SPATIAL DISTRIBUTION OF THE LARVAL INDICES OF
Aedes aegypti IN GUADALUPE, NUEVO LEÓN, MEXICO, WITH
CIRCULAR DISTRIBUTION ANALYSIS

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ABSTRACT: A census of all outdoor larval breeding sites (951) present in 361 dwellings in a neighborhood of
Guadalupe in northeastern Mexico was conducted in October 1997 to determine larval indices of Aedes
aegypti, and their relationship to human population density and vegetation type. Here we present a method that
allows finding the direction and extrapolating flight range of vectors, as parameters in the dynamics of dengue
transmission. By using circular statistics applied to each block of data, ranges (quantiles) were computed for
larval index type, adult-child (a:c) relationship, and vegetation. Flight angles were calculated for each
variable. Arguments corresponding to the mean angle of house (268°), recipient (265°), and Breteau (247°) indices
were 0.2321, 0.2331, and 0.2223, respectively. In addition, arguments for the mean angle of herbaceous (277°),
shrub (198°), and arboreal (333°) vegetation were 0.2589, 0.1984, and 0.2367, respectively, and the 3 were
located in the 4th quadrant. The a:c relationship was in 282°, with an argument of 0.2466, which indicates that
in this neighborhood in southern Guadalupe, both the human population density and the larval indices were
higher than in other areas.

KEY WORDS: Circular statistics, larval index, Aedes aegypti, dispersal

INTRODUCTION

Circular statistics have been useful in the directional statistical analysis of 2nd-order events. For example, under particular flight conditions, each of 7 butterflies was allowed to fly from the center of an experimental chamber 10 different times (Batschelet 1978). Circular statistics were used to estimate the mean angle (152°) of the flight directions with a minimum angular deviation.

In San Juan, Puerto Rico, Reiter et al. (1995) developed a method for marking eggs of Aedes aegypti (L.) with a rare alkali metal (rubidium) and showed that in an urban area, oviposition activity in a single gonotrophic cycle lasted several days and covered an area at least 840 m (55.4 ha) in diameter. They suggested that dispersal was driven by the search for oviposition sites.

Hausermann et al. (1971) carried out a study to determine the dispersion of genetically marked females of Ae. aegypti in Mississippi. The 1st phase was carried out in a transect 2 blocks wide, 3,200 ft to the north and 3,200 ft to the south. They found that the maximum dispersal was 1,900 ft to the south, whereas the circular distribution of marked females in positive ovitraps was mostly toward the northwest.

Trpis and Hausermann (1986) reported on the dispersal of Ae. aegypti when using the mark–release–recapture method in Mombasa, Kenya, Africa. The recapture rate of 4% indicated that the Shani Moyo village population was closed and relatively stable with little emigration. The villages are separated by natural barriers such as trees, bushes, and grass, which may restrict intervillage dispersal of the domestic form. Reuben et al. (1972) released marked mosquitoes from a tire dump. They found that mosquitoes moved an average distance of 23.2 m after day 1 and 120.7 m after day 5. McDonald (1977), in a study carried out among the villages of Rabai on the coast of Kenya, found that dispersal greater than 200 m from a village was characterized by a markedly reduced number of mosquitoes entering a village as well as a delay in their appearance in the landing-biting collections and the dispersal of mosquitoes between villages.

Surveillance programs are based on the house and Breteau larval indices, and a threshold of 3–5% in these indices is used as a high-risk indicator of transmission to humans of pathogens such as dengue viruses. Consequently, development of entomological measures more reliable than larval indices as epidemiological tools is necessary (Osnut and Caruthers 1990). This goal seems to have been achieved by the premise condition index (PCI) by Tun-Lin et al. (1995), which is designed to save labor costs. Moloney et al. (1998) used low-flight aerial surveillance in conjunction with PCI, and relied mostly on shaded areas in photographs, but found that aerial surveys could not substitute for standard data collections on the ground.

A strong correlation between the number of days with precipitation greater than 1 mm and the house and the Breteau indices was found in a colony of Merida, Yucatan. The most common larval production sites found were cans, tires, bottles, and vases. Many people burn their garbage in the back of their lots. This practice results in the accumulation of thousands of tin cans, which are shaded by the
denser vegetation found at the back of the lots and become good larval production sites (Winch et al. 1992). In Mexico, the general wind direction is from east to west and most rains come from the Gulf of Mexico.

The purpose of the present study was to apply circular statistics to the distributions of the larval indices of Ae. aegypti. The model demonstrated that this technique can be more readily applied in future works on vector dispersal.

