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THE ASSOCIATION OF *AEDES AEGYPTI* AND *AE. ALBOPICTUS* IN ALLENDE, NUEVO LEÓN, MEXICO

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ABSTRACT. The recent appearance of *Aedes Stegomyia albopictus* (Skuse) in Nuevo León (NL) worries health officials. It is a vector of dengue fever in Asia and is more resistant to lower temperatures than *Ae. aegypti.* The objective of this study was to learn about some ecological parameters of *Ae. albopictus* and their association with *Ae. aegypti,* and other culicids in Allende, NL, Mexico, during 1999. Allende is a small town close to metropolitan Monterrey, which has 4 million inhabitants. The design was random with monthly sampling of 175 ovitraps. Chi-square analyses were performed with data of presence, absence, frequency, and relative abundances. During the study, the species *Culex tarsalis* (Coquillet), *Cx. thriambus* (Dyar), *Cx. pipiens* (Linnaeus), *Cx. coronator* (Dyar and Knab), *Ae. albopictus, Ae. aegypti, Toxorhynchites rutilus* (Coquillet), and *Ae. triseriatus* (Say) were found. April is the month for large numbers of mosquito species. September had the highest populations in positive ovitraps (66.67%), followed by July (63.27% of traps). *Aedes aegypti* was the most abundant (65.13%), followed by *Ae. albopictus* (19.71%). Both *Ae. albopictus* and *Ae. aegypti* were found from April until December. *Aedes aegypti* was more abundant than *Ae. albopictus,* except in August, when they were similar ($\chi^2 = 0.197$, $P < 0.05$). We found significant association between the presence of both species for every study month ($\chi^2 = 9.837$, $P < 0.05$), with a contingency coefficient of 0.247. September and November were the months having the most mosquitoes in this association. Only considering *Ae. albopictus,* more were found in ovitraps in July (34.6%), followed by September (33.3%). However, its presence was not significant throughout the year. Of 2 zones, in town and at the river, prevalence indicated that *Ae. albopictus* preferred the river. This mosquito is in its establishment phase in this area and requires further studies.

KEY WORDS *Aedes albopictus, Ae. aegypti,* Allende, Dengue fever vector, Nuevo León, Mexico, public health

INTRODUCTION

Aedes albopictus (Skuse) has been reported in the American continent since 1985 (Karamjit 1991) and in Mexico since 1988, where it was reported as larvae in tires in Matamoros, Tamaulipas (CDC 1989). During 1993, it was reported in Ciudad Acuña and Piedras Negras, Coahuila (Ibañez and Martínez 1994). That same year, Rodríguez and Ortega (1994) found mosquito larvae in Muzquiz, Coahuila, in plastic containers together with *Toxorhynchites teobaldi.* Martínez (1995) carried out a search in 14 municipalities in the state of Nuevo León (NL) and obtained negative results. However, in 1998, it was detected in the municipality of Allende, NL (Orta, personal communication). *Aedes albopictus* and *Ae. aegypti* (L) belong to the *Stegomyia* subgenus. The former is an effective vector of dengue, yellow fever, and other arboviruses in Asian countries, and it prefers woody habitats (Hawley 1988, Schultz 1989, Estrada and Craig 1995). Thus, this phenomenon creates great concern, as it represents a serious threat to the public health in the state of NL. Our objective in this study was to generate information about the association between larvae and pupae in relation to other culicids, especially *Ae. aegypti.*

MATERIALS AND METHODS

Allende NL has an area of 186.923 km² and is located 25°17′N, 100°1′W (Fig. 1), at an altitude of 460 m. It is part of the southeast region of the state in the plain of the lower Rio Grande (INEGI 1986).

The selection of the work area was based on a search of a humid area (near Rio Ramos, with natural vegetation dominated by *Taxodium* sp.) and less humid areas with dwellings on the flats and hillocks near the Gran Sierra Plegada of the Sierra Madre Oriental. Allende is directly below the front of the Sierra Madre. The hydrology is type RH24 (INEGI 1998).

