Daily Pattern of Flight Activity of *Aedes albifasciatus* in Central Argentina

Francisco F Ludueña Almeida, David E Gorla

Centro de Investigaciones Entomológicas, Facultad de Ciencias Exactas, Físicas y Naturales, Universidad Nacional de Córdoba, Av. Vélez Sarsfield 299 (5000) Córdoba, Argentina

Aedes albifasciatus *is an important common mosquito in Central Argentina. It is a confirmed vector of the Western Equine Encephalitis and is responsible for loss of milk production in dairy cattle during peak populations. This paper reports the flight activity pattern of* Ae. albifasciatus *for different seasons, in the southern coast of the Mar Chiquita Lake (central Argentina). Data were collected by sampling two sites between 1992 and 1993 with CDC traps and human-bait captures.*

Adult mosquito population density, estimated by CDC trapping and human-bait, were highly correlated. However, when compared to other species, the proportion of Ae. albifasciatus *was higher in human-bait collections. Adult female populations were active only when temperature were higher than 6°C. Two daily biting peaks were observed (dusk and dawn) during the spring, summer and autumn, and only one peak during winter (around 15:00 pm). Adult abundance was significantly correlated (R^2=0.71; p<0.01) with temperature and illumination.*

Key words: flight activity - Culicidae - *Aedes albifasciatus* - abundance estimation

Aedes albifasciatus is a flood water mosquito occurring in the southern region of South America. Because of its reproductive strategy, periodic outbreaks with high population densities occur. The species has veterinary importance because females are able to transmit Western Equine Encephalitis (Avilés et al. 1990), but mostly because they periodically reduce milk production during population peak densities (Ludueña Almeida & Gorla, unpublished).

Similar to other flood water mosquitoes, female *Ae. albifasciatus* lay eggs able to survive in muddy areas that can dry out for several weeks up to four months. After a rainfall, the eggs present in the flooded areas hatch within 24 hr and the larvae develop to aduls within ten days at temperatures higher than 20°C (Ludueña Almeida & Gorla 1995).

After emergence, females seek a host to get a blood meal. Host seeking activity by active flight is mainly affected by temperature, wind, humidity and illumination (Bidlingmayer 1985). Because these factors change throughout the year, the mosquito flight activity patterns also change.

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Different mosquito species show different activity patterns on host seeking behaviour, being classified as diurnal, nocturnal and dawn or dusk mosquitoes. The first group includes some Sabethini and *Aedes* and *Psorophora* species. The second group includes mainly species of *Culex* and *Anopheles* (Forattini 1962). Either nocturnal or diurnal species show two types of flight activity. The first one, has only one daily activity maximum, as in *Haemagogus spegazzini* (Forattini 1962). The second, has two daily maxima at dawn and at dusk as in the Anophelini of the subgenus *Kerteszia* in southern Brazil (Forattini 1962).

Various authors report on the effect of temperature on mosquito activity. In the "tundra", the mosquitoes are not active below 5°C (Gjullin et al. 1961, Corbet & Danks 1973). The active dispersion in *Aedes* spp. would occur only when mean night temperatures exceed 15°C (Brust 1980). *Culex tarsalis* begins to fly and feed when temperatures are greater than 13°C, and 15°C, respectively (Bailey et al. 1965).

The estimation of adult relative density is commonly carried out using CDC light traps, but unless the captures are made at the same time of the day and with constant duration, density estimation may be biased due to changes in flight activity pattern throughout the year. In this paper, we present the results for daily pattern of flight activity of female *Ae. albifasciatus* during different seasons, and a method to correct the estimation of adult density based on environmental variables.

METHODS

The study was conducted along the southwestern coast of the Mar Chiquita Lake, near the town of La Para (30°S latitude, 63°W longitude). The southern coast of the Mar Chiquita Lake is the most important dairy region in Córdoba Province, central Argentina. The area has approximately 100,000 dairy cattle, producing a total average of 18,000 litres of milk, daily. Overall, the area is very flat and crossed by several creeks and two main rivers. During the rainy season, numerous temporary ponds appear where *Ae. albifasciatus* breed, periodically producing extremely high populations. Two sampling sites were selected, the first located 14 km east (Site 1) and the second located 5 km northeast (Site 2) of La Para town (for details of sample sites see Ludueña Almeida & Gorla 1995). Adult females were captured using two trapping techniques: CDC light traps baited with CO_2 (500 g of dry-ice wrapped with cardboard paper) and human-bait captures with a mechanical aspirator.

A CDC trap was operated continuously during a 24 hr period on each sampling occasion. Adults captured within periods of 1.5-2 hr intervals were caged individually in plastic containers. Samples were taken on two consecutive days of February, July, October and November 1992 and January and April 1993 at Site 1 and on May 1993 at Site 2.

