Epidemio — entomological survey of *Culex pipiens pallens* in Kyungpook, Korea*

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Introduction

Many surveys on the vector mosquitoes in Korea have appeared in literature

Hasegawa(1913) first found Anopheline mosquitoes in several locations of Korea, and ascertained their ability to transmit *P · vivax* malaria. Kobayashi(1929) made a survey on the seasonal prevalence of mosquito in Korea, and Yokoo(1944) in an investigation on the distribution and biology of the mosquitoes reported that *A · sinensis* seemed to serve as a vector of setariasis of domestic animals in Korea. During the period from 1950 to 1959, the movement of population and unsanitary conditions caused by the Korean War increased the prevalence of the mosquito — borne diseases to such extent that it become a major public health problem of nation — wide significance After the War, Anophelinae and Culicinae mosquitoes have been considered as the primary target to investigate in order to provide informations for the control of mosquito — borne diseases by a number of medical parasitologists and public health officials. Whang (1962) studied the biological observations on Anopheline mosquitoes in Korea. Shin et al. (1971) described on the seasonal prevalence of JE vector mosquitoes.

To attain self — sufficiency in rice production, the Korean Government in 1972 established a plan to expand the land by cultivating hilly areas, thus practicing land reclamation, and also accompanied the establishment of an irrigation system due to dam construction, improvement of agricultural technique, and intense use of agricultural chemicals Accordingly, increased rice production inevitably resulted in the expansion of mosquito larval habitats, and introduced important changes in the agroecosystems which determined the distribution and abundance of mosquitoes. Furthermore, rice paddies, parsley paddies, ground pools, gutters, ditches, sewers, cesspools, and fertilizer pits around houses produced important vector mosquitoes. The adult mosquito shelters in bushes near the houses The female mosquito begins to enter houses after sunset, increasing in number covering from 8 p.m to 4 a m, thus *Cx · pipiens pallens* is one of the most common and abundant mosquito species in houses and is strongly anthropophilic. This study has been proceeded as a part of our investigation in the epidemio — entomology and control of mosquito — borne diseases, since this species was found to play as the main vector of human filariasis and Japanese encephalitis prevalent in endemic areas of the World. The present paper summarizes the seasonal variation and the population dynamics of adult mosquitoes carried out in Kyungpook Province from 1984 to 1993.

Materials and Methods

1. Geographical conditions of surveyed areas:
Kyungpook Province is situated in the south
—east part of the Korea peninsula, having an
area of 19,700 square meters. Nine areas in the
Province were selected as vector mosquito survey
stations(Fig. 1). Keimyung University training
farm in Kyungsan county of the Province was
the main study area.

Another area was the Agricultural research
farm in Kyungpook Provinial office of Rural de-
velopment. It is located in Dongho village, a
northern district of Taegu city. The other areas
were seven rural villages located in the surround-
ing rice paddies of the Province The rice paddies
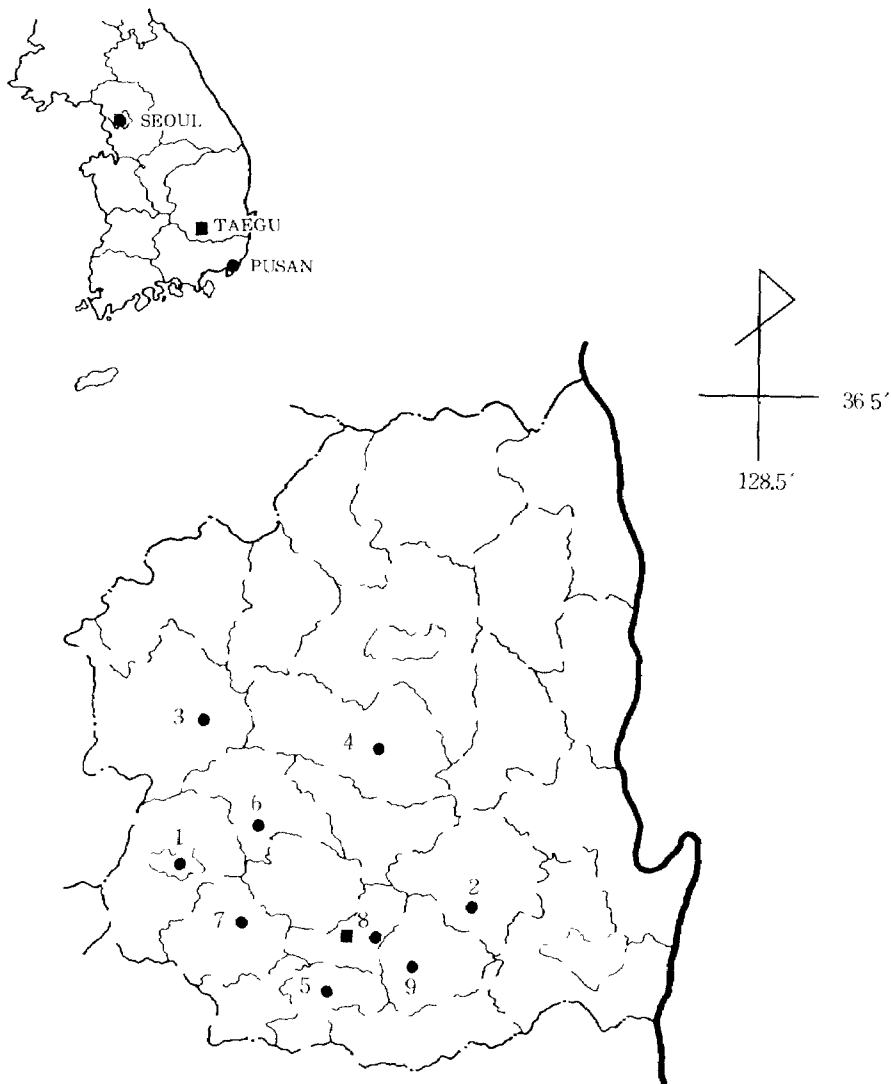irrigation begins in May and ends in late August

Fig. 1 Surveyed areas(●) in Kyungpook Province, Korea

or early September: During this period the rice paddies form the main breeding places for the vector mosquitoes. More details of the geographical conditions of surveyed areas were presented by Baik and Joo(1991).

The survey areas are under the influence of a typical continental climate of an eastern coast affected by both high atmospheric pressure from the cold continent and a low one from the Pacific Ocean in the summer season. Therefore, seasonal fluctuation of air temperature and precipitation, which is of fundamental importance to understand the dynamics of mosquito populations, is very great.

The meteorological data for the period of this survey was provided by the Taegu branch of Korea Meteorological Agency.

2. Light trap operation: In order to observe the seasonal prevalence of the vector mosquito populations, light trap collections were performed as follows A light trap was fixed 1.5m above the ground at trapping spots, the piggery A, the cow−shed B, and the house−dwelling C, and operated from dusk to dawn on one−night per week schedules. Mosquito collected at each station were counted by species.

3. Indices of mosquito abundance: In order to compare the annual abundance of *Cx · pipiens pallens*, mean percent index(MPI) which was proposed by Maeda et al.(1978), was used. MPI is calculated by the following procedure. If the total number of mosquitoes caught by *m*−time collection at a station of *i* in a year of *k* is given by

$$X_{ik} = \sum_{j=1}^{n} X_{ij}k,$$ where $X_{ij}k$ is the number of mosquitoes caught in each collection, MPI is shown in the following equation:

$$MPI_k = \frac{100}{n} \sum_{i=1}^{n} (X_{ik}/X_{io}),$$ where *n* is the number of station and X_{io} is the total number of mosquitoes caught at each station in 1986, when the stations for collection were being fixed. Seasonal prevalence can be also expressed by MPI

from the data of light trap collections as follows

$$MPI_{j \mu k} = n \sum_{j=1}^{n} (X_{u j k} / X_{\mu k})$$

4. Human baited trap: In order to determine the relative numbers and species of mosquito which were attracted by human beings, human baited trap were performed as follows. An open window $2.0 \times 1.5m$ permitted entry of mosquitoes.

All mosquitoes biting or attempting to bite were collected between 19:00 and 06:00 hours on one night in July and August in 1990−1993.

5. Colloection of resting mosquitoes: In order to determine the resting places of mosquitoes in daytime, oral aspirators, and hand nets, about 40 Cm in diameter, made of fine mosquito netting were used to catch adult mosquitoes resting in human and animal shelters. All the mosquito specimens were individually examined for species under a binocular dissecting microscope and counted.

