The age-composition of field populations and the survival rates in *Culex tritaeniorhynchus* Giles

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Abstract: The age-composition of natural populations of *Culex tritaeniorhynchus* was investigated in a rural district of Osaka Prefecture during the period from 1968 to 1973, and it was found that the seasonal fluctuations in the age-composition of *Cx. tritaeniorhynchus* populations were well correlated to the variation of mosquito abundance. The average parous rate of the populations was slightly higher in August (18.1%) than in July (15.4%). The daily survival rate of the female mosquitoes were thus estimated as 0.525 in July and as 0.555 in August, respectively. There was little difference in the daily survival rates among different years.

INTRODUCTION

The information on the age-composition of mosquito populations in the field is important to understand the spread of Japanese encephalitis virus (JEV) by mosquitoes.

It was shown by Hayashi and Kurihara (1965) that the physiological age of female *Culex tritaeniorhynchus* could be estimated by the determination of the count of follicular dilatations. So far, some few reports on the age-composition of natural populations of *Cx. tritaeniorhynchus* have been published (Harada *et al.*, 1967; Sasa *et al.*, 1968; Buéi *et al.*, 1968; Yajima *et al.*, 1971). Moreover, Davidson (1955) reported that the survival rate could be calculated from the square root of the proportion parous if the gonotrophic cycle occupied 2 days.

Recently, we studied the gonotrophic cycle of the *Cx. tritaeniorhynchus* mosquitoes inhabited in the field, and found that the time period of blood meal interval was 2.9 days in

the midst of summer season (Buéi *et al.*, 1980).

Based on the findings above, we investigated the seasonal age-composition of *Cx. tritaeniorhynchus* for 6 years from 1968 to 1973, and made an attempt to estimate the survival rate of *Cx. tritaeniorhynchus* populations in nature. The data obtained are presented in this paper.

MATERIALS AND METHODS

The study site

The investigation was carried out from June 1968 to September 1973 at Kurotori Village of Izumi City. The village is located within a distance of 30 km from Osaka City. The climate in summer was hot, the average temperature in August was 28°C, but in winter, it is relatively mild, the average temperature of 4°C in January. The average annual rainfall is around 1,300 mm.

Mosquito sampling

Cx. tritaeniorhynchus were collected at a cowshed. For determination of physiological age, the mosquitoes were caught by waving a

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hand-hold net for 1 hr period just after sunset, 1 or 2 nights per week. For estimation of population densities, the mosquitoes were caught by a light trap, which was operated inside cowshed from dusk to dawn. The collections were made consecutively every night during 4 months.

Age-grading methods

Unengorged females of *Cx. tritaeniorhynchus* were dissected in physiological saline. Either piece of the ovaries of individual mosquito was dried and examined for the absence of tracheolar coiling, by which the parous mosquitoes were selected (Detinova, 1962). In the mosquito which was found to be parous or doubtful, the remaining piece of the ovaries was kept in saline and further dissected with a sharpen wire needle for examination of the ovariole dilatations.

RESULTS

Age-composition of natural populations of *Cx. tritaeniorhynchus*

The age-composition of the populations in each month of the summer season is given in Table 1. About 82% of the total catch of *Cx. tritaeniorhynchus* were nulliparous females, about 18% 1-parous females, and a few 2-parous females. Three-parous or older females were not obtained.

The parous rates of mosquito populations varied from 18 to 42% in June, from 8 to 21% in July, and from 12 to 24% in August varied from 18 to 42% in June, from 8 to 1973. The average parous rate of the population in August retained 18.1%, being slightly higher than that in July (15.4%).

Seasonal change of age-composition

The seasonal change of the nulliparous rates of *Cx. tritaeniorhynchus* populations is shown as the weekly mean values in Fig. 1. The percentage of nulliparous females increased from July to the first week of September, and thereafter, it decreased markedly.

