Ecological studies on overwintering populations of
Culex pipiens pallens

2. Successive change of wing length and R-ratio of the females
entering and leaving an overwintering shelter

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Abstract: An ecological study was made on successive changes of wing-length distribution and wing length-to-R-ratio relation of *Culex pipiens pallens* females entering and leaving an overwintering shelter.

Shorter-winged mosquitoes were observed to enter the shelter in October earlier than longer-winged ones, most of which came in during late November and early December. From the change of skewness of the wing-length distribution, it was concluded that the shorter-winged mosquitoes decreased considerably during overwintering. However, the shorter-winged individuals including a few parous females were still found in a small proportion among the mosquitoes leaving the shelter.

The wing length-to-R-ratio relation for the monthly catches showed that both of these values were larger in the overwintering population than in the summer one. The regression coefficient between these 2 values was larger in the overwintering population except for population captured in October, which seemed to be in a transitional phase from the summer to the overwintering populations.

Discussions were given of coincidence of these findings with the conclusions so far made on overwintering aspects of *Cx. p. pallens*.

INTRODUCTION

In the previous study (Makiya, 1981), it was made clear from the analysis of wing-length distribution that overwintering *Culex pipiens pallens* populations in Japan were composed of 2 or 3 different wing-length groups, and that R-ratio of the wing vein was smaller in shorter-winged mosquitoes than in longer-winged ones.

A definite linear regression was observed between wing length and R-ratio of over-

wintering populations from various latitudes of Japan. Such a regression was also seen in each of these populations. A possible explanation of this result is that there are two ways of regressions: One is a geographical regression for the various populations from south to north and the other is seasonal one in each local population.

The present study was carried out to know when the shorter- and longer-winged mosquitoes enter or leave the overwintering shelter, and thereby to explain the causes of the left-skewed wing-length distribution observed in the overwintering population and of the seasonal regression between wing length and R-ratio of this mosquito.

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MATERIALS AND METHODS

Mosquito collection was made at an artificial cave (abandoned underground air-shelter) in Mihama Town, 40 km south of Nagoya City, central Japan. Mosquitoes entering the shelter were captured during the period from October, 1978 to April, 1979 with a funnel-shaped window trap (Trap I) attached to one of the doorways of the shelter. Other doorways were kept uncovered until early February so that overwintering mosquitoes could enter the shelter. After early February, these doorways were covered

with 2 similar traps (Traps II and III) to collect mosquitoes going out from the shelter. Mosquitoes trapped were recovered weekly by renewing the trap cages.

Left wing of all the mosquitoes was cut off and mounted on the glass slide with Hoyer's medium, and measurement was made of its length, R₂-cell and R₂-stem as already detailed (Makiya, 1973).

RESULTS

1. Successive change of wing-length distribution

The numbers of weekly collected mosqui-

Table 1 Number of *Culex pipiens pallens* females captured when entering and leaving an overwintering shelter

Time (week)		Number of mosquitoes	
		Trap I ¹⁾	Traps II and III ²⁾
Oct. II, III	(Oct. 7-Oct. 23, 1978)	18	(not set)
IV	(-Oct. 30)	11	"
Nov. I	(-Nov. 6)	1	"
II	(-Nov. 13)	34	"
III	(-Nov. 20)	8	"
IV	(-Nov. 27)	3	"
Dec. I	(-Dec. 4)	14	"
II	(-Dec. 11)	21	"
III	(-Dec. 18)	0	"
IV	(-Dec. 25)	0	"
Jan. I	(-Jan. 2, 1979)	0	"
II	(-Jan. 8)	0	"
III	(-Jan. 15)	3	"
IV	(-Jan. 22)	0	"
V	(-Jan. 29)	1	"
Feb. I	(-Feb. 5)	1	"
II	(-Feb. 11)	0	"
III	(-Feb. 17)	2	0
IV	(-Feb. 26)	(flooded due to heavy rain)	
Mar. I	(-Mar. 6)	0	73
II	(-Mar. 13)	0	59
III	(-Mar. 18)	2	52
IV	(-Mar. 24)	3	94
V	(-Mar. 30)	0	131
Apr. I	(-Apr. 9)	0	61
II	(-Apr. 15)	0	30
Total		122	500

¹⁾ Funnel-shaped window trap attached to a doorway with the mouth facing outside.

²⁾ The same type of traps attached to other doorways with the mouth facing inside.

toes are shown in Table 1. The total of *Cx. p. pallens* females captured by Trap I was 122, most of which were trapped before early December. Besides these females, a total of 67 males of this species were trapped during the same period. These female mosquitoes which came to the shelter for overwintering were referred to as "entering population." In Traps II and III which captured mosquitoes going out from the shelter after early March, 500 females of the same species were collected. These females were regarded as "leaving population" which had finished overwintering in this shelter.

A small number of female mosquitoes were captured intermittently by Trap I as late as March. After early March, however, the leaving mosquitoes outnumbered the entering ones.