6. Insecticide susceptibility test: In order to estimate insecticide resistance on *Cx · pipiens pallens*, blood−fed females of *Cx · pipiens pallens* were collcted from human and animal shelters with an insect net or with a sucking tube, and transferred into the cage. The mosquitoes were allowed to oviposit in an insectary at $30 \pm 1\,℃$ and 70−80 per cent relative humidity with 16 hours of illumination per day. The approximately 300 first instar were reared in enamel pans measuring 50×40 Cm filled to 2 Cm depth of water and fed on crushed powders of laboratory mouse pellets and adults were fed on 5% sugar solution.

Insecticide resistance was modified from those decribed by Yasutomi et al. (1986). Toxicities of the organophosphorus were determined with fourth instar

LC_{50} values were calculated from the average of two replicates. From these data the regression of the probit mortality on log dosage was computed and the LC_{50} were obtained.

7. Life table characteristics of *Cx · pipiens*

pallens: In order to estimate the effects of mating and/or male-female association on the life-span of adult $Cx \cdot pipiens$ *pallens*, the longevity of adults were tested by comparing six groups of male and female. All experiments were replicated two times and conducted an insectary in which the temperature $27 \pm 1°C$ and relative humidity was regulated between 75 ± 5 per cent. A 16L 8D photoperiod was established with 40 watt fluorescent light, and with 1.0 hour simulated dusk and dawn(Joo et al., 1988).

Adults were continuously offered 5.0 per cent sucrose solution in flask with cotton wads and changed to new solutions every 5 days. Each morning all dead individuals and egg rafts were removed and recorded.

The calculation procedures, formulae, and rationale used in this study was made according to the methods describing by Reisen et al (1979).

The methods have been summarized as follows:

1) Age specific survivorship, $I_x = Y_x / Yo$, where Y_x is the number of males alive on each day, x.

2) Age specific life expectancy, $e_x = T_x / I_x$, where $T_x = \sum_{x=1}^{w} L_x$ and $L_x = (I_x + I_{x+1})/2$ with w = the day the last individual died

3) Net reproductive rate per cohort, $Ro = a \sum_{x=1}^{w} I_x m_x$ where a = proportion of females that survive from egg through adult emergence, it is the proportion of adult females surviving to age x and $m_x = E_x s$ where E_x is the mean number of larvae(i. e., hatching eggs) produced per female per age interval and s = proportion of the offspring that were females.

4) Age of mean cohort reproduction, $To = a \sum_{x=1}^{w} (I_x m_x X / Ro)$ starting at $x=1$, the day of adult emergence, and Ro = net reproductive rate per cohort.

5) The innate rate of increase(r_m), $I = a \sum_{x=1}^{w} I_x m_x e^{-xrm(x+d)}$ and e is the base of natural logarithms and d is the length of time from

oviposition in the present generation to first oviposition in the offspring generation, a is the proportion of female that survive from the egg through adult emergence, and m_x is the mean number of female progeny produced by a female of age, x, and X is the age interval.

6) Mean generation time, $G = In Ro/r_m$, G was a more realistic estimate of generation time which included the larval stages and the nulliparous adult period, i. e., the time from oviposition to oviposition.

7) Effects of mating or association of the sexes on longevity In order to estimate the effects of mating and/or male-female association and egg productions on the longevity of adult $Cx \cdot pipiens$ *pallens* were tested by comparing seven group of male and female. All experiments were replicated two times and performed in an insectary in which the temperature was maintained $27 \pm 1°C$ and relative humidity was regulated between 70 to 80 per cent. A 16L 8D photoperiod was established with five 40-watt fluorescent light, and with 1 hour simulated dusk and dawn. Adults were continuously offered 5.0 per cent sucrose solution in flask with cotton wads and changed to new solutions every 5 days.

Each morning all dead individuals were removed and their sex determined and recorded. The standard one way analysis of variance was used to interpret the results. Values for egg-to-adult survival(a) and proportion female(s) were set equal to 1.0 and 0.5, respectively. Our experience has shown that these values are very close to those obtained using several species and strains of vector mosquitoes reared in the laboratory.

The length of time required for larval development from egg to adult emergence was determined 10 days or 5.0 intervals where an interval equals 2 days

Results

The ten years' observations of the earlist dates

in which *Cx · pipiens pallens* begin to be collected by light traps and air temperature and humidity at that time in Kyungsan county, Kyungpook Province, Korea are listed in Table 1. *Cx · pipiens pallens* were first collected in the light traps from 1984 to 1993 in April, between the 10th and 24th days, but on March 29 in 1989. At that time the air temperature ranged from 3.4 to 26.7℃ and humidity from 41 to 68 per cent. The average number of *Cx · pipiens pallens* per trap-night was 0.3 to 2.3.

Table 2 shows the dates of peak population of *Cx · pipiens pallens* and the meteorological data at that time. The highest population density of *Cx · pipiens pallens* from 1984 to 1993 was observed during the period from early July to late July, but in mid-June in 1987. The air temperature was between 17.6 to 32.4℃ and relative humidity from 75 to 88 per cent. Maximum number of *Cx · pipiens pallens* in 1984 was 369.0 per trap-night. It subsequently showed a marked increase in 1985 and in 1986, reached a maximum of 2,540.7 in 1987, followed by a decrease. In 1990 the number increased again to 1,117 0.

Table 1. 10 years' observations of the earliest dates when *Cx · pipiens pallens* appeared in Kyungsan county, Kyungpook Province, Korea, with meteorological data

Year	Earliest date when mosquito appeared	Temperature (Range ℃)	Humidity(%)	Average No./ trap-night
1984	April 19	8.2 - 22.6	65	0.5(1/2)*
1985	April 24	7.8 - 26.7	56	0.7(2/3)
1986	April 10	14.0 - 23.7	61	0.3(1/3)
1987	April 16	4.8 - 22.7	48	0.7(2/3)
1988	April 13	6.8 - 23.1	41	0.3(1/3)
1989	March 29	3.4 - 18.0	48	0.3(1/3)
1990	April 11	7.7 - 24.3	52	2.3(7/3)
1991	April 11	12.1 - 19.6	68	0.7(2/3)
1992	April 8	9.2 - 22.1	66	0.3(1/3)
1993	April 14	14.8 - 22.4	45	0.7(2/3)

* Number in parentheses means the total number of female mosquitoes per traps.

Table 2. Date of peak population of *Cx · pipiens pallens* and meteorological data at that time

Year	Date of peak Population	Temperature (Range ℃)	Humidity(%)	Average No./ trap-night
1984	July 8	23.3 - 29.5	80	369.0(1,845/5)*
1985	July 18	21.8 - 32.1	79	586.3(1,768/3)
1986	July 25	22.0 - 28.3	84	1,277.0(3,831/3)
1987	July 23	20.6 - 28.6	88	2,540.7(7,622/3)
1988	July 13	23.1 - 32 4	88	1,219.0(3,657/3)
1989	June 15	17.6 - 28.1	75	585.0(1,755/3)
1990	July 12	24.3 - 31.2	76	1,117.0(3,351/3)
1991	July 18	20.2 - 23.0	85	796.3(2,389/3)
1992	July 15	21.1 - 28.5	82	722.0(2,166/3)
1993	July 9	16.6 - 29 6	71	1,096.7(3,290/3)

* Number in parentheses means the total number of female mosquito per trap-night.

Tabel 3 shows the dates *Cx · pipiens pallens* were not collected in the surveyed area according to the year studied. *Cx · pipiens pallens* was not observed from the area in early and late November, between November 7 in 1990 and November 29 in 1985. The air temperature at that time ranged from 0.8 to 18.3℃ and humidity from 38 to 90 per cent.

Table 4 summarizes the seasonal prevalence of *Cx · pipiens pallens* collected by light traps in Kyungsan county, from 1984 to 1993. In general, *Cx · pipiens pallens* was collected in 8 months, from April to November in every year studied,

but 9 months in 1989. For instance, in 1987, the average number of female *Cx · pipiens pallens* per trap—night in April was 0.2, it subsequently increased 6.6 in May and 132.8 in June, and reached the maximum number, 1,184.2 in July In August, the average number decreased to 382.1, in Septmeber 99.2, in October 13.6, in November 0.8, and none were collected in December

The general patterns of seasonal prevalence of *Cx · pipiens pallens* in the other years are similar to those for 1987, but the patterns of monthly changes in 1988 and 1989 are dissimilar to those for 1987. In 1989, *Cx · pipiens pallens* first appeared in late March, it subsequently increased and reached a maximum of 359.6 in June, followed by a decrease In 1985, the high population of *Cx · pipiens pallens* appeared during the periods of July and September

The results of relative abundance and MPI calculation for *Cx · pipiens pallens* in successive years after 1984 are listed in Table 5 and illustrated by Fig. 2.

