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A STUDY ON THE BIONOMICS OF INDOOR RESTING MOSQUITOES IN KANDY

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SUMMARY A twelve month indoor resting mosquito survey was carried out in five residential areas in Kandy during 1985—86. A total of 11,761 adults, comprising 19 species belonging to 6 genera were identified. *Culex quinquefasciatus* (83%), *Aedes aegypti* (10%), *Armigeres subalbatus* (3%) and *Culex pseudovishnui* (2%) were the main species. Density fluctuation patterns of *Cx quinquefasciatus* and *Ae aegypti*, were different among the five sites, probably due to local factors. In *Cx pseudovishnui* however, the patterns were more uniform. No marked density variations were seen in *Ar subalbatus*. As could be expected, the indoor resting populations of *Cx quinquefasciatus* and *Ae aegypti* were dominated by engorged and post-engorged females. However, this phenomenon was also observed in *Ar subalbatus* and *Cx pseudovishnui*, indicating that a proportion of the population that enters houses continues to rest indoors during ovarian maturation. Temporal variations in monthly mean parous rates and overall mean densities of *Cx quinquefasciatus* generally showed an inverse trend. The overall monthly mean densities of *Cx quinquefasciatus* and *Ae aegypti* did not show a significant correlation with climatological parameters such as rainfall, temperature and humidity. It is suggested that the observed overall age composition indicating a short life span (0.3% with 3 ovariole dilatations) and the absence of sustained high densites, are major factors contributing to the non-endemicity of bancroftian filariasis in Kandy.

INTRODUCTION

Studies on mosquitoes and mosquito-borne disease in urban areas in Sri Lanka are largely confined to the southwestern coastal areas with special emphasis given to bancroftian filariasis. The bionomics and the vectorial role of mosquitoes in urbanised areas in other parts of the country, such as Kandy, are yet to be studied. Published information on the mosquito fauna in Kandy is largely limited to the studies on mosquitoes in Udawattakele forest reserve, situated in the heart of the city [2, 3, 14, 15]. Amerasinghe and Munasingha[3] giving some preliminary findings on the ecology of potential vectors in the Kandy urban area, have listed the presence of *Culex quinquefasciatus* Say and *Aedes aegypti* Linnaeus collected from indoors, *Culex tritaeniorhynchus* Giles and *Armigeres subalbatus* (Coquillett) collected from cattle bait, and the latter species and *Aedes albopictus* (Skuse) from human bait collections.[4] In an urban situation like Kandy, one useful method of investigating the bionomics of potential vectors of human disease is the systematic sampling of indoor resting mosquitoes. As is well known, endophily and endophagy are two behavioural traits that can have a significant impact on the potential of mosquito species to transmit disease. In this paper, we present information on species composition, age structure and population dynamics of indoor resting mosquitoes, obtained on a twelve month survey carried out in residential areas.in Kandy.

The Study area

The city of Kandy is situated in hilly terrain at an altitude of 500m above mean sea level. The city is divided into 23 administrative wards. The central part of the city is highly urbanised whereas the peripheral areas are semi-urban or rural. The city covers an area of approximately 28 km^2 and contains over 24,000 permanent residential, and about 5000 commercial premises. The population is approximately 91,000 (1981 census, the Kandy Municipal Council) with a population density of over 3000 per km^2 (Fig. 1).

The size and the structure of houses vary widely, but generally the walls are of brick and mortar and the roof is tiled or covered with asbestos. The city is provided with a piped water supply. Waste-water drainage in the city centre is through underground drains and concrete-slab covered road drains. The outlying areas have open drains, partly masonry and partly earthen. According to Municipality sources septic tanks are the dominant latrine system but bucket latrines are also present. In the peripheral rural areas, pit latrines are not uncommon. Paddy cultivation is carried out within the city with the exception of the city centre.

The Kandy area receives a mean annual rainfall of 1990 mm. The annual mean minimum temperature is 19.1°C, the mean maximum temperature is 28.4°C and the mean relative humidity is between 73—93% RH (Fig. 2).

MATERIALS AND METHODS

Five residential areas situated within the city were chosen as the study sites. These were Suduhumpola, Hantana, Katugastota, Aruppola and Dodanwela. (see Fig. 1)

The indoor resting mosquito survey was initiated in September 1985 and carried out until August 1986. Each of the five sites was visited monthly during the second and third weeks of the month. The sampling gap between the first and the last site in each month did not exceed 10 days so that the collections from all sites were comparable. Initially, 30 houses were selected randomly from each site and it was intended to visit the same house throughout the survey period. During the survey period 20-25 of the houses were visited. However, it was not always possible to visit the same houses due to closure of the premises or house-holder refusal. On such occasions, those houses were replaced by others located in the immediate vicinity.

Collections were done between 0800—1200 hr. A two—man team spent 15 min in each housing unit collecting resting mosquitoes by means of battery powered aspirators and hand nets. Collections from individual houses were held in separate vials, transported to the laboratory and stored at 4°C until processing the following day.

