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Effect of Interspecific Mosquito Competition on Mosquito Suppression with Sterile Mosquitoes

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Abstract. In the interactive dynamical models, we include two different competing wild mosquito species and sterile mosquitoes which are the same type as one of the competing wild mosquitoes. We study the dynamics of the interspecific competition models in different circumstances. We explore how the interspecific competition affects the wild mosquito control with releases of sterile mosquitoes and establish a new release threshold based on the effect of the competition. Numerical examples are provided in each case to illustrate the impact on the mosquito control.

AMS subject classifications: 34C60, 34D20, 92D25, 92D30, 92D40, 92D45

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1 Introduction

In applying the sterile insect technique (SIT) [1–4, 8, 27] to mosquito control, the focus has been on a specific species of mosquitoes such as Aedes aegypti, or Aedes albopictus, and the released engineered sterile mosquitoes are of the same type. As a result, the effect of interspecific interactions between different mosquitoes species have been ignored. Accordingly, while a good number of various mathematical models based on ordinary,

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partial differential equations, or difference equations have been formulated and investigated, modeling studies have basically been focused on only the interactive dynamics of the same type of wild and sterile mosquitoes [2, 6, 12–14, 17–21, 26, 28–32, 34].

There are over 3,500 mosquito species on Earth and over 200 types of mosquitoes live in the continental United States and US territories. Among those, about 12 types spread germs that can make people sick [7, 11]. Note that interspecific competitions are ubiquitous in the biological world and occur between two or more different mosquitoes which often have an influence on the dynamics of mosquito populations. For example, both Aedes aegypti and Anopheles stepehensi are container breeding mosquitoes and co-exist which may result in larval competition [10]. When Aedes albopictus develops larvae in the eastern United States, it commonly co-occurs with resident mosquitoes, most notably the eastern tree-hole mosquito, Aedes triseriatus, which results in interspecific competitions [15, 16, 25]. Aedes albopictus and Culex pipiens larvae living in the same breeding site compete for resources [23]. The spatial distributions of Aedes aegypti and Aedes albopictus frequently overlap that creates interspecific competition due to the limitation of food supply [22]. Thus, when we utilize SIT to suppress and eradicate the mosquitoes that spread mosquito-borne diseases and establish strategies of release of sterile mosquitoes, the interspecific competitions cannot be ignored and their effects need to be well understood and investigated.

To have better understanding of such effects, mathematical models have been formulated in [33] where two mosquito species w and z compete for limited resources and the interspecific competition is described by a Lotka-Volterra competition system. Sterile mosquitoes of the same type as w are released to interact with mosquitoes w and, as a result, with z too, even not purposely. How the releases of sterile mosquitoes impact the ecology of the interspecific competition is investigated in [33]. In this study, we focus on how the interspecific competition affects the release threshold and the interactive dynamics of the mosquitoes. We refine the model for interactive wild and sterile mosquitoes and the interspecific competition model in Sections 2 and 3, respectively. We give further mathematical analysis for the model with the interspecific competition and the interactive sterile mosquitoes in Section 4. We provide, for each category, numerical examples to illustrate our findings. We give detailed discussions to show how the inclusion of interspecific competition affects the model dynamics of the interactive wild and sterile mosquitoes mathematically as well as biologically in Section 5.

2 Interactive model with wild and sterile mosquitoes of same type of species

We first consider a species of wild mosquitoes living in the field and assume that the population dynamics of the species are governed by the following logistic-type equation:

$$\frac{dw}{dt}=\alpha_w(1-\xi_w w)w-\mu_w w,$$