Figure 1 shows successive change of wing length of the entering and leaving populations by histogram and mean value. The overall wing-length distributions of the entering and leaving populations are shown by histograms A and B respectively, which represent the cumulative frequencies of the weekly collections.

It can be said from Fig. 1 that the shorter-winged mosquitoes came in the shelter in October earlier than the longer-winged ones, most of which were trapped during the period from late November to early December. As shown by histogram A, the cumulated wing-length frequency of the entering mosquitoes resulted in a left-skewed type of distribution which was encountered frequently in other overwintering populations of this species (Makiya, 1973, 1974a, b, 1981, Makiya *et al.*, 1971, Makiya and Sakurai, 1975). By using the method of Cassie (1954), the mean wing length and standard deviation of the shorter- and longer-winged groups in the entering population were estimated to be 152.5 and 6.9 units, 176.5 and 8.9 units, respectively.

Little change was observed in the mean wing length of the leaving population compared with that of the entering one. The cumulative wing-length distribution of the leaving population was less skewed than that of the entering one as shown by histogram B. The difference of the skewness is shown

Fig. 1 Successive change of wing-length distribution of *Cx. p. pallens* females entering and leaving an overwintering shelter

The distribution is shown by the frequency (%) of mosquitoes in each class and the average wing length is indicated by solid circle or open triangle (1 unit = 0.025 mm). Histograms A and B represent the cumulated frequencies for the entering and leaving populations, respectively. The degree of skewness of these distributions are shown in Fig. 2 by cumulative percentage in probability paper scale.

more clearly in Fig. 2 by the cumulative percentage on probability graph paper. Figure 2 shows that some 10% of the left-skewed component in the entering population was not noticeable in the leaving one, and that wing-length frequency was distributed more normally with a smaller standard deviation in the leaving population. This means that the percentage of the shorter-winged mosquitoes decreased considerably during over-

Fig. 2 Cumulative percentage of wing-length distributions on probability graph paper

Left-skewness of the wing-length distribution decreased from A (entering population) to B (leaving population).

wintering due probably to their high mortality rate.

The skewness (α_3) decreased from -0.853 to -0.473 during the overwintering period. However, the normality of the wing-length distribution of the leaving population was not yet satisfied at 5% level due to the existence of the shorter-winged group. This suggested that the leaving population still consisted of 2 different wing-length groups. The mean wing length and standard deviation of the 2 groups were calculated on the probability graph paper as 161.5 and 7.7 units, 175.5 and 7.0 units, respectively.

Two shorter-winged individuals out of 301 leaving mosquitoes (0.66%) were determined as parous by ovarian tracheation.

2. Monthly change of the wing length-to-R-ratio relation

In the previous report (Makiya, 1981),

R-ratio of the wing vein was found smaller in the shorter-winged group than in the longer-winged one of overwintering population. As a result, a definite linear regression was observed between the wing length and R-ratio values.

In order to see this point, the monthly average of R-ratio was plotted against the mean wing length in Fig. 3. The overall regression coefficient for the overwintering population was calculated to be 0.796, which was significant at 5% level.

For comparison, similar results for summer populations in the nearby area are given in the same figure. These summer populations were sampled in a wide range of Nagoya City area. The overall regression coefficient for the summer populations was determined to be 0.408, which was significant at 5% level but smaller than the above value for the overwintering populations.

The regression coefficient for each monthly catch is shown in the figure as the slope of the regression line. It should be noticed that both wing length and R-ratio were larger in the overwintering population than in the summer one, and that the monthly values of

Fig. 3 Monthly change of wing length-to-R-ratio relation in the summer and overwintering populations

Monthly average of the 2 values in the summer and overwintering populations is shown with open and solid circles, respectively. Regression coefficient for each monthly catch is given as the slope of the regression line.

regression coefficient were also larger in the overwintering population except in October. The entering population captured in October were considered to be in a transitional phase from the summer to overwintering populations.

Between wing length (x) and R-ratio (y), a regression line was obtained as $y = 0.684x + 1.422$ (x in mm) for the whole-year data in Fig. 3. This suggests that wing length and R-ratio of this species fluctuate roughly along this regression line in this area.

DISCUSSION

In the present study, a successive change of wing-length and R-ratio values was examined with *Cx. p. pallens* females which were captured before and after overwintering.

Small-sized mosquitoes, which made up the shorter-winged component of the overwintering population, were observed to enter the overwintering shelter earlier than the longer-winged mosquitoes which became the majority of the overwintering population. From the viewpoint of monthly values of wing length and R-ratio, the population collected in October were intermediate between the summer and overwintering populations. This result may give a further support for the authors' concept that the shorter-winged group in the overwintering population are survivors of the summer populations. The terms of "shorter-" and "longer-winged" in the present study do not mean the "brachy-" and "macropterous" in the phase polymorphism.