MATERIALS AND METHODS

This study was done in an area located in the Municipality of Guadalupe, Nuevo León, Mexico, to the east of the metropolitan area of Monterrey, with a population of 4 million. The coordinates are 25°39'34"N and 100°11'02"W and 100°11'26"W west longitude. A census of all larval breeding sites (951) present at 361 dwellings was conducted in October 1997 to determine the larval indices of house, Breteau, and container habitats (Kumate and Llauces 1989). Also, the vegetation indices (herbaceous, shrubs, and arboreal) and the adult-child (a/c) relationship were assessed. Ranges (quartiles) were generated for each index, as well as for the vegetation and the a/c population.

The rectangular coordinates of the mean angle ($a_{av}$) are determined by: $X = (\cos a) \bar{r}$ and $Y = (\sin a) \bar{r}$, where $a$ is the angle in the measurement $i$ and $n$ is the numbers of measurements. The longitude of the vector is $r = (X^2 + Y^2)^{1/2}$. The value of $r$ varies inversely with the variance of the data. Therefore, $r$ is a measure of concentration and $1 - r$ is a measure of dispersal. Lack of dispersal would be indicated by $1 - r = 0$, and maximum dispersal is indicated by $1 - r = 1.0$. $\cos a_{av} = X/r$ or $\sin a_{av} = Y/r$ determine the mean angle. This is the angle that indicates the radius of the diameter that is closer to the central tendency of most of the data. Finally, the test of Watson and Williams was carried out to compare the half angles of 3 populations (Zar 1999).

To locate any point on a plane, both the angle $a$ with respect to a given starting direction, and the straight-line distance $r$ from some reference point are specified. Intervals began in the east at 37°, 100°, 140°, 180°, 220°, 260°, 300°, and 330°. The intermediate angle was determined for each half-interval ($18.5°, 68.5°, 120.0°, 160°, 200°, 240°$).

<table>
<thead>
<tr>
<th>Statistics</th>
<th>House</th>
<th>Breteau</th>
<th>Container</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\bar{r}$</td>
<td>0.3556</td>
<td>0.2226</td>
<td>0.2331</td>
</tr>
<tr>
<td>$a_{av}$</td>
<td>280°</td>
<td>247°</td>
<td>265°</td>
</tr>
<tr>
<td>AD</td>
<td>66.05</td>
<td>71.45</td>
<td>70.96</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vegetation index</th>
<th>h</th>
<th>s</th>
<th>a</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h$</td>
<td>0.2589</td>
<td>0.1984</td>
<td>0.2567</td>
</tr>
<tr>
<td>$s$</td>
<td>0.277</td>
<td>0.318</td>
<td>0.335°</td>
</tr>
<tr>
<td>$a$</td>
<td>0.6975</td>
<td>0.7255</td>
<td>0.7078</td>
</tr>
</tbody>
</table>

k, herbaceous; s, shrubs; a, arboreal.
Table 2. The descriptive circular statistics for the adult–child relationship (a/c) and larval and vegetation indices.

<table>
<thead>
<tr>
<th>Statistics</th>
<th>House</th>
<th>Breteau</th>
<th>Container</th>
<th>h</th>
<th>s</th>
<th>a</th>
<th>a/c</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>18.28</td>
<td>29.13</td>
<td>2.02</td>
<td>0.65</td>
<td>0.79</td>
<td>0.75</td>
<td>2.50</td>
</tr>
<tr>
<td>SD</td>
<td>13.09</td>
<td>25.32</td>
<td>1.99</td>
<td>0.29</td>
<td>0.21</td>
<td>0.24</td>
<td>0.84</td>
</tr>
<tr>
<td>Q1</td>
<td>0-1.44</td>
<td>0-8.88</td>
<td>0-0.56</td>
<td>0-0.50</td>
<td>0.40-0.61</td>
<td>0.20-0.53</td>
<td>0-2.07</td>
</tr>
<tr>
<td>Q2</td>
<td>7.45-16.67</td>
<td>8.89-21.82</td>
<td>0.57-1.08</td>
<td>0.51-0.68</td>
<td>0.62-0.87</td>
<td>0.54-0.87</td>
<td>2.08-2.48</td>
</tr>
<tr>
<td>Q3</td>
<td>16.68-28.75</td>
<td>21.83-39.97</td>
<td>1.09-3.28</td>
<td>0.69-0.87</td>
<td>0.88-0.98</td>
<td>0.88-0.98</td>
<td>2.49-3.00</td>
</tr>
<tr>
<td>Q4</td>
<td>28.76-40.66</td>
<td>39.38-93.33</td>
<td>3.29-6.76</td>
<td>0.88-1.00</td>
<td>0.99-1.00</td>
<td>0.96-1.00</td>
<td>3.91-4.14</td>
</tr>
</tbody>
</table>

\( \alpha \): mean angle; SD: standard deviation; Q: quartile

280.0° and 330.0°, respectively. The ranges of the indices were added and plotted for each half angle.