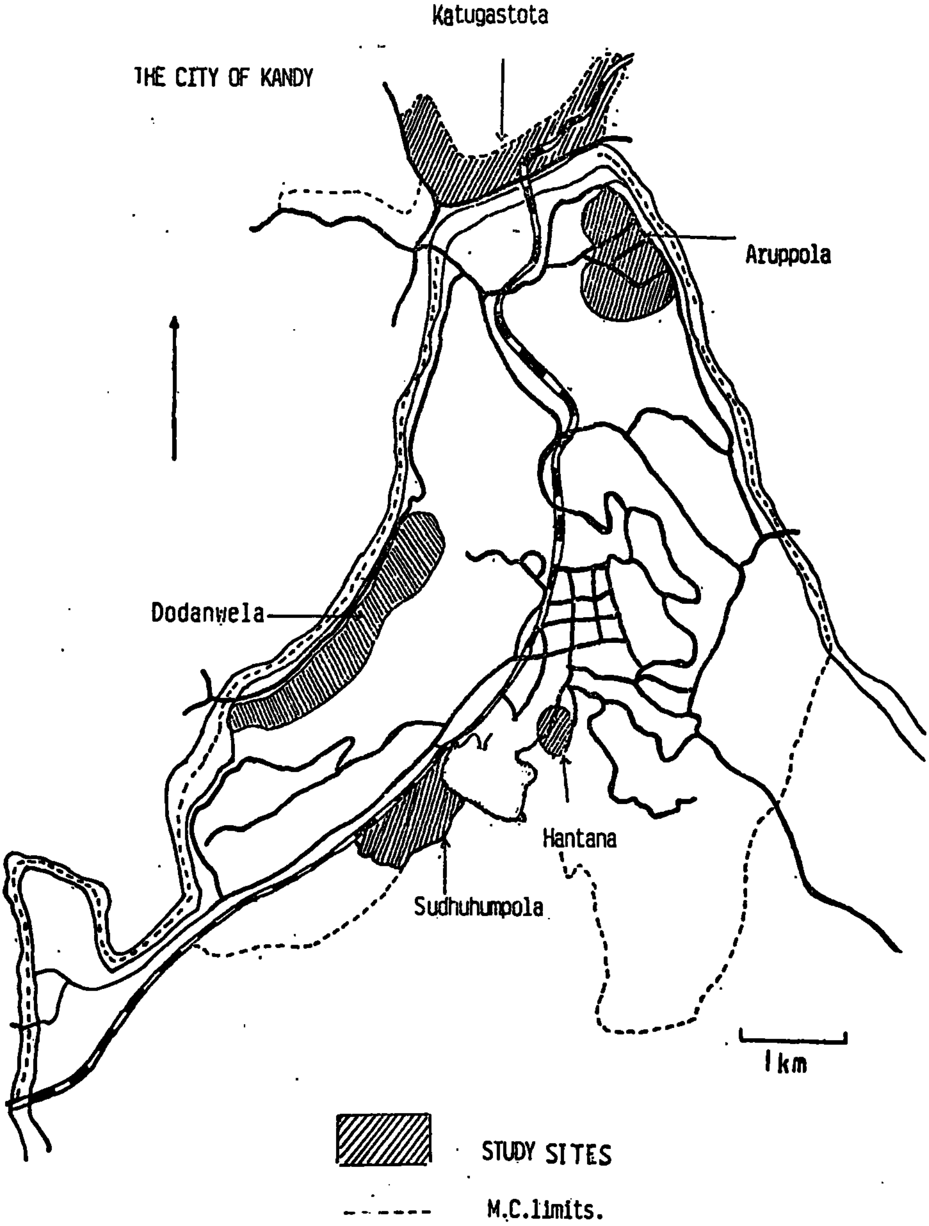

Fig. 1. Map of Kandy showing study sites.
(▬) roads ; (⋅ ⋅) railway line ;
(∽) Mahaweli river.

