Revista de Saúde Pública
ISSN: 0034-8910
revsp@usp.br
Universidade de São Paulo
Brasil

Favaro, Eliane A; Dibo, Margareth R; Pereira, Mariza; Chierotti, Ana P; Rodrigues-Junior, Antonio L; Chiaravalloti-Neto, Francisco

Aedes aegypti entomological indices in an endemic area for dengue in Sao Paulo State, Brazil

Revista de Saúde Pública, vol. 47, núm. 3, junio, 2013, pp. 588-597
Universidade de São Paulo
São Paulo, Brasil

Rev Saúde Pública 2013;47(3):588-97

Artigos Originais

DOI: 10.1590/S0034-8910.2013047004506

Eliane A Favaro[I]

Margareth R Dibo[II]

Mariza Pereira[III]

Ana P Chierotti[II]

Antonio L Rodrigues-Junior[IV]

Francisco Chiaravalloti-Neto[V]

Aedes aegypti entomological indices in an endemic area for dengue in Sao Paulo State, Brazil

Indicadores entomológicos de *Aedes aegypti* em área endêmica de dengue, São Paulo, Brasil

ABSTRACT

OBJECTIVE: To evaluate the most productive types of properties and containers for *Aedes aegypti* and the spatial distribution of entomological indices.

METHODS: Between December 2006 and February 2007, the vector's immature forms were collected to obtain entomological indices in 9,875 properties in the Jaguare neighborhood of Sao Jose do Rio Preto, SP, Southeastern Brazil. In March and April 2007, a questionnaire about the conditions and characteristics of properties was administered. Logistic regression was used to identify variables associated with the presence of pupae at the properties. Indices calculated per block were combined with a geo-referenced map, and thematic maps of these indices were obtained using statistical interpolation.

RESULTS: The properties inspected had the following *Ae. aegypti* indices: Breteau Index = 18.9, 3.7 larvae and 0.42 pupae per property, 5.2 containers harboring *Ae. aegypti* per hectare, 100.0 larvae and 11.6 pupae per hectare, and 1.3 larvae and 0.15 pupae per inhabitant. The presence of yards, gardens and animals was associated with the presence of pupae.

CONCLUSIONS: Specific types of properties and containers that simultaneously had low frequencies among those positive for the vector and high participation in the productivity of larvae and pupae were not identified. The use of indices including larval and pupal counts does not provide further information beyond that obtained from the traditional Stegomyia indices in locations with characteristics similar to those of São José do Rio Preto. The indices calculated per area were found to be more accurate for the spatial assessment of infestation. The *Ae. aegypti* infestation levels exhibited extensive spatial variation, indicating that the assessment of infestation in micro areas is needed.

DESCRIPTORS: ***Aedes*, growth & development. Insect Vectors. Disease Vectors. Vector Control. Epidemiological Surveillance. Dengue, prevention & control.**

I Laboratório de Virologia. Faculdade de Medicina de São José do Rio Preto. São José do Rio Preto, SP, Brasil

II Laboratório de Vetores. Superintendência de Controle de Endemias. São José do Rio Preto, SP, Brasil

III Diretoria de Combate a Vetores. Superintendência de Controle de Endemias. São Paulo, SP, Brasil

IV Departamento de Medicina Social. Faculdade de Medicina de Ribeirão Preto. Universidade de São Paulo. Ribeirão Preto, SP, Brasil

V Departamento de Epidemiologia. Faculdade de Saúde Pública. Universidade de São Paulo. São Paulo, SP, Brasil

Correspondence:
Francisco Chiaravalloti-Neto
Departamento de Epidemiologia
Faculdade de Saúde Pública - USP
Av. Dr. Arnaldo, 715
01246-904 São Paulo, SP, Brasil
E-mail: franciscochiara@usp.br

Received: 8/16/2012
Approved: 1/19/2013

Article available from: www.scielo.br/rsp

RESUMO

OBJETIVO: Avaliar os tipos de imóveis e de recipientes mais produtivos para o desenvolvimento de *Aedes aegypti*e a distribuição espacial de indicadores entomológicos.

MÉTODOS: Foram realizadas coletas de formas imaturas de mosquitos para obtenção de indicadores entomológicos em 9.875 imóveis no bairro Jaguaré, no município de São José do Rio Preto, SP, entre dezembro de 2006 e fevereiro de 2007. Aplicou-se questionário sobre as condições e características de imóveis em março e abril de 2007. Utilizou-se regressão logística para identificar as variáveis associadas com a presença de pupas nos imóveis. Índices calculados por quadra foram combinados com mapas georreferenciados, possibilitando a produção de mapas temáticos por meio de interpolação estatística.

RESULTADOS: Os imóveis inspecionados apresentaram os seguintes índices para *Ae. aegytpi*: Índice de Breteau de 18,9, 3,7 larvas e 0,42 pupas por imóvel, 5,2 recipientes com *Ae. aegypti* por hectare, 100,0 larvas e 11,6 pupas por hectare, e 1,3 larva e 0,15 pupa por habitante. Presença de quintal, jardim e animais associaram-se com a presença de pupas.