The seasonal abundance of *Cx. tritaeniorhynchus* is shown in Fig. 2. The size of the mosquito population was expressed by the modified geometric mean known as the Williams' mean. A main peak of abundance

of *Cx. tritaeniorhynchus* was seen between the late July and early August when the percentages of nulliparous females were very high. This indicated that a large number of

Table 1 Percentage of age-composition and daily survival rates of *Culex tritaeniorhynchus* at Kurotori, Izumi City, Osaka Prefecture

Year	Month	No. of dissected	Physiological age-group*			Daily survival rate
			N	1-P	2-P	
1968	June	70	61.4	37.1	1.4	0.720
	July	140	86.4	13.6	0	0.503
	August	203	86.2	13.3	0.5	0.505
1969	June	88	67.0	33.0	0	0.682
	July	285	91.9	8.1	0	0.420
	August	427	87.6	12.4	0	0.487
1970	June	84	82.1	17.9	0	0.553
	July	553	84.6	15.2	0.2	0.525
	August	697	83.4	16.2	0.4	0.538
1971	June	185	69.2	29.2	1.6	0.666
	July	551	83.3	16.5	0.2	0.540
	August	480	18.7	18.1	0.2	0.557
1972	June	119	58.0	42.0	0	0.741
	July	423	82.5	17.0	0.5	0.548
	August	400	75.8	23.0	1.3	0.613
1973	July	278	79.1	20.5	0.4	0.583
	August	237	76.4	22.8	0.8	0.608
Total		5,220	81.5	18.1	0.4	
Mean	June	546	67.5	31.8	0.6	0.679
	July	2,230	84.6	15.2	0.2	0.525
	August	2,444	81.9	17.6	0.5	0.555

* N: Nulliparous, 1-P: 1-parous, 2-P: 2-parous.

Fig. 1 Weekly mean values of nulliparous rates of populations of *Cx. tritaeniorhynchus* from 1968 to 1973

Fig. 2 Seasonal changes of the weekly mean numbers of females and the nulliparous rates in *Culex tritaeniorhynchus* populations at the Kurotori area, Izumi City, Osaka Prefecture, 1968–1973

Table 2 The expectation of transmissive life of *Culex tritaeniorhynchus* at a rural district in Osaka

	July	August
Parous rate	0.154	0.181
Gonotrophic cycle (days)	2.9	2.9
Daily survival rate, p	0.525	0.555
Life expectancy, $1/(-\log_e p)$	1.55	1.70
Extrinsic incubation period in days, n	10	10
Rate of survival till being transmissive, p^n	0.00159	0.00277
Expectancy of transmissive life, $p/(-\log_e p)$	0.00247	0.00470

young mosquitoes were emerging during that period. Therefore, it seems to be reasonable to conclude that the fluctuations in the nulliparous rate were correlated to the changes in mosquito abundance.

Daily survival rate

The estimated daily survival rates in *Cx. tritaeniorhynchus* populations are shown in

Table 1. The average daily survival rates of the mosquitoes in July and August were calculated as 0.525 and 0.555, respectively.

With regard to the JEV infection of *Cx. tritaeniorhynchus*, the life expectancy of infective mosquitoes could be calculated using the McDonald's formula (McDonald, 1973). In Table 2, are shown the calculated values of infective life expectancy of *Cx. tritaeniorhynchus* in July and August. The life expectancy of mosquitoes, $-1/\log_e p$, was estimated as 1.55 day in July and as 1.70 day in August. The former was slightly shorter than the latter.

Takahashi (1976) made the close experiments on the JEV secretion of *Cx. tritaeniorhynchus*, and clarified that the majority of infected mosquitoes emerged in mid-summer will become virus-transmissible on day 10 after the infection. The rate of the infected mosquitoes surviving until being transmissible is then given by p^n , where n represents the period in days required to render *Cx. tritaeniorhynchus* transmissible. The surviving rate calculated was 0.00159 in July and

0.00277 in August. Using these values, the expectancy of transmissive life of the mosquito was calculated by $-p^n/\log_e p$ as 0.00247 in July and 0.00470 in August.

