BITING ACTIVITY OF *AEDES SCAPULARIS* (RONDANI) AND *HAEMAGOGUS* MOSQUITOES IN SOUTHERN BRAZIL (DIPTERA: CULICIDAE)*

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ABSTRACT: The biting activity of a population of *Aedes scapularis* (Rondani), *Haemagogus capricornii* Lutz and *Hg. leucocelaenus* (Dyar and Shannon) in Southern Brazil was studied between March 1980 and April 1983. Data were obtained with 25-hour human bait catches in three areas with patchy residual forests, named "Jacaré-Pepira", "Lupo" Farm, and "Sta. Helena" Farm, in the highland region of S. Paulo State (Brazil). Data obtained on *Ae. scapularis* were compared with those formerly gathered in the "Ribeira" Valley lowlands, and were similar, except in the "Lupo" Farm study area, where a pre-crepuscular peak was observed, not recorded at the "Jacaré-Pepira" site or in the "Ribeira" Valley. In all the areas this mosquito showed diurnal and nocturnal activity, but was most active during the evening crepuscular period. These observations support the hypothesis about the successful adaptation of *Ae. scapularis* to man-made environments and have epidemiological implications that arise from it. As for *Haemagogus*, results obtained on the "Lupo" and "Sta. Helena" regions agree with previous data obtained in several other regions and show its diurnal activity. The proximity of "Lupo" Farm, where *Hg. capricornii* and *Hg. leucocelaenus* showed considerable activity, to "Araraquara" city where *Aedes aegypti* was recently found, raises some epidemiological considerations about the possibility of urban yellow fever resurgence.

UNITERMS: *Aedes scapularis. Haemagogus capricornii. Haemagogus leucocelaenus.* Vectors, insects. Haematophagy. Ecology vectors. Arbovirus infections, transmission.

INTRODUCTION

From the epidemiological point of view, *Aedes scapularis* is among those mosquitoes of the Neotropical region deserving attention. Being a very common and widespread species, its increasing adaptation to modified environments and to domiciliarity, have made it an important subject of research (Forattini[6], 1961; Forattini et al.[13], 1987). Its competence and epidemiological capacity to transmit infective and parasitic agents such as yellow fever and Venezuelan equine encephalitis viruses in Central and South America, an many other arboviruses in the Amazon region of Brazil and in Trinidad, as well as Bancroftan filariasis in Southern Brazil has been long recognized (Arnell[1], 1976; Lhuillier et. al.[24], 1981).

During 1975-1976 epidemics of human encephalitis occurred in Southern S. Paulo State, Brazil, reaching some coastal areas and the "Ribeira" Valley region. A virus recovered from human cases was recognized as an etiological agent and named Rocio virus (Lopes et al.[26], 1978). Evidence indicated that mosquitoes were involved in its transmission, and because of the abundance of *Ae. scapularis* together with its feeding habits and behaviour associated with man in epidemic areas, this species was considered a potential vector (Forattini et al.[9,10,11], 1978, 1981). Its vector competence for Rocio virus transmission has been demonstrated under experimental conditions, even showing a degree of variation in "per os" infection rates (Mitchell and Forattini[28], 1984; Mitchell et. al.[30], 1986). Among several hypothesis that might explain these variations, in susceptibility are those that relate the occurrence of populations with different behaviour patterns.

Mosquitoes of the genus *Haemagogus* play a leading role in the transmission of sylvan yellow fever in the Neotropical region. After demonstrations that these mosquitoes are capable of transmiting this virus by biting, various species of this genus were found naturally infected in South America (Whitman[39], 1951; Pinheiro et al.[36], 1981). In addition to yellow fever virus and certain other arboviruses, Mayaro virus has been isolated from naturally infected mosquitoes in an epidemic region (Hoch et al.[21], 1981). Southern Brazil is included in the distributional area of *Hg. capricornii* and *Hg. leucocelaenus*, which are considered potential vectors of forest yellow fever. Although the epidemiological patterns is characteristic of jungle environments, riverine gallery forests may provide the bridge for epizootic propagation along their course to other areas. Moreover, patches of residual forests in modified environments can provide shelters for *Haemagogus* and non-human primates that may be involved in the maintenance of the virus cycle. From such areas these mosquitoes may invade plantations or villages close to the forest, and even enter houses (Brès[2], 1986). Another question deserving attention is the reinvasion of South America by *Ae. aegypti* and the threat of the resurgence of urban and rural yellow fever (Groot[19], 1980; Lima[25], 1985). These considerations need to be studied in regions modified for agricultural purposes so as to clarify possible risks to human populations.

