

Spatial Pattern of the Dengue Vector in Iquitos, Peru

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Dengue is a disease primarily transmitted by the mosquito *aedes aegypti*. There are an estimated 100 million cases worldwide each year. The mosquito can also transmit dengue hemorrhagic fever (DHF), which is a more serious illness. Even if medically treated, DHF leads to death in about 1% of cases.

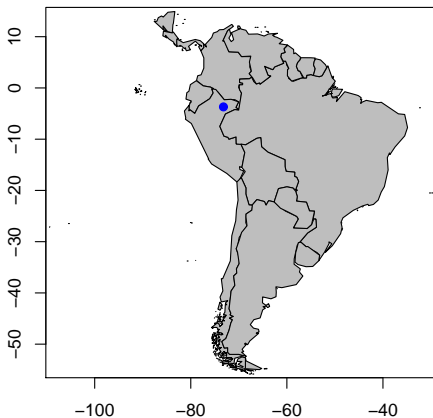
With no vaccine or medicine, emphasis is naturally on prevention. Understanding the spatial distribution of the mosquito plays a central role in effectively designing and implementing mosquito control.

Aedes Aegypti means “mosquito”



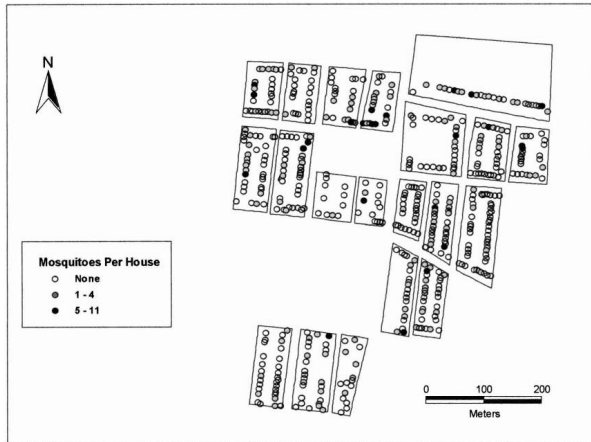
Iquitos, Peru: population 345,000

Location of Iquitos, Peru



- ▶ Two neighborhoods were chosen in the city
- ▶ Each house in the neighborhood was a collection point (528, 481 houses resp.)
- ▶ At each house, the number of adult and pupal *ae. aegypti* were recorded
- ▶ Also the number of water containers and containers testing positive for pupae

Sample of Data, Maynas neighborhood



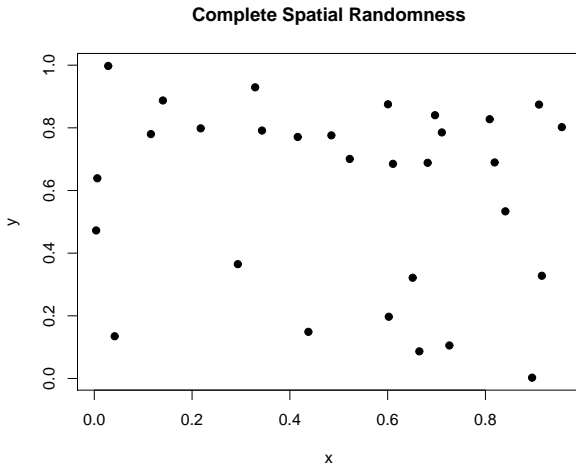
1. Determine underlying spatial structure of *Ae. aegypti* infestations
 - ▶ Identify presence or absence of clustering by four variables: adults, pupae, contaminated water containers, and all water containers
 - ▶ Use K-functions to identify clustering
 - ▶ Use G-statistics to identify individual members of clusters

The K-function

- ▶ Describes the number of pairs of observations between a point centered on a disk of radius d