A total of 175 ovitraps, or artificial larval habitats, of transparent (white) plastic 1-gallon jugs filled with well water were placed randomly in the study area; 35 were placed near the river and 140 near dwellings (Fig. 1). These jugs were collected once a month and evaporated water was replenished. The opening was 0.04 m². The water in the jug was sampled by pipette and not removed. Site choice showed that more jugs were placed near houses and near the river. For identification, most of the material was raised to maturity.

Chi-square analysis (Zar 1999) was carried out for the purpose of testing the association in positive traps of culicids, the locality, and months. Also, contingency coefficients were calculated to estimate the association among species. The average numbers of all culicids found were determined, as well as the relative positivity of *Ae. albopictus.*

RESULTS

A total of 4,535 mosquito larvae and pupae were found in ovitraps from December 1998 to Decem-

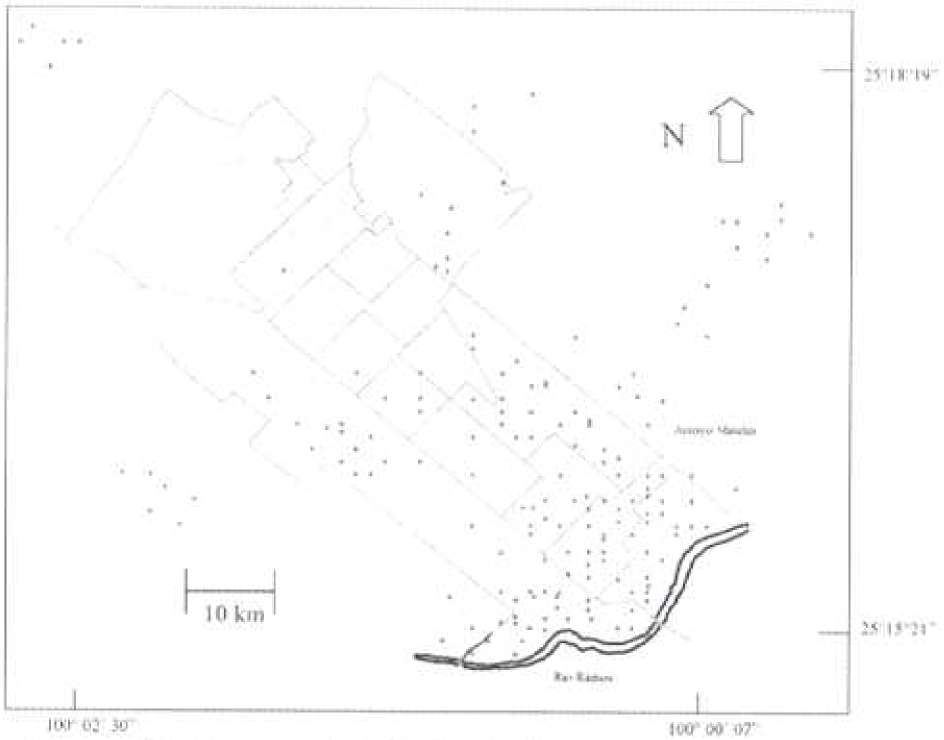

Fig. 1. Ovitraps (175) of transparent plastic of 1-gallon jugs filled with well water in Allende, NL.

ber 1999. Of these larvae and pupae, 894 were *Ae. albopictus*. The sampling zones were the margins of Rio Ramos and the populated area of Allende, including a cemetery. Some 75 traps were positive for *Ae. albopictus* of the total sampling during the study (Table 1 and Fig. 1).

The 8 species of culicids found were *Cx. tarsalis*, *Cx. thriambus*, *Cx. pipiens*, *Cx. coronator*, *Ae. albopictus*, *Ae. aegypti*, *Tx. rutilus*, and *Ae. triseriatus* and 2 not identified.

In July, we registered the largest number of positive traps for *Ae. albopictus* and *Ae. aegypti* (Fig. 2). The positive trap percentage for *Ae. albopictus* in July was 34.69%, followed by September, with 33.33%. In November, we found 24.39% of positive traps for this species. December 1999 was the month that registered the smallest percentage (3.45%) of *Ae. albopictus*.