The number of mosquitoes captured during each interval was used to estimate the potential number of mosquitoes per hour. This number was divided by the total number of mosquitoes captured during a 24 hr period to obtain the proportion of active mosquitoes for each time unit (1 hr).

Human-bait captures were conducted every 1-2 hr during the daylight hours (from 6 am to 9 pm during the summer months and from 8 am to 7 pm during the winter months) for ten consecutive minutes. Samples were taken on two consecutive days of April, July and October 1992 and January 1993 in Site 1 and on two consecutive days of May 1993 in Site 2.

Based on the number of mosquitoes captured during each 10 min period, an estimate of the number of mosquitoes per 1 hr was determined. The total number of mosquitoes captured in one day was estimated by summation of the partial captures. A cubic function was used to describe the relation between the cumulative proportion of mosquitoes trapped and the cumulative temperature from the beginning of the sample collections of a particular date. The accumulated temperature (AT) was calculated as:

$$AT = \sum_{i=1}^{n} t(i) - MT$$

where: i = collection period within a day; n= number of total collections during a day; t(i)= temperature of period i; MT= minimum threshold (6°C, see below)

As the two sampling techniques for mosquito collection (CDC trapping and human-bait captures) can have different biases, a correlation analysis was done between collections with each technique, at specific sites and dates from March 1991 to November 1992. Relative daily density of *Ae. albifasciatus* and the rest of the species were considered. Also, the proportion of *Ae. albifasciatus* captured by each technique was compared by a t test (using arc sin transformed data) (Sokal & Rohlf 1979).

A linear regression through the origin between the cumulative proportion of captured mosquitoes and cumulative temperature was calculated for each of the five sampling occasions, and a regression between these five slopes and average temperature of the sampling date was carried out.

Temperature and illumination were measured with a maximum-minimum thermometer and a luxometer at the beginning and the end of the 1.5-2 hr intervals of CDC trapping and during the 10 min period for human-bait.

Captured mosquitoes were brought to the laboratory, where they were identified to species. Data presented here will be shown for *Ae. albifasciatus* and for all species, including *Ae. albifasciatus*, combined.

The modality of the frequency distribution of the proportion of active mosquitoes at any particular hour was carried out plotting the cumulative proportion of daily mosquito catch on a probit scale. A linear trend on that scale indicates a one-peak activity pattern, whereas a sigmoid-shaped curve indicates a two-peak activity pattern. To study the randomness of the residuals around the fitted linear function, the median non parametric test was used (Sokal & Rohlf 1979).

RESULTS

Density estimations of *Ae. albifasciatus* with the two sampling techniques were highly correlated ($R^2 = 74.9\%$, $p < 0.001$, n=22). However, the proportion of *Ae. albifasciatus* captured from human-bait was higher (t test, $p<0.0001$, n=22) than the proportion captured by the CDC trap (0.75 and 0.32, respectively). Data on collections from human-bait showed that *Ae. albifasciatus* was active only when the temperatures were greater than 6°C (Fig. 1). In the following considerations, this value will be considered as the minimum temperature threshold.