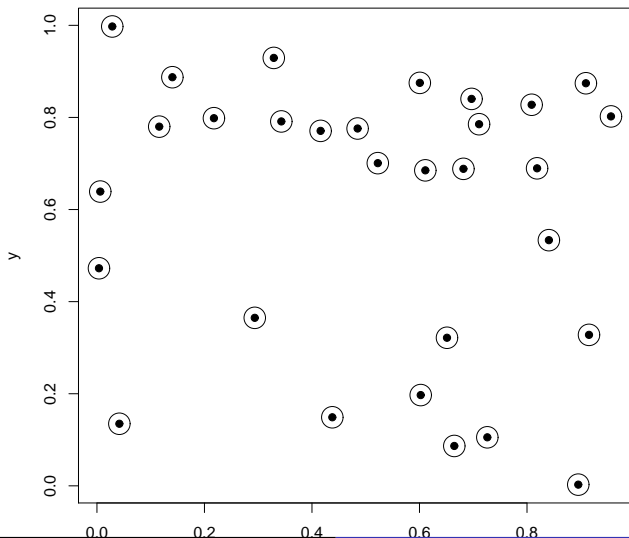
$$\hat{K}(d) = \frac{A}{N^2} \sum_i \sum_j u_{ij}^{-1} I_d(d_{ij} < d)$$

- ▶ A is the area of study
- ▶ N is the number of points
- ▶ d_{ij} is the distance between the i 'th and j 'th observed point
- ▶ u_{ij} is the border correction (if $d_{ij} <$ distance to border of set, $u_{ij} = 1$. Otherwise, u_{ij} is the proportion of the circumference that lies within A).