Figure 3 demonstrates a law-like relation between amount of rainfall (X axis) by the size of the *Ae. aegypti* (Y axis) population. The degrees of freedom adjusted (df Adj) coefficient of determination is $r^2 = 0.9731$. The equation of Fig. 3 is $Population = a + b((Rainfall)^2(\sqrt{Rainfall})) + c(Rainfall)^3$. For *Ae. albopictus*, df Adj $r^2 = 0.9999$ or, effectively, absolute at unity. The equation of Fig. 4 is $Population = a + b(Rainfall) + c(Rainfall)\sqrt{(Rainfall)} + d(Rainfall)^2$.

Table 1. Species found by month of sampling. NI, not identified.

	Dec	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Aedes aegypti				X	X	X	X	X	X	X	X	X
Ae. albopictus				X	X	X	X	X	X	X	X	X
Culex pipiens				X	X	X	X		X			
Cx. coronator			X	X								
Cx. tarsalis	X											
Cx. thriambus		X										
Toxorhynchites rutilus				X	X	X	X		X			
Ae. triseriatus										X	X	
NI		X									X	X

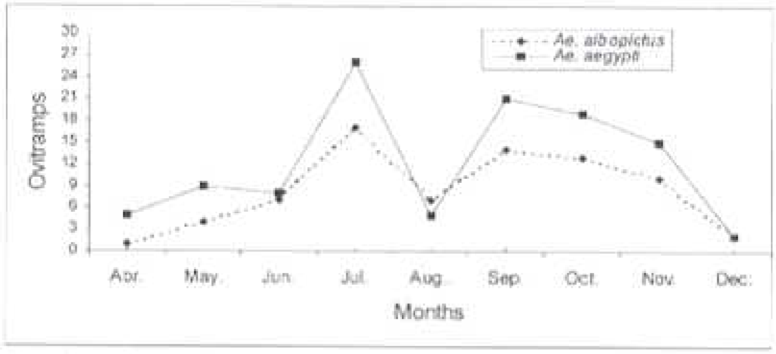

Fig. 2. Positive ovitraps for *Ae. albopictus* and *Ae. aegypti* during the study period.

Regarding the accumulative abundance during the sampling months, *Ae. aegypti* was the dominant species except in December, February, and March, when it was not found; this species included 65.13% of the culicids found during the study period. *Aedes albopictus* reached 19.71% of total culicids found. *Culex pipiens* was found in 3rd place regarding the relative abundances, with 6.34%, followed by *Cx. coronator* with 3.22%, *Cx. thriambus* and *Cx. tarsalis* with 2.91% and 1.72%, respectively. Less than 1% was registered for *Tx. rutilus*, *Ae. triseratus*, and the unidentified species.

Aedes aegypti was in greater proportion than *Ae. albopictus*, except in August, when they had similar frequencies ($\chi^2 = 0.1968$, $P < 0.05$). According to the number of traps studied by month, a significant association between both species was found in September and November. Considering the positive traps during the period of a year, a significant association between the major species existed ($\chi^2 = 9.837$, $P < 0.05$), with a contingency coefficient of 0.247. There was almost no association of similar population sizes by month; however, we obtained preference in the sampling zones, showing that *Ae. albopictus* can be found near the river (Tables 2 and 3) more often than *Ae. aegypti*.

Logistic regression (forward, conditional) was used, demonstrating a significant difference ($P < 0.01$) between *Ae. albopictus* and the humid vs. dry localities, indicating a clear relation to rainfall. However, *Ae. aegypti* did not show this relation. This equation is

$$\begin{aligned} \textit{Albopictus} &= -2.114 - 0.403(\textit{Aegypti}) \\ \text{Significance} & \qquad\qquad 0.490 \\ &+ 1.687(\textit{Zone}) + 0.089(\textit{Month}) \\ & \qquad 0.004 \qquad\qquad 0.489 \\ &+ 0.015(\textit{Precip}). \\ & \qquad 0.005 \end{aligned}$$