For these reasons a programme was initiated to investigate mosquitoes biting habits with regard to man in several environmental situations in Southern Brazil. Studies on daily activities and seasonal variations were focused on areas of S. Paulo State territory in the higland region. Results obtained for *Ae. scapularis* were compared with data from the "Ribeira" Valley, a lowland region near the Atlantic coast, which was the site of previous studies (Forattini et al.[11], 1981). The present paper reports results relating to *Ae. scapularis* and to two *Haemagogus* species, obtained from that programme.

MATERIALS AND METHODS
The Study Areas

All areas chosen for these studies are sites modified for agricultural purposes. Residual patches of forest and riverine gallery forests are characteristic landscap features of these areas. The studies were performed in the three following places:

1. "Jacaré-Pepira" Valley in "Dourado" County

2. "Lupo" Farm in "Araraquara" County

3. "Santa Helena" Farm in the County of "São João da Boa Vista"

The "Jacaré-Pepira" Valley area is essentially represented by a gallery of secondary woodland along the river margin, surrounded by extensive pasture lands. Its characteristics have already been described (Forattini[8], 1987). The latitude of the three localities corresponds to nearly 22°S and the longitudes vary between 46° and 49°W (Figure 1). The mean altitude is of 400-500m in "Dourado", 500-600m in "Araraquara" and 600-800m in "São João da Boa Vista". In the "Ribeira" Valley the altitude is 0-180m above sea level. The macroclimate has a rainfall pattern that includes, as a general rhythm, two seasons consisting of a rainy warm one from October to March with an average annual rainfall of 1,000-1,100mm, and a drier and cooler one from April to September with 200-300mm of rainfall (Departamento de Águas e Energia Elétrica[5], 1972).

"Lupo" Farm is situated in the neighbourhood of "Araraquara" city, nearly 4km from the urban boundary. The collection site was a patch of residual forest surrounded by extensive open fruit and sugar-cane plantations and pasture lands. "Santa Helena" Farm is situated 12km south of the city of "São João da Boa Vista" and the collection site was located in a preserved residual forest patch, situated in the middle of extensive plantations and near human settlement. On "Lupo" Farm the ground topography is flatter than on "Santa Helena" Farm where uneven land predominates.

Mosquito Sampling

The mosquitoes were collected by means of 25-hour human bait catches. The methodology used in the collections and in the calculation of Williams' means ($\bar{X}_w$) and Nielsen "crep" unit intervals for the crepuscular periods, have already been fully described (Haddow[20], 1954; Nielsen[32], 1961; Forattini et al.[11], 1981).

Annual and monthly rainfall data were obtained from official records of the S. Paulo State civil service ("Fundação SEADE"[14,15,16], 1981-1983 year books) or directly from "Secretaria de Obras e Meio Ambiente" (S. Paulo State)*. These data are routinely recorded by

several meteorological stations and for the purposes of this research, the following two were selected (Figure 1):

1. "Bariri" Station (22°06'S; 48°45'W; 445m altitude) for the "Jacaré-Pepira" and the "Lupo" Farm observations.

2. "Campininha" Station (22°18'S; 47°11'W; 600m altitude) for the "Santa Helena" Farm observations.