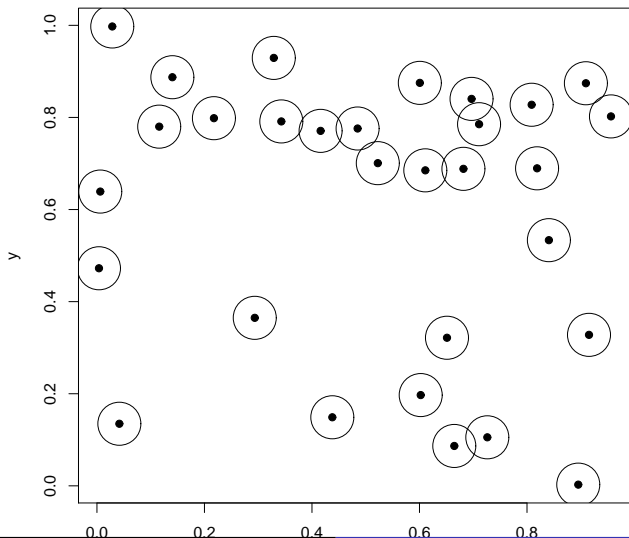
Simulation, Complete Spatial Randomness

Complete Spatial Randomness, $d=0.2$



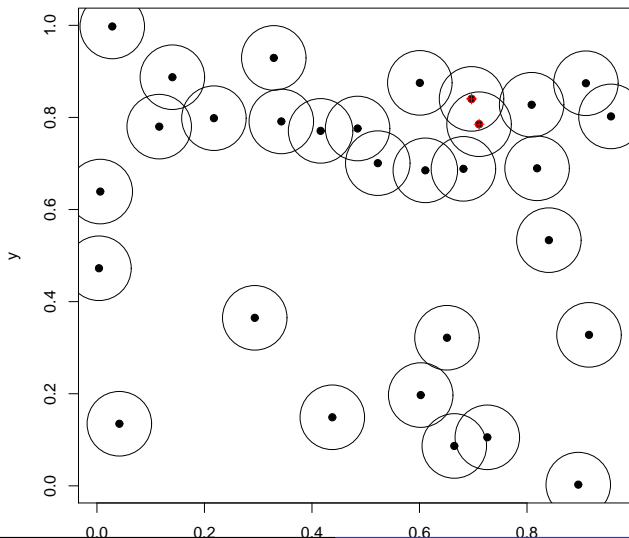
Simulation, Complete Spatial Randomness

Complete Spatial Randomness, $d=0.4$



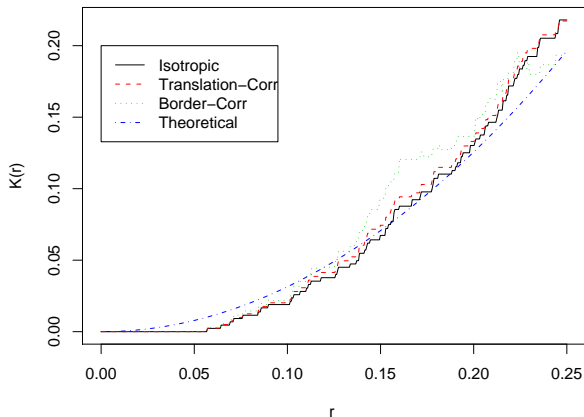
Simulation, Complete Spatial Randomness

Complete Spatial Randomness, $d=0.6$



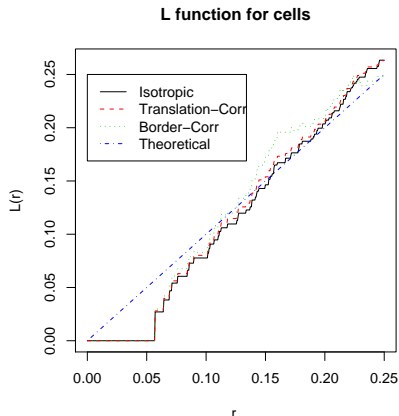
K-function for simulated CSR data

K function for CSR Simulation

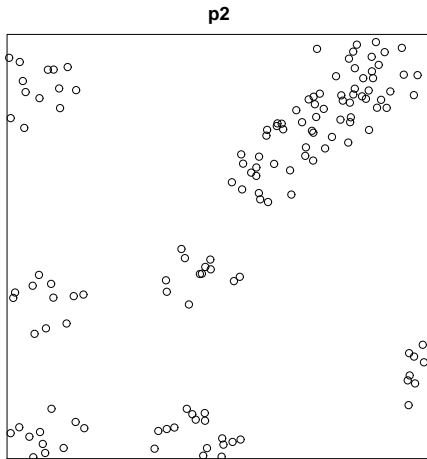


L-function for simulated CSR data

- ▶ It's common to write $\hat{L}(d) = \sqrt{\hat{K}(d)/\pi}$, and $\hat{L}(d)$ has expectation d and approximate variance $1/2(\pi N^2)$.