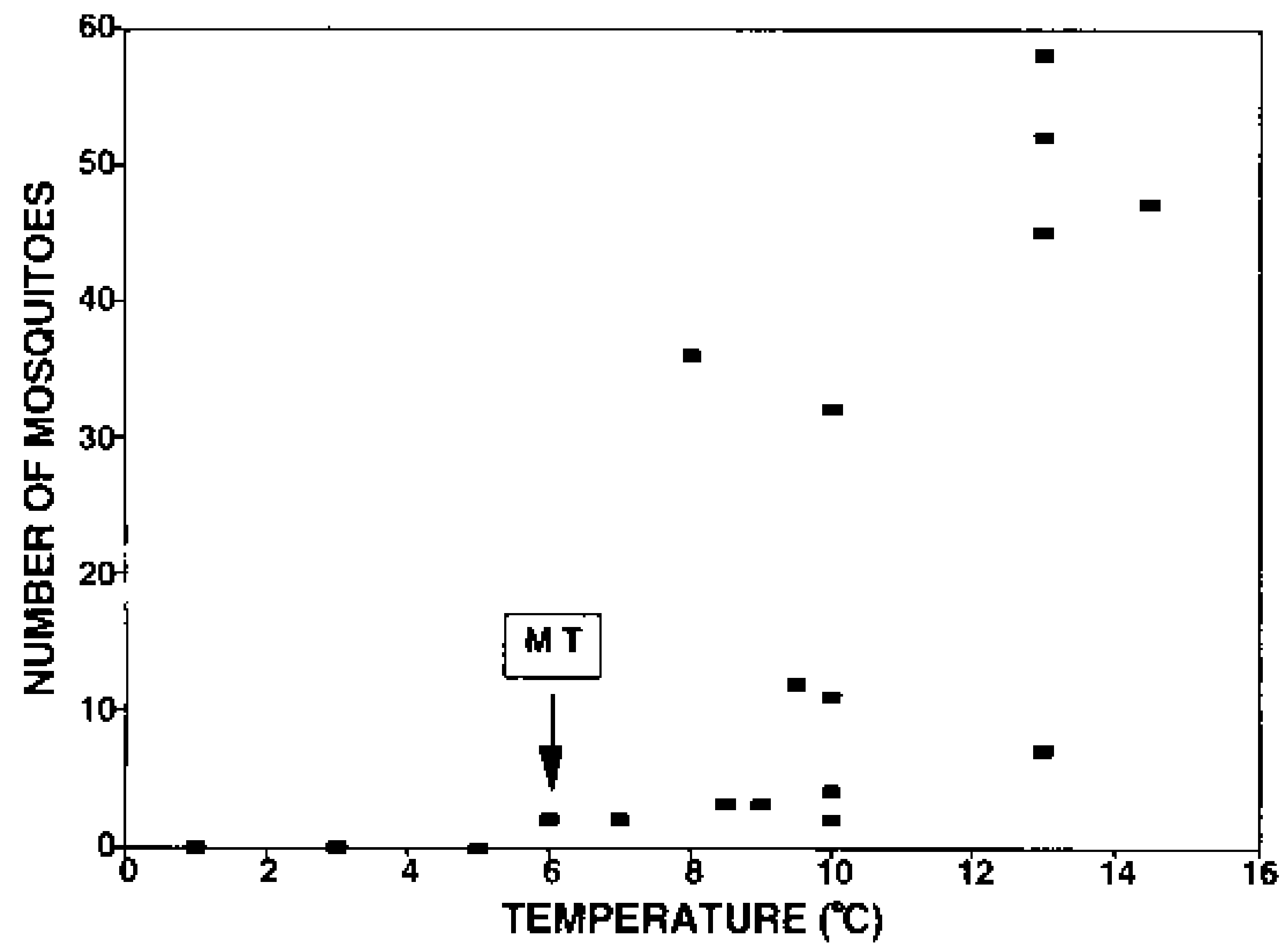

Fig. 1: number of *Aedes albifasciatus* captured from human-bait during 10 min periods, at different temperatures. The arrow marks the temperature below which mosquitoes were not active.