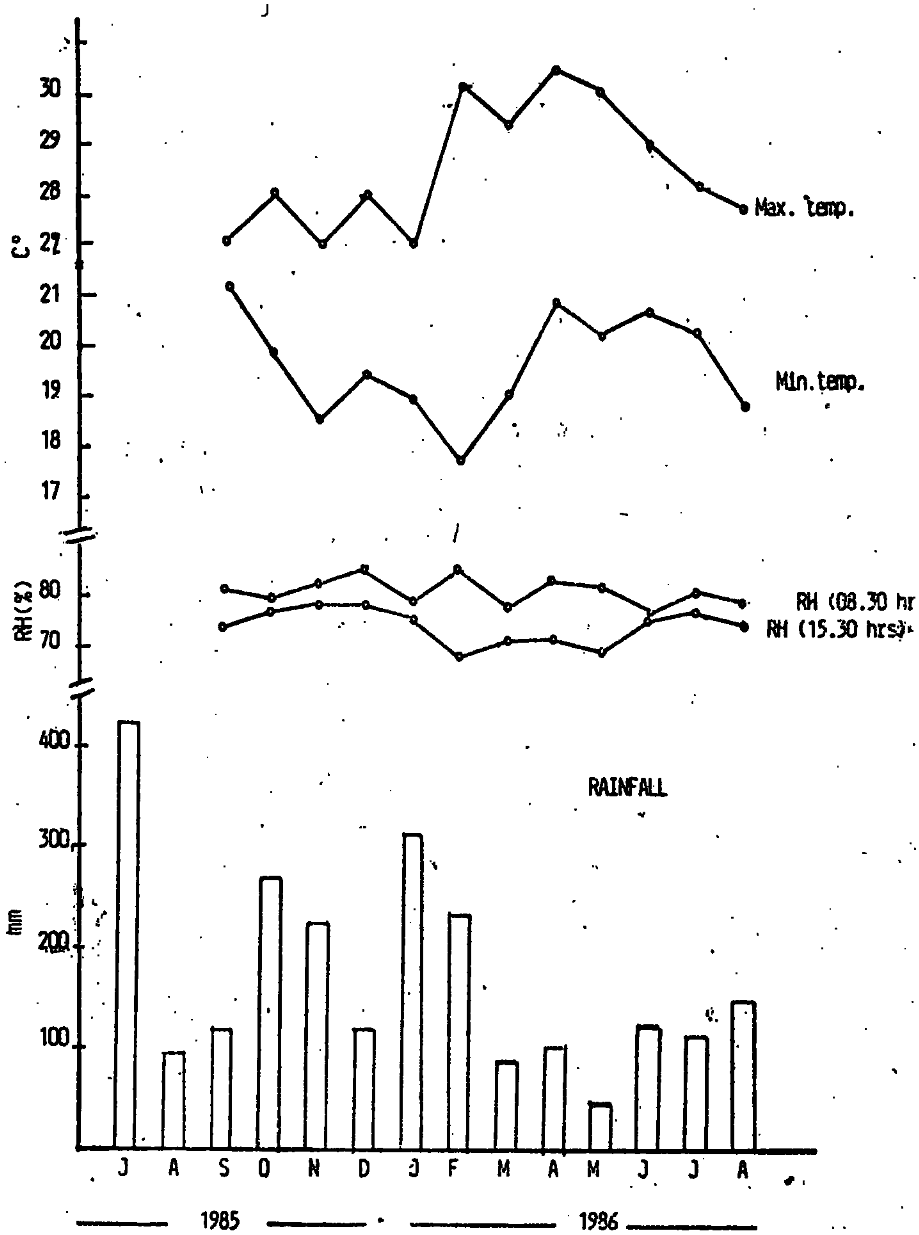

Fig. 2. Meteorological data* for Kandy during the study period.

* *Sources.*—Meteorology Department, Colombo; Central Agricultural Research Institute Gannoruwa.

Taxonomic identifications were done using keys produced by Ramalingam[17], and reference specimens deposited in the Department of Zoology, University of Peradeniya. Identified mosquitoes were sexed and females were sorted according to the abdominal condition as unfed, freshly fed, half-gravid and fully-gravid. They were then dissected to determine the stage of ovarian development[5]. The ovaries of unfed and freshly fed *Cx quinquefasciatus* were dissected further to determine age composition by the number of ovariole dilatations.[6,18]

Meteorological data in relation to monthly rainfall (recorded at the Raja Veediya station), mean maximum and mean minimum temperatures and mean relative humidity (recorded at the Central Agriculture Research Station, Gannoruwa) during the study period is shown in Figure 2.

RESULTS

Species composition and sex ratio

A total of 11,761 adult mosquitoes comprising 6 genera and 19 species were collected during the survey period (Table 1). *Cx quinquefasciatus* dominated the indoor resting mosquito fauna and together with *Ae aegypti* (10.3%), comprised 93% of the total. These two species and *Ar subalbatus* (2.7%), were collected regularly during the survey. The sex ratios show that the females were dominant over males in all the species.

TALBE 1. Adults collected in the indoor resting mosquito survey in Kandy

Species	Total	Sex Ratio M:F.	% of the total
1. *Culex (Culex) quinquefasciatus* Say	9651	1:2.3	82.7
2. *Culex (Culex) pseudovishnui* Colless	245	1:7.4	2.1
3. *Culex (Culex) bitaeniorhynchus* Giles	93	1:1.4	0.8
4. *Culex (Culex) tritaeniorhynchus* Giles	46*		0.4
5. *Culex (Culex) fuscocephala* Theobald	27	1:12.5	0.2
6. *Culex (Culex) gelidus* Theobald	17	1:7.5	< 0.1
7. *Culex (Culex) mimulus* Edwards	02*		< 0.1
8. *Culex (Lutzia) fuscanus* Wiedemann	16	1:4	< 0,1
9. *Culex (Lophoceromyia)* spp	01*		< 0.1
10. *Aedes (Stegomyia) aegypti* (Linnaeus)	1202	1:1.6	10.3
11. *Aedes (Stegomiyia) albopictus* (Skuse)	16	1:17	< 0.1
12. *Aedes (Finlaya) aureostriatus* (Doleschall)	01*		< 0.1
13. *Armigeres (Armigeres) subalbatus* (Coquillett)	315	1:2.3	2.7
14. *Mansonia (Mansonioides) uniformis* (Theobald)	33*		0.3
15. *Malaya genurostris* Leicester	02*		< 0.1
16. *Anopheles (Anopheles) barbirostris* Van der Wulp	01*		< 0.1
17. *Anopheles (Anopheles) peditaeniatus* (Leicester)	01*		< 0.1
18. *Anopheles (Cellia) subpictus* Grassi	01*		< 0.1
19. *Anopheles (Cellia) vagus vagus* Donitz	01*		< 0.1

* Only females were collected.

Trophic status and age composition

Data on the trophic status of females of the main indoor resting species are summarised in Table 2, and show that all 4 trophic classes were represented in this component of the population of these species. Age composition studies by assessment of parity status were done only for *Cx quinquefasciatus*, of which a sufficiently large sample was obtained. Data from collections from the different sites were pooled to give mean parity rates in each month of the survey (Table 3). The study shows that overall, 59.8% of the females were parous, but only 5.5% were surviving to lay more than one batch of eggs.

TABLE 2. Trophic status of the main indoor resting species in Kandy

Species	Number dissected	Number in each category (Percentage) UF	FF	HG	FG
1. *Culex quinquefasciatus*	5750	358(6.2)	2351(40.9)	1330(23.1)	1711(29.8)
2. *Aedes aegypti*	668	93(13.9)	168(25.1)	177(26.5)	230(34.4)
3. *Armigeres subalbatus*	169	63(37.3)	25(14.8)	18(10.6)	63(37.3)
4. *Culex pseudovishnui*	112	20(17.9)	49(43.7)	14(12.5)	29(25.9)

UF = unfed : abdomen deplete, no trace of blood, ovaries stage 1 or 2 of Christophers (1960)
FF = freshly fed : more than half of the abdomen filled with blood, ovaries at stage 2
HG = half gravid : abdomen half filled with blood, ovaries at stage 3—4
FG = fully gravid : a trace or no blood, ovaries at stage 5.

