Light, Housing, and Distance on *Rhodnius prolixus* Migration

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Introduction

Trypanosoma cruzi is the cause of Chagas' disease in Central and South America, an illness that is quickly becoming a widespread disease in the region. It is transmitted through triatomines, more commonly referred to as kissing bugs, and can lead to chronic symptoms and heart complications. In its early stages, it displays mild flu-like symptoms. For this study, we examine one of these vectors, *Rhodnius prolixus*, which was used to model migration of triatomines in a study done by Cordovez and Erazo in a small village in Brazil[1]. Typically, *Rhodnius prolixus* reside in the canopy of jungle trees and rely primarily on blood meals for sustenance and growth. Near rural villages, kissing bugs leave their tree habitats to fly into nearby homes, often spending several days in close proximity to their human hosts before flying back to the jungle to shelter and lay eggs.

The Cordovez and Erazo model took into account the effect of distance and presence of light to look at different migration of bugs to houses. Our model builds upon that and takes into account different wavelengths of light that cause differing attractiveness of bugs [2] as well as the inverse square law of light that mitigates the effect of light at longer distances. Finally, we also took into account the effect of the presence of a house at a patch which greatly increases the likelihood that a bug will migrate there, to the tune of 5 to 15 times[3] .

Model Development

The established model for our study looked specifically at a small village in the Casanare department of Colombia called Chavinave, that was encompassed by Gallery Forest. The model used looked at the population of *R. prolixus* eggs, nymphs and adults to observe migration patterns of *R. prolixus* between different patches. The study specifically looked at the effect on migration due to the presence or absence of light and how far away the new patch was from the original patch.

The majority of the parameters and parameter values were kept the same between the two models save for one: the α_{ij} term, which represented the attraction of plot *i* on the migrating bugs from plot *j* in an adjacency matrix *A* . The α_{ij} term in the original model had light as a binary variable that was twice as attractive versus similar non-lighted patches, and distance degradation of light as a linearly decreasing term. The new α_{ij} term has modified L_{ji} and D_{ji} light and distance components while applying two new terms: S_{ji} and H_{ji}, which quantified the effect of migrating to the same patch and migrating to a patch with a house. We examined the veracity of the original model as well as the effects of our changes by creating 8 hypothetical patches with varying distances, light wavelengths, and housing structures.

The new model and parameters is as follows:

$$\frac{dE_i}{dt} = \lambda A_i - \frac{1}{\tau}E_i - \delta_E E_i$$

$$\beta_j = \frac{\sigma(N_i + A_i)}{\eta + (N_i + A_i)}$$

$$\frac{dN_i}{dt} = \frac{1}{\tau}E_i\left(1 - \frac{N_i + A_i}{K_i}\right) - \frac{1}{\gamma}N_i - \delta_E N_i$$

$$\alpha_{ji} = S_{ji}H_{ji}(L_{ji} + 1)\left(\frac{200^2 - D_{ji}^2}{200^2}\right)$$

$$\frac{dA_i}{dt} = \frac{1}{\gamma}N_i - \delta_A A_i - \beta A_i + \sum_{j=1}^{n} \alpha_{ji}\beta_j A_j$$

Symbol	Name	Units	Value
λ	Birth rate	individual/(day*individual)	1.3
δ_E	Nymph Mortality Rate	1/day	0.001
δ_N	Nymph Mortality Rate	1/day	0.004
δ_A	Adult Mortality Rate Indoors	1/day	0.05
δ_{AN}	Adult Mortality Rate Outdoors	1/day	0.005
τ	Egg Mortality Rate	day	15.4
γ	Residency time from nymph to adult	day	211
K_i	Carrying Capacity in patch *i* (houses)	individual	20
σ	Maximum per capita migration rate	individual/(day*individual)	0.1
η	Number of individuals at which half of the maximum per capita migration rate occurs	individual	1×10^{-6}
H_{ji}	Attraction of House v. No House	dimensionless ratio	1,5
S_{ji}	Internal-Patch Migration	dimensionless ratio	0,1
L_{ji}	Light Prescence and Attraction	dimensionless ratio	0,0.5,1
D_{ji}	Euclidean distance between patchs *j* and *i*	meter	-