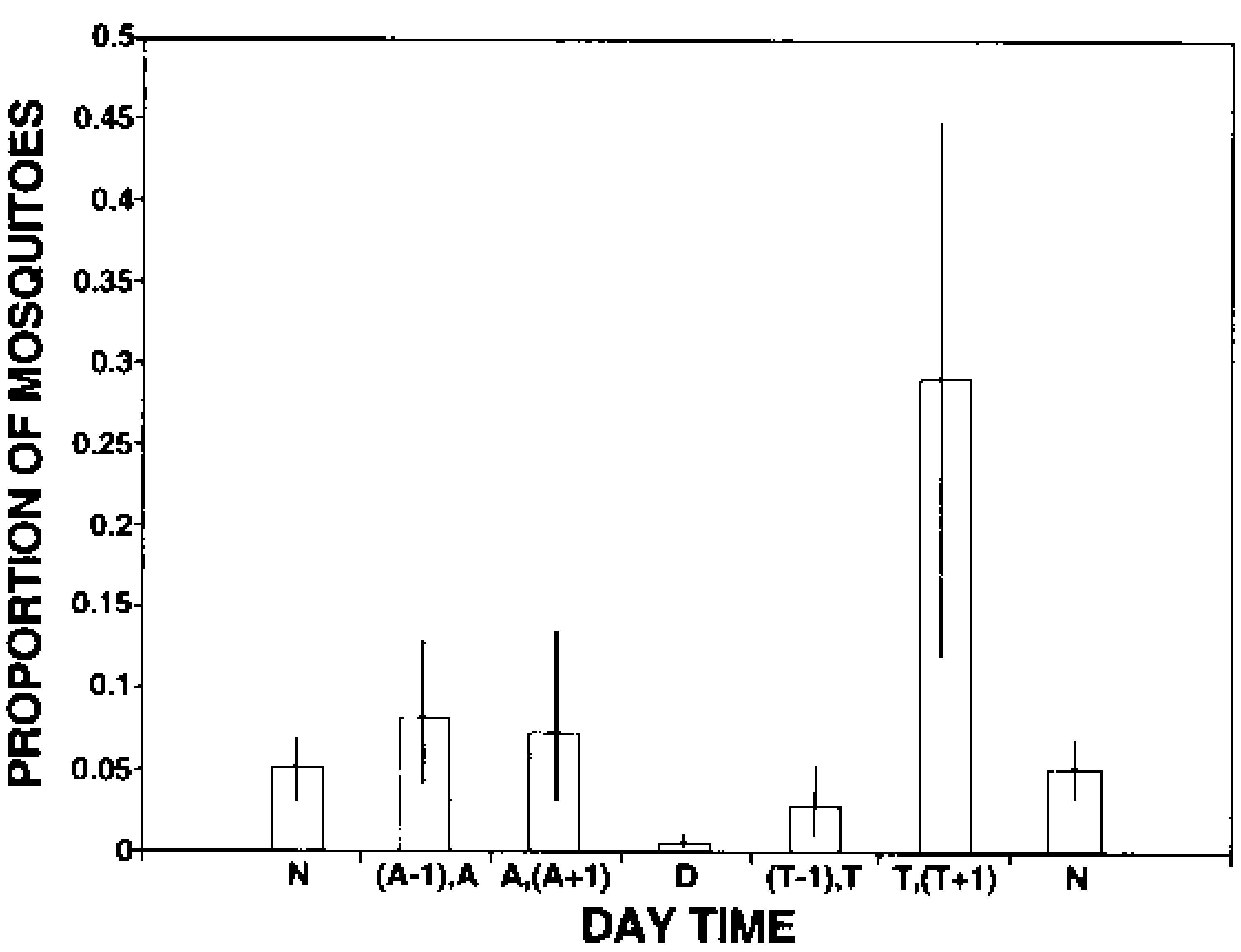

Fig. 2: daily distribution of *Aedes albifasciatus* (CDC trapping), showing the number of mosquitoes captured during 1 hr intervals during the months when minimum temperatures were greater than 6°C (average of five samples). N: average capture during 1 hr intervals of nighttime; (A-1), A: 1 hr before sunrise (A); A, (A+1): 1 hr after sunrise; D: average capture during 1 hr of daylight; (T-1), T: 1 hr before sunset (T); T, (T+1): 1 hr after sunset.