It was found that the total number of *Cx · pipiens pallens* progressively increased during the initial 4 years from 1984 to 1987, followed by a decrease. A marked decrease on MPI was obtained in 1989

In Table 6, the results of the number of total

Tabel 3. Dates of disappearance of *Cx · pipiens pallens* and meteorological data

Year	Date of disappearance of mosquito	Temperature (Range ℃)	Humidity (%)
1984	November 10	9.8−13.5	90
1985	November 29	0.8− 5.8	54
1986	November 20	4.5−13.5	42
1987	November 19	2.6−13.0	39
1988	November 23	2.8−13.8	58
1989	November 15	4.7−14.2	64
1990	November 7	8.4−18.3	52
1991	November 14	4.2−12.4	38
1992	November 25	−3.3− 3.5	63
1993	November 17	11.0−17.4	78

Table 4. Seasonal prevalence of *Cx · pipiens pallens* by average numbers collected in each traps during ten years in Kyungsan county, Kyungpook Province

Year	Average number of female mosquito per trap−night								
	March	April	May	June	July	August	September	October	November
1984	0	1.5	16.8	45.3	125.4	33.4	18.3	1.2	0.3
1985	0	1.8	13.4	224.0	371.2	113.0	270.6	11.1	3.7
1986	0	1.3	6.3	153.8	889.5	559.3	170.3	3.6	0.3
1987	0	0.2	6.6	132.8	1,184.2	382.1	99.2	13.6	0.8
1988	0	0.6	14.1	225.0	725.2	285.7	103.1	13.3	2.6
1989	0.1	0.3	30.5	359.6	284.8	114.8	64.0	5.4	1.3
1990	0	0.8	22.1	255.6	566.9	200.9	73.9	2.4	1.4
1991	0	0.4	22.4	294.5	529.5	340.9	44.6	9.1	1.7
1992	0	0.1	12.8	201.0	507.8	371.2	122.8	1.9	0.5
1993	0	0.8	23.2	720.5	671.3	351.5	74.6	1.9	0

Table 5. Relative abundance of *Cx · pipiens pallens* for ten years since 1984

Year	At the 3—stations located in suburban areas	Mean percent index
1984	8,236	38.05
1985	11,011	41.21
1986	24,126	100.00
1987	25,372	114.87
1988	19,483	95.47
1989	9,944	47.13
1990	13,483	71.82
1991	15,504	64.97
1992	16,509	81.33
1993	22,274	81 05

and engorged female *Cx · pipiens pallens* by light traps collected at three locations during the period from 1984 to 1993 are listed. The overall rate of engorgement, as calculated by dividing the number engorged with the total, which reflect the efficiency of blood —sucking activity in 1988 were in the order of 2.6 per cent on cow—stall, 1.9 per cent on piggery and 1.8 per cent on human dwelling. The general patterns of engorgement rates in the othere years are similar to those for 1988, but in 1985, 1987 and 1992 are dissimilar.

Table 7 shows the monthly fluctuation in the blood —sucking rates of *Cx · pipiens pallens*. The blood sucking rates varied greatly by different months in every year. The rate was 0.8—4.5 per cent in June, 0.4—2.5 per cent in July, 0.2—3.5 per cent in August, 0.1—4.2 per cent in September, 0.6—3.0 per cent in October and none in November, respectively.

The numbers of *Cx · pipiens pallens* by light trap collections in a pigsty and on human bait methods through the night at interval of one hour
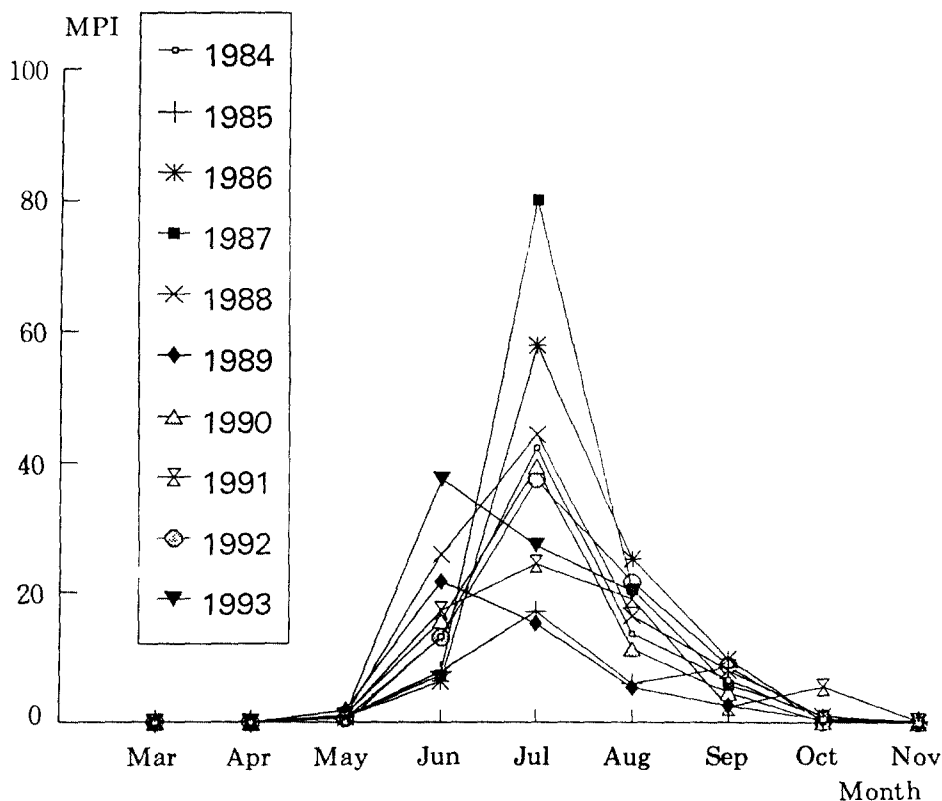

Fig. 2. Annual prevalence of *Culex pipiens pallens* as shown in MPI calculated from the data of mosquito collecton at 3 stations.

Table 6. Comparison of total and engorged number of Cx · *pipiens pallens* collected by light traps at piggery A, cow –stall B, and house –dwelling C

Year	Location	No. collected	No engorged(^o_o)
1984	A	3,176	91(2.8)*
	B	4,141	119(2.9)
	C	946	10(1 1)
	Subtotal	8,236	220(2.7)
1985	A	8,084	141(1 7)
	B	1,755	20(1 1)
	C	1,172	11(0 9)
	Subtotal	11,011	172(1.6)
1986	A	14,200	115(0.8)
	B	7,315	132(1.8)
	C	2,611	12(0.5)
	Subtotal	24,126	259(1.1)
1987	A	13,334	132(1.0)
	B	8,364	91(1.1)
	C	3,674	73(2.0)
	Subtotal	25,372	296(1.2)
1988	A	8,698	163(1.9)
	B	7,510	199(2.6)
	C	3,275	59(1.8)
	Subtotal	19,483	421(2 2)
1989	A	4,770	108(2.3)
	B	3,604	68(1 9)
	C	1,570	32(2 0)
	Subtotal	9,944	208(2 1)
1990	A	5,353	37(0.7)
	B	5,351	34(0.6)
	C	2,779	1(0 04)
	Subtotal	13,483	72(0.5)
1991	A	8,849	65(0 7)
	B	4,850	32(0 7)
	C	1,805	9(0.5)
	Subtotal	15,504	106(0.7)
1992	A	7,784	55(0.7)
	B	5,772	67(1.2)
	C	2,953	23(0 8)
	Subtotal	16,509	145(0.9)
1993	A	14,802	90(0 6)
	B	5,789	20(0.3)
	C	1,683	15(0 9)
	Subtotal	22,274	125(0 6)
	Total	165,942	2,024(1 2)

* Number in parentheses means the percentage of engorged females

Table 7. Monthly fluctuation of total and engorged number of Cx · *pipiens pallens* collected by light trap during ten years' 1984 − 1993