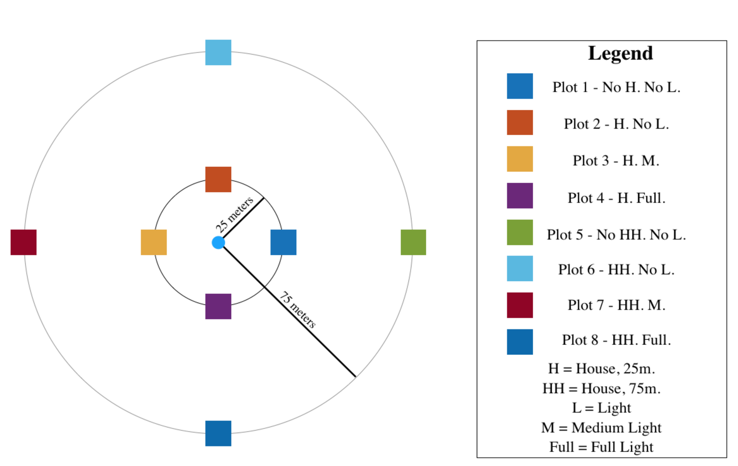
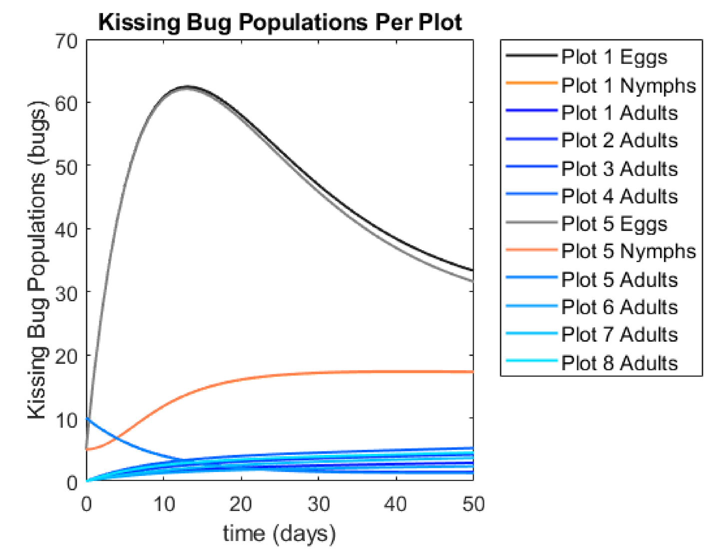


Figure 1. Studied Patch Designations

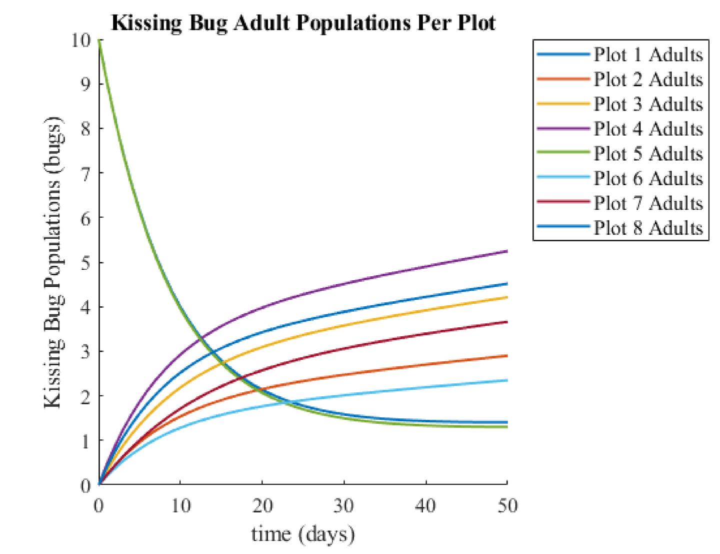
Relevant Figures

Modified Model:



a)

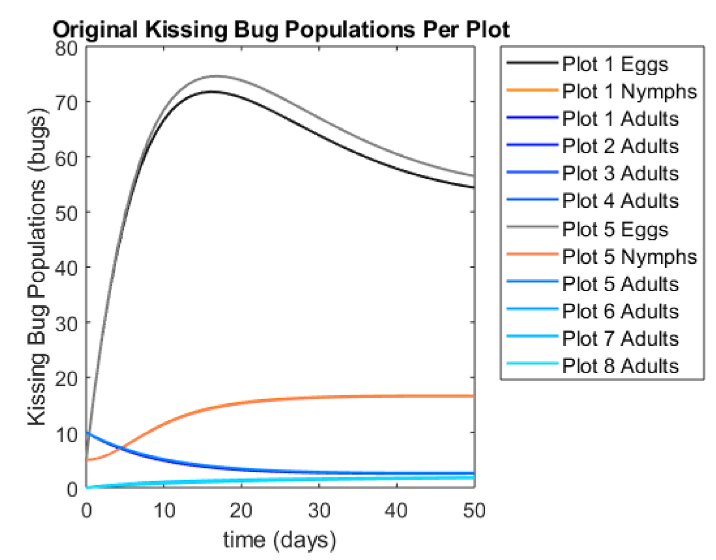
Figure 2a. Total kissing bug populations per plot