CONCLUSÕES: Não foram identificados tipos específicos de imóveis e de recipientes que fossem pouco frequentes dentre aqueles com a presença do vetor e, ao mesmo tempo, que apresentassem elevada participação na produtividade de larvas e pupas. O uso de índices baseados na quantificação de larvas e pupas não traria informações além daquelas obtidas com os índices estegômicos tradicionais em localidades com características similares a São José do Rio Preto. Os índices calculados por área apresentaram maior acurácia para avaliar espacialmente a infestação, e a infestação por *Ae. aegypti* apresentou grande variabilidade espacial, apontando a necessidade de realizar avaliações de infestação em microáreas.

DESCRITORES: *Aedes*, crescimento & desenvolvimento. Insetos Vetores. Vetores de Doenças. Controle de Vetores. Vigilância Epidemiológica. Dengue, prevenção & controle.

INTRODUCTION

Dengue fever is a major disease that affects populations in developing tropical countries. The key prevention strategy is vector control, but this strategy has not been successful in controlling the disease.[8] There is criticism regarding the ability of routinely used entomological indicators to estimate the vector density. Researchers[3,4,6,14] and the World Health Organization (WHO)[26] suggest that the number of pupae per inhabitant and the number of pupae per area are more appropriate entomological indices for assessing the risk of an epidemic.

It is necessary to identify the areas and properties at greatest risk when monitoring *Ae. aegypti* populations to guide control practices.[9,24] Identifying the most productive types of containers, i.e., those from which the majority of adult *Ae. aegypti* mosquitoes likely originate, can facilitate the development of a more effective strategy for controlling the vector's infestation level by focusing control activities on these categories and making control programs more efficient.[18,26]

This study aimed to evaluate the most productive types of properties and containers for *Ae. aegypti* and the spatial distribution of entomological indices.

METHODS

This study was carried out in the city of Sao Jose do Rio Preto, Sao Paulo state, Southeastern Brazil (20º48'36"S; 49º22'59"W), which had a population of 415,509 inhabitants in 2006. This area has a tropical climate, a mean annual temperature of 25°C and a mean annual rainfall of 1,410 mm. There is a dry period from

May to October and a wet period between November and April. Dengue has been considered endemic to the city since 2000.[12] Jaguare, an urban neighborhood in Sao Jose do Rio Preto, comprising 11,000 properties, was selected for this study because it had the highest level of *Ae. aegypti* infestation according to previous entomological surveys.

This study was based on a cross-sectional entomological survey of all properties in the study area. The survey was performed between December 2006 and February 2007, covering the most favorable period for *Ae. aegypti* development, by a field research team that visited the properties, counted potential containers and collected all of the 3rd and 4th stage Culicidae larvae and all of the pupae that were present. The volume of water was recorded for the containers harboring Culicidae. The larvae and pupae collected were identified and quantified. The properties were grouped into nine types and the containers were classified into nine types.

Interviewers revisited the properties that had previously been inspected and administered a questionnaire to residents and those responsible for the properties in March and April 2007. The variables included in the questionnaire were those related to the characteristics of the properties and the residents and were selected from among those considered by WHO to be determinants of the occurrence of dengue.[26] The following information was obtained for the residential properties: the home's characteristics and condition (apartment or house, number of residents and rooms, presence of animals, and existence of a garden or yard); the head of the household's level of education, sex, and age; and the socioeconomic level of the family. The socioeconomic level was based on a score derived from the Brazilian Economic Classification Criterion and was divided into five levels, from A, the highest, to E, the lowest.[a] This score represents the sum of the points given for the head of the household's level of education, for the presence and number of salaried employees living in the house and for the presence and number of televisions, radios, toilets, cars, vacuum cleaners, VCRs or DVD players, refrigerators and freezers in the home. Information on the number of rooms, the presence of animals, and the existence of a garden or yard was collected for the following non-residential property types: businesses; factories or construction sites; and schools, churches, and other property types.

The entomological indices were calculated for the entire neighborhood: the Breteau index (BI); the number of containers harboring *Ae. aegypti* per hectare and per inhabitant; and the number of *Ae. aegypti* larvae and pupae per property, per hectare, and per inhabitant. The number of inhabitants was estimated based on information gathered from the interviews, and the area of each property's lot was obtained from a map of the lots.

The percentage distribution of the inspected properties that contained larvae and pupae, the BI value, the number of containers harboring *Ae. aegypti* per hectare, the larva and pupa productivity, and the number of *Ae. aegypti* larvae and pupae per property and per hectare were all calculated based on the property type. Productivity was calculated as the percentage of the total number of larvae or pupae that were located on a particular type of property or in a particular type of container.[4,6]

Logistic regression was used to identify the variables associated with the presence of pupae, which was the dependent variable, and to estimate odds ratios. The data obtained from the questionnaire and the property areas were regarded as independent variables. Apartments were excluded from the analysis because of their low index values.

The percentage distribution of the containers inspected, the containers harboring *Ae. aegypti* larvae and pupae, and the larva and pupa productivity were analyzed based on the type of containers. The percentage distribution of the number of containers harboring larvae and pupae and the larva and pupa productivities were analyzed based on the type of container and the volume of water contained.