Year	March		April		May		June	
	No. collected	No. engorged(%)	No. collected	No. engorged(%)	No. collected	No. engorged(%)	No. collected	No. engorged(%)
1984	0	0	0	0	0	0	2,113	95(4.5)
1985	0	0	0	0	199	2(1 0)	2,464	50(2.0)
1986	0	0	12	0	120	2(1 7)	1,846	16(0.9)
1987	0	0	2	0	79	2(2.5)	1,594	24(1.5)
1988	0	0	7	0	201	3(1 5)	5,401	119(2 2)
1989	1	0	3	0	457	7(1.5)	4,315	100(2.3)
1990	0	0	7	0	266	0	3,067	33(1.1)
1991	0	0	4	0	336	1(0.3)	3,534	30(0.8)
1992	0	0	2	0	153	3(2.0)	2,412	36(1.5)
1993	0	0	10	0	278	0	10,808	77(0.7)

July		August		September		October		November	
No. collected	No. engorged(%)	No. collected	No. engorged(%)	No. collected	No engorged(%)	No. collected	No. engorged(%)	No. collected	No engorged(%)
4,156	92(1.2)	1,378	12(0.9)	594	21(3 5)	22	0	0	0
4,083	69(1.7)	1,356	15(1.1).	2,706	31(1.1)	167	5(3.0)	44	0
13,343	67(0 5)	6,712	60(0.9)	2,692	113(4.2)	54	1(1 9)	4	0
17,763	187(1 1)	4,585	77(1 7)	1,190	6(0 5)	150	0	10	0
8,702	149(1 7)	3,428	119(3 5)	1,547	30(1.9)	159	1(1.6)	31	0
3,133	79(2.5)	1,378	22(1 6)	576	0	65	0	14	0
6,803	28(0.4)	2,411	10(0.4)	887	1(0 1)	29	0	13	0
5,825	46(0 8)	5,113	25(0.5)	535	2(0 4)	137	2(1.5)	20	0
7,617	93(1.2)	4,454	8(0.2)	1,842	5(0.3)	23	0	6	0
6,042	13(0.2)	4,218	24(0.6)	895	11(1 2)	23	0	0	0

are shown by the order of the date in Table 8. The biting activity was continued throughout the night In light trap collection in a pigsty, Cx · *pipiens pallens* attempted to feed from 19.00 onward, and the peak number of the mosquito showed two peaks, one between 20 00−21 00 hour and another between 02 00−03.00 hour. The hourly distribution of Cx · *pipiens pallens* was not apparent of the human baited trap, because a very small number only were collected. When the air temperature was between 24.1 and 33 9℃ and the humidity 67−76 per cent in the surveyed field

The grand total of the number of Cx · *pipiens pallens* collected on human−baited trap at hourly intervals in Kyungsan county in 6 nights, cumulative percentage and the theoretical numbers per each hour expected from the normal frequency distribution are shown in Table 9 and illustrated Fig. 3−A and Fig. 3−B

The total numbers of Cx · *pipiens pallens* collected on human−baited trap were 468. The mean and standard deviation calculated from this study were 23.27 ± 3.27 hours The value of chi − square was 126.54 with the degree of freedom of 11, and thus the probability was about 0.001. The figures show that the biting rhythm

Table 8. The results of overnight *Cx · pipiens pallens* collected by light trap in a pigsty and on human baited trap(1990－1993)

Hour	Jul 27 1990		Aug 13 1990		Aug 24 1990		Aug.14 1991		Jul 29 1992		Aug.18 1993	
	Ligtht trap	Human trap	Light trap	Human trap	Light trap	Human trap	Light trap	Human trap	Light trap	Human trap	Light trap	Human trap
18－19	0	0	0	0	0	0	1	0	1	0	8	0
19－20	16	0	6	0	20	3	11(2)	3	13	11	48(2)	41
20－21	92	6	53	2	47	7	31(2)	2	67	6	48	21
21－22	57	6	25	1	30	7	28	0	83(1)	13	57	31(1)
22－23	22	0	13	0	15(3)	3	11	4	71	14	36	58(1)
23－24	27	2	24	1	20	1	12	1	70(1)	3	32	41
24－01	35	6	12	3	23	3	24	1	94(1)	16(1)	3(2)	44(1)
01－02	17	0	35	1	24	0	29	1(1)	117(1)	5	56(2)	28
02－03	27(1)*	2	28(1)	0	20	1	41(2)	0	55	6	39(2)	7
03－04	6	4	22	2	5	0	11	1	74(1)	7	55(2)	10
04－05	9	2	13(1)	0	9	0	6	1	75(2)	14	43(1)	11
05－06	3	0	11(1)	2	5	0	1(1)	0	53(1)	1	26(1)	1
Total	311(1)	28	242(3)	12	218(3)	25	206(7)	14(1)	773(8)	96(1)	480(11)	293(3)
Tempera-ture(℃)	33.0－26.1		33.9－24.1		30.8－25.0		27 7－21.5		35.1－24 7		26 8－20.0	
Humidity (%)	43－88		30－80		52－88		56－85		43－86		69－91	

* Number in parentheses means number of engorged female mosquitoes.

Table 9 Frequency distribution and cumulative percentage of *Cx · pipiens pallens* collected on human baits at hourly intervals at Kyungsan county(1990－1993)

Time of collection	Freq	Z	P	F	$\dfrac{(f-\mathbf{F})^2}{\mathbf{F}}$	Cum. %
17 . 00－18 : 00	0	－1.61	0.0537	25.1316	25.1316	0
18 : 00－19 . 00	0	－1.31	0.0414	19.3752	19.3752	0
19 : 00－20 00	58	－1 00	0.0636	29.7648	26.7842	12.39
20 00－21 : 00	44	－0.70	0.0833	38.9844	0.6453	21.79
21 . 00－22 . 00	58	－0.39	0.1063	49.7484	1.3687	34.19
22 . 00－23 : 00	79	－0.09	0.1158	54.1944	11.3539	51.07
23 : 00－24 . 00	49	0.22	0.1230	57.5640	1.2740	61.54
24 : 00－01 00	73	0.53	0.1148	53.7264	6.9142	77.14
01 : 00－02 · 00	35	0.83	0.0948	44.3663	1.9774	84.62
02 . 00－03 . 00	16	1.14	0 0762	36.6616	10.8402	88.03
03 00－04 · 00	24	1.44	0.0522	24.4296	0.0075	93.16
04 00－05 . 00	28	1.75	0.0348	16.2864	8.4247	99.15
05 : 00－06 : 00	4	2.06	0.0204	9.5472	3.2231	100.00
06 . 00－	0		0.0197	9.2195	9.2195	
Total	468		1.000	468.0000	126.5395	

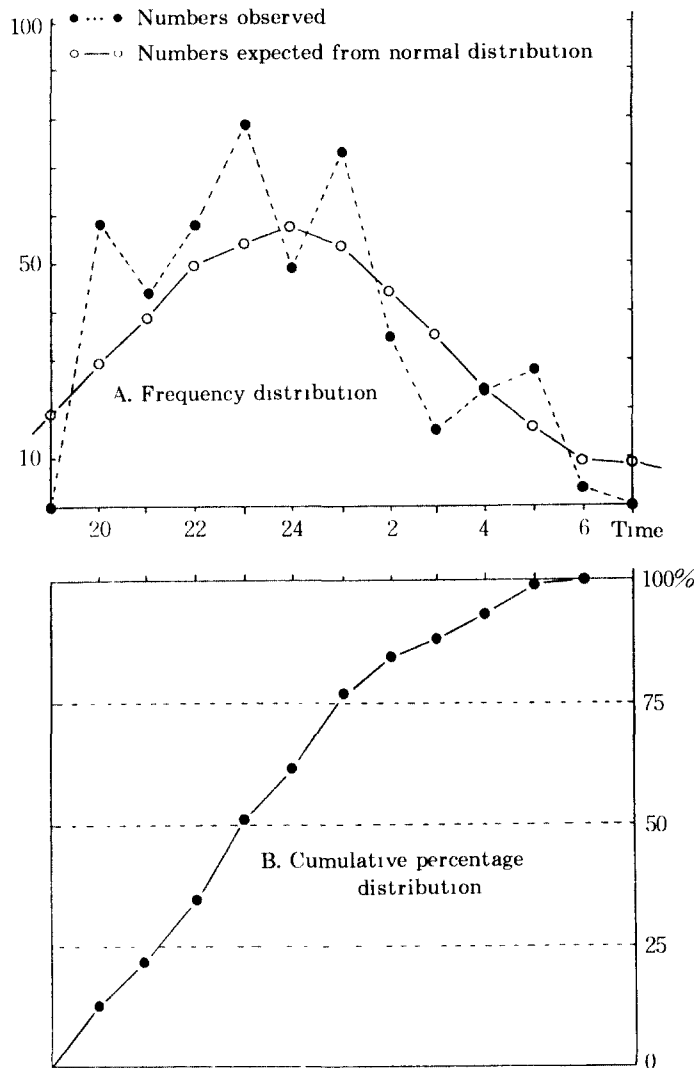Remark　Freq . Frequency
　　　　Cum. %　Cumulative percentage.

