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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 extrapolar flight range of vectors, as parameters in the dynamics of dengue transmission. By using circular statistics applied to each block of data, ranges (quartiles) were computed for larval index type, adult–child (a/c) relationship, and vegetation. Eight angles between 37 and 300° were used. Circular distribution was determined by using mean angle (*a*) and argument (*r*) from the sum of ranges for each variable. Arguments corresponding to the mean angle of house (260°), recipient (265°), and Breteau (247°) indices were 0.2321, 0.2331, and 0.2225, respectively. In addition, arguments for the mean angle of herbaceous (277°), shrub (318°), 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 light 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 of 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 40% indicated that the Shauri 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 virus. Consequently, development of entomological measures more reliable than larval indices as epidemiological tools is necessary (Onstad and Carruthers 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

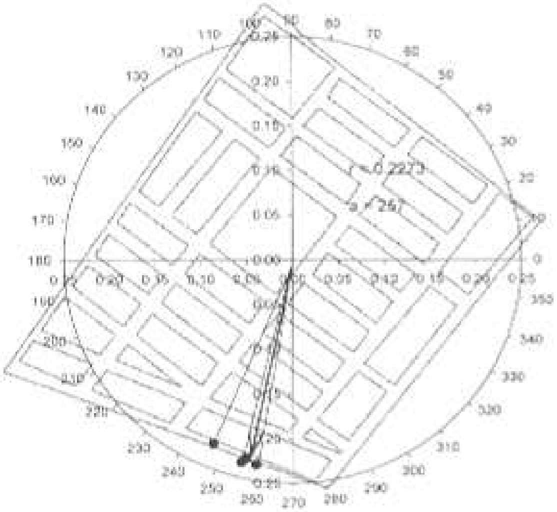

Fig. 1. Mean angle (a) and longitude of vector (r) of 3 larval indices.

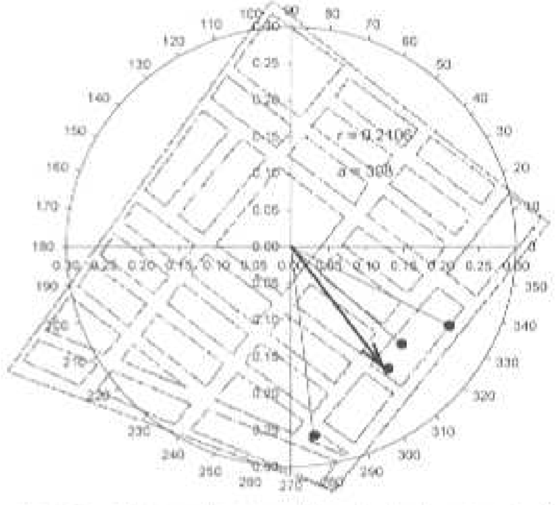

Fig. 2. Mean angle (a) and longitude of vector (r) of 3 vegetation indices.

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″ and 25°39′56″N, 100°11′02″ and 100°11′26″ 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 Llausas 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_m) are determine by: $X = (\cos a_i)/n$ and $Y = (\sin a_i)/n$, where a_i 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 $1 - r = 1.0$. $\cos a_m = X/r$ or $\sin a_m = Y/r$ 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 some 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°, 200.0°, 240.0°,

Table 1. Descriptive circular statistics, including the center of gravity (r) addressing the mean angle (a_m) and angular deviation (AD) of the larval and vegetation indices.

Statistics	Larval index			Vegetation index[1]		
	House	Breteau	Container	h	s	a
r	0.3356	0.2226	0.2331	0.2589	0.1984	0.2367
a_m	260°	247°	265°	277°	318°	333°
AD	66.05	71.45	70.96	69.75	72.55	70.78

[1] h, herbaceous; s, shrubs; a, arboreal.

Table 2. The descriptive circular statistics for the adult–child relationship (a/c) and larval and vegetation indices.

Statistics[1]	Larval index			Vegetation index[2]			a/c
	House	Breteau	Container	h	s	a	
a_m	18.28	29.13	2.02	0.65	0.79	0.75	2.50
SD	13.09	25.32	1.99	0.29	0.21	0.24	0.84
Q1	0–7.44	0–8.88	0–0.56	0–0.50	0.40–0.61	0.20–0.53	0–2.07
Q2	7.45–16.67	8.89–21.82	0.57–1.08	0.51–0.68	0.62–0.87	0.54–0.87	2.08–2.48
Q3	16.68–28.75	21.83–39.97	1.09–3.28	0.69–0.87	0.88–0.98	0.88–0.95	2.49–3.00
Q4	28.76–40.00	39.38–93.33	3.29–6.76	0.88–1.00	0.99–1.00	0.96–1.00	3.01–4.14

[1] a_m, mean angle; SD, standard deviation; Q, quartile.
[2] h, herbaceous; s, shrubs; a, arboreal.

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 (a_m), 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 angle 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 ± 72.55°. 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 (a_m), standard deviations (SD), and quartiles (Q*ij*) 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 ± 25.32), and the container index quartiles varied from 0.00 to 6.76% (2.02 ± 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 0.00–4.14 (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 120.0°, 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).

Mean angle (%)	Larval index			Vegetation index[1]			a/c
	House	Breteau	Container	h	s	a	
18.5	5.0	5.5	7.0	7.0	10.5	11.5	8.5
68.5	10.0	9.0	9.0	8.5	10.5	10.5	7.0
120.0	5.0	6.5	5.8	3.5	4.5	3.0	4.5
160.0	4.5	5.0	3.0	3.5	5.0	4.5	3.0
200.0	9.0	9.5	9.2	7.5	6.0	6.0	1.5
240.0	16.5	18.5	18.0	13.5	9.5	6.5	11.5
280.0	10.0	7.5	9.0	12.0	11.0	10.0	10.0
330.0	12.0	11.5	12.0	10.5	14.0	14.0	15.0

[1] h, herbaceous; s, shrubs; a, arboreal.

lez (1997), we found that $a = 169.36°$ and $r = 0.2340$ for the distance of dispersal, and $a = 91.07°$ and $r = 0.3064$ for the percentage of females recaptured agreed with their results. The direction of the wind, the presence of shade, and refuge and oviposition site availability influenced the mosquito flights. The half angle of the 3 vegetation indices was 277–333° and did not show any significant effect 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 *Ae. aegypti.*

DISCUSSION

The larval distribution of *Ae. 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 maximum 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 region, which has the highest density of humans, as one at high risk for disease transmission.

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