The indices calculated per block were combined with a geo-referenced map of the centroids of the blocks that were considered samples of a continuous geographical phenomenon in physical space and could be used in a Gaussian stochastic process. The indices were transformed using the Box-Cox family of transformations[17] to improve their approximation for a normal distribution. The ordinary kriging method was used to obtain a mathematical model and to construct thematic maps with statistical interpolation using a method that estimates the generalized and weighted least squares, where the weighting is defined by a semivariance function. Choropleth thematic maps of the indices were generated with five categories (per quintile).

This study was approved by the Sao Jose do Rio Preto School of Medicine, Research Ethics Committee (Process 271/2005).

RESULTS

A total of 10,994 properties were identified in Jaguare. The total number of properties inspected was 9,875 (89.8%). *Ae. aegypti* were collected from 1,051

[a] Associação Brasileira de Empresas de Pesquisa. Critério de classificação econômica Brasil. São Paulo; 2012 [cited 2012 Dec 28]. Available from: http://www.abep.org/novo/FileGenerate.ashx?id=285

properties and from 1,867 of the 33,611 containers inspected. A total of 36,119 larvae were found in 1,788 containers located on 1,015 properties and 4,178 pupae were found in 647 containers located on 442 properties. For the neighborhood as a whole, the *Ae. aegypti* BI was 18.9, and 3.7 larvae and 0.42 pupae were found per property. After calculating the area of the properties inspected (361.2 hectares), the indices were calculated: 5.2 containers harboring *Ae. aegypti* per hectare and 100.0 larvae and 11.6 pupae per hectare.

Of the 9,875 properties inspected, 8,238 were residential and interviews were conducted for 81.9% of them. A total of 22,171 inhabitants (3.3 inhabitants per home), was found. An estimated 27,072 inhabitants were estimated for the houses investigated in the entomological survey, which allowed for the calculation of the indices: 0.07 containers harboring *Ae. aegypti* per inhabitant and 1.3 larvae and 0.15 pupae per inhabitant.

Table 1 shows the types of properties listed in decreasing order based on the pupa productivity values. Houses accounted for 81.0% of the properties inspected. Of the properties with larvae, 83.9% were houses, with a productivity of 79.2%. Of the properties with pupa, 80.4% were houses, with a productivity of 77.8%. Business sites had the highest number of larvae per hectare and factories and construction sites had the highest numbers of pupae per hectare. Empty lots, squares and apartments had the lowest number of larvae and pupae per hectare. Schools, churches, and other types of properties had the highest BI value and the greatest numbers of larvae and pupae per property, although the numbers of larvae and pupae per hectare were similar to those for apartments. The productivities of properties with larvae and pupae based on the type of property also had a similar distribution (Table 1).

Table 2 shows the results of the logistic regression model for the presence/absence of pupae in houses and non-residential properties. Questionnaires were administered to 6,680 homes and to 668 non-residential properties. The presence of dogs, chickens, gardens, and both partially unpaved and totally unpaved yards had OR values above unity that were statistically significant for homes. The same results were found for the presence of either a partially unpaved or totally unpaved yard for non-residential properties (Table 2).

Of the households to which the questionnaire was administered, 39.8% had gardens, 33.0% had partially unpaved or totally unpaved yards, 55.6% had dogs and 2.6% had chickens. At least one of these characteristics was found in 75.5% of the households in question. Houses with the presence of these characteristics corresponded to productivities of 88.1% and 92.1% for larvae and pupae, respectively.

A partially or totally unpaved yard was present at 20.5% of non-residential properties assessed. Properties with these types of yards corresponded to productivities of 38.0% for larvae and 45.5% for pupae. If we consider the houses and the non-residential properties with the characteristics described above, adding in fenced lots and common areas, the proportion of properties would be 65.7% of all of the properties in Jaguare, with productivities of 75.1% and 80.2% for larvae and pupae, respectively.

Nine types of containers were ranked in decreasing order based on pupa productivity (Table 3). The first five containers accounted for 62.1% of the containers inspected, including 71.4% and 70.0% of those containing larvae or pupae, respectively, and 70.1% and 73.8% of larva and pupa productivity, respectively. Pots, plants, fixed containers and animal drinking water containers were the most frequently inspected types, although the first two were among the five most pupa-productive container types. Canvases and car parts were present at lower frequencies (2.8% and 1.7% of the containers, respectively). However, these containers represented 6.8% and 9.4% of the containers harboring pupae and 13.0% and 10.8% of the productivity, respectively, and were among the five most productive container types.

The containers were also ranked according to pupa productivity. Containers with volumes less than one liter of water represented 62.8% and 56.8% of containers harboring larvae and pupae, respectively, and had productivities of 47.7% and 43.9%, respectively. When these containers were considered together with containers with volumes of one to ten liters of water, they totaled 93.6% and 91.5% of the containers that were positive for larvae and pupae, respectively, and 89.2% and 81.5% of the productivity, respectively. (Table 4)

The maps of the indices calculated per property distinguished areas with similar infestation levels (Figure 1 A, B and C). The maps of the indices calculated per hectare also distinguished areas with similar infestation levels (Figure 1 D, E and F) but exhibited differences from the maps based on the per property indices.

The indices show all the Northern region of Jaguare as having had higher levels of infestation. Despite the similarities among the indices, the northern region was found to be more prominent and broader when using the indices calculated per hectare. The indices per property identified certain areas with high levels of infestation that were not identified when the indices calculated per hectare were used, such as in the southern and westernmost regions of Jaguare.