Fig. 3. Total numbers of *Culex pipiens pallens* collected on human baits at hourly intervals at Kyungsan county.

of this mosquito observed under this method takes a pattern significantly different from a normal frequency distribution, though it look like somewhat similar.

The main points of the discrepancy between the observed and the expected numbers were shown in the hours near midnight, as illustrated in Fig. 3 — A.

The cumulative percentage distribution of the number of *Cx · pipiens pallens* collected at hourly intervals derived from the grand total is roughly

on a sigmoid curve. From the figure 3—B is shown that about 50 percent of the mosquito attacking human being in a night can be collected before midnight.

In Table 10, the features of biting rhythms by the mosquito species as calculated from frequency distributions by the time of collections were represented.

Significant differences were shown in the mean and standard deviations by the species and/or different traps. *Cx · pipiens pallens* collected on

human baited trap with the standard deviation of about 3.27 and by light trap with 2.93.

An sinensis on human and light traps with the similar values were found.

Cx · tritaeniorhynchus showed the values from

3 27 in light trap to 2 35 on human baited trap.

Table 11 shows the results of classifications of female *Cx · pipiens pallens* collected at hourly intervals by engorgement and ovarian development.

Table 10. Summary of patterns of biting rhythm of mosquitoes as calculated from frequency distributions by the time of collections

Mosquito species	Trap	Total No collected	Mean of time collected	SD in hours
Cx · pipiens pallens	Light	2,230	0:05	2 93
	Human	468	23 27	3 27
Cx · tritaeniorhynchus	Light	702	23 38	3 27
	Human	35	22 99	2 35
An · sinensis	Light	1,347	22 84	2 92
	Human	112	0 34	2 32

Remark The mean and the standard deviation were calculated from the frequency distribution by the class interval of an hour.

Table 11 Classification of female *Cx · pipiens pallens* collected at hourly intervals by engorgement and ovarian development

Time of collection	1990. 7. 27−28 A − B − C	1991 8. 14−15 A − B − C	1992. 7. 29−30 A − B − C	1993. 8. 18−19 A − B − C
18 00−19 00	0−0−0	0−0−0	0−0−0	0−0−0
19 00−20 00	0−0−0	3−0−0	11−0−0	21−0−0
20 00−21 00	6−0−0	2−0−0	5−0−1	29−1−1
21.00−22 00	6−0−0	0−0−0	13−0−0	55−1−2
22 00−23 00	0−0−0	4−0−0	12−0−2	40−0−1
23 00−24 00	1−0−1	1−0−0	3−0−0	41−0−1
24 00−01:00	5−0−1	1−0−0	14−1−1	42−1−1
01 00−02.00	0−0−0	0−1−0	5−0−0	28−0−0
02 00−03.00	2−0−0	0−0−0	6−0−0	7−0−0
03 00−04:00	4−0−0	1−0−0	7−0−0	10−0−0
04 00−05:00	2−0−0	1−0−0	10−0−4	11−0−0
05 00−06:00	0−0−0	0−0−0	1−0−0	1−0−0
Total	26−0−2	13−1−0	87−1−8	284−3−6

Remark A Unengorged and ovaries undeveloped.
B Midgut engorged with fresh blood and ovaries undeveloped.
C Unengorged and ovaries with yolk developments.

The numbers listed for each hour's collection were arranged by the order of A unengorged and ovaries undeveloped, B: engorged with fresh blood and ovaries undeveloped, and C with more or less developed ovaries A represent the mosquitoes which were looking for a host, while B

were in those which had a blood meal in the same night and C were those which were in the status of blood digestion and yolk developments, or just before oviposition. As shown in Table 10, it was found that almost all mosquitoes caught on human baits at Kyungsan station during the hours

from 18:00 to 06 00 were in status A, or those in search of a host The total numbers collected from 03·00 to 06 00 at Kyungsan station were composed of A 38, B 0, and C 4.

Table 12 shows the organophosphate resistance

levels of larval *Cx · pipiens pallens* reared for one generation in the laboratory from collections in several counties of Kyungpook Province and compares with that of susceptible strain.

In general, high resistance to organophosphate

Table 12 Resistance level and resistance ratio of larval *Cx · pipiens pallens* for tested insecticides

Location	Malathion		Diazinon		Fenitrothion		Fenthion	
	LC$_{50}$	R/S	LC$_{50}$	R/S	LC$_{50}$	R/S	LC$_{50}$	R/S
Kyungsan	0 140*	33.3	0 095	6.3	0 040	51.9	0.020	14.1
Kimcheon	0.130	31 0	0.119	7.9	0.0275	35.7	0.0188	13.2
Yeongcheon	0 095	22.6	0.127	8.5	—	—	0.0225	15.8
Sangju	0.345	82 1	0.116	7.7	0.041	53.2	0.0220	15.5
Wiseong	0.160	38.1	·	—	0.0375	48.7	0.01667	11.7
Dalseong	0.109	26.0	0.075	5.0	0.0295	38.3	0.0175	12.3
Kumi	0.223	53 1	—	—	—	—	—	—
Seongju	0 175	41 7	0.150	10.0	—	—	—	—
Suseong	0.090	21.4	—	—	0.0021	2.8	—	—
Susceptoble strain**	0.0042		0.015		0.00077		0.00142	

* Number means LC$_{50}$ value in ppm.
** Data of Gasawara strain reported by Department of Medical Entomology, NIH, Japan.

compounds in nine colonies of *Cx · pipiens pallens* was observed The larval *Cx · pipiens pallens* were found to have resistance against malathion and diazinon with LC$_{50}$ values of 0.090−0.345 ppm and 0.075−0.150 ppm, respectively. The LC$_{50}$ values of the Sangju colony to malathion was about 83.14 times as high as that of susceptible strain, followed by Kumi colony with the ratio of 53.10 times and Seongju colony with 41 67 times. Yeongcheon and Suseong colonies were the least resistant.

Tests with diazinon showed that the resistance ratio of the Seongju colony was the highest, being present in nearly 10.0 times and the Dalseong colony was the least resistant. The more increased resistance of larval *Cx · pipiens pallens* to fenitrothion and fenthion were discovered in three localities, the LC$_{50}$ values being 48.7−51 9 ppm for fenitrothion and 14.1−15.5 ppm for fenthion, respectively. These larvae also became about 15−20 times more resistant to fenitro-

thion than another colony collected from the Suseong area.

The biological and life table characteristics of Kyungsan colony of *Cx · pipiens pallens* are shown in Table 13. The life expectancy of *Cx · pipiens pallens* in this study was 25.83 ± 13.19 days for males and 30.32 ± 11.74 days for females.

The net reproductive rate was found to be 28.6 per cent living female offspring/female per generation, and the generation time was 20.5 days.

In Table 14, the effects of mating or association and/or egg deposit on female lifespan of *Cx · p · pallens* were summarized. In the group of females associated with equal number of males, the average lifespan of females was longer than that of males.

Whereas the repeated addition of young males to a group of mated females shortened the average lifespan, compared with virgin females. Also, in the groups of mated males, the average life span were shorter than that of virgin males.

