Seasonal Observation on Some Population Attributes of *Aedes albopictus* Females in Nagasaki, Japan, with Emphasis on the Relation between the Body Size and the Survival.

Akemi SUZUKI*, Yoshio TSUDA, Masahiro TAKAGI and Yoshito WADA

Department of Medical Entomology, Institute of Tropical Medicine, Nagasaki University, 1−12−4, Sakamoto, Nagasaki 852, Japan

Abstract: Human bait collections of *Aedes albopictus* females were made 27 times from May to August, 1990 in Nagasaki, Japan. Seasonal variation was observed in the density, the body size as measured by the wing length and the parous rate of host-seeking females. Early in the observation period, generally the density was lower, the body size was larger and the parous rate was lower. However, when compared in each time period, clear positive correlation was recognized between the body size and the parous rate. It was also found that females with retained mature eggs or with heavily damaged wings had, on average, larger body size, suggesting the longer survival in larger females.

Key words: *Aedes albopictus,* density, body size, parous rate, survival.

INTRODUCTION

Survival rate of vector insects determines the length of expected life, and therefore is an important parameter affecting the transmission dynamics of vector-borne diseases. Baily (1982) suggested through mathematical studies that vectors with longer expected life have a higher vectorial capacity. The survival rate is influenced by many physiological and ecological factors but much attention has been paid to the relation between the survival rate and the body size of mosquitoes, where in most studies the parous rate is used as a substitute for the survival rate and the wing length for the body size. Thus, the parous rate was compared in host-seeking mosquitoes with different wing sizes and/or the wing length was compared in parous and nulliparous mosquitoes.

Different results have been reported in the relation between the body size and the parity in many species of mosquitoes. The positive correlation was suggested between the wing length and the parity in *Aedes aegypti* (Nasci, 1986a), *Ae. atlanticus* (Nasci, 1986b), *Ae. punctor* (Packer and Corbet, 1989), *Ae. sierrensis* (Hawley, 1985), *Ae. taeniorhynchus* (Nasci, 1987), *Ae. triseriatus* (Haramis, 1983; Nasci, 1988), *Ae. vexans* (Nasci, 1986b), *Culex nigripalpus* (Day *et al.*, 1990), *Cx. salinarius* (Nasci, 1986b), *Psorophora columbiae* (Nasci, 1986b), *Mansonia*

* Present address: Instituto Adolfo Lutz, Av. Dr. Arnaldo, 355, São Paulo-SP 01246, Brazil.
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dyari (Lounibos *et al.*, 1990), *Anopheles crucians* (Nasci, 1987), *An. dirus* (Kitthawee *et al.*, 1990, in laboratory) and *An. maculatus* (Kittayapong *et al.*, 1992). On the other hand, no significant correlation was detected in *Ae. hendersoni* (Walker *et al.*, 1987), *Ae. sollicitans* (Nasci, 1987), *Ae. triseriatus* (Landry *et al.*, 1988; Walker *et al.*, 1987), *Culiseta melanura* (Lorenz *et al.*, 1990), *Cs. morsitans* (Anderson and Edman, 1990) and *An. dirus* (Kitthawee *et al.*, 1992).

The present paper reports the results of seasonal observation on some population attributes of *Ae. albopictus* females in Nagasaki with emphasis on the relation between the body size and the survival.

MATERIAL AND METHODS

Human bait collections of mosquitoes were made 27 times from May to August, 1990 in Nagasaki, Japan. Host-seeking female mosquitoes were individually collected by using glass vials (2cm in diameter and 5cm high) for 10 min in the morning at 9 places in and near the campus of Nagasaki University School of Medicine. Collected mosquitoes were immediately kept in an ice box to avoid death and wing damage. Identification of female mosquitoes was carried out in the laboratory under a stereoscopic microscope and *Ae. albopictus* were counted. The wing length was measured with an ocular micrometer and the degree of wing damage was observed and scored according to the Perry's classification (Detinova, 1962). Then the mosquitoes were dissected and retained mature eggs in ovaries, if any, were counted. After these observations, the ovaries were dried on a slide glass and the parity was determined by the tracheolation method (Detinova, 1962).

The above population attributes of *Ae. albopictus* females were examined seasonally and discussed. Emphasis was put on the relation between the body size and the survival.

RESULTS

A total of 1250 host-seeking females of *Ae. albopictus* female mosquitoes were obtained by 27 collections from late May to late August, 1990 at 9 places in Nagasaki. The numbers of 2-5 successive collections (2 in late May, 5 in early June and 4 in others) were pooled to show the seasonal trend.