Table 1. Properties inspected, Breteau Index (BI), number of containers harboring *Ae. aegypti* per hectare, properties with *Ae. aegypti* larvae and pupae, larva and pupa productivity (%), and numbers of larvae and pupae per property and per hectare according to the type of property. Jaguare neighborhood of Sao Jose do Rio Preto, Southeastern Brazil, December 2006 to February 2007.

Type of property	Properties inspected (%) (total of 9,875 properties)	BI	Number of containers harboring *Ae. aegypti* per hectare	Properties with *Ae. aegypti* (%)		Productivity (%)		Number of *Ae. aegypti* per property		Number of *Ae. aegypti* per hectare	
				Larvae (in 1,015 properties)	Pupae (in 442 properties)	Larvae (total of 36,119)	Pupae (total of 4,178)	Larvae	Pupae	Larvae	Pupae
House	81.0	18.0	7.3	83.9	80.4	79.2	77.8	3.6	0.41	145.8	16.6
Business	7.6	26.9	5.3	7.8	9.1	11.1	11.1	5.3	0.61	242.8	11.2
Factory or construction site	1.3	50.4	10.2	2.0	2.4	2.7	3.8	7.5	1.21	151.7	24.4
School, church, and other types[a]	0.7	88.9	0.9	1.8	2.5	2.6	3.3	13.3	1.99	11.8	1.7
Fenced lot	2.2	21.9	2.5	2.6	2.5	2.7	2.5	4.6	0.48	60.0	6.3
Empty lot or square	4.3	5.9	0.4	1.1	2.0	0.9	1.1	0.8	0.10	5.4	0.7
Common area	0.4	40.5	21.1	0.5	0.5	0.7	0.3	6.5	0.32	168.5	8.4
Apartment	2.5	1.7	1.6	0.3	0.5	0.1	0.1	0.2	0.01	16.8	1.2
Heath unit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0
All properties	100.0	18.9	5.2	100.0	100.0	100.0	100.0	3.7	0.42	100.0	11.6

[a] Other types included zoo, club, soccer fields, sports fields or courts, and federal road police station.

Table 2. Variables included in the logistic regression model for the presence of *Ae. aegypti* pupae in houses and non-residential properties (businesses; factories and construction sites; and schools, churches and other types). Jaguare neighborhood of Sao Jose do Rio Preto, SP, Southeastern Brazil, December 2006 to February 2007.

Dependent variable	Property type	Independent variable	Situation	Odds Ratio (95%CI)	p
Presence or absence of *Ae. Aegypti* pupae	House	Presence of dogs	Yes (x no)	1.51 (1.18;1.93)	0.001
		Presence of chickens	Yes (x no)	2.03 (1.24;3.31)	0.005
		Presence of a garden	Yes (x no)	1.33 (1.03;1.71)	0.028
		Presence and type of yard	Partially unpaved (x no)	1.77 (1.35;2.32)	0.000
			Unpaved (x no)	2.61 (1.75;3.90)	0.000
	Non-residential	Presence and type of yard	Partially unpaved (x no)	5.02 (1.72;14.69)	0.003
			Unpaved (x no)	4.70 (1.49;14.75)	0.008

DISCUSSION

We did not find specific types of properties that presented, at the same time, low frequencies among those positive for the vector and high participation in the productivity of larvae and pupae. Residences, the most common property type, had larva and pupa productivities close to the percentage of houses among the properties inspected. None of the other types of properties stood out as contributing a larger percentage of productivity.

Apartments, which have been recognized as having a low risk of vector presence in Sao Paulo, Southeastern Brazil,[7] empty plots of land, squares, and health units were found to have low entomological indices. Cities with characteristics similar to those of Sao Jose do Rio Preto should consider these results when planning vector control activities.

Property types such as businesses, factories, and construction sites had the highest values for larvae and pupae per hectare. This is in agreement with data collected in Peru, which showed the importance of non-residential properties in the production of *Ae. aegypti*.[13] One limitation of using the number of pupae per inhabitant as a dengue risk index is the difficulty in estimating the size of population at risk in non-residential properties.[13] One viable alternative for locations with these types of properties is the use of the number of pupae per hectare.

Some of the characteristics of the properties could be used to identify the properties most likely to contain the vector. The presence of yards, gardens and animals could be used as criteria for selecting properties that should receive more intense vector control. The association between gardens and yards and the presence of

Table 3. The percentage distribution of containers harboring *Ae. aegypti* larvae and pupa and their productivity (%) based on the types of containers. Jaguare neighborhood of Sao Jose do Rio Preto, Southeastern Brazil, December 2006 to February 2007.

