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Understanding Effects of Temperature and Precipitation in the Dynamics the Mosquito Population

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Mosquito populations are crucial factors in understanding the spread of mosquito-borne diseases. Deterministic models can be used to analyze these populations by incorporating local mosquito characteristics, temperature, and precipitation data [1]. Moreover, temperature is recognized as a significant factor influencing disease transmission [2].

This study utilizes real weather data from the Global Data Assimilation System (GDAS) alongside trap data collected from Miami-Dade County (2017-2019) to analyze mosquito populations. Additionally, information from traps in the same area is accessible to verify and refine the model preditions and parameters [3].

An ODE model with time-dependent parameters to simulate the mosquito (Ae. aegypti) population (in a community) is represented by the following equations [3]:

$$\frac{dJ}{dt} = b(t)\left(1 - \frac{J}{K(t)}\right)A - (d(t) + \mu_1(t))J \tag{1}$$

$$\frac{dA}{dt} = 0.5d(t)J - \mu_2(t)A \tag{2}$$

where J represents the immature mosquito population in the aquatic stage at time t, and A represents the adult female mosquito population at time t. This model considers adult female Aedes aegypti because only female mosquitoes seek blood meals and could be attracted to traps. The parameters $b(t)$, $d(t)$, $\mu_1(t)$, and $\mu_2(t)$ are time-dependent entomological parameters obtained by composing the time-dependent temperature function and the corresponding temperature-dependent entomological function[4].

System (1)-(2) suggests that the carrying capacity to sustain the immature mosquito population could be directly influenced by the cumulative rainfall in the region. Accumulated rainfall creates water puddles and fills containers, providing ideal breeding sites for Ae. aegypti mosquitoes. Consequently, cumulative rainfall may positively impact the carrying capacity. The relationship is expressed as $K(t) = K(1 + \alpha P_n(t))$, where K represents the baseline carrying capacity, α denotes the intensity of rainfall's impact on the carrying capacity, and $P_n(t)$ serves as an index reflecting the cumulative effect of rainfall over the past days at time t. To compute this index, the cumulative rainfall over n days and compile the corresponding time series data. Two critical points are

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identified: (a) $(J, A) = (0, 0)$, and (b) $(J, A) = (K(t)\,(b(t)d(t) - 2.0d(t)\mu_2 - 2.0\mu_1 \cdot \mu_2))/(b(t)d(t))$, $(0.5K(t)\,(b(t)d(t) - 2.0d(t)\mu_2 - 2.0\mu_1\mu_2))(b(t)\mu_2)$.

Figure 1 illustrates how temperature and precipitation influence the critical points. To further explore this relationship, the numerical solution of the ODE system should be analyzed while varying the cumulative precipitation, alongside a reduced model assuming a constant baseline carrying capacity (represented by the red line in the figure). The P7, P21, and P47 lines represent the cumulative effects of integrating rainfall over 7, 21, and 47 days with an impact factor of 0.5. These lines indicate that cumulative values modulate the female mosquito populations.

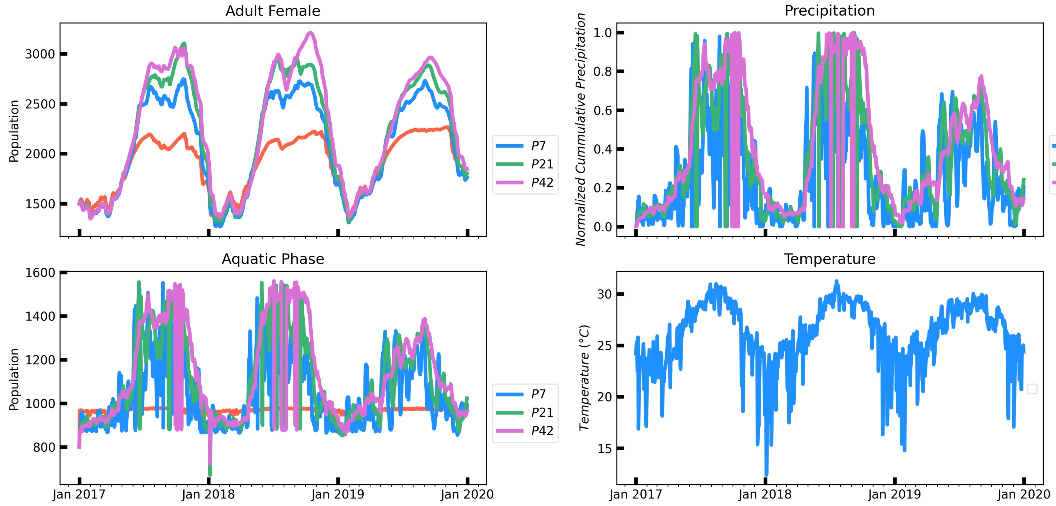

Figure 1: The temporal variations of population dynamics in adult female mosquitoes and larvae, normalized cumulative precipitation, and temperature over time, assuming $\alpha = 0.5$.. Source: authors.

Finally, this analysis aims to ascertain whether the solution can adequately explain the data obtained from the traps, thereby enhancing our understanding of mosquito population dynamics in response to environmental factors.

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