Basic Properties and Qualitative Dynamics of a Vector-borne Disease Model with Vector Stages and Vertical Transmission

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This work systematically discusses basic properties and qualitative dynamics of vector-borne disease models, particularly those with vertical transmission in the vector population. Examples of disease include Dengue and Rift Valley fever which are endemic in Sub-Saharan Africa and understanding of the dynamics underlying their transmission is central for providing critical informative indicators useful for guiding control strategies. Of particular interest is the applicability and derivation of relevant population and epidemic thresholds and their relationships with vertical infection. This study demonstrates how the failure of R_0 derived using the next-generation method compounds itself when varying vertical transmission efficiency, and shows that the host type reproductive number gives the correct R_0. Further, novel relationships between the host type reproductive number, vertical infection and ratio of female mosquitoes to host are established and discussed. Analytical results of the model with vector stages show that the quantities Q_0, Q_0^v and R_0^c, which represent the vector colonization threshold, the average number of female mosquitoes produced by a single infected mosquito and effective reproductive number, respectively, provide threshold conditions that determine the establishment of the vector population and invasion of the disease. Numerical simulations are also conducted to confirm and extend the analytical results. The findings imply that while vertical infection increases the size of an epidemic it in turns reduces its duration, and control efforts aiming at reducing the critical thresholds Q_0, Q_0^v and R_0^c to below unity are viable control strategies.

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