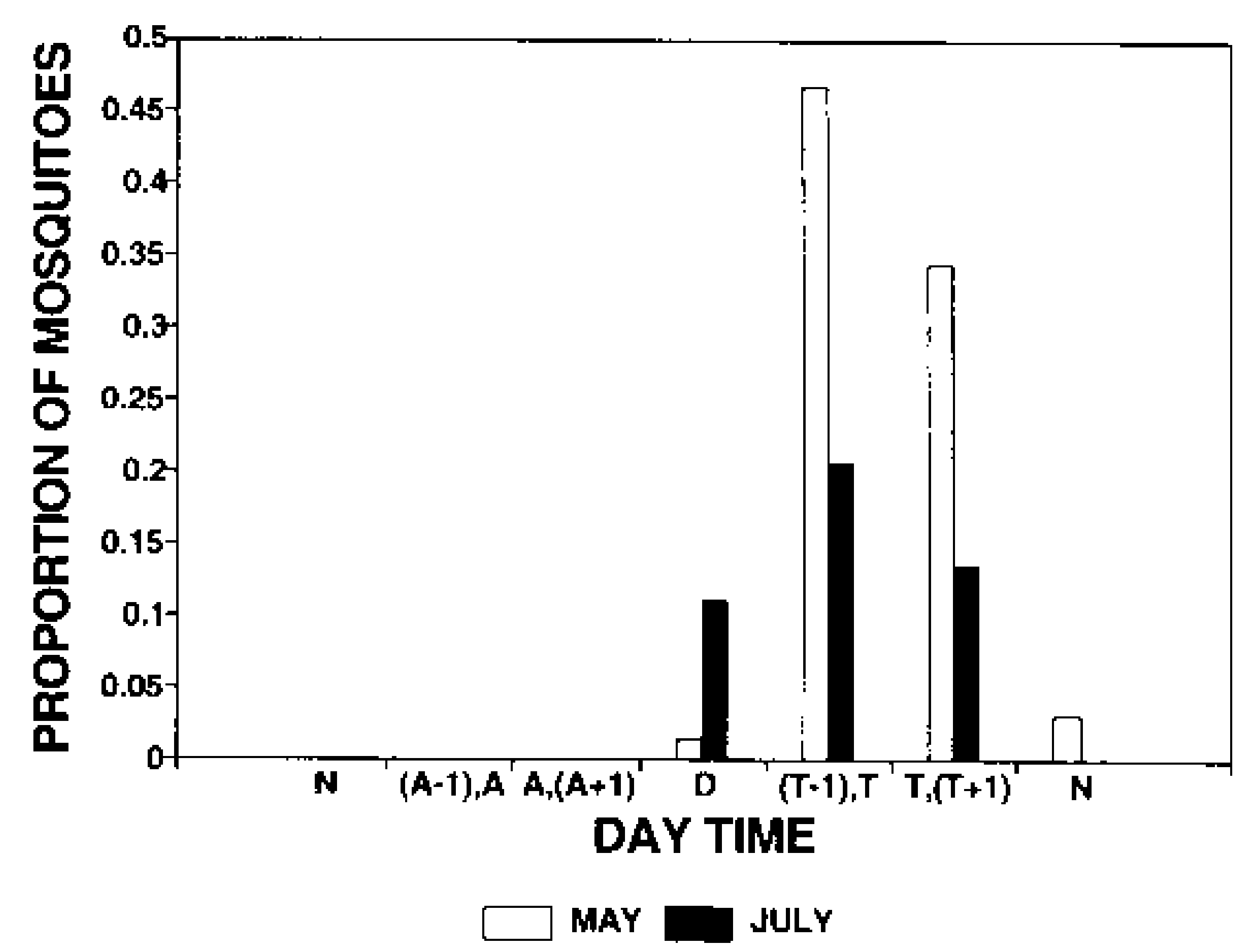

Fig. 3: daily distribution of *Aedes albifasciatus* (CDC light + CO_2), showing mosquitoes captured during 1 hr intervals for months when the minimum temperatures were lower than 6°C. N, A, T idem as in Fig. 2.

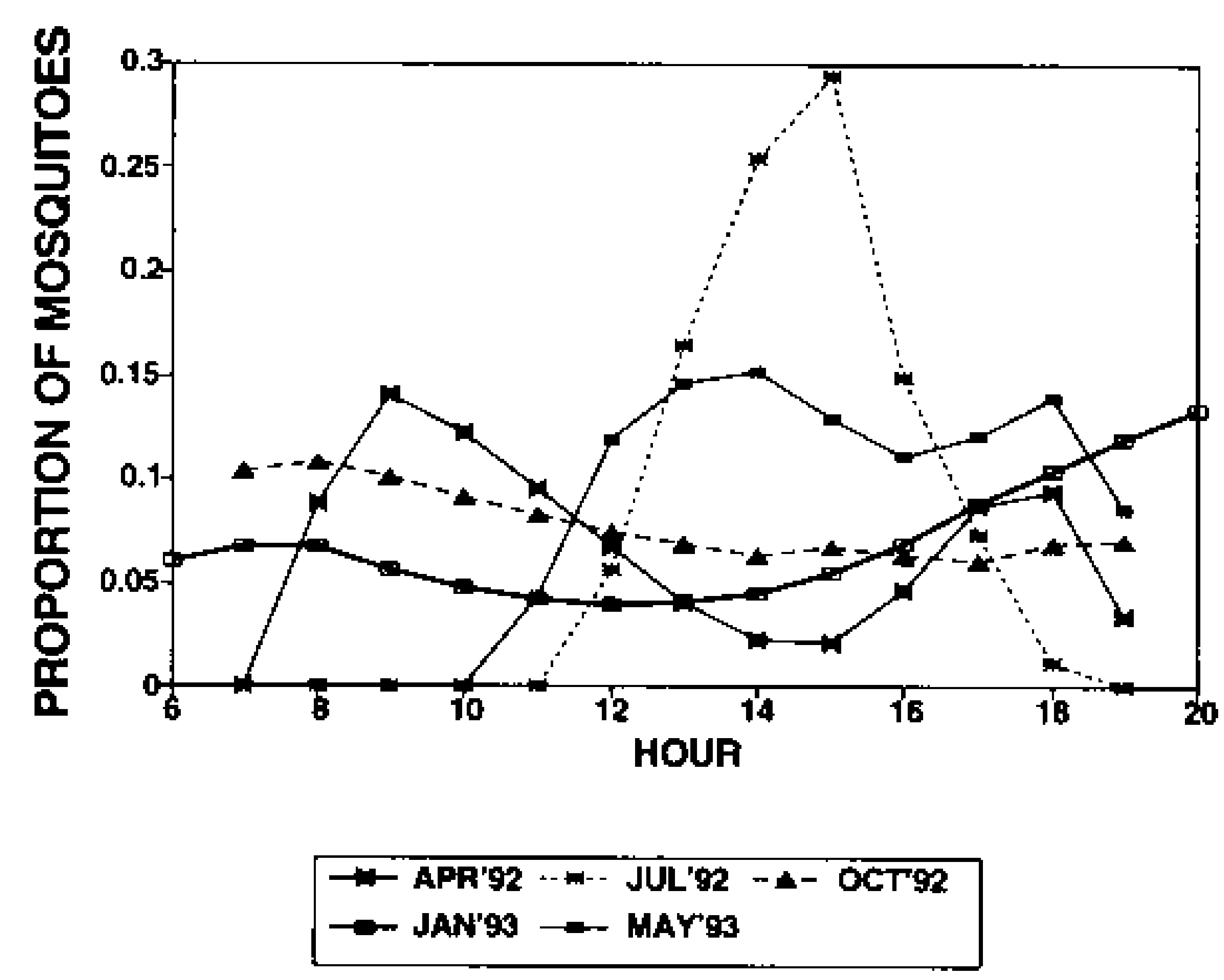

Fig. 4: daily distribution of *Aedes albifasciatus* for different seasons and for captures over human bait.