TABLE 3. Overall age composition and the mean parous rates of *Culex quinquefasciatus** in Kandy

Month	Sept. '85	Oct. '85	Nov. '85	Dec. '85	Jan. '86	Feb. '86	Mar. '86	Apr. '86	May '86	June '86	July '86	Aug. '86	Total	%
Number examined	319	81	154	210	208	294	177	251	172	106	145	95	2212	100
NP	137	27	63	93	55	129	66	88	59	39	81	52	889	40.2
1P	173	50	80	109	147	151	108	148	82	57	58	39	1202	54.3
2P	09	04	11	08	06	14	03	15	27	08	06	04	115	5.2
3P	—	—	—	—	—	—	—	—	04	02	—	—	06	0.3
Mean parous rate (%)	57.0	66.6	59.0	55.0	73.6	56.2	62.7	65.0	65.7	63.2	44.2	46.3	59.8	

* in unfed and freshly fed cohorts

Population dynamics

Site-related monthly variations in mean densities of the 4 main species, expressed as the geometric means of adults (males+females) per man-hour of collection, are shown in Figure 3. Monthly overall mean densities (all sites combined) are given in Table 4. There was no uniformity in density fluctuation patterns in *Cx quinquefasciatus* and *Ae aegypti* among the 5 sites. *Culex pseudovishnui* showed a more uniform pattern, with a major peak during December in the Suduhumpola, Hantana, Katugastota and Aruppola sites. Two peaks, one in November and the other in June, were observed at Dodanwela. No marked variations in density were noted in the case of *Ar subalbatus*. Variations in

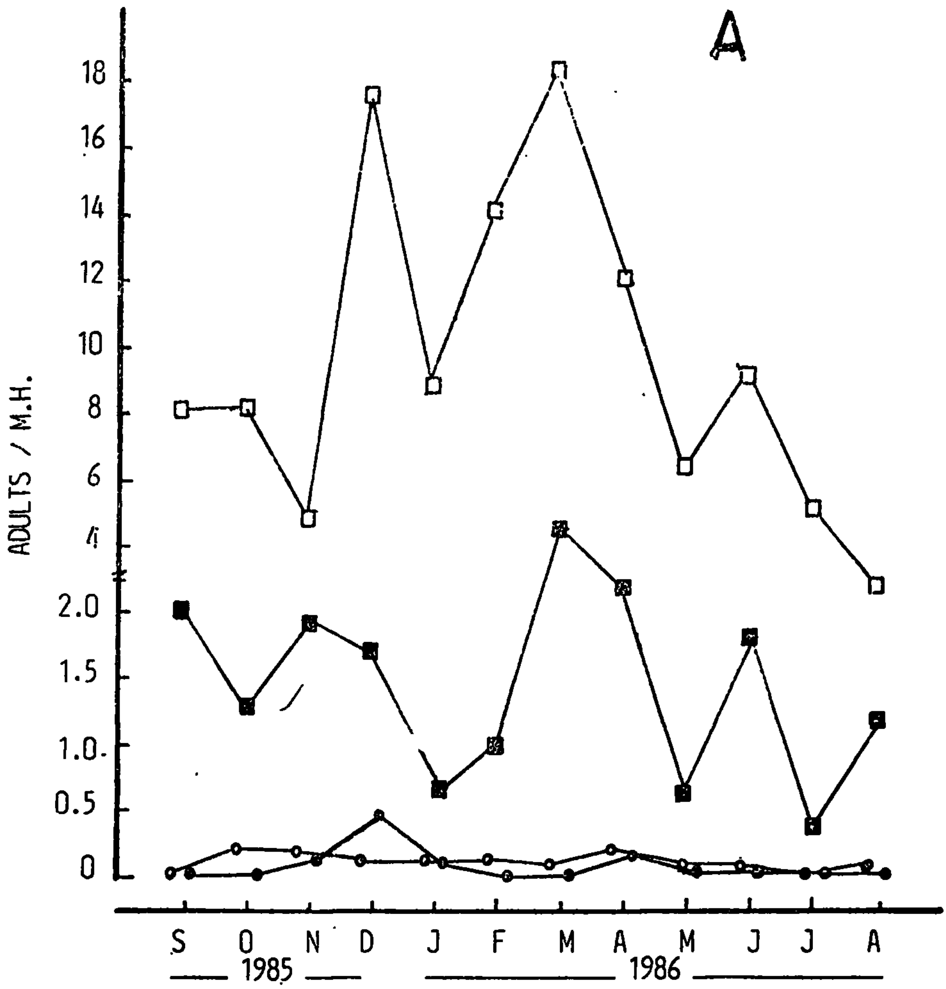

Fig. 3a. Fluctuations in the monthly mean densities of the main indoor resting species in