Type of container	Containers inspected (n = 33,611)	Containers harboring larvae (n = 1,788)	Containers harboring pupae (n = 647)	Larva productivity (n = 36,119)	Pupa productivity (n = 4,178)
	%	%	%	%	%
Pot (pot, bucket, basin, or bottle)	39.1	28.3	28.1	26.3	26.5
Plant (flower pot, plant plate, or natural container)	14.0	21.8	18.0	18.8	14.3
Canvas (canvas or other cover)	2.8	4.8	6.8	5.2	13.0
Car part	1.7	8.3	9.4	8.2	10.8
Drum (drum, gallon, or other large container)	4.5	8.2	7.7	11.6	9.2
Fixed container (drain, tile, toilet and other objects that are part of the property's structure)	20.1	8.3	8.0	6.8	9.1
Tyre	2.6	10.5	11.9	12.8	7.8
Animal drinking water container	10.8	4.7	5.1	5.3	4.9
Construction material	4.4	5.1	5.0	5.0	4.4
Total	100.0	100.0	100.0	100.0	100.0

Table 4. The percentage distribution of containers harboring *Ae. aegypti* larvae and pupa and their productivity (%) based on the types of containers and their water volumes (<1L, 1-10L and >10L). Jaguare neighborhood of Sao Jose do Rio Preto, SP, Southeastern Brazil, December 2006 to February 2007.

Type of container	Larvae						Pupae					
	Containers (%)			Productivity (%)			Containers (%)			Productivity (%)		
	<1L	1-10L	>10L	<1L	1-10L	>10L	<1L	1-10L	>10L	<1L	1-10L	>10L
Pot	20.0	6.4	2.1	14.1	9.3	3.0	18.4	7.4	2.5	14.3	9.6	2.7
Plant	17.9	3.6	0.0	13.2	5.4	0.0	14.9	3.1	0.0	10.3	4.1	0.0
Canvas	2.6	2.1	0.2	2.4	2.6	0.2	2.6	3.5	0.6	1.8	4.3	6.9
Can part	6.1	1.7	0.4	4.8	2.7	0.7	5.7	3.0	0.6	7.1	3.3	0.4
Drum	2.7	3.5	2.0	2.6	5.2	3.9	1.9	3.5	2.5	1.6	4.6	3.1
Fixed container	2.7	4.6	1.1	1.5	3.5	1.8	2.5	4.1	1.3	1.0	3.9	4.1
Tyre	5.9	4.6	0.1	5.4	7.5	0.0	6.4	5.4	0.0	3.7	4.0	0.0
Animal drinking water container	1.8	2.6	0.4	1.5	2.7	1.1	1.9	2.5	0.8	2.1	1.5	1.3
Construction material	3.1	1.7	0.1	2.2	2.6	0.1	2.5	2.2	0.2	2.0	2.3	0.0
Subtotal	62.8	30.8	6.4	47.7	41.5	10.8	56.8	34.7	8.5	43.9	37.6	18.5
Total		100.0			100.0			100.0			100.0	

the vector agrees with the criteria used to define the premise condition index, which was created to identify properties with higher probabilities of vector presence,[23] and agrees with other studies.[10,15]

Following the WHO guidelines,[4] studies were conducted to identify the most productive containers, and several of these studies identified container types that simultaneously had low frequencies among the inspected containers and high levels of productivity.[1,2,4,6,14,16,18,25] Thus, the focus of control activities on these types of containers would increase, at least theoretically, the effectiveness of vector control.

It was not possible to identify the most productive types of containers because over half of the container types were responsible for 70% to 75% of all larvae and pupae. Their productivity was slightly higher than their percentage of the total number of containers inspected or of the number of containers harboring larvae and pupae. This result differs from those obtained by other authors, who identified types of containers with a high productivity of pupae.[1,2,4,6,14,16,18,25]

The best candidates for productive container types for pupae are canvases, car parts, drums and tires, which were found at low frequencies among the inspected containers and had levels of pupa productivity well above those frequencies. However, these four container types (11.6% of those inspected) accounted for 40.6% of pupa productivity, which is insufficient to ensure the success of the vector control program if the elimination and/or treatment strategies focused only on these containers.

An important difference between Jaguare and the areas studied by these authors[1,2,4,6,14,16,18,25] should be noted: Jaguare has a relatively low frequency of large containers. This low frequency is associated with the fact that the population of Sao Jose do Rio Preto does not need to store water regularly because there is an almost universal water supply system in place. Without the presence of the large containers that produce adult mosquitoes, the infestation is associated with the widespread availability of containers with a small volume of water, as found in a study carried out in city of Rio de Janeiro, Southeastern Brazil.[22]

It was not possible to identify the most productive property and container types in Jaguare. The strategy of larval and pupal counting to identify the most productive types of containers[4] will not benefit vector control in locations with characteristics comparable to those found in this neighborhood, as it did in locations in which large containers are present. However, this study identified characteristics of properties that influence the pattern of vector infestation and this information should be considered when planning vector control activities.