The data from CDC trapping and human-bait captures show that adults were more abundant during the hours of dawn and at dusk during spring, summer and autumn, i.e. a bimodal flight activity pattern (Figs 2, 4). During the winter months, only one activity period was observed: at dusk according to CDC trapping (Fig. 3), or at noon by human-bait captures (Fig. 4).

The distribution of the proportion of mosquitoes captured on human bait along a day showed a significant linear fit (r 0.88, $p<0.01$) with time on a probit scale for all seasons. However, only the data for July showed residuals randomly distributed around the fitted line (Fig. 5).

Temperature and illumination (considered together in a multiple correlation analysis) were significantly correlated with the proportion of mosquitoes captured by CDC trapping (R^2= 92% for all species and 71% for *Ae. albifasciatus*, n=41) (Table I). A separate analysis for each environmental variable showed that the proportion of all mosquitoes captured within each sampling period by CDC trapping was highly correlated with illumination in autumn, spring and summer (when minimum temperatures were greater than 6°C) but not in winter. Temperature was also significantly

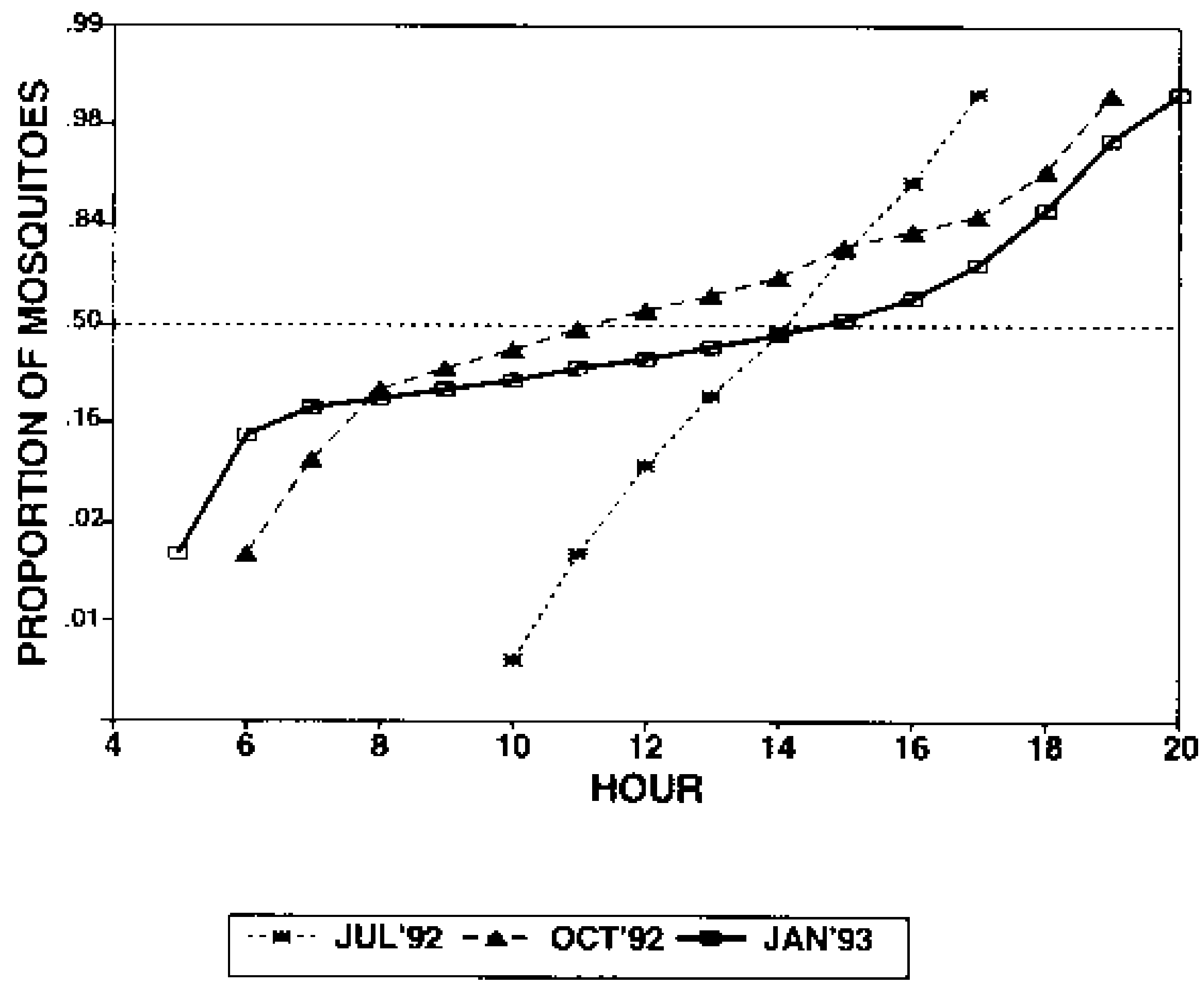

Fig. 5: probit analysis of the cumulative proportion of *Aedes albifasciatus* captured over human bait. Residual analysis showed that only data for July have one mode, whereas data for October and January are bimodal.

correlated with total mosquito abundance. *Aedes albifasciatus* showed a similar trend, although the correlation for summer was low (Table II). Biting activity estimated from human-bait catches was not correlated with illumination and temperature for *Ae. albifasciatus*. However, the cumulative proportion of *Ae. albifasciatus* captured in human-bait for each sampling occasion (n = 5) was highly correlated with cumulative temperature over the minimum temperature threshold, according to a cubic function (Table III). A linear regression between the same variables was significant, and the slopes of these lines were also highly correlated with the mean temperature of the sampling date, according to the power model $b = 1.499\ T_{(m)}^{-1.88}$ (where b is the slope and $T_{(m)}$ is the mean temperature of sampling date) ($R^2 = 98.9$, $p<0.001$) (Table III).

