Malaria Transmission Systems and their Role in Malaria Control & Elimination

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# Introduction

Human malaria transmission is caused by more than 70 species of anopheline vectors. Each species has its own characteristic ecology, blood feeding times, host preferences, and habits. Differences in when and where contact occurs between humans, malaria vectors, and vector control affect transmission, the ability to measure it, and the prospects for malaria control and elimination. Here, we present a very simple model of malaria

# Methods

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| Name | Parameter Description |
| b | Proportion of bites by infectious mosquitoes that cause an infection |
| r | Rate that humans recover from an infection |
| a | Human blood feeding rate (1/a is interval between human blood meals) |
| g | Per-capita death rate of mosquitoes |
| c | The proportion of mosquitoes infected after biting an infectious human |

Let (or denote the number of forest-going men (or infected men) who spend an average proportion of time in villages, and in the forest. Let (or represent the number of forest non-going people (or infected people) in the village. Let and represent the size of the village and forest vector populations, the number of infected vectors in each location, and the number of infectious vectors. Using a familiar Ross-Macdonald parameter notation (Table), subscripted by location, we have the following equations:

# Results

Invasion: If parasites invade either the forest or the village

Coverage:

Effect Sizes:

# Discussion

All available evidence suggests that adult men aged 15-50 form a distinct and important sub-population for malaria transmission because they participate in both forest malaria and village malaria. By most measures, the risk of malaria is much lower in the remaining population including children and women aged 15-50. A parsimonious and simple model can be formulated to explain this pattern:

1. Transmission in villages occurs at a low level;
2. Transmission among adult men in forests occurs at a much higher level.

We can formulate this into a model, though many of the points arising could probably be guessed at without the model.

The model is almost comically simple, but it can be used to make a few very profound points. First, if there were no transmission in the forest, then there would be no reason for the risk of malaria to be higher in men. Similarly, if there were no transmission in the village, then there would be no risk in the village. It means that coverage targets for malaria in the villages are low and may have already been met, but coverage targets in the forest could be extremely high. This is the math that supports the two conclusions made above.

Second, and perhaps more importantly, it is entirely possible that if transmission in the forest ended, that transmission in the villages would also be interrupted. Without interrupting malaria transmission in forests, it is very hard to test this hypothesis.

Third, the definition of coverage mainly applies to biting by vectors in the villages. When the men go into the forest, home-based net ownership has little to do with vector-intervention contact for the forest vectors. There must be a separate definition of “coverage” for purposes of measuring vector control in the forests.

The conclusions we draw from these equations are the following:

1. We believe Cambodia’s remaining problem is essentially an operational problem. There are, at present, no really good options for controlling forest malaria. Some practical options (largely untested) are:
   1. Enhanced case management. This is the best option, but it is not yet clear whether it is adequate for all situations, but it would need to be coordinated among all the populations using a forest – the forest’s “catchment.”
   2. Active case detection in adult males. For example, adult males could be paid to report to a clinic once every 2-3 months, screened, and treated.
   3. A vaccine
   4. Wearable vector protection (e.g. personal area repellant patches).
2. The dominant problem for malaria elimination in Cambodia at the present is forest malaria; it is not clear whether there would be any problems remaining under present conditions if forest malaria were interrupted.

With this summary, we emphasize that the most critical gap for elimination is having at least one credible option for forest malaria.