Indices based on larval and pupal counts showed a geographical pattern of infestation similar to that obtained with indices based on the presence of larvae and pupae in containers. Therefore, the indices based on larval and pupal counts do not provide further information regarding the mosquito infestation level. This finding is in agreement with other studies that showed that the BI is an appropriate entomological index for use in low-infestation areas.[19,20] This result is in accordance with the findings for Jaguare because this area's infestation level is low compared with those in some

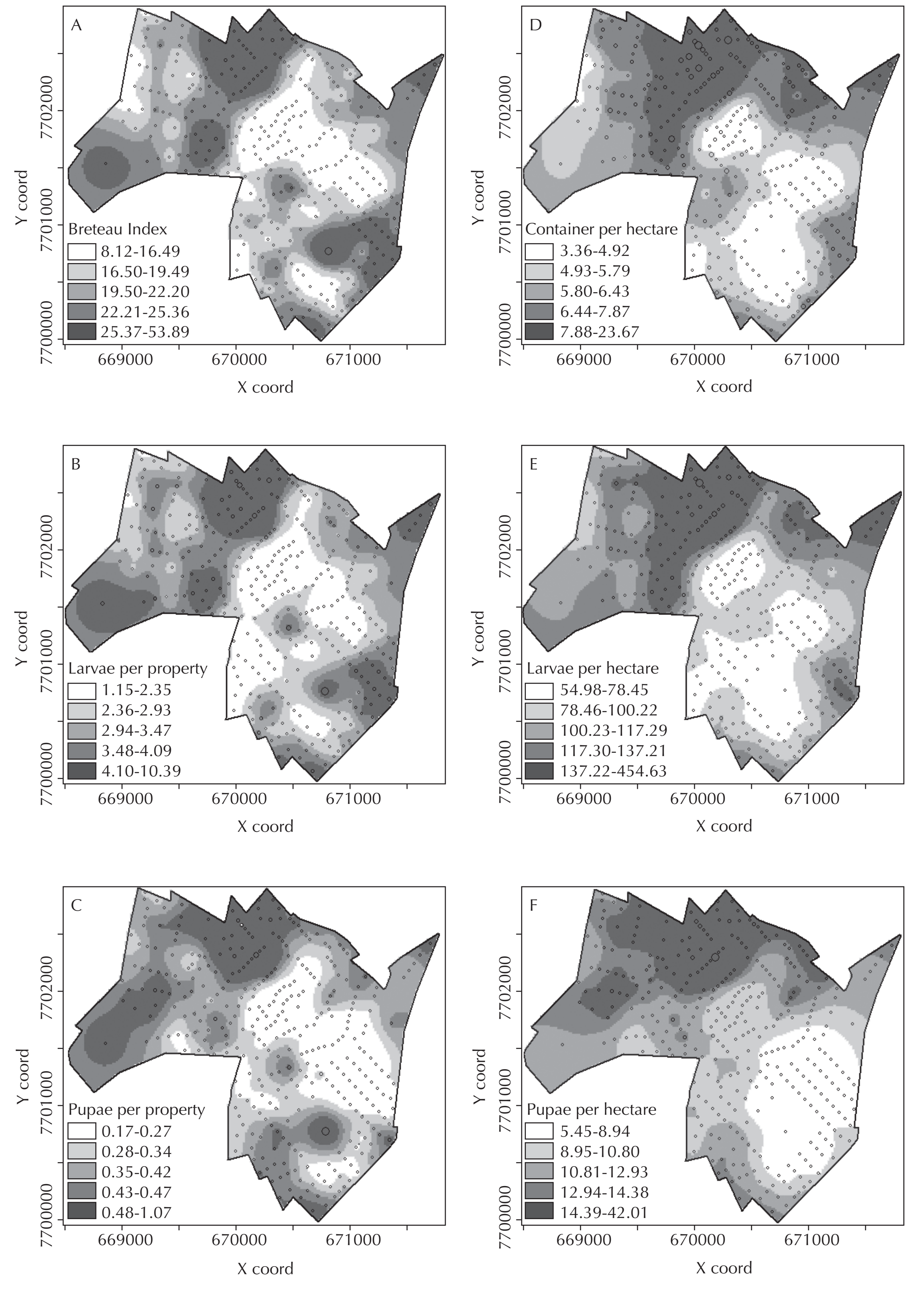

Figure. Breteau Index (A), number of *Ae. aegypti* larvae per property (B), number of *Ae. aegypti* pupae per property (C), number of containers harboring *Ae. aegypti* per hectare (D), number of *Ae. aegypti* larvae per hectare (E), and number of *Ae. aegypti* pupae per hectare (F). Jaguare neighborhood of Sao Jose do Rio Preto, Southeastern Brazil, December 2006 to February 2007 (UTM, SAD 69, Zone 22).

locations studied by the authors who defend the use of pupal counts along with demographic data.[1,2,4,6]

The main difference observed among the infestation maps in the geographical region evaluated was associated with the use of indices calculated per property or hectare. One reason for this difference is the presence of properties with large lots. The inclusion of such properties in the calculation of the BI increases the BI value because properties with large areas are more likely to include more than one container with *Ae. aegypti* per property. This effect was observed at properties such as schools, churches, and others, which had the highest BI values. However, when the indices for these property types were calculated per hectare, the probability of finding immature forms of the vector was similar to that of apartments. The fact that the northern region was found to be more prominent and broader for the indices calculated per hectare is related to the higher density of buildings in this area.

Indices calculated per hectare appear to be more accurate for assessing infestation in geographical areas and are more useful for identifying the areas with the highest infestation levels. Indices calculated per area may be more appropriate measures for assessing the risk of dengue.[4,6,14] The use of area-based indices in the planning, directing and evaluating of vector control activities could produce more effective control strategies.