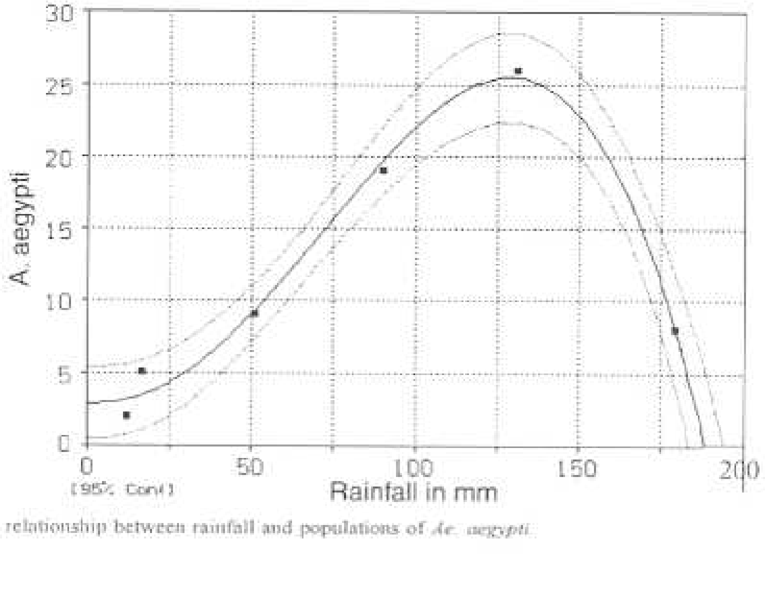

Fig. 3. The relationship between rainfall and populations of *Ae. aegypti*.

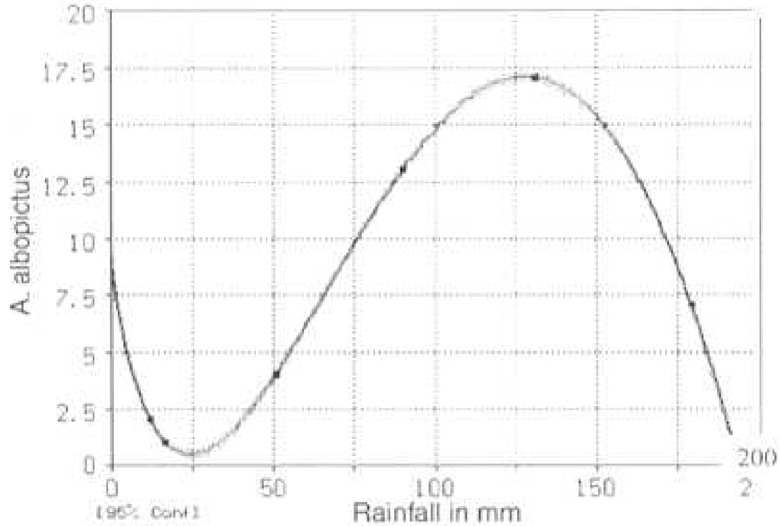

Fig. 4. Relation between rainfall and *Ae. albopictus*.

DISCUSSION

Aedes albopictus larvae and pupas were found in Allende from April 1998 to the final sampling winter months, confirming its presence in NL. Despite his search, Martínez (1995) could not find this species in this state. Here, the first sampling month for *Ae. albopictus* is April, agreeing with the data of Rodríguez and Ortega (1994), who reported its presence in the same month in Muzquiz, Coahuila, during 1993.

The lowest percentage of positive larvae of all the mosquitoes collected was in March with 2.04%, whereas the highest percentage was found in September, with 66.67%.

A chi-square analysis, considering only the positive traps for culicids during all the time of study, resulted in a significant association of 9.837 for *Ae. albopictus* and *Ae. aegypti*, with a contingency coefficient of 0.247, showing a lower figure for significant association of these species by months at $\alpha = 0.05$.

Cold can cause rain, yet in other respects, the temperature regime described has nothing to do with the prevalence of mosquitoes because, in general, temperature is not a limiting factor. In stark contrast, it is well known that rainfall, because it dictates availability of oviposition sites, controls the mosquito populations. *Aedes aegypti* is more prevalent than *Ae. albopictus*; however, the reasons for this are unknown. Regardless, the equations of Figs. 3 and 4 are the necessary and sufficient proof that these mosquito populations universally oscillate according to amounts of rainfall.