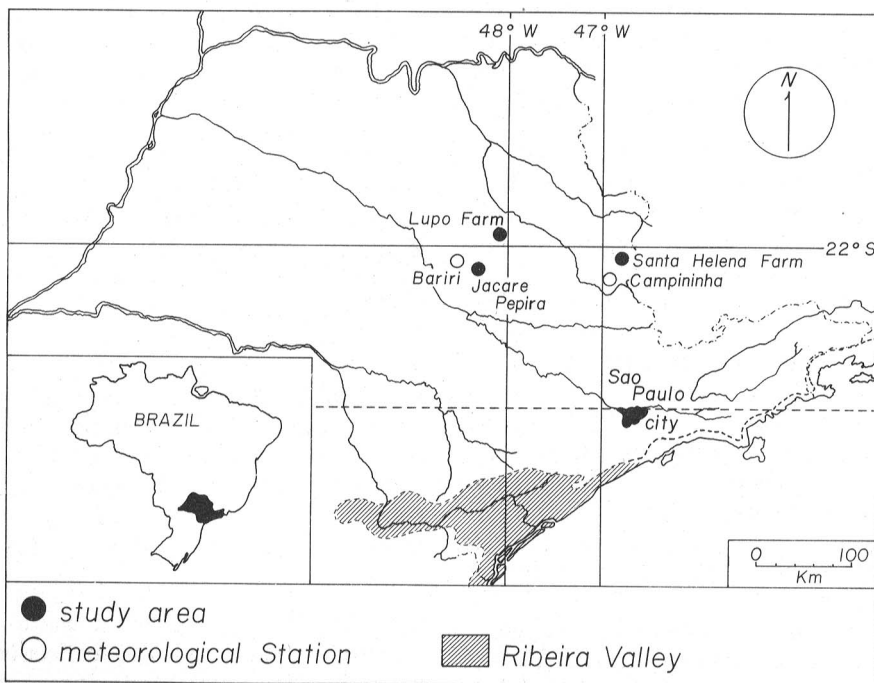These choices were based on proimity to the study areas and their respective biogeographical similarity.

Fig. 1 - Map of S. Paulo State, Brazil, showing the study areas on the highland plateau and in the "Ribeira" Valley lowland region. Dotted line represents the eastern border of the plateau.

In the "Jacaré-Pepira" area human bait catches were made twice a month, once each alternate week, from March 1980 to April 1982. In the areas of "Lupo" and "Santa Helena" Farms collections were carried out monthly from April 1981 to April 1983, always in the same previously chosen week of the month.

RESULTS

Mosquitoes Collected

A total of 4,383 mosquitoes were caught with human bait, distributed according to the study areas as presented in Table.

Aedes Scapularis

The only reliable data to compute the hourly activities of the 25-hour human bait catches were obtained in "Jacaré-Pepira" and on "Lupo" Farm. The results of the twice-monthly collections in the former area, and the

TABLE

Mosquitoes collected with 25-hour human bait in the study areas.

Species	"Jacaré-Pepira"	"Lupo" Farm	"Santa Helena" Farm
Ae. scapularis	789	338	82
Hg. capricornii	2	225	588
Hg. leucocelaenus	2	977	1,390

monthly ones in the latter, are shown in Figure 2, together with previously published data from the "Ribeira" Valley region. The 52 collections carried out in "Jacaré-Pepira" and the 25 on "Lupo" Farm, showed a distinct increase in crepuscular activity corresponding to sunset, and a much smaller, not so obvious one, at dawn. This pattern of biting activity was similar for all the three areas (Figure 2).

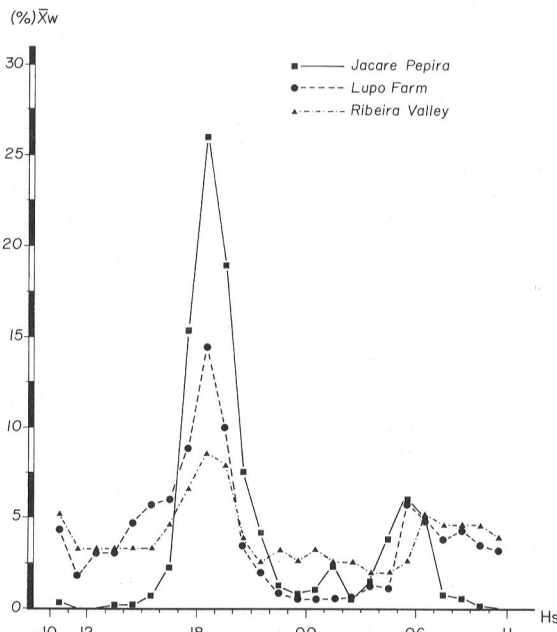---

* 1983 data. Unpublished report.

Fig. 2 - Hourly activity of *Aedes scapularis* caught at human bait, during regular catches in the "Jacaré-Pepira" and "Lupo" Farm areas, compared with the data formerly obtained in the "Ribeira'" Valley region.

(%) $\overline{X}_w$ — Williams' means percentage of the total obtained.