Fig. 1 shows the seasonal change in the mean number per collection. The density of female mosquitoes was low in late May but increased toward late June, then remained to be stable up to late August. This is the usual seasonal pattern in Nagasaki (Mori and Wada, 1978).

The mean wing length of the female mosquitoes collected was measured for the body size, and its seasonal change is given in Fig. 2. The mosquitoes were large in size early in the season and small in the late season.

Among the 1250 *Ae. albopictus* females in total, the parity could be determined in 1225 females. Ovaries of 8 females were infected with *Coelomomyces* sp. (one in June, two in July and 5 in August). The seasonal change of the parous rate is shown with the 1225 females in Fig. 3. The rate steadily increased from late May to late June, then remained to be rather constant.

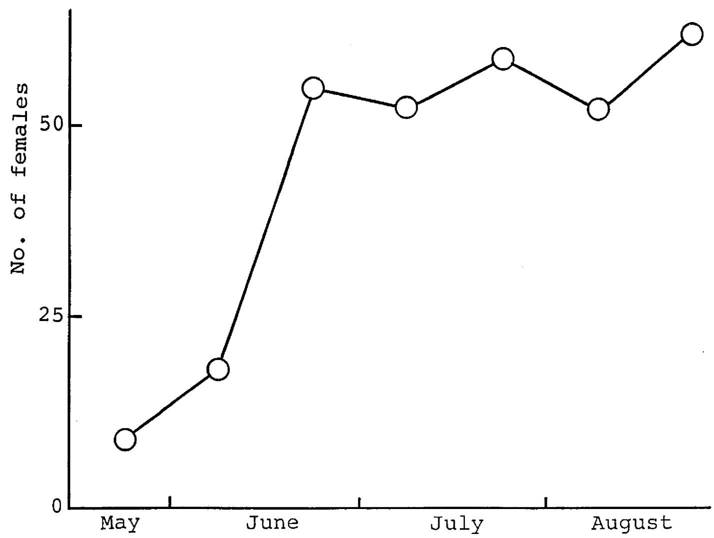

Fig. 1. Seasonal change in the mean number per collection of *Aedes albopictus* host-seeking females, 1990.

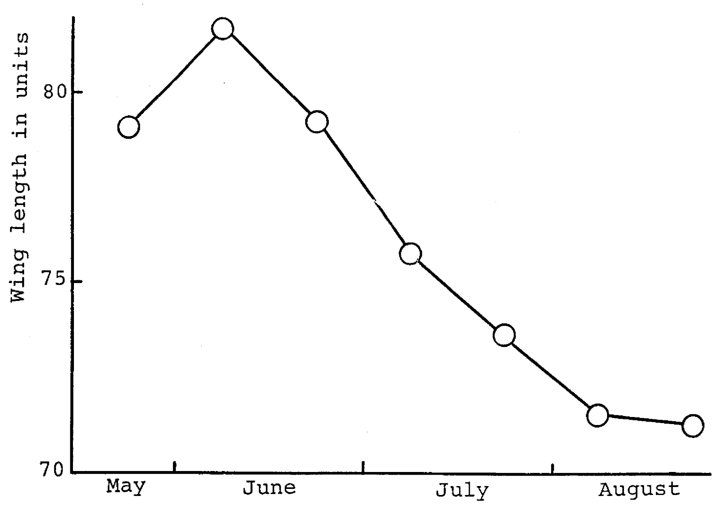

Fig. 2. Seasonal change in the mean wing length of *Aedes albopictus* host-seeking females, 1990. 1 unit of wing length=0.04mm.

The mean wing length of parous and nulliparous female mosquitoes in each time period is separately given in Table 1. It is noticed that the parous mosquitoes were always larger than the nulliparous ones during the study period. The difference was significant in the total (t-test, $p<0.05$) and both in early and late June ($p<0.01$). The relation between the body size (wing length) and the parous rate in June was further analyzed.

The mosquitoes were divided into 5 size groups of equal range (10 units = 0.4mm) of wing length and the parous rate was calculated for each size group, as shown in Table 2. The parous rate, subjected to the arcsin transform, was positively correlated with the size group of wing length in early June ($r=0.987$, $p<0.01$) and in late June ($r=0.950$, $p<0.01$).

