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The impact of human and vector distributions on the spatial prevalence of malaria in sub-Saharan Africa

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Abstract

Eradication of malaria from the world in the latter part of the twentieth century proved an elusive, albeit desirable, objective. Unfortunately, resurgence of malarial incidence is currently underway. Key to understanding effective control schemes such as indoor residual spraying (spraying insecticide inside houses to kill the malarial vector mosquitoes) is the impact of spatial distributions for communities exposed to the malarial vector mosquito populations. Densities of human dwellings in small communities vary considerably in regions exposed to larval breeding sites. We extend prior modeling work to explore the spatial impact and diffusive transport of mosquito population densities on various distributions of human populations on relatively small landscape representations. Bistable dynamics of our reaction-diffusion model, that excludes advective transport, suggest two temporal phases for infection. An initial rapid phase occurs during transitions from initial homogeneous or spatially confined infections to peak levels over the course of days, and a relaxation phase develops to a steady-state over weeks or months, suggesting successful intervention methods likely require recognising the phase of infection. We further observe a strong dependence of human infection and recovery on distributions of susceptible human populations with some degree of independence from mosquito distributions given an adequate supply of mosquito vectors to sustain infections. A subtle and complex interplay between human dwelling densities, mosquito diffusion and infection rates also emerges. With a sufficiently fast diffusive transport of mosquitoes, our model indicates that relative timescales for infection rates are slower, leading to lower rates of infection. This suggests that, although we here only