Hs — hours

Crepuscular and pericrepuscular activity, as exhibited at human bait around sunset has been plotted against "crep" units in Figure 3. This activity corresponds to collections in "Jacaré-Pepira" and on "Lupo" Farm during the period from 17.00-20.00 hours, and show that peak biting occurred during and around the vespertine crepuscular period (0.0-1.0 "crep" intervals). By comparing the three graphs it is possible to distinguish a precrepuscular peak obtained at "Lupo" Farm, and rather similar endocrepuscular peaks followed by clear posterior eocrepuscular ones at "Jacaré-Pepira" and in the "Ribeira" Valley.

The greatest numbers of *Ae. scapularis* were caught, in human bait catches during the periods corresponding to the cold months, from June to August, and at the beginning of the hot season, from October to November (Figure 4). This behaviour was similar to that previously observed in the "Ribeira" Valley (Forattini et al.[11], 1981) and seems to be associated with the period immediately prior to an increase in rainfall.

Haemagogus *species*

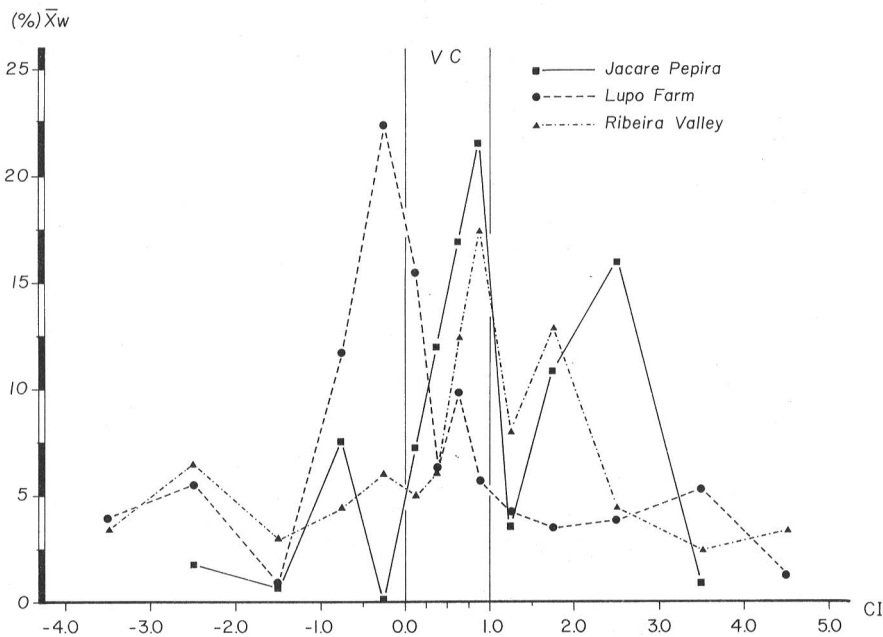Available data concerns catches of *Haemagogus capricornii* and *Hg. leucocelaenus* at the

Fig. 3 - Vespertine crepuscular and pericrepuscular activities of *Aedes scapularis* with human bait in "Jacaré-Pepira" and on "Lupo" Farm, compared with the data formerly obtained in the "Ribeira" Valley region.

(%) $\overline{X}_w$ — Williams' means percentage of the total obtained.

CI — Nielsen "crep" intervals, corresponding to 5.00 - 8.00 pm.
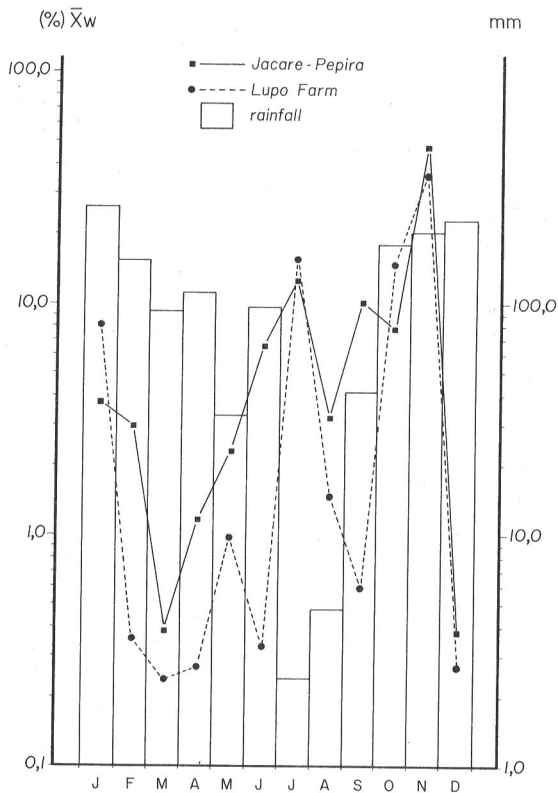
VC — Vespertine crepuscular period.