(A) Suduhumpola

□ *Culex quinquefasciatus* o *Armigeres subalbatus*

▩ *Aedes aegypti* • *Culex pseudovishnui*

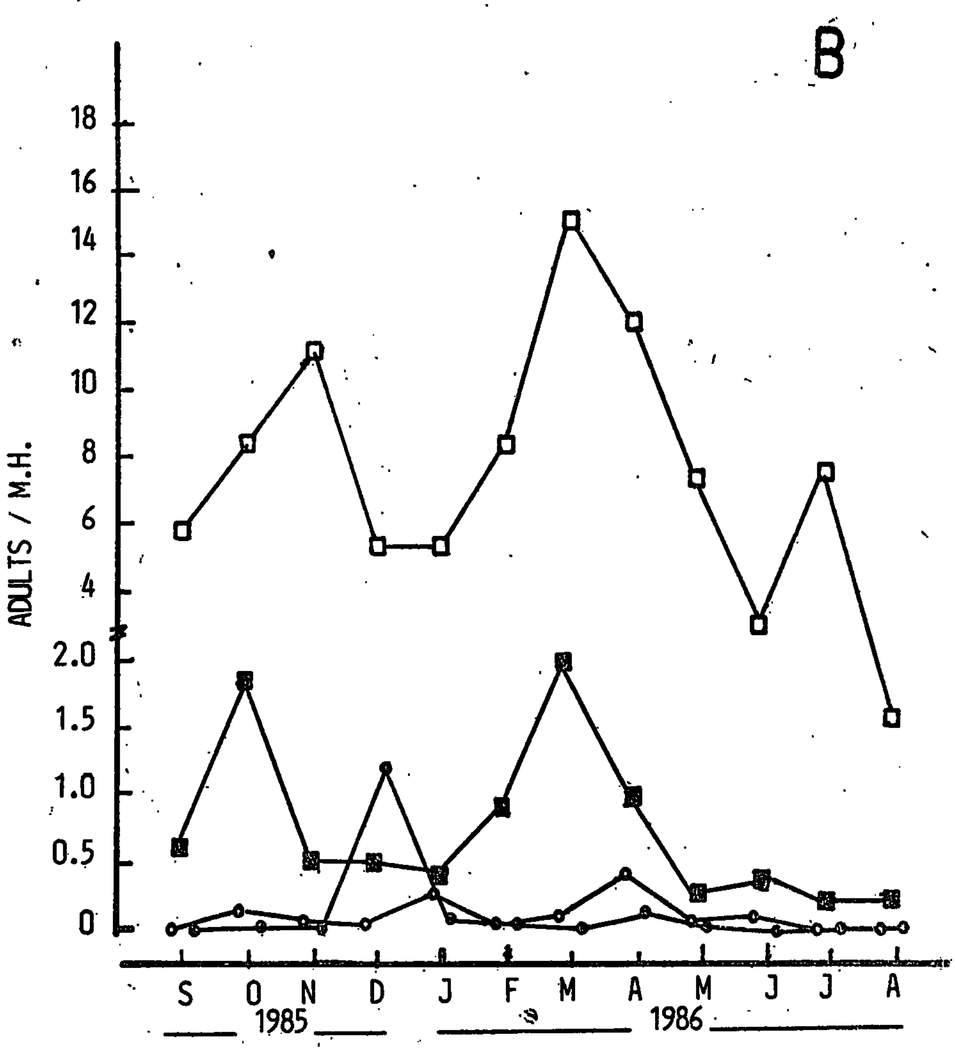

Fig. 3b. Fluctuations in the monthly mean densities of the main indoor resting species in (B) Hantana

□ Culex quinquefasicatus
○ Armigeres subalbatus
▩ Aedes aegypti
● Culex pseudovishnui

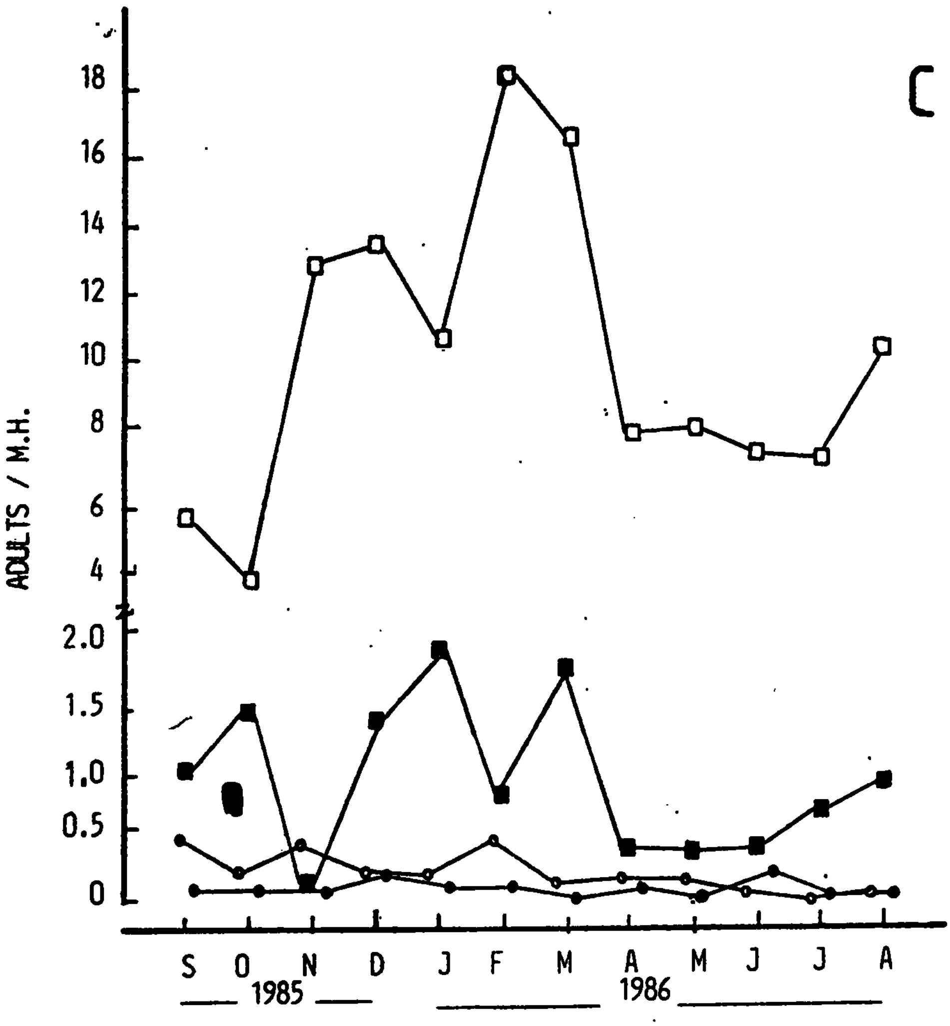

Fig. 3c. Fluctuations in the monthly mean densities of the main indoor resting species in (C) Katugastota

□ *Culex quinquefasciatus* ○ *Armigeres subalbatus*

■ *Aedes aegypti* ○ *Culex pseudo vishnui*.

