S1: Supplemental Document

Model Equations

Human Dosing Model with Movement in the High Transmission Area

$$
\begin{aligned}
\frac{dS_H}{dt} &= \mu - \Lambda_H S_H + \omega P_H + \sigma A_H - cS_H + (1-b)r_2 T'_{H3} + r_2 T_{H2} - \mu S_H + \frac{p_{21}}{m}[S_L - S_H] \\
\frac{dD_H}{dt} &= \lambda\rho\Lambda_H S_H - aD_H + (\nu + d\Lambda_H)\rho A_H - \mu D_H + \frac{p_{21}}{m}[D_L - D_H] \\
\frac{dA_H}{dt} &= (1-\lambda\rho)\Lambda_H S_H - gA_H - \sigma A_H - cA_H - (\nu + d\Lambda_H)\rho A_H - \mu A_H + \frac{p_{21}}{m}[A_L - A_H] \\
\frac{dT_{H1}}{dt} &= aD_H - r_1 T_{H1} - \mu T_{H1} + \frac{p_{21}}{m}[T_{L1} - T_{H1}] \\
\frac{dT'_{H1}}{dt} &= r_1 T_{H1} - r_2 T'_{H1} - \mu T'_{H1} + \frac{p_{21}}{m}[T'_{L1} - T'_{H1}] \\
\frac{dT_{H2}}{dt} &= cS_H - r_1 T_{H2} - \mu T_{H2} + \frac{p_{21}}{m}[T_{L2} - T_{H2}] \\
\frac{dT'_{H2}}{dt} &= r_1 T_{H2} - r_2 T'_{H2} - \mu T'_{H2} + \frac{p_{21}}{m}[T'_{L2} - T'_{H2}] \\
\frac{dT_{H3}}{dt} &= cA_H - r_1 T_{H3} - \mu T_{H3} + \frac{p_{21}}{m}[T_{L3} - T_{H3}], \\
\frac{dT'_{H3}}{dt} &= r_1 T_{H3} - r_2 T'_{H3} - \mu T'_{H3} + \frac{p_{21}}{m}[T'_{L3} - T'_{H3}] \\
\frac{dP_H}{dt} &= gA_H + r_2 T'_{H1} + br_2 T'_{H3} - \omega P_H - \gamma\Lambda_H P_H - \mu P_H + \frac{p_{21}}{m}[P_L - P_H] \\
\frac{dS_{Ha}}{dt} &= \omega' P_{Ha} - \Lambda_H S_{Ha} - \mu S_{Ha} + \frac{p_{21}}{m}[S_{La} - S_{Ha}] \\
\frac{dD_{Ha}}{dt} &= \lambda'\rho\Lambda_H S_{Ha} - aD_{Ha} + \nu'\rho A_{Ha} - \mu D_{Ha} + \frac{p_{21}}{m}[D_{La} - D_{Ha}] \\
\frac{dA_{Ha}}{dt} &= (1-\lambda'\rho)\Lambda_H S_{Ha} - gA_{Ha} - \nu'\rho A_{Ha} - \mu A_{Ha} + \frac{p_{21}}{m}[A_{La} - A_{Ha}] \\
\frac{dT_{Ha}}{dt} &= aD_{Ha} - r_1 T_{Ha} - \mu T_{Ha} + \frac{p_{21}}{m}[T_{La} - T_{Ha}] \\
\frac{dT'_{Ha}}{dt} &= r_1 T_{Ha} - r_2 T'_{Ha} - \mu T'_{Ha} + \frac{p_{21}}{m}[T'_{La} - T'_{Ha}] \\
\frac{dP_{Ha}}{dt} &= \gamma\Lambda_H P_H + r_2 T'_{Ha} + gA_{Ha} - \omega' P_{Ha} - \mu P_{Ha} + \frac{p_{21}}{m}[P_{La} - P_{Ha}]
\end{aligned} \tag{1H}
$$