Fig. 4 - — Seasonal incidence of *Aedes scapularis*
     at human bait in the "Jacaré-Pepira" and
     "Lupo" Farm areas, compared to rainfall.
     (%) $\overline{X}_W$ — Williams' means percentage of
               the total obtained.
          mm — monthly rainfall means in mm.
           M — months

"Lupo" and "Santa Helena" Farms; and monthly 25-hour human bait collections provide the results presented in Figure 5. Clear diurnal activities were recorded for both species, with peaks around midday, that ar at 11.00-12.00 hours at "Santa Helena" Farm, and other peaks in the afternoon, between 14.00-16.00 hours on "Lupo" Farm.

Studies on seasonal incidence showed greatest activity of both *Haemagogus* species during the rainy and hot months, with peaks coinciding with the October-January period as shown in Figure 6 at "Lupo" and "Santa Helena" Farms. No remarkable differences were observed between the two mosquito species.

DISCUSSION

There has been little previous research on the daily activity petterns of *Ae. scapularis*. Observations formerly made in Southern Brazil showed diurnal and nocturnal activity with a significant increase during the sunset period (Forattini[7], 1965). This pattern was afterwards

confirmed for the same Brazilian region (Forattini et al.[11], 1981; Oliveira and Silva[35], 1985; Guimarães e Victório[18], 1986). However, in Northern South America, at least in Surinam and French Guyenne, this mosquito was observed as being mainly diurnal with increased activity during the afternoon, between 12.00 hours and 15.00 or 16.00 hours, with no vespertine crepuscular peaks or nightly activity (Kruijf[22], 1972; Degallier et al.[4], 1978). These two dissimilar behavioural patterns may suggest the presence of distinct populations or even species, and so more detailed studies in several biogeographical areas, as here in Southern Brazil, would seem to be appropriate.

During the present observations the biting activity of *Ae. scapularis* generally confirmed the above-mentioned pattern. Results obtained in the highland region, as compared with those formerly observed in the lowland "Ribeira" Valley (Forattini et al.[11], 1981), showed broadly similar diel and seasonal activity patterns. Nevertheless, considering the crepuscular period around sunset, it was possible to identify endocrepuscular and pericrepuscular peaks (Figure 3). Catches in "Jacaré-Pepira" showed great similarity to those observed in the "Ribeira" Valley in that a clear endocrepuscular peak occurred, followed by another, upsurge in activity giving a postcrepuscular or eocrepuscular peak. In contrast the "Lupo" Farm population exhibited different behaviour, showing a well-marked precrepuscular peak without any other evident later peak. Since *Ae. scapularis* is usually considered to be a diurnal mosquito, the action of some exogenous stimulatory factor occurring during the vespertine period, such as light and/or microclimatic conditions, or even some endogenous factor, probably accounts for its observed patterns. Obviously both will modify the pattern of the observed diel biting cycles, and so it seems pertinent to raise the question of the existence of different populations at "Lupo" Farm, "Jacaré-Pepira" and the "Ribeira" Valley, which have different behaviours.

