the effect your changes have on the graph of malaria transmission potential. In each case see how the malaria transmission varies across the three years which are the start and end month, how high is the peak and estimate the areas under the epidemic curves in each year.

See how the transmission values relate to the time series of temperature and rainfall and how these vary from year to year.

### Rainfall

A good place to start is changing the rainfall threshold. Look at the effect of increasing the threshold which means that more rain is required across four consecutive months to allow the malaria to start to develop, or reduce it to see the affect of requiring less rain.

Then move onto the temperature, but first return the rainfall setting to the original value.

### Temperature

You can raise the average temperature by changing the temperature increment to a smaller negative number e.g. –2. Look at the temperature graph (red) first to see the effect this has on average monthly temperatures and then look at the effect this has on the transmission potential graph (purple).

To lower the average temperature put a larger negative number in the temperature increment (e.g. –8).

This may mean that for some months the temperature is not above the 18 degree Celsius sporogonic threshold and so there is not transmission potential (or this may reduce transmission potential by lowering the sporogonic and gonotrophic cycle measures below the degree day thresholds.

**Mosquito survival**

Put the temperature setting back to the original value.

Now look at the mosquito survival. At 0.5, this means that only half the female mosquitoes that go for a blood meal survive to lay their eggs at the end of that cycle.

This value is within the range of published values. Increase this value to 0.6 so 60% of the mosquitoes survive and see the impact on the transmission potential .

Then try a range of other values.

**Multiple changes**

OK, you are probably ready to start varying more than one parameter at a time. Try changing all three of these parameters. What you may find is that it becomes difficult to follow what is causing what effect. This is a good illustration as to why we use models to do the work for us!