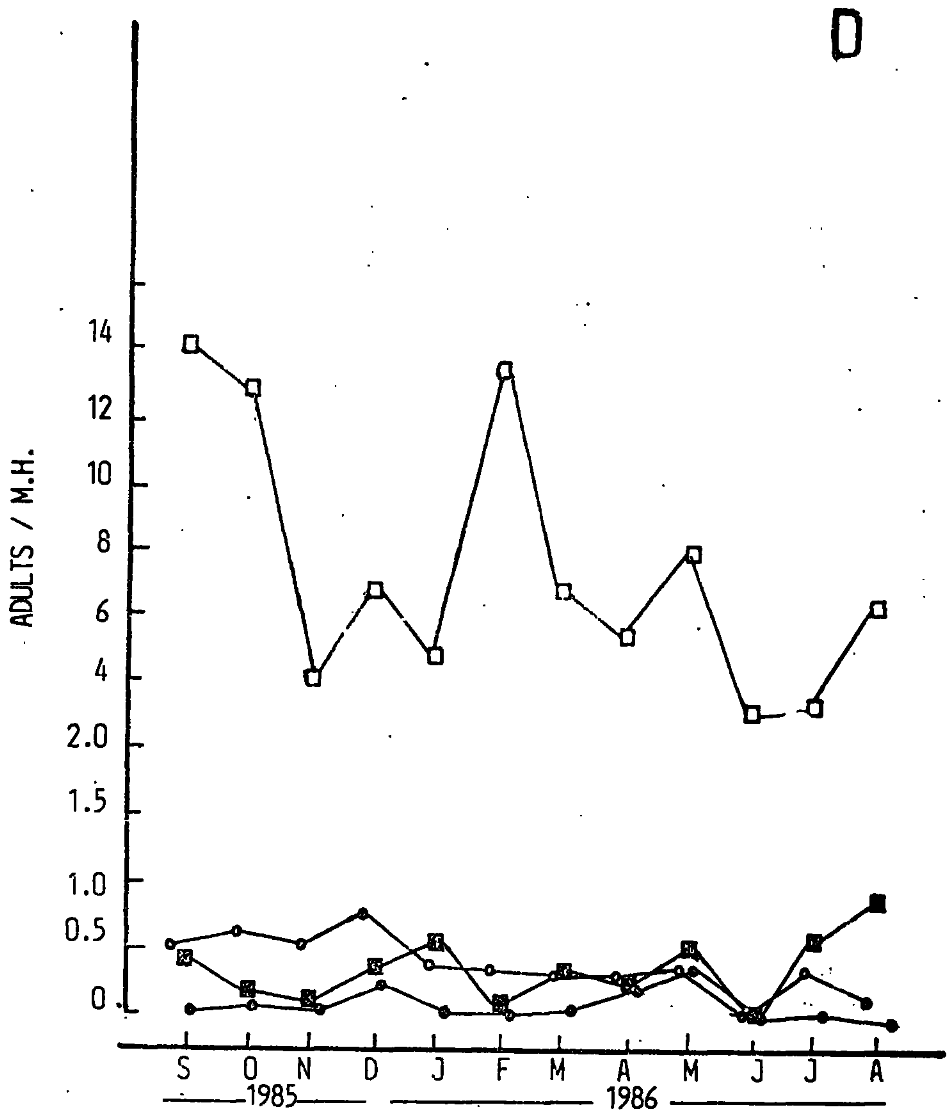

Fig. 3d. Fluctuations in the monthly mean densities of the main indoor resting species in (D) Aruppola

□ Culex quinquefasciatus
○ Armigeres subalbatus
▩ Aedes aegypti
● Culex pseudovishnui

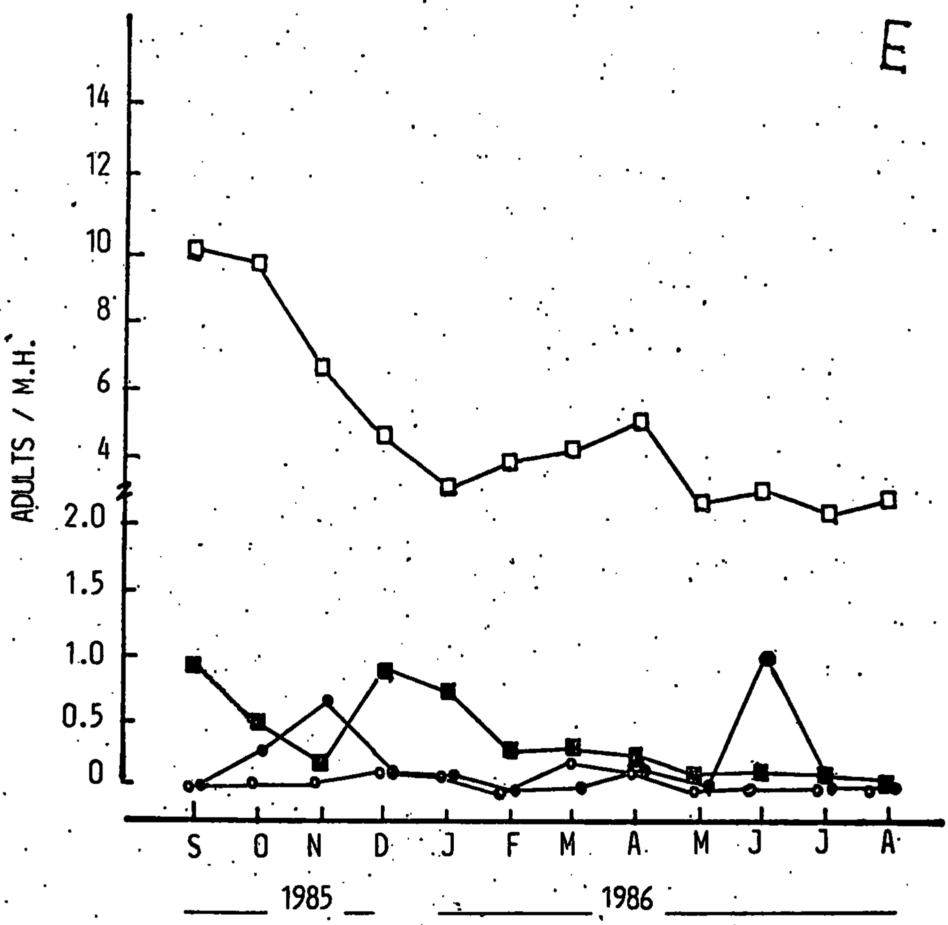

Fig. 3e. Fluctuations in the monthly mean densities of the main indoor resting species in (E) Dodanwela.