A predictive model found that under the most favorable conditions for both the virus and mosquitoes, the transmission threshold was 0.25 *Ae. aegypti* pupae per inhabitant,[5] which is higher than the value found in this study (0.15). Different dengue serotypes are present in Sao Jose do Rio Preto. DENV-1 was first detected in 1990, DENV-2 in 1998, and DENV-3 in 2005.[11,12] In 2006, a high incidence of dengue was recorded in the city (2,934 cases per 100,000 inhabitants), with the highest incidence occurring in Jaguare (5,092 cases per 100,000 inhabitants). Although Jaguare's population is partially immune to DENV-1, 2 and 3 and despite the low number of pupae per inhabitant found during the study period, dengue transmission occurred in this neighborhood in 2007, with an incidence of 1,281 dengue cases per 100,000 inhabitants between January and May.[b]

This result is consistent with the observation of Scott & Morrison[21] (2010) that entomological thresholds for the occurrence of dengue fever are especially low. However, it is worth noting that the 0.15 pupae per inhabitant corresponded to the average value of this index for Jaguare. Although the spatial distribution of this index was not determined due to the already discussed difficulty in estimating the size of population at risk for non-residential properties,[13] the spatialization of the other indices revealed the existence of a significant spatial variation in the levels of *Ae. aegypti* infestation. The number of pupae per hectare (11.6 on average) exhibited a large spatial range (between 5.5 and 42.0) showing that the presence of the vector, and consequently the risk of dengue, had heterogeneous behavior in space. Using spatial analysis tools to assess *Ae. aegypti* infestation allows the infestation levels be evaluated in micro areas.

The use of a single entomological survey can be considered a limitation of this study. However the implementation of the survey during the most favorable period for the vector and its coverage of most properties in the study area enabled us to reach conclusions: specific types of properties and containers with low frequencies among those positive for the vector and simultaneous high participation in the productivity of larvae and pupae were not identified; some of the property characteristics could be used to identify the properties that had the highest probability of containing the vector; the use of indices including larval and pupal counts does not provide further information beyond that obtained from the traditional Stegomyia indices in locations with characteristics similar to those found in Jaguare; indices calculated per area were more accurate for the spatial assessment of infestation; and the *Ae. aegypti* infestation levels presented extensive spatial variation, pointing to the need to assess the level of infestation in micro areas.

ACKNOWLEDGMENTS

To Marlene CG Souza, Edmilson Rodrigues de Oliveira, Célio Vamberto, Nivaldo Firmino da Silva, Fernando Roberto de Oliveira and Cícero Alves da Silva for their assistance with the field work; to Beatriz AC Belini, Neuza FA Santana and Perpétua MM Sereno of the Laboratorio de Vetores da Superintendencia de Controle de Endemias for their assistance with the laboratory work.

REFERENCES

1. Barbazan P, Tuntaprasart W, Souris M, Demoraes F, Nitatpattana N, Boonyuan W, et al. Assessment of a new strategy, based on *Aedes aegypti* (L) pupal productivity, for the surveillance and control of dengue transmission in Thailand. *Ann Trop Med Parasitol.* 2008;102(2):161-71. DOI:10.1179/136485908X252296

[b] Secretaria de Saúde do Estado de *São Paulo.* Centro de Vigilância Epidemiológica Prof. Alexandre Vranjac. Dengue: dados estatísticos. São Paulo; 2012 [cited 2012 Mar 13]. Available from: http://www.cve.saude.sp.gov.br/htm/zoo/dengue_dados.html

2. Barrera R, Amador M, Clark GG. Use of the pupal survey technique for measuring *Aedes aegypti* (Diptera: Culicidae) productivity in Puerto Rico. *Am J Trop Med Hyg*. 2006;74(2):290-302.

3. Barrera R. Dinámica del dengue y *Aedes aegypti* en Puerto Rico. *Rev Biomed*. 2010; 21(3):179-95.

4. Focks DA. A Review of entomological sampling methods and indicators for dengue vectors. Gainsville: World Health Organization; 2003.

5. Focks DA, Brenner RJ, Hayes J, Daniels E. Transmission thresholds for dengue in terms of *Aedes aegypti* pupae per person with discussion of their utility in source reduction efforts. *Am J Trop Med Hyg.* 2000;62(1):11-80.

6. Focks DA, Chadee DD. Pupal survey: an epidemiologically significant surveillance method for *Aedes aegypti*: an example using data from Trinidad. *Am J Trop Med Hyg.* 1997;56(2):159-67.

7. Glasser CM, Arduino MB, Barbosa GL, Ciaravolo RMC, Domingos MF, Oliveira CD, et al. Comportamento de formas imaturas de *Aedes aegypti*, no litoral do Estado de São Paulo. *Rev Soc Bras Med Trop*. 2011;44(3):349-55. DOI: 10.1590/S0037-86822011005000042

8. Gubler DJ. Dengue urbanization and globalization: the unholy trinity of the 21st century. *Trop Med Health*. 2011;39(4 Suppl):3-11. DOI:10.2149/tmh.2011-S05

9. Lagrotta MTF, Silva WC, Santos-Souza R. Identification of key areas for *Aedes aegypti* control through geoprocessing in Nova Iguaçu, Rio de Janeiro State, Brazil. *Rev Saude Publica.* 2008;24(1):70-80. DOI: 10.1590/S0102-311X2008000100007