b)

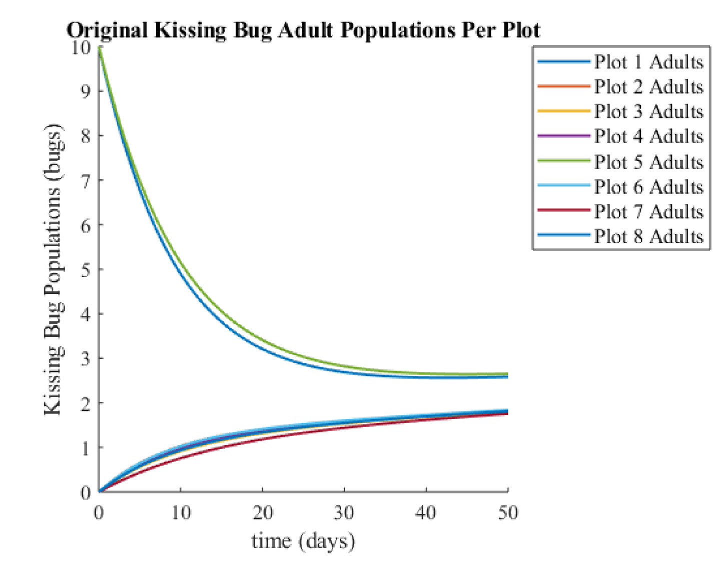
Figure 2b. Adult bug populations per plot

Original Model:



a)

Figure 3a. Total kissing bug populations per plot



b)