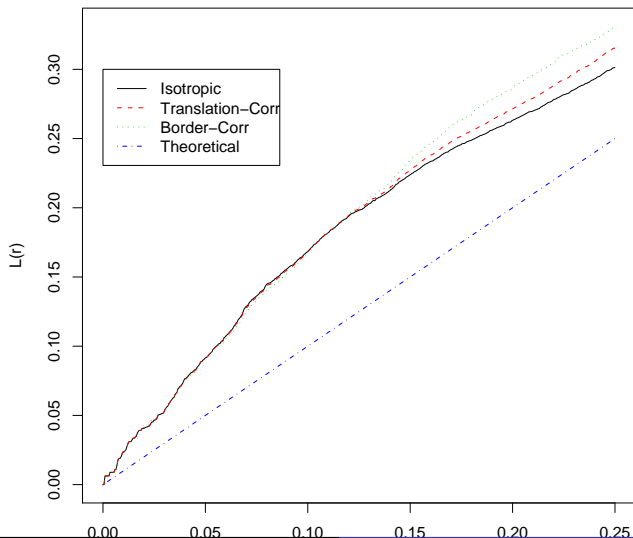


Simulated Data with Clustering

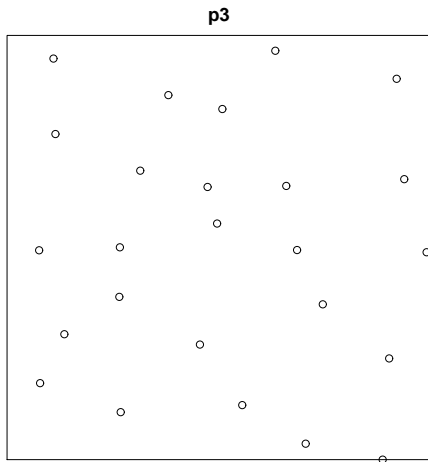


Simulated Data with Clustering

L function for Clustered Process

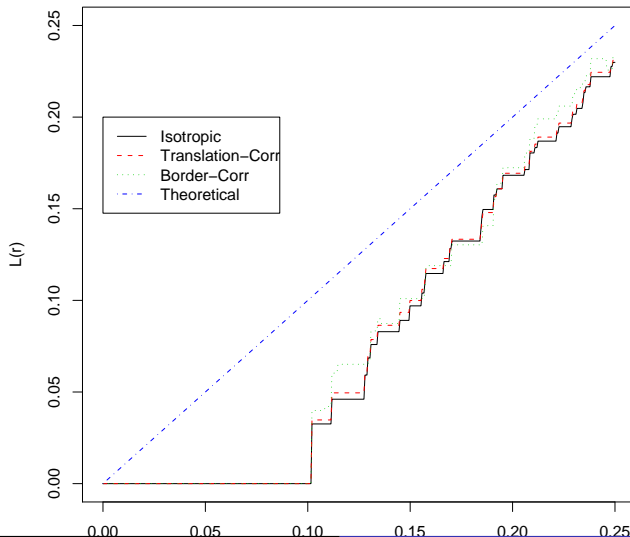


Simulated Data with Dispersion



Simulated Data with Dispersion

L function for Process with Repulsion



- ▶ The L-function above is for 0/1 variables, but there is an analogue for weighted point processes. Now, let there be x_i mosquitoes at position i , where $x_i \geq 0$ for all i .

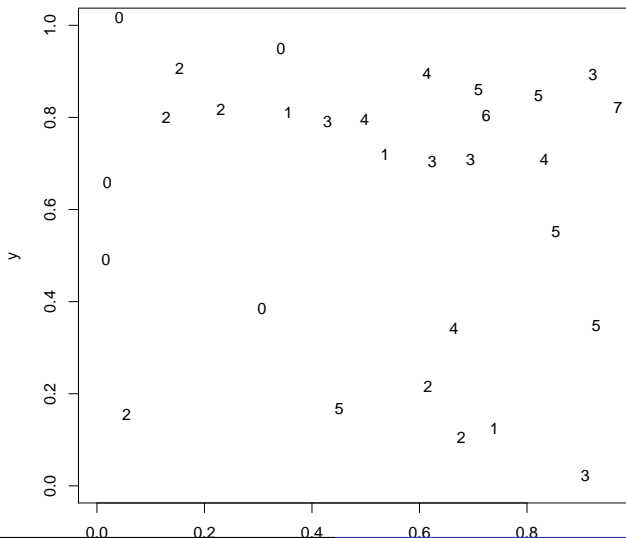


$$\hat{L}_w(d) = \left[\frac{\left(A \sum_i \sum_j u_{ij}^{-1} I_d(d_{ij} \leq d) x_i x_j \right)}{\pi \left[(\sum_i x_i)^2 - \sum_i x_i^2 \right]} \right]^{1/2}$$

- ▶ This version weights points with larger numbers of mosquitoes, so it may identify clustering with fewer points.

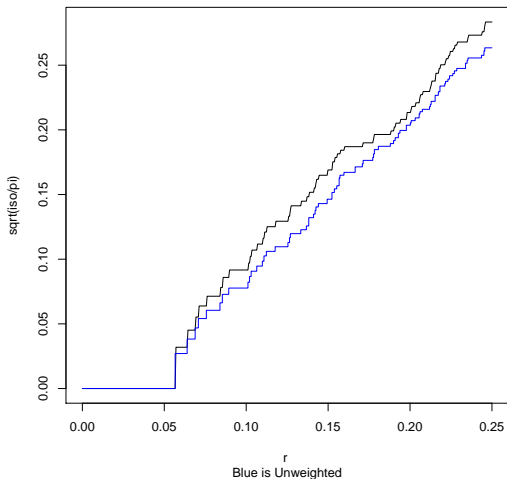
Simulated Data, Weighted L-function

Marked Point Process, Intensity Proportional to x



Simulated Data, weighted L-function

Weighted and Unweighted L-functions



Results for Adult Mosquitoes

Table 1: L-functions for adult mosquitoes in Maynas

Distance (meters)	House	Adult mosquitoes	House Increment	Adult Increment
10	16.33	22.86	13.33	22.86
20	27.13	36.79	10.80	13.93
30	38.70	50.58	11.57	13.79
40	52.85	61.13	14.15	10.55
50	65.67	74.24	12.82	13.11
60	76.70	83.94	11.03	9.70
70	88.03	93.71	11.33	9.77
80	100.98	104.12	12.95	10.41
90	111.77	113.10	10.79	8.98
100	122.19	120.57	10.42	7.47