□ Culex quinquefasciatus ○ Armigeres subalbatus

■ Aedes aegypti ● Culex pseudovishnui

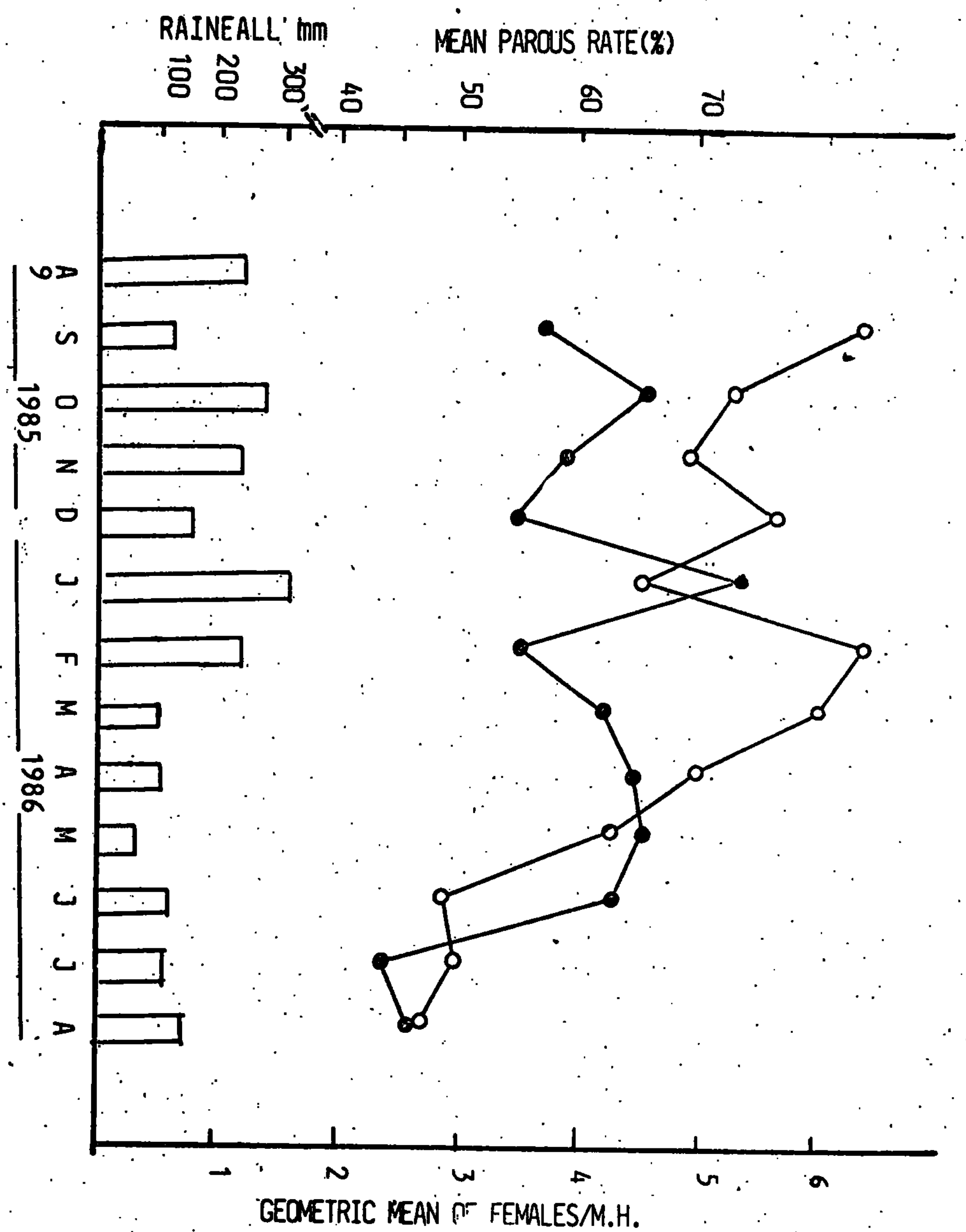

Fig. 4. Fluctuations in the overall mean densities of females and mean parous rates of *Culex quinquefasciatus* compared with the rainfall pattern.

● mean parous rate ○ overall mean density monthly mean parous rates and changes in overall mean female densities of *Cx quinquefasciatus* showed a trend of inverse correspondence except in July and August (Figure 4).

TABLE 4.—Monthly overall mean densities of adults (per man hour) of main indoor resting species in Kandy (all sites combined)

Month	*Cx. quinquefasciatus*	*Ae. aegypti*	*Ar. subalbatus*	*Cx. pseudovishnui*
September	8.42	1.00	0.19	0.00
October	7.54	1.08	0.23	0.06
November	7.35	0.65	0.29	0.12
December	10.81	0.99	0.25	0.41
January	5.99	0.86	0.23	0.08
February	10.79	0.62	0.24	0.02
March	0.38	1.46	0.28	0.02
April	7.24	1.31	0.25	0.15
May	7.61	0.38	0.15	0.05
June	4.70	0.60	0.10	0.18
July	4.48	0.40	0.12	0.00
August	4.36	0.64	0.05	0.00

Monthly overall mean densities of the more prevalent species, *Cx quinquefasciatus* and *Ae aegypti*, *Ar subalbatus* and *Cx psudovishnui* were not correlated with meteorological factors such as rainfall, temperature and relative humidity (Table 5). It must be noted that mosquito densities were compared to both the corresponding and previous month's rainfall (the latter to allow for the time lag in immature development). Density comparisons with temperature and humidity were made for corresponding months only, and these were all not significant.