Figure 3b. Adult bug populations per plot

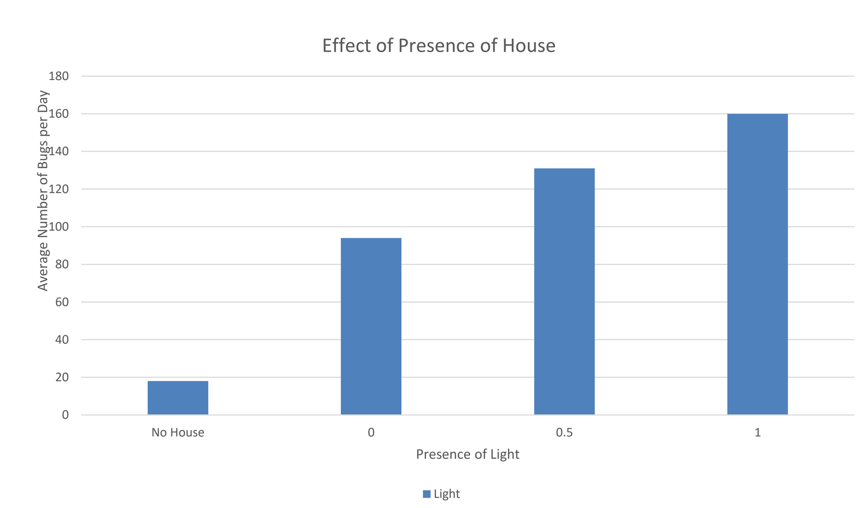


Figure 4. Effect of including a House versus Light attractions

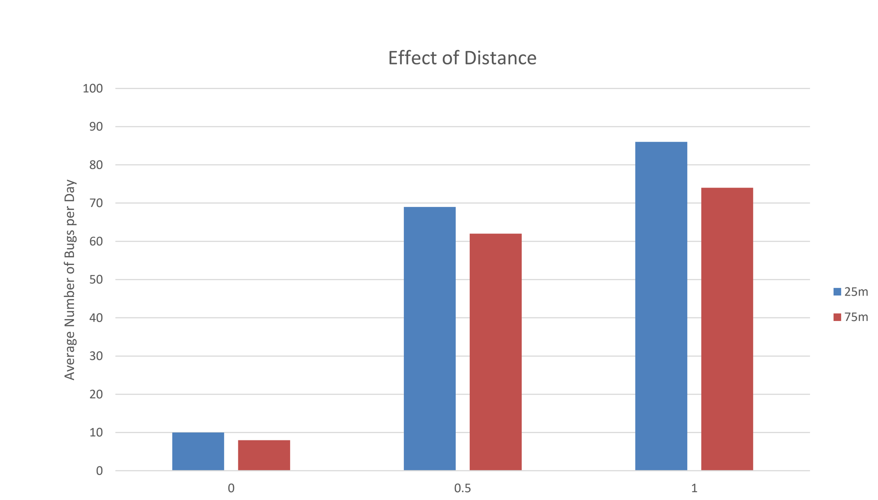


Figure 5. Effect of varying Distance versus Light attractions

Results

The map of patches went through modeling using the new model and the original model taken from Cordovez and Erazo. Instead of having a medium light term, those patches were treated as full light terms and had an L_{ji} value of 1. Looking at the difference in original model applied to the map, there was a convergence of each of the models to the same value. At equilibrium, the average number of bugs per day that reached every patch turned out to be around 9.5. For the new model data, the model reached equilibrium at 10, 47, 69, 86, 8, 37, 62, and 74 bugs/day for patches 1-8 respectively. In the original model for the first 50 days, the no house populations never reach below the house populations. In the new model, however, house patches have a population higher than that of patches with no houses by day 15.

The data shows that the patch at 25m distance, with a fully attractive light, and presence of a house is the most attractive (Patch 4). This patch had an average number of bugs visiting at 86 bugs per day. The lowest condition by far was the patch at 75m, with no house and no light (Patch 5). This patch had an average value of 8 bugs visiting. Looking at the housing data, the patch with the lowest average number of bugs per day that also had a house was Patch 6. Patch 6 was at 75m away and had no light. The results show a large variation in the new model with very little variation in each patch when compared to the old model

Discussion

Analysis of the two data sets comprised of comparing them. The old model showed very little variation between each patch while the new model showed striated data with clear difference between each of the conditions. In terms of our new model, the parameter that had the largest effect on data was the house term. While distance definitely had an effect on intensity of light and therefore attractiveness, it was mentioned in Cordovez and Erazo that R. prolixus doesn't have preference in difference as long as its under 200m. The increasing factor of 5 was what determined attraction to any patch so a patch could have a not very attractive light or no light at all but still be attractive to bugs because of the presence of a house.

Although presence of a house has the biggest impact, in order to prevent infestation, getting rid of a home is unfeasible. Instead, for control of this vector species, one could consider one way light filters or mitigating use of light. Along with this, taking a home away from R. prolixus infested trees would also be advised to prevent infestation even further. Overall, the new model presented showed an even more nuanced look at how *R. prolixus* migrates to different patches depending on the conditions of that patch. The original model was too simple in how the effects of light and distance affected migration. This new model has took into account both and even eliminated self looping migration.

In order to make this model even better, some further modifications could be added to it. In terms of attractiveness, a term for temperature and temperature variation could be added. Along with this, gender disparities could be taken into account when modeling these populations as well. Another possibility that could be explored is the conditions of the environment not just the patches. For example if the path to get to a certain patch is unfavorable, more wind, that area is colder, etc., then it would make sense for the bug to choose a different more favorable patch to venture to even if the patch with the unfavorable path is optimal.

Sources:

(1) Erazo, Diana, and Juan Cordovez. "The Role of Light in Chagas Disease Infection Risk in Colombia." Parasites & Vectors, BioMed Central, 5 Jan. 2016, parasitesandvectors.biomedcentral.com/articles/10.1186/s13071-015-1240-4.

(2) Somers-Yeates, Robin, et al. "Shedding Light on Moths: Shorter Wavelengths Attract Noctuids More than Geometrids." *Redirecting*, Hindawi, 23 Aug. 2013, dx.doi.org/10.1098%2Frsbl.2013.0376.

(3) Barbu C, Dumonteil E, Gourbière S (2010) Characterization of the Dispersal of Non-Domiciliated Triatoma dimidiata through the Selection of Spatially Explicit Models. PLoS Negl Trop Dis 4(8): e777. doi:10.1371/journal.pntd.0000777