Left-skewed portion of the wing-length distribution decreased considerably by the time when the population left the overwintering shelter. This observation coincides with the previous findings that the shorter-winged mosquitoes had shorter lives (Makiya and Sakurai, 1975) and had less lipid content as an overwintering energy source (Sakurai and Makiya, 1981).

However, a small number of the shorter-winged group including parous individuals was still found in the leaving population. This fact should be taken into consideration, because these survivors may have a possibility of reserving arboviruses in nature.

It was confirmed from the studies so far made that an overwintering population is composed of mixed components which differ considerably in wing length and R-ratio. This large change of R-ratio against wing length was considered to cause the larger regression coefficient in the overwintering population than in the summer one (0.796 vs. 0.408).

It was suggested that R-ratio (y) and wing length (x) of this mosquito fluctuate along a line $y = 0.684x + 1.422$ during the year. The slope of this line indicates the degree of the variation of R-ratio against wing length, which is regarded to reflect the seasonal variation of these 2 values in this area. For overwintering populations of various latitudes of Japan, a regression line $y = 1.962x + 3.915$ was determined in the previous study. This line is considered to reflect the degree of geographical variation of this species in Japan. The former regression coefficient (0.684) for the seasonal variation in this area is much smaller than the latter one (1.962) for the geographical variation of overwintering populations in Japan.

The monthly average of R-ratio in this area ranged from a minimum of 3.83 to a maximum of 4.51. This range of the mean R-ratio fell within the known range for *Cx. p. pallens* of Japan (Ishii, 1979).

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REFERENCES

- Cassie, R. M. (1954): Some uses of probability paper in the analysis of size frequency distributions. *Aust. J. Mar. Freshwater Res.*, 5: 513-522.
- Ishii, T. (1979): On the *Culex pipiens* group in Japan. Part III. A historical review of its research 3. Review of the adult characters (2). *J. Sci. Univ. Tokushima*, 12: 43-60 (in Japanese, with English summary).
- Makiya, K. (1973): Morphological differentiation between adult females of *Culex pipiens pallens* and *Culex pipiens molestus* by the application of discriminant function. *Jap. J. Sanit.*

- Zool.*, 23(3): 225-235 (in Japanese, with English summary).
- Makiya, K. (1974a): Population dynamics of mosquitoes in Nagoya district. VI. Composition rate of the long- and short-winged mosquitoes in overwintering population of *Culex pipiens pallens*. *Jap. J. Sanit. Zool.*, 25(2): 125-133 (in Japanese, with English summary).
- Makiya, K. (1974b): Population dynamics of mosquitoes in Nagoya district. VII. Relation between wing length distribution and parous rate in the overwintering *Culex pipiens pallens* females. *Jap. J. Sanit. Zool.*, 25(3): 229-235 (in Japanese, with English summary).
- Makiya, K. (1981): Ecological studies on overwintering populations of *Culex pipiens pallens* 1. Wing-length distribution and R-ratio of the overwintering females from various latitudes of Japan. *Jap. J. Sanit. Zool.*, 32(2): 95-104.
- Makiya, K. and H. Sakurai (1975): Survival of the overwintering house mosquito, *Culex pipiens pallens*, with special reference to the relation between wing length and survival rate. *Jap. J. Sanit. Zool.*, 26(1): 7-14.
- Makiya, K., N. Kumada, Y. Shogaki and S. Ohya (1971): Population dynamics of overwintering mosquitoes in Aichi Prefecture, with special reference to wing length distribution of *Culex pipiens pallens*. *Jap. J. Sanit. Zool.*, 22(3):

186-199 (in Japanese, with English summary).
 Sakurai, H. and K. Makiya (1981): Body compositions of *Culex pipiens pallens*, with special reference to body size of overwintering females. *Jap. J. Sanit. Zool.* 32(1): 72-74.

摘 要

アカイエカ越冬個体群の生態学的研究

2. 越冬場所に入出入りする雌蚊集団の翅長とR比の経時的変化

越冬場所（防空壕）に入出入りするアカイエカの雌集団を週ごとに捕集し、その翅長と翅脈R比の変化を調べた。

短翅型の蚊は長翅のものより早く10月に、長翅型の蚊の大部分は11月下旬～12月上旬に越冬場所に侵入することがわかった。越冬後防空壕を出て行く集団で翅長分布の歪みが少なくなることから、短翅型の割合がかなり減少するものと推定されたが、それでもなお短翅型の雌蚊は少数ながら残存しており、経産蚊も認められた。

越冬場所に入出入りする集団では、翅長とR比が夏のものより大きかった。翅長・R比間の回帰係数も冬の集団で大きく、このことは越冬集団が翅長・R比の差の大きい長翅・短翅型の混成集団であることを示唆する従来の結果と一致するものと思われた。10月の侵入蚊は回帰係数が小さい点では、夏のものから越冬集団への移行期にあるものと推定された。