TABLE 5.—Spearman Rank Order Correlation Coefficients (r_s), n=12, between selected meteorological factors and the monthly overall mean density of the main indoor resting mosquito species

Species	*Rainfall*[a]	*Mean max. temp*	*Mean min. temp*	*Mean RH*
1. *Cx. quinquefasciatus*	0.34 ns	0.19 ns	—0.06 ns	—0.35 ns
2. *Ae. aegypti*	0.09 ns	—0.07 ns	0.10 ns	0.29 ns
3. *Ar. subalbatus*	0.56 ns	0.17 ns	—0.23 ns	0.18 ns
4. *Cx. pseudovishnui*	—0.11 ns	0.08 ns	0.08 ns	—0.16 ns

(*a*) In testing correlation with rainfall, monthly overall mean densities were tested with the previous month's rainfall to allow for the time lag in immature development.

DISCUSSION

The predominance of *Cx quinquefasciatus* in indoor mosquito fauna has been observed elsewhere in the country : for instance, Abdulcader,[1] Lambrecht,[12] Jayasekera, Chelliah, Jansen and Pathmanathan[10] in the southwestern coastal areas of the country. This is probably valid for the urban areas of the country as a whole. In Lambrecht's study [12], a relatively high proportion of other species such as *Mansonia uniformis* Theobald, *Ar subalbatus*, *Ae aegypti*, *Cx gelidus* Theobald and *Cx tritaeniorhynchus*, were taken, collectively amounting to 25.3% of the total catch. In the pesent study in Kandy *Ae aegypti* (10%) was the only major contributor other than *Cx quinquefasciatus*, the rest of the species collectively totalling 7%. Interestingly, Jayasekera *et al*[10] in 1986 reported an even more extreme situation in Sri Jayawardenepura, where *Cx quinquefasciatus* comprised almost 95% of the catch and all other species (including *Ae aegypti*) collectively totalled only 5%. As expected for endophilic species like *Cx quinquefasciatus* and *Ae aegypti* the major component of the indoor resting population consisted of engorged and post-engorged individuals. Surprisingly, a similar phenomenon was seen in *Ar subalbatus* and *Cx pseudovishnui* as well, indicating that a proportion of these basically exophilic and exophagic mosquitoes were either feeding and resting indoors, or feeding outdoors on hosts other than humans and subsequently moving indoors to rest during the ovarian maturation. The latter phenomenon has been observed in the case of *Cx pseudovishnui* in Kandy (Amerasinghe, F. P. unpublished data).

The marked site-related differences in temporal abundance patterns of *Cx quinquefacsiatus* and *Ae aegypti* indicate the influence of localized factors on the populations of these two species. In an urban setting such as Kandy, the major factor is probably the availability and distribution of breeding sites which, in the case of these two species, are mainly man-made : septic tanks and other polluted water collections for *Cx quinquefasciatus*, and small artificial containers for *Ae aegypti*. Localized rainfall patterns would also be important, since available breedng sites would be recharged periodically. In the hilly terrain of Kandy, extremely localized showers are a common phenomenon. It is not surprising, therefore, that the crude overall densities of these two species were not correlated to general trends in rainfall and other climatological parameters. Similar results have been reported from the low country southwestern coastal areas of Sri Lanka [1, 18]. However, the inverse temporal correspondence observed in the variations of parous rates and female density in *Cx quinquefasciatus* in the present study, probably does have some relation to rainfall. Collections in the months immediately following those with high rainfall (e.g. October-November 1985, January-February 1986) were characterised by high densities and low parous rates, indicating the influx of newly emerged nullipars into the population. The opposite was seen after months of low rainfall (September, December 1985, March-May 1986), as recruitment declined and the population aged.

Endemic bancroftian filariasis transmitted by *Cx quinquefasciatus* is absent in the Kandy area. It seems that the short life span of *Cx quinquefasciatus* as shown by parity data in the present study, might partially account for the absence of transmission. The average proportion of females with three or more dilatations, which presumably have lived long enough to become potential carriers of infective larvae was only 0.3 %, as against 11 % shown by Samarawickrema in 1967[18] and 8.3 % by Lambrecht and Fernando in 1974[13] in the filariasis endemic area. Further, low to moderate density levels of *Cx. quinquefaciatus* in the present study, compared to the filariasis endemic belt, .[12,18] may also contribute to the non-endemicity in Kandy. It seems evident that the conditions prevailing in Kandy area are less favourable for the maintenance of *Cx quinquefasciatus* populations than in the endemic belt.

The other frequently occurring indoor resting species, *Ae aegypti*, *Ar subalbatus* and *Cx pseudovishnui*, are of significance as arboviral or nematode carriers in Sri Lanka. *Aedes aegypti* is the principal vector of dengue and dengue haemorrhagic fever. This species and *Ar subalbatus* are potential vectors of *Dirofilaria repens*,[8,10] the common dog filarial parasite which is of zoonotic importance to man. *Armigeres subalbatus* has also been incriminated as the vector of *Seteria digitata*, a common filarial parasite of cattle[19]. *Cx pseudovishnui* has been found to harbour Japanese encephalitis virus in nature, in the Kandy area[16]. These results clearly indicate the necessity for vector incrimination studies to assess the disease transmission risk of indoor resting mosquitoes to the residents of Kandy. Further, long term studies aimed at identifying localized factors affecting mosquito densities would povide valuable information for the control of these mosquitoes.

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