TABLE I

Multiple regression analysis of the proportion of *Aedes albifasciatus* and all mosquitoes species (dependent variables, Y) as a function of illumination (I, in lux) and temperature (T, average of the sampling period). The model is Y=exp (aT+bI), where a and b are constants (n=41)

	Temperature		Illumination		R^2
Proportion of *Ae. albifasciatus*	a	-0.1267	b	-0.0045	0.7118
	p	0.0159	p	0.0019	
Proportion of all species	a	-0.0717	b	-0.0047	0.9255
	p	0.0005	p	0.0000	

TABLE II

Simple correlation analysis of mosquito CDC capture and illumination and temperature during the sampling period. R^2 is the coeficient of determination; p and NS represent the significance of the R^2: significance level and not significant, respectively

		Illumination		Temperature	
		Aedes albifasciatus	All species	*Aedes albifasciatus*	All species
February 92	R^2	79.99	79.05	62.90	64.32
	p	0.00048	0.00058	0.00619	0.00526
July 92	R^2	0.00	4.55	15.66	7.58
	p	NS	NS	NS	NS
October 92	R^2	82.58	83.59	57.05	63.88
	p	0.00460	0.00394	0.04959	0.03102
November 92	R^2	77.14	74.85	62.87	72.19
	p	0.00083	0.00122	0.00622	0.00186
January 93	R^2	49.52	83.81	9.71	59.37
	p	0.04914	0.00142	NS	0.02525
April 93	R^2	61.87	76.10	24.22	13.16
	p	0.04634	0.02340	NS	NS
May 93	R^2	16.59	40.96	23.23	10.75
	p	NS	0.03393	NS	NS

TABLE III

Regression and correlation analysis of the cumulative proportion of *Aedes albifasciatus* captured over human bait (Y) as a function of the cumulative temperature along the date of capture (X) in different seasons. Results are presented for a cubic equation $Y = aX + bX^2 + cX^3$, with a, b and c as constants and for a linear function passing through the origin. The slopes of the linear function are significantly correlated with the average temperature (T_m) of the sampling date according to the model $1.499\ T_m^{-1.88}$

	Cubic function results				Linear function results	
	a	b	c	R^2	slope	R^2
April 92	0.0237	$-3.40 * 10^{-4}$	$1.72 * 10^{-6}$	0.97	0.00827	0.77
July 92	0.1130	$-1.09 * 10^{-3}$	$-1.30 * 10^{-4}$	0.99	0.08214	0.92
October 92	0.1053	$-5.90 * 10^{-5}$	$1.67 * 10^{-7}$	0.99	0.00559	0.92
January 93	0.0047	$-2.20 * 10^{-5}$	$5.27 * 10^{-8}$	0.97	0.00287	0.93
May 93	0.0296	$-4.60 * 10^{-4}$	$5.52 * 10^{-6}$	0.99	0.02036	0.99