Conclusions from K-functions

1. Statistically significant clustering of adults at 10m
 - ▶ 19 permutations of adult mosquito counts based on CSR
 - ▶ Pointwise minimum and maximum of $\hat{L}(10m)$ were (11.88, 19.10)
 - ▶ 22.86 falls above the upper range
2. Weaker evidence that *ae. aegypti* cluster to 20 or 30 m
 - ▶ Adult increments exceed house increment (13.93 vs. 10.80, 13.79 vs. 11.57)
3. Only other significant clustering result is pupae at 10m

Identifying Specific Members of Clusters

- ▶ The local statistic G_i^* is used to identify individual members of clusters



$$\hat{G}_i^*(d) = \frac{[\sum_j w_{ij}(d)x_j - W_i^* \bar{x}]}{s \left(\frac{[NS_{1i}^* - W_i^{*2}]}{(N-1)} \right)^{1/2}}$$

- ▶ $w_{ij}(d)$ is the matrix of 0/1 entries indicating i and j are neighbors at distance d
 - ▶ $W_i^* = \sum_j w_{ij}(d)$
 - ▶ $S_{1i}^* = \sum_j w_{ij}^2$
- ▶ $\hat{G}_i^*(d)$ is approximately standard normal (Zhang, 2008)
- ▶ For each site, conclude it's in a cluster if $G_i^* \geq 2.575$, which is the 0.01 significance level for a two-sided test.

Clusters of Adult Mosquitoes, G_i^* – statistic

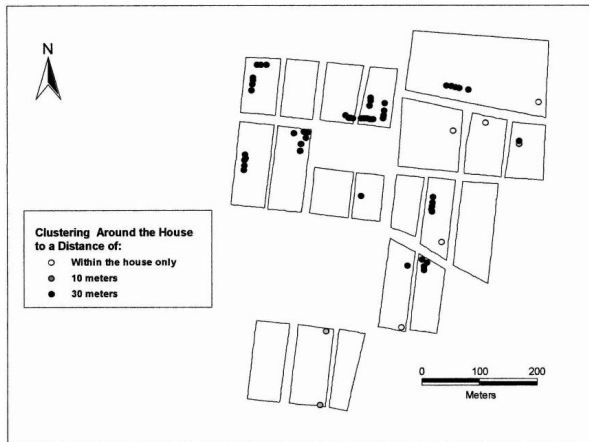
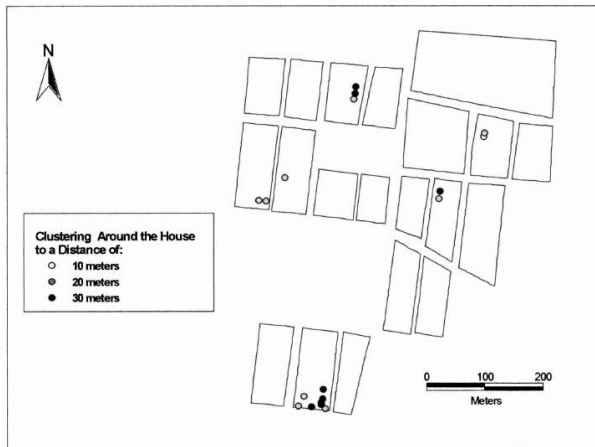


FIGURE 3. Clusters of *Aedes aegypti* adults in the Maynas study based on the number of mosquitoes in houses.

Clusters of Pupae, G_i^* – statistic



- ▶ Study supports using the household as the basic unit for entomological surveys
- ▶ Superficially supports focal insecticide treatment where all households within 50-100 m are treated with insecticide following a confirmed case of dengue, with three shortcomings:
 1. One must study time stability of the spatial clustering, since there is a delay between being bitten and being diagnosed
 2. Infected people can themselves transmit the disease over far greater distances
 3. People may not seek medical attention

Questions?

Reference: Characteristics of the Spatial Pattern of the Dengue Vector, *Aedes Aegypti*, in Iquitos, Peru, Getis, Morrison, Grey, Scott, American Journal of Tropical Medicine and Hygiene, 2003