Table 13. Biological and life table characteristics of Kyungsan colony of *Cx · pipiens pallens*

	Biological & life table characteristics
Ecological factors	
Geographical distribution	Temperate(whole Korea)
Breeding place	Open sewage
Seasonal activity	Hibernate in cellar and/or caves in winter
Morphological factors	
Adult	
Wing length(mm) Male	2.6−4.0
Female	3.2−5.1
Larva	
Siphonal index	3.8−4.9
1st siphonal hair	Usually 3 branched
Hair −siphon ratio	1.40
Fecundity	
No raft/cage	35−46
No of eggs	181
Egg shaped	elongate
Fertility:	
No. larvae/raft	173
Hatching(%)	95.49
Physiological factors	
Egg production	Anautogenous
Copulating behavior	Non−stenogamous
Life table statistics	
e Mean life expectancy at emergence Male	25.83 ± 13.19
Female	30.32 ± 11.74
r_o Net reproductive rate	28.6
r_m. Innate rate of increase	0.164
G Generation time in days	20.5

Discussion

Since the establishment of experimental infections of *Wuchereria bancrofti* to vector mosquitoes by Mochizuki(1911)and Yamada(1927), and since the isolation of the larvae of all stages from *Cx · pipiens pallens* in nature by Yamashita(1955), from *Ae · togoi* by Oshima(1956), and from *Cx·*

vishnui and *An · sinensis* by Nagahana(1957), the ecological and epidemiological studies on the subject of vector mosquitoes have been carried out by many investigators in south and east Asia, including Thailand, Indonesia, China, Japan, and Korea As a result, it has been demonstrated that approximately 100 species belonging to 10 Genus, i e, *Culex, Aedes, Anopheles, Armigeres, Mansonia, Heizmannia, Tripteroides, Toxorhynchites,*

Table 14. Effects of mating or association and/or egg deposit on female lifespan of *Cx · pipiens pallens*(1993)

Group	Average days lived	
	1	2
Virgin females	33.90 ± 13.84	35.11 ± 11.09
Females with equal number of males until male died	29.67 ± 11.56	29.55 ± 11.14
Females with equal number of males until male died (on blood meal)	30 32 ± 11.74	29.22 ± 12.55
Females with multiple groups of males	40.45 ± 13.25	40.23 ± 13.11
Females with multiple groups of males (on blood meal)	37 95 ± 14.41	37.33 ± 14.16
Females with half of No. of males	40.24 ± 10 66	39.06 ± 10.03
Virgin males	24.52 ± 15.99	26.56 ± 16.53

Psorphora, and *Culiseta*, play the important role in transmitting filariasis. Many investigators have so far made studies on the prevalence of filariasis among the residents in Korea, and on the infection rate for infective larvae of *B · malayi* in various vector mosquitoes   .

Recent epidemiological studies on filariasis in Korea revealed a marked reduction in its prevalence among the residents(Seo, 1978). In addition, the vector mosquito studies indicated the reduction in the infection of the mosquito with the infective larvae of B · malayi(Lee et al., 1986). However, the details of the ecology, biology and control of *Cx · pipiens pallens* have not yet been studied in Korea because of the lack of attention given to the problem of *Cx · pipiens pallens* as a vector host.

As for the seasonal distribution in numbers of the vector mosquitoes in Korea, there have been reported by many investigators in an attempt to estimate the population dynamics of *Cx · tritaeniorhynchus*(Shin et al., 1971, Self et al.,1973; Pae et al, 1976; Frommer et al., 1977 & 1979; Lee et al, 1984, Joo and Wada, 1985, Baik and Joo, 1991), and of *An · sinensis*(Kobayashi, 1929, Yokoo, 1944, Paik et al., 1965, Hong, 1970, Lee et al., 1986, Joo and Kang, 1992, and Kang and Joo, 1993), but as a part of survey on the vector mosquitoes of malaria and Japanese encephalitis,

only few studies on the bionomics of *Cx · pipiens pallens* have been published This is the first report on a complete year's collection with one night per week schedules. It seems that the month of highest average catch in night was July, when the temperature was between 17.6℃ and 32.4℃ and the humidity 75–88 per cent. The earliest date of appearance and disappearance in this survey was in late March or early and/or mid April and in early and/or late November each year. The main factors contributing to the earliest date of appearance and the change in the density of the *Cx · pipiens pallens* each year were considered to be temperature, humidity and breeding places such as a variety of artificial containers and/or other types of stagnant waters, hosts, natural enemies and insecticides including other toxic chemicals.

A study of Joo and Wada(1985) reported that *Cx · tritaeniorhynchus* represented about 70.0 per cent of the total numbers in mid–August and early September, while *An · sinensis* was only dominant in mid–July and high population of *Cx · pipiens pallens* appeared during the periods of May and July. They also commented that in the general patterns of seasonal prevalence, *Cx · tritaeniorhynchus* first appeared in mid–June, and were trapped in large numbers during the periods from mid–August to early September, showing a

simple sharply pointed one peak curve, while, *C\ · pipiens pallens* was found to be active through almost the entire season showing irregular curves with several peaks.

From the results presented in Table 4, the patterns of prevalence of *C\ pipiens pallens* differed from year to year As seen in 1985, *C\ · pipiens pallens* was caught in late April, and prevalent with first peak in July and with second in September While, in 1989 this species was collected already in late March and were trapped in large numbers in mid—June, showing a simple sharply pointed one peak curve.

The seasonal prevalence of *C\ · pipiens pallens* has been presented usually in the number of the mosquitoes collected by a light trap, but the numbers were found to fluctuate day by day. Therefore, the total or average number seems to be unfit for comparison of the annual abundance of mosquitoes. Makiya(1975) in a study on the fluctuation of population size of mosquitoes observed with light traps, proposed the use of Williams' mean obtained by $\log(X+1)$ transformation of the data of serial mosquito collections with a light trap

This transformation is effective to normalized the variation between the mosquito numbers, and may be useful to show population abundance from the data on number of mosquitoes collected at stations sampled at random. However, it seemed very difficult to estimate fluctuation pattern of *C\ · pipiens pallens* in the whole area from a result in a certain sampling site. On the basis of this point, the mean per cent index(MPI), being calculated from the totals of vector mosquito collection at stations in comparison with those in the standard year, were used for the comparison of the abundance of vector mosquitoes. The results shown in Table 5 indicate that a marked decrease in MPI was obtained in 1988—1992, and accompanied with a decrease in the number of mosquitoes. As for the main reasons for the decrease in population levels of *C\ · pipiens pallens*, it was considered to be due to the decrease of

breeding place, resting place, source of blood meal, high temperature, small precipitation, water management, natural enemies and insecticides including other toxic chemicals.

Among the factors, temperature and precipitation are meteorological, therefore, they can not be controlled by present powers of man. On the other hand, water management, source of the blood meal(virtually pig and cattle etc.), nature enemies and chemicals are more or less under the control by man

In the results shown in Table 5 and Table 7, remarkable decrease of *C\ · pipiens pallens* has been found in recent years and the tendency of the decrease in number of this species is likely to be case not only in this surveyed area, but all over Korea. The main factors responsible for the recent decrease of *C\ · pipiens pallens* and other vector mosquitoes in Korea can hardly be explained, but there are several factors, possibly being due to spraying of insecticides against mosquitoes, oiling of mosquito breeding places, cutting down of grass aroud dwellings, etc The improvement of the terrestrial configuration, though not necessarily performed only for mosquito control, might have affected its breeding, at least to a certain extent, resulting in reduction of their numbers

In practice, the reduction of the vector popoulation in 1980's seem to be due to the change of insecticides from BHC to organophosphorus compounds, the introduction of intermittent irrigation of rice paddies and/or early planting of rice, and the use of new herbicides that are effective in indirect control of mosquito larvae

As for the survey on the host preference of vector mosquitoes, Sasa et al (1950) in a two years' observations on the seasonal activities and zoophilism of mosquitoes in Tokyo reported that the attraction order of animals to mosquitoes by using animal—baited traps as follows: chicken〉horse〉goat〉rabbit for *C\ · pipiens pallens*, and horse〉goat〉chicken〉rabbit for *C\ · tritaeniorhynchus*

Wada(1966) stated from the comparison of mosquitoes catches at dwelling houses and cow-sheds that *Cx · pipipens pallens* was strongly anthropophilic, *Ae · togoi* rather zoophilic, and *Ar · subalbatus* strongly zoophilic. Wada et al.(1967) collected mosquitoes at various animal sheds and dwelling houses and by dry-ice-trap, and reported that *Cx · tritaeniorhynchus* was strongly zoophilic and probably in a lesser extent ornithophilic, *An · sinensis* was zoophilic, and *Cx · pipiens pallens* was anthropophilic and also ornithophilic.

The results obtained in this study, the overall rate of engorgement which reflected of blood sucking activity in 1987 was in the order of 2.0 per cent on human dwelling, 1.1 per cent on cow-stall, and 1.0 per cent in piggery. In basis of the previously reported data and our own figures, it is concluded that *Cx · pipiens pallens* was strongly anthropophilic and also zoophilic.