DISCUSSION

The daily flight activity pattern of *Ae. albifasciatus* is clearly bimodal from spring to autumn, showing minor variations on the time of maximum activity according to changes in sunrise and sunset time. Various authors have described bimodal patterns in the daily flight activity of different mosquito species (Forattini 1962, Bidlingmayer 1985). In general, *Ae. vexans, Ae. abnormalis* showed two biting and flight activity peaks, occuring at dawn and at dusk, when captured with truck-traps or over human baits (Haddow 1960, Knight & Henderson 1967, Bidlingmayer 1985). Maximum human-bait capture rates for many *Aedes* spp. and *Anopheles* spp. occur 15 to 30 min after sunset, and after 75 min for *Culex* spp. (Wright & Knight 1968). However, the bimodal pattern of *Ae. albifasciatus* activity was not maintained throughout the year. When minimum temperatures were less than 6°C, the morning peak was not observed while the evening peak was shifted towards the hours of highest illumination. For other species, the maximum temperature threshold does not affect flight activity, but the maximum illumination threshold would inhibit it (Bidlingmayer 1985). Although from our data it is not possible to calculate an upper activity threshold, they do suggest that when the minimum daily temperature is higher than 6°C, the catches decrease at higher illuminations; but when the minimum daily temperature is below 6°C, the flight rates increase at higher illuminations, when the temperature is over the minimum threshold. Wind speed also affected mosquito capture rate, especially for light traps located in open terrains during October-November. This is in agreement with negative correlation between the capture rates of *Ae. albifasciatus* and wind speed reported by Hack et al. (1978) in a study carried out in Corrientes (NE Argentina).

Human-bait catches show that the rate of changes of the cumulative proportion of captured mosquitoes during a day is negatively correlated with the average temperature of the same day. Although the estimations of *Ae. albifasciatus* based on CDC trapping and catches over human bait were highly correlated, the difference in the proportion of this species captured by each sampling technique suggests that approximately half of the *Ae. albifasciatus* population constitutes part of the 'resting fraction' and is not actively seeking hosts.

A key issue in the control of mosquito populations is the monitoring activities to estimate population abundance. If adult trapping (either using CDC traps or collection by human-bait) is made always at the same time of the day throughout the year, the abundance estimation will be biased because of the changing flight pattern of the females shown in this study. The quality of the abundance estimation, and hence the efficiency of control actions for the mosquitoes, could be improved using the results based on these studies.

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REFERENCES

Avilés G, Sabattini MS, Mitchell JC 1990. Peroral susceptibility of *Aedes albifasciatus* and *Culex pipiens* complex mosquitoes (Diptera: Culicidae) from Argentina to Western Equine Encephalitis Virus. *Rev Saúde Púb São Paulo 24:* 265-269.

Bailey SF, Eliason DA, Hoffman BL 1965. Flight and dispersal of the mosquito *Culex tarsalis* Coquillett in the Sacramento Valley of California. *Hilgardia 37:* 73-113.

Bidlingmayer WL 1985. The Measurement of Adult Mosquito Population Changes - Some Considerations. *J Am Mosq Control Assoc 1:* 328-348.

Brust RA 1980. Dispersal behavior of adult *Aedes sticticus* and *Aedes vexans* (Diptera: Culicidae). *Can Ent 112:* 31-42.

Corbet PS, Danks HV 1973. Seasonal emergence and activity of mosquitoes (Diptera: Culicidae) in a high-arctic locality. *Can Ent 105:* 837-872.

Forattini OP 1962. *Entomologia Médica. Vol. I. Parte Geral, Diptera, Anophelini.* Fac. Hig. Saúde Publ. Dep. Parasitol, São Paulo, 662 pp.

Gjullin CM, Sailer R, Stone A, Travis BV 1961. *The Mosquitoes of Alaska (Agriculture Handbook # 182).* Agricultural Research Service. United States Department of Agriculture. Washington D.C., 98 pp.

Hack WH, Torales GJ, Bar ME, Oscherov B 1978. Observaciones etológicas sobre culícidos de Corrientes. *Rev Soc Entomol Argentina 37:* 137-151.

Haddow AJ 1960. Studies on the biting habits and medical importance of East African mosquitoes in the genus *Aedes*. I. Subgenera *Aedimorphus, Bankoinella* and *Dunnius. Bull Entomol Res 50:* 759-779.

Knight KL, Henderson C 1967. Flight periodicity of *Aedes vexans* (Meigen) (Diptera: Culicidae). *J Georgia Entomol Soc 2:* 63-68.

Ludueña Almeida FF, Gorla D 1995. The Biology of *Aedes (Ochlerotatus) albifasciatus* Macquart, 1838 (Diptera: Culicidae) in Central Argentina. *Mem Inst Oswaldo Cruz 90:* 463-468.

Sokal RR, Rohlf FJ 1979. *Biometria. Principios y Métodos estadísticos en la investigación biológica.* Translated by Lahoz León, M. H. Blume Ediciones. Madrid, 832 pp.

Wright RE, Knight KL 1968. Evening Crepuscular Activity of Some Iowan Mosquitoes (Diptera, Culicidae). *J Kansas Entomol Soc 41:* 45-47.