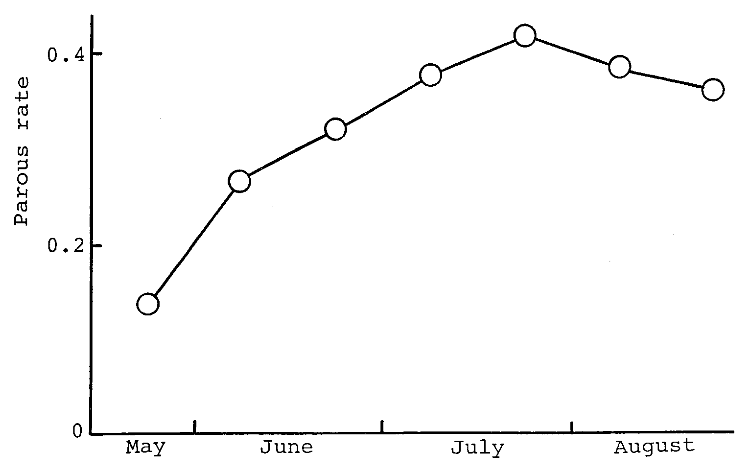

Fig. 3. Seasonal change in the parous rate of *Aedes albopictus* host-seeking females, 1990.

Table 1. Mean wing length (±sd) of parous and nulliparous host-seeking females of *Aedes albopictus.*

Period		No. collections	No. examined	Parous	Nulliparous	t
May	late	2	18	80.25±9.465	79.21±10.977	0.171
Jun.	early	5	90	84.88±6.681	79.97± 8.889	2.726**
	late	4	220	81.06±8.651	77.67± 9.593	2.678**
Jul.	early	4	208	76.23±7.220	75.02± 8.460	1.112
	late	4	235	74.33±7.936	72.47± 8.604	1.724
Aug.	early	4	207	71.59±8.074	71.51± 7.571	1.078
	late	4	247	71.97±7.959	70.62± 8.019	1.322
Total		27	1225	75.44±8.803	74.16± 9.133	2.496*

1 unit of wing length=0.04mm.
* $p<0.05$ ** $p<0.01$

Most host-seeking females had ovaries in the Christopher's stage 1 and 2, but some of them were found to retain mature eggs. The frequency distribution of the number of mature eggs retained in ovaries of females is shown in Table 3. Although 1195 females (95.6%) did not have mature eggs, the remaining ones (4.4%) showed various numbers of retained mature eggs ranging from one to 95. Table 4 gives the comparison of mean wing length in females with and without retained mature eggs in each observation period. The mean wing length was always larger in the females with retained mature eggs than those without, though the difference was significant (t-test) only in early June, early and late August and total (see Table 4). Longer survival in females with larger body size was suggested, because excluding a very few autogenous females (Mori, 1979), all the females with retained mature eggs have fed on blood meal at least once and probably oviposited therefore survived for a certain period, while a part of the females without mature eggs are certainly newly emerging ones.

The frequency distribution of the degree of wing damage in parous and nulliparous mosquitoes is shown in Table 5. The distribution differed significantly ($D=0.296$, $p<0.01$, Kolmogorv-Smirnov two-sample test, Sokal and Rohlf, 1981), and the wing of parous mosquitoes was more heavily damaged than that of nulliparous ones. In Table 6, the average

Table 2. Relation between wing size and parous rate of *Aedes albopictus* host-seeking females collected in June, 1990. The numeral in parentheses shows the sample size.

Size group*	Early June**	Late June***
1		0.00 (3)
2	0.11 (9)	0.31 (35)
3	0.20 (25)	0.35 (63)
4	0.43 (40)	0.45 (91)
5	0.56 (16)	0.57 (28)

* Group 1, 2, 3, 4 and 5 include mosquitoes with wing length of 50−59, 60−69, 70−79, 80−89 and 90−95 units, respectively, where 1 unit=0.04mm.
** $r=0.987$ ($p<0.01$)
*** $r=0.950$ ($p<0.01$)

Table 3. Frequency distribution of the number of mature eggs retained in ovaries of *Aedes albopictus* host-seeking females.

No. of eggs	Frequency	No. of eggs	Frequency	No. of eggs	Frequency
0	1195	6	1	51	1
1	24	8	1	64	1
2	10	13	1	78	1
3	4	25	1	95	1
4	5	28	1		
5	2	37	1	Total	1250

wing size of parous and nulliparous mosquitoes was compared in each class of wing damage, and it was found that parous mosquitoes were larger than nulliparous ones in any wing damage class, though statistically significant difference was recognized only in the damage class of score 1 ($t=3.917$, $p<0.001$).

Table 4. Mean wing length (±sd) of *Aedes albopictus* host-seeking females with and without retained mature eggs.