Human Dosing Model with Movement in the Low Transmission Area

$$
\begin{aligned}
\frac{dS_L}{dt} &= \mu - \Lambda_L S_L + \omega P_L + \sigma A_L - cS_L + (1-b) r_2 T'_{L3} + r_2 T_{L2} - \mu S_L + mp_{12}[S_H - S_L] \\
\frac{dD_L}{dt} &= \lambda\rho\Lambda_L S_L - aD_L + (\nu + d\Lambda_L)\rho A_L - \mu D_L + mp_{12}[D_H - D_L] \\
\frac{dA_L}{dt} &= (1-\lambda\rho)\Lambda_L S_L - gA_L - \sigma A_L - cA_L - (\nu + d\Lambda_L)\rho A_L - \mu A_L + mp_{12}[A_H - A_L] \\
\frac{dT_{L1}}{dt} &= aD_L - r_1 T_{L1} - \mu T_{L1} + mp_{12}[T_{H1} - T_{L1}] \\
\frac{dT'_{L1}}{dt} &= r_1 T_{L1} - r_2 T'_{L1} - \mu T'_{L1} + mp_{12}[T'_{H1} - T'_{L1}] \\
\frac{dT_{L2}}{dt} &= cS_L - r_1 T_{L2} - \mu T_{L2} + mp_{12}[T_{H2} - T_{L2}] \\
\frac{dT'_{L2}}{dt} &= r_1 T_{L2} - r_2 T'_{L2} - \mu T'_{L2} + mp_{12}[T'_{H2} - T'_{L2}] \\
\frac{dT_{L3}}{dt} &= cA_L - r_1 T_{L3} - \mu T_{L3} + mp_{12}[T_{H3} - T_{L3}], \qquad (1L) \\
\frac{dT'_{L3}}{dt} &= r_1 T_{L3} - r_2 T'_{L3} - \mu T'_{L3} + mp_{12}[T'_{H3} - T'_{L3}] \\
\frac{dP_L}{dt} &= gA_L + r_2 T'_{L1} + br_2 T'_{L3} - \omega P_L - \gamma\Lambda_L P_L - \mu P_L + mp_{12}[P_H - P_L] \\
\frac{dS_{La}}{dt} &= \omega' P_{La} - \Lambda_L S_{La} - \mu S_{La} + mp_{12}[S_{Ha} - S_{La}] \\
\frac{dD_{La}}{dt} &= \lambda'\rho\Lambda_L S_{La} - aD_{La} + \nu'\rho A_{La} - \mu D_{La} + mp_{12}[D_{Ha} - D_{La}] \\
\frac{dA_{La}}{dt} &= (1-\lambda'\rho)\Lambda_L S_{La} - gA_{La} - \nu'\rho A_{La} - \mu A_{La} + mp_{12}[A_{Ha} - A_{La}] \\
\frac{dT_{La}}{dt} &= aD_{La} - r_1 T_{La} - \mu T_{La} + mp_{12}[T_{Ha} - T_{La}] \\
\frac{dT'_{La}}{dt} &= r_1 T_{La} - r_2 T'_{La} - \mu T'_{La} + mp_{12}[T'_{Ha} - T_{La}] \\
\frac{dP_{La}}{dt} &= \gamma\Lambda_L P_L + r_2 T'_{La} + gA_{La} - \omega' P_{La} - \mu P_{La} + mp_{12}[P_{Ha} - P_{La}].
\end{aligned}
$$

Models (1H) and (1L) form a 32×32 system of linear ordinary equations with one non-trivial steady state in 32 coordinates. The steady state value can be computed and its exact value numerically found for reasonable experimentally observed malaria related parameter ranges.

References

[1] O'Meara WP, Smith DL and McKenzie FE (2006). Potential impact of intermittent preventive treatment (IPT) on spread of drug resistant malaria. PLoS Medicine 3(5): 0633-0642.