Mosquito prevalence exactly follows the rainfall regime. November–April is an annual drought, yet, in the year 2000, there were rains in November. In May, convection currents, mainly from the Gulf of Mexico, although also along the Pacific coast, bring moderately light rains as altitude is gained in the mountains or cold fronts are contacted. Many of these cold fronts come off the Great Plains. June is likely to be a dry month. By August and through early October, cyclonic currents bring the greatest amount of rain, which nationally is about 700 mm/year, although it exceeds 2,000 mm/year in some areas. After rains, runoff is very fast in swollen streams, influenced by the short distances from the mountains to the sea as well as poor soil infiltration. Evaporation rates are almost always very high, emphasizing the importance of shade for container

Table 2. Chi-squared values and Pearson correlation coefficient with significances of *Aedes albopictus*, *Ae. aegypti*, and other culicids, and months of positive sampling. The inverse association of other culicids by month is significant.

Culicids	χ^2	df	Significance	R	Significance
Ae. albopictus	9.485	8	0.303	0.093	0.261
Ae. aegypti	10.560	8	0.228	−0.007	0.934
Other culicids	18.85[1]	8	0.016	−0.267	0.001

[1] Indicates significant dependence.

Table 3. Chi-squared values and Pearson correlation coefficient with significances of *Aedes albopictus*, *Ae. aegypti*, and other culicids, and the sampling zones: humid vs. less humid.

Culicids	χ^2	df	Significance	*R*	Significance
Ae. albopictus	11.465[1]	1	0.001	−0.276	0.001
Ae. aegypti	30.590[1]	1	0.000	0.465	0.000
Other culicids	11.837[1]	1	0.001	−0.294	0.000

[1] Indicates a highly significant dependence.

mosquito survival. Mosquito prevalence drops in step with the runoff to return to the drought steady state of about 6 months, inhibiting dengue transmission. This drought is usually October–March. The May and August–September rains are both based on storm and hurricane activities, first in the Atlantic and second in the eastern Pacific.

A firm understanding of local climate is an essential basis for mosquito control and dengue prevention. We are concerned most with increases in towns and cities because of local rains leaving standing water. When to spray, with what, and where is a complex cost/benefit problem that is partly undefined because the disease impact is poorly accounted for. Time lost from work and from school, and health care, specifically due to dengue, are costs to industry and government revenues that can be expressed in dollars if, and only if, all problem components are known. This unknown and little-studied equation could be used to justify control and surveillance expenditures.

Although certain neighborhoods have been identified as persistent dengue recyclers in metropolitan Monterrey, there are at present no correlations including climate variables, sizes of various mosquito populations per month, and number of dengue cases. Because *Ae. albopictus* has appeared in Nuevo León only within the past 23 years, unless children receive dengue education, it is unreasonable to look for community awareness that could be beneficial through citizen reduction of standing water, cleanups, and the use of truck-distributed temephos-treated water for water drums.

Our information implies that spraying to kill adult mosquitoes should be carried out immediately after rain in May and after the July–October rains. Costs of mosquito control might be vastly lowered by water-container temephos treatments and adult spraying in high-incidence neighborhoods without piped water, even though this view might seem overly optimistic. Such traditional insecticide action should be accompanied by a public cleanup campaign in May as well as in August–September that, at a minimum, requires advertising, particularly on television. Public awareness of the disease symptoms is needed as part of a motivation for cleanup. Comparative annual and monthly *Aedes* populations along with spraying times and amount of spray by truck hours per area or another measure are unavailable in Allende and most other areas.

The curves in Figs. 3 and 4 can act as standards for mosquito population expansion with rain in this and other climatic regimes. An interruption in the rise of such a curve could indicate spraying success. The use of plain and sticky ovitraps with water or hay infusions to indirectly monitor adult populations is obviously the essential sentinel, even though dry viable embryonated eggs are neglected in this discussion. We have indicated when to spray—immediately after rain—but not where to use insecticide as yet. This cost-conditioned decision would, of course, also be influenced by ovitrap information obtained per locality.

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