RESULTS

A census of all outdoor larval breeding sites (951) present in 361 dwellings in a neighborhood of Guadalupe, part of metropolitan Monterrey in northeastern Mexico, was conducted in October 1997 to determine the larval indices of Ae. aegypti, and the indices of vegetation types.

Circular descriptive statistics are given for the length of the mean vector (r) in the direction of the mean angle (\( \alpha \)), and the angular deviation (AD) of the larval index and of the vegetation index (Table 1). The housing index presented a mean angle of 260 ± 66.05° and tended to the south. The Breteau index presented a mean angle of 247 ± 71.45° (Table 1). The container index presented mean angle of 265 ± 70.96°. This index presented a more homogeneous distribution than the other indices. No significant differences were found among the angles means of the 3 larval indices (F = 2.10, P > 0.05), and the best estimate of the population mean was 257° (Fig. 1).

For the herbaceous vegetation, the mean angle was 277 ± 69.75°. The vegetation shrubs presented a mean angle of 318 ± 72.35°. The arboreal vegetation had a mean angle of 333 ± 70.78°. Herbaceous vegetation was distributed more homogeneously than the shrubs. No significant differences were found among the mean angles of the 3 indices of vegetation (F = 2.35, P > 0.05). The best estimate of the population mean was 308° (Fig. 2).

Means (\( \alpha \)), standard deviations (SD), and quartiles (Q) for the larval and the vegetation indices are shown in Table 2, along with the a/c relationship. The house index quartiles varied from 0.00 to 40.00% (18.28 ± 13.09). The Breteau index quartiles varied from 0.00 to 93.33% (29.13 ± 25.12), and the container index quartiles varied from 0.00 to 67.76% (2.07 ± 1.99) (Table 2). The vegetation indices were 0.00-1.00 (0.65 ± 0.29) for herbaceous vegetation, 0.40-1.00 (0.79 ± 0.21) for shrubs, and 0.20-1.00 (0.75 ± 0.24) for arboreal vegetation. The a/c index varied from 0.60-4.14 (2.50 ± 0.84).

The sum of the ranges was the lowest (4.5, 5.0, and 3.0) in the larval index interval of 140.0°-180.0° (160.0°), whereas the sum of the ranges was highest (16.5, 18.5, and 18.0°) in the interval of 220.0°-260.0° (240.0°) (Table 3). For the vegetation types (Table 3), the half angle was 126.0°, and the sum of the ranges was the lowest (3.5, 4.5, and 3.0), although in the final angle (330.0°), the sum of the ranges was higher (10.5, 14.0, and 14.0). The a/c relationship (Table 3) was lower (3.0) in the intermediate angle of 160.0°, but was higher (15.0) in the angle of 330.0°.

When comparing the mean angle and length of the mean vector of marked–released–recaptured female Ae. aegypti with the data of Ordoñez-Gonzá-

Table 3. Circular distribution of the ranges (sum of larval index, vegetation index, and the adult–child relationship (a/c).
leiz (1997), we found that $a = 169.3^\circ$ and $r = 0.2340$ for the distance of dispersal, and $a = 91.07^\circ$ and $r = 0.3064$ for the percentage of females re-
captured agreed with their results. The direction of the wind, the presence of shade, and refuge and
exposition site availability influenced the mosquito
flights. The half angle of the 3 vegetation indices
was $277^\circ - 333^\circ$ and did not show any significant ef-
fect on the flight pattern ($F = 2.10, P > 0.05$). The
presence of refuges is important in determining the
directions of the flights of female Aedes aegypti.

**DISCUSSION**

The larval distribution of Aedes aegypti was toward
the southwest. However, Hausermann et al. (1971),
in a transect of 2 blocks with the width of 3,200 ft
both to the north and south, found that the maxi-
mum dispersal was 1,900 ft to the south, whereas
the circular distribution of positive ovitraps with
marked females was mostly toward the northwest.
The larval and vegetation indices identified this re-

gion, which has the highest density of humans, as
one at high risk for disease transmission.

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