10. Maciel-de-Freitas R, Peres RC, Souza-Santos R, Lourenço-de-Oliveira R. Occurrence, productivity and spatial distribution of key-premises in two dengue-endemic areas of Rio de Janeiro and their role in adult *Aedes aegypti* spatial infestation patter. *Trop Med Int Health*. 2008;13(12):1488-94. DOI: 10.1111/j.1365-3156.2008.02162.x

11. Mondini A, Bronzoni RVM, Nunes SHP, Chiaravalloti-Neto F, Massad E, Alonso WJ, et al. Spatio-temporal tracking and phylodynamics of an urban Dengue 3 outbreak in São Paulo, Brazil. *PLoS Negl Trop Dis*. 2009;3(5):448. DOI:10.1371/journal.pntd.0000448

12. Mondini A, Chiaravalloti-Neto F, Sanches MGY, Lopes JCC. Análise espacial da transmissão de dengue em cidade de porte médio do interior paulista. *Rev Saude Publica.* 2005;39(3):444-51. DOI: 10.1590/S0034-89102005000300016

13. Morrison AC, Sihuincha M, Stancil JD, Zamora E, Astete H, Olson JG, et al. *Aedes aegypti* (Díptera: Culicidae) production from non-residential sites in the Amazonian city of Iquitos, Peru. *Ann Trop Med Parasitol.* 2006;100(Suppl 1)1:73-86. DOI:10.1179/136485906X105534

14. Nathan MB, Focks DA, Kroeger A. Pupal/demographic surveys to inform dengue-vector control. *Ann Trop Med Parasit.* 2006;100(Suppl 1):1-3.

15. Nogueira LA, Gushi LT, Miranda JE, Madeira NG, Ribolla PEM. Short Repot: Application of an alternative *Aedes* species (Diptera: Culicidae) surveillance method in Botucatu city, São Paulo, Brazil. *Am J Trop Med Hyg.* 2005;73(2):309-11.

16. Pilger D, Lenhart A, Manrique-Saide R, Siqueira JB, Rocha WT, Kroeger A. Is routine dengue vector surveillance in central Brazil able to accurately monitor the *Aedes aegypti* population? Results from a pupal productivity survey. *Trop Med Int Health*. 2011;16(9):1143-50. DOI: 10.1111/j.1365-3156.2011.02818.x

17. Quinn GP, Keough MJ. Experimental design and data analysis for biologists. Cambridge: Cambridge University Press; 2002. DOI:10.1017/CBO9780511806384

18. Romero-Vivas CM, Arango-Padilha R, Falconar AKI. Pupal-productivity surveys to identify the key container habitats of *Aedes aegypti* (L.) in Branquilla, the principal seaport of Colombia. *Ann Trop Med Parasitol.* 2006;100(Suppl 1):87-95. DOI:10.1179/136485906X105543

19. Sanchéz L, Cortinas J, Pelaez O, Gutierrez H, Concepción D, Stuyft P. Breteau Index threshold levels indicating risk for dengue transmission in areas with low *Aedes* infestation. *Trop Med Int Health*. 2010;15(2):173-5. DOI: 10.1111/j.1365-3156.2009.02437.x

20. Sanchéz L, Vanlerberghe V, Afonso L, Marquetti MC, Guzman MG, Bisset J, et al. *Aedes aegypti* Larval Indices and Risk for Dengue Epidemics. *Emerg Infec Dis*. 2006;12(5):800-6. DOI:10.3201/eid1205.050866

21. Scott TW, Morrison AC. Vector dynamics and transmission of dengue vírus: implications for dengue surveillance and prevention strategies: vector dynamics and dengue prevention. *Curr Top Microbiol Immunol.* 2010;338:115-28. DOI:10.1007/978-3-642-02215-9_9

22. Silva VC, Scherer PO, Falcão SS, Alencar J, Cunha SP, Rodrigues IM, et al. Diversidade de criadouros e tipos de imóveis frequentados por *Aedes albopictus* e *Aedes aegypti*. *Rev Saude Publica*. 2006;40(6):1106-11. DOI: 10.1590/S0034-89102006000700021

23. Tun-Lin W, Kay BH, Barnes A. The premise condition index: a tool for streamlining surveys of *Aedes aegypti*. *Am J Trop Med Hyg.* 1995;53(6):591-4.

24. Tun-Lin W, Kay BH, Barnes A. Understanding productivity, a key to *Aedes aegypti* surveillance. *Am J Trop Med Hyg.* 1995;53(6):595-601.

25. Tun-Lin W, Lenhart A, Nam VS, Rebollar-Téllez E, Morrison AC, Barbazan P, et al. Reducing costs and operational constrainsts of dengue vector control by targeting productive breeding places: a multi-country non-inferiority cluster randomized trial. *Trop Med Int Health.* 2009;14(9):1143-53. DOI: 10.1111/j.1365-3156.2009.02341.x

26. World Health Organization. Dengue: Guidelines for diagnosis, treatment, prevention and control. Geneva: World Health Organization; 2009.

This study was funded by *Fundação de Amparo à Pesquisa do Estado de São Paulo* (FAPESP) (Process nº 2005/02800-8).
The authors declare that there are no conflicts of interests.