No other behavioural differences were observed between the three regions studied, for example, the seasonal incidences were quite similar, with increased activity soon after the start of the rains followed by a rapid decline in numbers, even in the hot rainy season (Figure 4). Taking into account regional differences it is clear that the pattern of rainfall will likely be very variable, so generally the activity and density of *Ae. scapularis* will vary
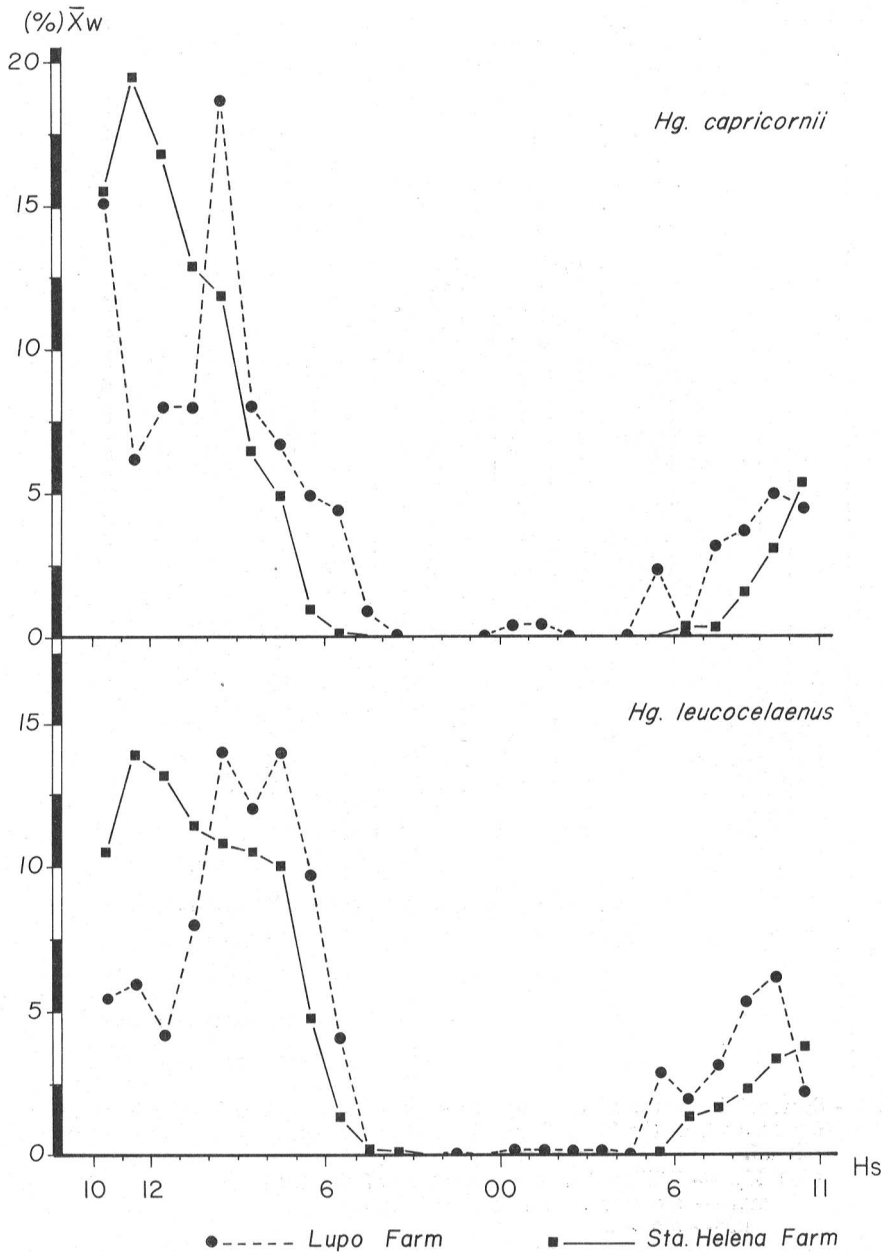
Fig. 5 - Hourly activity of *Haemagogus capricornii* and *Hg. leucocelaenus* at human bait during regular catches in the "Lupo" and "Sta. Helena" Farms areas.
(%) $\overline{X}_W$ — Williams' means percentage on the total obtained.
Hs — hours.