Cx · pipiens pallens blood feeding success observed in this study was sometimes a reflection of mosquito abundance. In practice, *Cx · pipiens pallens* abundance during 1987 was greater than in other years observed, but monthly engorgement success was not always linked to overall mosquito collected abundance. In 1989 *Cx · pipiens pallens* was most abundant in July, but engorgement of female mosquitoes had the highest rate in May with 2.5 per cent, followed by August with 1.7 per cent and June with 1.5 per cent.

Although main factors for variant monthly fluctuation of engorged number of *Cx · pipiens pallens* in this study are not readily apparent, it is considered to be associated with rainfall, wind, and humidity, etc. Such consideration was also recognized by Russel(1986), Baik and Joo(1991), and Joo and Kang(1992).

In earlier studies of the biting rhythm of vector mosquitoes, Kanda et al.(1975) in a survey of periodicity of the microfilariae and the bionomics of the vectors found that *An · sinensis, Ae · vexans* and *Cx · tritaeniorhynchus* bit from 20.00 onwad, but *Cx · pipiens pallens* first appeared at 22.00.

The biting cycles of these mosquitoes were all different.

They also reported that the peak number of *An · sinensis* was 34 during one hour between 23.00 and 24.00, but *Cx · tritaeniorhynchus* showed two peaks, one between 22.00 and 23.00 and another between 04.00 and 05.00.

Joo and Wada(1985) reported that the results of hourly catches of mosquitoes by human-baited traps had clearly shown differences in the biting rhythm among the vector mosquitoes of Kyungpook Province, such as the facts that *Cx · tritaeniorhynchus* and *An · sinensis* were rather constantly active all through a night with more or less inconspicuous peaks twice a night, while *Cx · pipiens pallens* exhibited an irregular curve, and the numbers of *Ae · vexans nipponii, Cx · vagans* and *Ar · subalbatus* were very small and were not sufficient for estimating the biting rhythm.

In this study the nocturnal activity of *Cx · pipiens pallens* is in general the most active for one or two hours after sunset with a high peak at 20.00-21.00, decreasing gradually towards the time several hours after midnight, becoming a little active again towards sunrise. Thus, these results indicate that the noctural activity of *Cx · pipiens pallens* and other vector mosquito females was not always similar by collection methods even on the same night. It has been known that many environmental factors such as light, temperature, humidity, wind, etc. are essential in influencing the flight activity of the mosquitoes.

Although these factors should be important in estimating the pattern of nocturnal activity of the mosquitoes reflected by the catches by different traps, this data can hardly be explained by only the hourly changes of these factors, because the meteorological conditions were considered nearly the same night at the sites where the collections were made(Wada et al., 1975; Joo and Wada, 1985; Baik and Joo, 1991. Joo and Kang, 1992).

A study of Clements(1963) assumed that vector mosquitoes were able to locate human settlements or animal sheds over considerable distance by an active process and did not arrive simply through random flight It is considered that mosquitoes are attracted to a host by wind-borne stimuli, such as carbon dioxide, scent, heat, and moisture etc However, it is not know over what distance these factors are effective from the host From their studies on the nocturnal activity and host preference on all catches by different methods, Wada et al.(1970) stated that if daytime resting place had been reasonably near to attractive hosts, the mosquitoes would have been attracted by wind-borne stimuli from the hosts, while if the mosquitoes had rested quite far from hosts, they would have flied firstly through mosquito avenue and then would have been attracted to the hosts by wind-borne stimuli.

In the basis of previously reported data and our own figures, the nocturnal activity of newly emerged females of *Cx · pipiens pallens* begins from May and becomes active from June through October, while at night the females begin to enter the houses one or two hours after sunset and the feeding becomes active from 20 00 through 04 00.

As previously indicated by Sasa et al.(1968), it was shown in this study that in studying the biting rhythm of a mosquito species, it was necessary to make direct counts of the mosquitoes that were actually biting on a host, and results of some other indirect methods of observation, such as the use of traps in animal baited huts or collection on the walls of animal houses, were considered to be often misleading. The most reliable estimates on the mosquito density in relation to the force of transmission of a disease in an area, or on the host selection habits of a mosquito species, can be obtained also with the different mosquito count per day on various host species. Results of this study have clearly shown the difference in the biting rhythm among the principal species of this area, such as the facts that *Cx · pipiens pallens* exhibits a irregular curve with one conspicuous peak near the midnight

As for the study on the general patterns of biting rhythm of the vector mosquitoes based on large samples, Sasa et al.(1964) reported that *Cx · pipiens* was found to become most active during a few hours' period around midnight, with the standard deviations of about 2.20 hours, while those of *Cx · tritaeniorhynchus* and *Ae · vexans* were more widely distributed throughout the night with larger values of standard deviations. *An · sinensis* seemed to represent a type closely related to the former with the value of 2.18 hours.

In this study, the grand total of the numbers of *Cx · pipiens pallens* collected on human baits in 6 nights was 468. The mean time calculated was 23.27, and the standard deviation was 3.27 hours. From the Fig. 3, it was found that about 61.54 percent of this mosquito attacking human being in a night could be collected before the midnight, or about 80.0 percent could be collected from 19:00 to 01 00.

The facts are useful in saving the labour of a collector in making comparative studies on the vector mosquito population between different locations and/or by the seasons. Similar results were obtained by Sasa et al.(1964) and Kato (1955) in Japan

Engorged females with blood at night usually shelter under bushes near houses in the daytime. This mosquito is, however, stronger in habit of resting in houses than other ones and in some cases a great number of engorged as well as unfed females and also males are found resting in houses poorly built in places shady and sheltered from wind and surrounded by bushes.

As for the study on the insecticide resistance for vector mosquitoes and other arthropods of medical importance in Korea, Hurlbut et al. (1952) reported for the first time that the body lice was DDT-resistant. Thus organophosphorus compounds were introduced into Korea as a sub-

stitute for DDT and many organophosphate, carbamate and pyrethroid compounds have also been imported for medical and / or agircultural pest control.

Hwang et al.(1965) in a study of insecticide susceptibility test of *Culex* mosquitoes reported that *Cx · pipiens pallens* was found to be resistant to DDT and susceptible to both dieldrin and malathion. Ree et al (1979) studied the control effects of agricultural pesticides against mosquito populations of rice paddies breeding species, and reported that the mortality rates of *Cx · tritaeniorhynchus* in the first day after treatment were 33.2 per cent to BPMC, 65.6 per cent to diazinon, 32.4 per cent to fenitrothion and 6.2 per cent to malathion, while *Cx · pipiens pallens* showed high mortality rates to the all tested insecticides They also commented that *Culex* mosquitoes had developed a high degree of resistance to some insecticides, and that organophosphorus and carbamate insecticides seriously affected the population of the aquatic organisms in the rice paddies besides vector mosquitoes. In recent years Baik and Joo(1991) reported that *Cx · tritaeniorhynchus* had developed high resistance to most of the insecticides as compared with the results of susceptible strains reported by Yasutomi and Takahashi(1987). Similar results of insecticides resistance of vector mosquitoes were reoprted by Shim and Kim(1980, 1981), Yasutomi et al.(1986), Baik and Joo(1987), Joo and Kang(1992), Kang and Joo(1993) who also reviewed published observations from the other parts of the world.

In view of the above stated facts that *Cx · pipiens pallens* easily develops high grades of resistance against insecticides such as malathion, diazinon, fenitrothion and fenthion.

In the present study, the larval *Cx · pipiens pallens* showed high resistance to malathion and fenitrothion with LC$_{50}$ values of 0.090 − 0.345 ppm and 0.0021 − 0.041 ppm, respectively.

The more increased resistance to malathion and fenitrothion was discovered in *Cx · pipiens*

pallens collected in Sangju county. The results obtained in this study indicate that the resistance ratio to organophosphorus compounds in some colonies of *Cx · pipiens pallens*, relative to susceptible colonies, were nearly 2.8 − 82.1 times.

In fact, the Korean have been striving for self − sufficiency in rice by increasing yields on existing paddy acreage and they have relied on chemical fertilizers and insecticides. According to the Bureau of Agricultural production, approximately 12.0kg of insecticides and fungicides were applied to one hectare of the rice paddies by farmers, 7 − 8 times during the period from June to September in each year, for the control of agricultural pests.

The intense use of insecticides and fungicides for the control of agricultural pests and medical insects, which transmit the communicable diseases, by government officials and by farmers have greatly influenced the populations of the mosquito larvae and their predators.

Therefore, pesticide application in rice paddies must be carefully reviewed by the agricultural authorities.