DISCUSSION

Detinova (1962) studied the age-composition of populations of *Anopheles maculipennis* in Moscow and reported that very old females, in their tenth to twelfth gonotrophic cycle, were found almost daily in July, and that the nulliparous rate of females during the whole season was smaller than the uniparous rate of females. She concluded that the deficit of nulliparous females in nature was caused by the greater proportion of the physiologically young females remained in nature.

Gillies and Wilkes (1965) studied the age-composition of populations of *Anopheles gambiae* and *An. funestus* in Tanzania, in which the oldest mosquitoes that he found were one 12-parous female of *gambiae*, and two females of *funestus* those had at least 13 and 14 dilatations, respectively. Samarawickrema (1968) also found 5-parous females of *Mansonia uniformis* as the oldest mosquitoes in Ceylon (Sri Lanka).

Corbet (1963) showed that the parous rate of mosquito populations differed markedly among species. It is generally shown that the parous rates of mosquitoes are high in the tropics probably owing to their longer survival (Laurence, 1963; de Meillon *et al.*, 1967; Samarawickrema, 1967, 1968; Kay, 1979).

In Japan, the parous females of field populations of *Cx. tritaeniorhynchus* were found to be 1- to 3-parous, and the most of them were 1-parous (Harada *et al.*, 1967; Yajima *et al.*, 1971). The parous mosquitoes of *Cx. tritaeniorhynchus*, as far as we examined, consisted mostly of the 1-parous females as shown in Table 1, which suggests their shorter survival in nature. The same trend was also demonstrated in the mosquito survey in Okayama Prefecture (Sasa *et al.*, 1968).

It was reported that there was little monthly fluctuation in the natural mortality of *Cx. fatigans* in Burma (de Meillon *et al.*, 1967) and also in that of *Cx. fatigans* and *M. uni-*

formis in Ceylon (Sri Lanka) (Samarawickrema, 1967, 1968). On the other hand, Reuben (1963) found the seasonal fluctuation of the natural mortality of *Culex vishnui* in South India. He reported that the estimated mortality of *Cx. vishnui* was low during the period from August to January, ranging from 6 to 14%, whereas it was higher namely in the period from February to July. He also pointed out that the season of JEV transmission in this area corresponded to the season when the mosquito mortality was low.

In Osaka Prefecture, the recent greatest outbreak of human JE (346 patients) occurred in 1966. We reported in the previous paper that the parous rate of the population of *Cx. tritaeniorhynchus* in that year was 20.8% in July and 27.4% in August (Buéi *et al.*, 1968). The estimated probability of mosquito survival through 1 day was 0.582 in July and 0.640 in August. These values were not so much different from the survival rates of mosquitoes which were obtained in the period from 1968 to 1973.

As seen in Table 2, the proportion of infected *Cx. tritaeniorhynchus* which would survive for 10 days was extremely small. The actual threshold density was calculated as $1/0.00159=629$ in July, and $1/0.00227=361$ in August. Based on these findings, it would be supposed that only 1 mosquito might survive long enough to transmit JEV to a host out of 629 or 361 mosquitoes infected originally.

From such a view point, it may be concluded that the abundance of *Cx. tritaeniorhynchus* must be an important factor enlarging JE epidemics.

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摘 要

コガタアカイエカの年令構成と生存率

日本脳炎ウイルスをとりこんだコガタアカイエカが伝播可能となるまで、どのくらいの割合で生存しているかを推定することは、その地域での伝播の度合を知るうえに必要なことである。

大阪府下のある地域で採集したコガタアカイエカ個体群について、1968～1973年の6年間、年令構成の季節的、年次的に変動する様相を観察した。その結果、未経産蚊率の変動は蚊の発生数の変化によって生ずること、8月の平均経産率(18.1%)は7月のそれ(15.4%)に比べてわずかに高いことを示した。

さきに報告したごとく、本蚊の野外における gonotrophic cycle は2.9日であったので、これらから日あたりの生存率が推定された。すなわち、7月は0.525、8月は0.555であった。これらの値の年による変動はさほど大きくはないように思われる。