from place to place depending on the type of rainy season (Causey and Santos[3], 1949; Kruijf[22], 1972; Guimarães and Arlé[17], 1984; Oliveira et al.[34], 1985). Nevertheless, the influence of rainfall on the density of *Ae. scapularis* will be variable because it has drought-resistant eggs, and utilizes ground-pools as breeding places. Analysing catches in relation to rainfall distribution in the Brazilian Amazon region showed that the population density of *Ae. scapularis* is not only governed by the preceeding amount of rainfall, but by alternating wet and dry periods (Kruijf et al.[23], 1973). These wet and dry periods are more commonly recorded in Southern than Northern Brazil, mainly in the so-called dry season, and this may explain to some extent the increased activity of *Ae. scapularis* at that time (Forattini et al.[11], 1981).
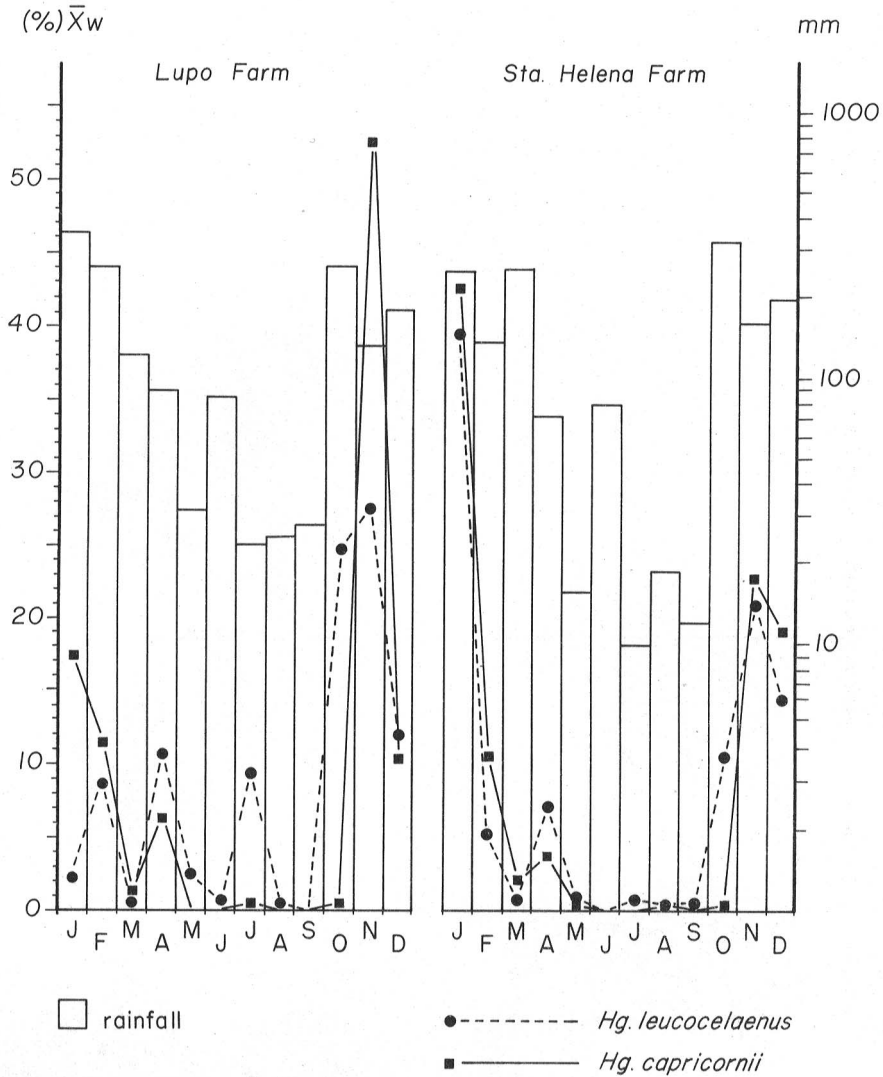
Fig. 6 - Seasonal incidence of *Haemagogus capricornii* and *Hg. leucocelaenus* at human bait, in the "Lupo" and "Sta. Helena" Farms areas, compared to rainfall.

(%) $\bar{X}_w$ — Williams' means percentage of the total obtained.

mm — monthly rainfall means in mm.

m — months.

These observations confirm the clear characteristics of the activity and density of *Ae. scapularis* in modified environments resulting from human action. "Jacaré-Pepira" and "Lupo" Farm represent areas more highly modified than the "Santa Helena" Farm, where residual forest has been better preserved and the mosquito density is very low. So these results agree with those formerly obtained in the "Ribeira" Valley, and support the hypothesis that the species has a high degree of adaptability to man-made environments (Forattini et al.[11,12], 1981, 1986). Such adaptability seems to be widespread in South America, showing a clear tendency to endophily and to

domiciliarity on the part of this species (Forattini et al.[10,13], 1978, 1987; Roberts et al.[37,38], 1981, 1985; Oliveira[33], 1984). The epidemiological significance of this behaviour warrants further study, especially as recent observations in Northern Argentina suggest that *Ae. scapularis* may be involved in a chain of secondary transmission of the Venezuelan equine encephalitis virus (Mitchell et al.[29], 1985).