Period		Without mature eggs		With mature eggs		t
		No.[a]	Wing length[b]	No.	Wing length	
May	late	17	78.12±10.45	2	87.00±1.41	1.171
Jun.	early	91	81.09± 8.65	6	90.67±3.56	2.687**
	late	219	79.09± 9.29	8	83.38±9.04	1.284
Jul.	early	205	75.56± 7.86	6	79.33±7.23	1.160
	late	232	73.43± 8.25	8	77.13±3.83	1.247
Aug.	early	199	71.31± 7.76	9	78.22±6.80	2.625**
	late	232	70.95± 8.02	16	75.63±6.61	2.280*
Total		1195	74.88± 9.02	55	79.85±7.82	4.020***

a) No. of females examined. b) 1 unit=0.04mm
* $p<0.05$ ** $p<0.01$ *** $p<0.001$

Table 5. Frequency distribution of the degree of wing damage in parous and nulliparous host-seeking females of *Aedes albopictus.*

Damage score*	Parous	Nulliparous	Total
1	252	492	744
2	262	162	424
3	48	8	56
4	1	0	1
Total	563	662	1225

* According to the Perry's classification (Detinova, 1962). Wing damage becomes great with increasing score.

Table 6. Mean wing length (±sd) in parous and nulliparous host-seeking females of *Aedes albopictus* with different wing damage score.

Damage score[a]	Parous		Nulliparous		t
	No.[b]	Wing length[c]	No.	Wing length	
1	252	75.62±8.91	492	74.22±9.04	1.997*
2	262	75.18±8.70	162	74.09±9.54	1.200
3	48	75.79±8.95	8	71.50±6.39	1.297

a) See Table 5. b) No. examined. c) 1 unit=0.04mm.
* $p<0.05$

DISCUSSION

The female population of *Ae. albopictus* in early season was characterized by larger body size and lower parous rate in comparison with smaller body size and higher parous rate in late season (Figs. 2 and 3). However, this does not indicate the negative correlation between the body size and the parous rate, because both the parameters are influenced by many factors. The body size of mosquitoes is generally larger early in the breeding season in Nagasaki due to lower temperatures and relatively larger amounts of larval food. The parous rate is subject to vary by the recruitment rate of adults, the length of a gonotrophic cycle etc., in addition to the real longevity (Tsuda *et al.*, 1991). The reason for seemingly lower parous rates early in the breeding season can be explained by the fact that the population was increasing (Fig. 1). Actually, the positive correlation was clearly shown if we compare in each observation period the body size in parous and nulliparous females (Table 1) or the body size and the parous rate (Table 2).

Besides the parous rate, the longevity in the field can be indirectly assessed by the retention of mature eggs and the degree of wing damage. The examination of both the two parameters in relation to wing length implies that larger females of *Ae. albopictus* survive longer (Tables 4, 5 and 6). Thus, all evidences reported here with *Ae. albopictus* suggest longer survival and therefore greater reproduction potential in larger females.

Opposite results were reported in *Ae. triseriatus*. Haramis (1983) and Nasci (1988) recognized the positive correlation between the body size and the parity, while Walker *et al.* (1987) and Landry *et al.* (1988) did not. Although Walker *et al.* (1987) did not find the effect of body size on survival by mark-release-recapture experiment only with laboratory-reared normally sized and large mosquitoes, they added that the results may not adequately answer the question of whether larger mosquitoes live longer than smaller ones when the entire range of body sizes of natural populations is considered. Landry *et al.* (1988) reported that there was no strong evidence that increased size of females is advantageous to survival, but again stated that extremely small mosquitoes may have a decreased probability of survival.

It was reported that host-seeking females were, on average, larger than emerging ones in *Ae. aegypti* (Nasci, 1986a) and in *Ae. punctor* (Packer and Corbet, 1989). In *Ae. albopictus,* such small females that are not encountered in the field can be produced by rearing larvae in poor nutritional conditions (Mori, 1979). The correlation between the body size and the survival was detected in *An. dirus* in the laboratory (Kitthawee *et al.*, 1990), but not in the field (Kitthawee *et al.*, 1992). Thus, some small females would not survive long enough to seek a blood meal successfully at least in some mosquito species.

The survival rate of mosquitoes is usually estimated by the parous rate, but often these two parameters are not accurately correlated with each other. In *Ae. albopictus,* for example, the pre-feeding period is longer and multiple feeding is more frequently necessary to develop mature eggs in females reared under higher larval density and poorer nutritional condition (Mori, 1979). It is important in the transmission of disease how often infective mosquitoes take blood, therefore not only the parous rate but also the blood-feeding activity would be required to be studied.

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