With regard to both *Haemagogus* species, the available data obtained at "Lupo" and "Santa Helena" agree with those obtained in the residual or primitive forests of other Brazilian and South American regions. Hourly

and seasonal incidence of activity shows a very constant and widespread pattern (Causey and Santos[3], 1949; Kruijf[22], 1972; Neves and Silva[31], 1973; Pinheiro et al.[36], 1981; Guimarães and Arlé[17], 1984; Guimarães and Victório[18], 1986). However, small variation was observed in the biting cycles between the two study areas, in that peak activity as earlier on "Santa Helena" Farm, corresponding to midday, and later at "Lupo" Farm where it occurred during the early afternoon (Figure 5). It seems likely that these differences are related to distinct local features involving climatic and other aspects peculiar to the residual forests. At "Lupo" Farm the woods are mode modified that on "Santa Helena" Farm, and it is reasonable to suppose that more forested conditions at "Santa Helena" enhances more primitive behavioural aspects, such as the earlier peak biting activity at noon for these mosquitoes. No differences relating to their seasonal incidence, which is directly associated to rainfall were, found (Figure 6).

Both *Hg. capricornii* and *Hg. leucocelaenus* are known to be potential arbovirus vectors and on several occasions adults were observed invading open areas with plantations, and even villages or houses close to the forest (Pinheiro et al.[36], 1981; Méndez et al.[27], 1984). This behaviour must be considered together with the possibility of viruses penetrating into these residual forests by means of the migration of vertebrate reservoirs, which may result in virus transmission to man when he enters that environment or lives close to it. Besides this, it must be remembered that the reinvasion of Brazilian territory by *Ae. aegypti* may provide favourable conditions for the propagation of the yellow fever virus from these rural environments to the urban one. A good example of this possibility is represented by the situation at "Lupo" Farm where *Haemagogus* mosquitoes are common, and the farm is only about 4km from "Araraquara" city where the urban yellow fever mosquito. *Ae. aegypti*, was recently found, that is since June 1986*.

FORATTINI, O. P. & GOMES, A. de C. Atividade hematófaga de mosquitos *Aedes scapularis* (Rondani) e *Haemagogus* no sul do Brasil (Diptera: Culicidae). **Rev. Saúde públ.**, S. Paulo, 22:84-93, 1988.

RESUMO: No período de março de 1980 a abril de 1983 foi estudada a atividade hematófaga de uma população de *Aedes scapularis* (Rondani), *Haemagogus capricornii* Lutz, *Hg. leucocelaenus* (Dyar e Shannon), na região sul do Brasil. Os dados foram obtidos com o emprego de isca humana, mediante captura de 25 horas de duração e correspondente a três áreas, contendo manchas de floresta residual, denominadas Jacaré-Pepira, Fazenda Lupo e Fazenda Santa Helena. Os resultados relativos a *Ae. scapularis* foram comparados com as coletas anteriormente feitas em áreas de planície da região do Vale do Ribeira e que revelaram comportamento semelhante, exceto na Fazenda Lupo, onde foi observado um pico pré-crepuscular que não foi registrado em Jacaré-Pepira ou no Vale do Ribeira. Em todas as áreas aquele mosquito demonstrou atividade diurna e noturna. Essas observações alicerçam a hipótese sobre a capacidade de adaptação de *Ae. scapularis* em ambiente alterado pelo homem e as implicações epidemiológicas daí decorrentes. Quanto a *Haemagogus*, os dados obtidos nas Fazendas Lupo e Santa Helena concordam com os primeiros resultados obtidos em diversas outras regiões, nas quais se revela o caráter diurno de sua atividade. Nas proximidades da Fazenda Lupo, onde *Hg. capricornii* e *Hg. leucocelaenus* mostraram considerável atividade, está a cidade de Araraquara, onde o *Ae. aegypti* foi recentemente encontrado, e assim cabem considerações epidemiológicas, sobre a possibilidade de ocorrência de febre amarela urbana.

UNITERMOS: *Aedes scapularis. Haemagogus capricornii. Haemagogus leucocelaenus.* Insetos vetores. Hematofagia. Ecologia de vetores. Infecções por arbovirus, transmissão.

* Data of the "Superintendência de Controle de Endemias" (Endemies Control Department). Unpublished.

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