Resistance being higher among colonies of *Cx · pipiens pallens* in this study suggests that this is probably related to some difference in the opportunity of contacting insecticides and fungicides. However, because the tests were conducted on larvae, against which the product is less potent, these results may not fully reflect that existing in adults. Further work along this problem is needed.

In the earlier studies on the biologic and age specific life table characteristics for vector mosquitoes of medical importance, there have been many investigators since World War II.

Hamilton(1948) reported that in 80.0 per cent of 70 species ranging from invertebrates to human beings the life span of the females was longer than that of the males Cole(1954) has reviewed and discussed the use of the life table in the study of organisms other than man and has encouraged its wider application in ecological

studies. A study of Weidhaas et al.(1971) reported informations about the dynamics of a population of C. p. quinquefasciatus, Walter and Hacker(1974) studied the variation in life table characteristics of same species. Additional observations on the lifespan of vector mosquitoes were presented by Conway(1970), Lopez(1972), McCrav et al.(1972), Shrover and Siverly(1972), Southwood et al.(1972), Hacker et al.(1973), Joo et al.(1988), and Baik and Joo(1991).

As for the survey on the actual number of generations since colonization from the field, Reisen et al.(1979) in a study of geographical variation among the life table characteristics of Cx. tritaeniorhynchus from Asia reported that the number generations in the laboratory were found to be significantly correlated with the percentage hatch($r = 0.878$, $p < 0.01$), the net reproductive rate($r = 0.735$, $0.01 < p < 0.05$) and the innate rate of increase($r = 0.885$, $p < 0.01$).

Similar results were obtained by Crovello and Hacker(1972) who also found that their more highly adapted laboratory strains of Ae. aegypti had higher values of R_0 and r_m.

Conversely, Flovel and Machado—Allison(1976) reported that there was little difference between the fecundity, fertility, survivorship, etc. of the first 5 generations of Ae. aegypti colony maintained in their laboratory and the parent field population.

In our study the Kyungsan colony tested had been maintained in continuous laboratory culture under insectary conditions similar to the life table test conditions for at least 24 generations, and all had gone through more than 29 total generations in the laboratory. We felt that this time period was sufficient to adapt the colony to our test conditions.

From their studies on the field assessment of mating competitiveness of male Cx. tritaeniorhynchus carrying a complex chromosomal aberration, Baker et al.(1979) reported that although selection for mating and perhaps reproductive behavior such as feeding, oviposition, etc. occurred during the colonization of Cx. tritaeniorhynchus, natality and mortality schedules might not be altered genetically as well.

Therefore, our test conditions may have allowed a reasonabel phenotypic expression of the genetically determined life table characteristics of the strains tested. However, these results may not indicate the magnitude of expression under natural conditions.

Our results show that females survive much longer than males, the former having an average of life span of 29.78 days, as against an average of 26.84 days for the latter.

Scorza(1972), who terminated his experiments at 30 days, reported that less than 50 per cent of the females died within this period. Gomerz et al.(1977) reported an average adult life of 60.25 days in females fed only sucrose.

The adult male survival curves obtained in this study are similar to those reported by Crovello and Hacker(1972) for strains of Ae. aegypti and Gomerz et al.(1977) and Joo et al.(1988) for strains of Cx. p. quinquefasciatus. The less longevity of males appears to be a biological characteristics of the species; females are fertilized soon after emergence and one copulation by a single male is enough for all subsequent ovipositions. Once the males have completed their reproductive function, it appears that they are no longer necessary in the population.

Thus there would be less selection pressure for male longevity as originally suggested by Gomerz et al.(1977). In adult female life expectancy at emergence was generally less than strains of Ae. aegypti(Crovello and Hacker, 1972) and Cx. pipiens quinquefasciatus(Gomera et al., 1977; Joo et al., 1988).

The net reproductive rate of the Kyungsan colony in this study was 28.6.

A study of Reisen et al.(1979) reported that the net reproductive rate of 9 strains of Cx. tritaeniorhynchus from 4 countries in Asia ranged from 14.4 to 98.5 living female offspring/female per generation, generation times ranged from 22.2

to 29.8 days, and the innate rate of increase ranged from 0.088 to 0.0192.

Gomerz et al (1977) studied the population analysis of *Cx · pipiens fatigans* under laboratory conditions, and reported that net reproductive rate(R_o) was 161 4, generation time(G) was 44.7 days, and the intrinsic rate of natural increase (r) was 0.01

Walter and Hacker (1974) reported that survivorship of *Cx · p · quinquefasciatus* was high at the earlier ages and then falled off at late stages

Crovello and Hacker(1972) studied 13 strains of *Ae · aegypti*, demonstrating that the formosus form which exists in forests had lower reproductive potentials than the typical form which lives in urban and suburban areas. They speculated that the forest probably provides a more homogenous environmental stress than the urban habitat and that urban populations have adapted to a fluctuation environment which is probably related to variation in the availability of larval habitats.

Our figure has been to draw attention to the fact that variation at the population level of integration can be readily shown to exist in this species of mosquito.

In addition to studying the adaptive strategies employed by mosquito populations, life tables can be of value in implementing mathematical models of mosquito populations(Conway, 1970, Cueller, 1969. Miller et al., 1973) which can be extracted from the life table

The exact causes of the shorter lifespan of the mated females with repeated addition of young males can hardly be explained, this detrimental effects may have resulted from the facts that the females were "bothered" excessively or they simply may have acquired too much of something which affected their physiology under the particular set of circumstances at hand. Such consideration was also recognized by Liles(1965), and Joo et al.(1988)

In the study of the longevity and productivity of adult male and female mosquitoes, Liles(1965)

found that up to about two weeks of age, association or mating with males of similar age increased the life span over that of virgin females even if the mating or association period was as brief as one hour

Similar results were obtained by Joo et al. (1988), Liles and Delong(1960)

In the view of the above stated facts that the mated females lived about as long as the unmated ones, in spite of greater egg production, indicating a probable benefit from the males or "male effect".

The shorter life span of mated males than that of virgin males is unresolved, but more rapid utilization of nutrient reserves in the males is the likely reason for them

In fact, the males consumed and digested only carbohydrate materials yet reserves of many types are utilized in sperm production. Energy expenditure is also probably greater in mated than in virgin males Also, it should be made clear that the effects may be due to association of the sexes alone rather than to the mating process.

Mating was observed in all cases where sexes were together, but a much greater rate in the younger mosquitoes. Such considerations were also recognized by Joo et al (1988), Liles(1965), Suleman and Reisen(1979), and others.

Summary

In order to determine the seasonal prevalence and population dynamics of *Cx · pipiens pallens* in relation to the epidemics of Japanese encephlitis and human filariasis, and ecology of these vector mosquito in Kyungpook Province, studies were carried out during the period from 1984 to 1993.

Cx · pipiens pallens first collected in April between the 8th and 24th days, but in March from the 29th day in 1989, and trapped in large numbers during the perioed from early July between 8th and 25th. There was a gradual decrease from mid−September, with a very small numbers

of them collected until late November in every year.

The total number of *Cx · pipiens pallens* progressively increased during the initial 4 years from 1984, followed by a decrease. A marked decrease on MPI was obtained in 1989.

In the trend of nocturnal activity of *Cx · pipiens pallens*, with oncoming darkness, this mosquito become very active, gradually decreasing in activity towards the time several hours after midnight, becoming a little active again toward dawn.

The larval *Cx · pipiens pallens* showed higher resistance levels and resistance ratios against 4 organophosphorus compounds.

In the adult horizontal life table characteristics of Kyungsan colonies of *Cx · pipiens pallens* under insectary conditions, life expectancy was 25.83 ± 13.19 days for males and 30.32 ± 11.74 days for females The net reproductive rate was 28.6 and generation time was 20.5 days.

Key words *Culex pipiens pallens*, Kyungpook province, Seasonal prevalence, light trap, Human baited trap, life table, insecticide susceptibility test

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=국문초록=

韓國에 있어서 빨간 집모기의 疫學的, 媒介動物學的 調査

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慶北地域에서의 빨간 집모기의 季節的 出現消長과 그 生態를 調査하기 위해서 1984年부터 1993年 까지 慶山郡 1個所에 誘蚊燈으로 1週日에 한번씩 成蟲을 採集하였다.

誘蚊燈에 처음으로 빨간 집모기가 採集되는 날짜는 年度別로 큰 差異를 나타내었으며, 1989年을 除外하고는 4月 8日부터 24日 사이에 採集되었고, 誘蚊燈 1個當 採集된 個體數는 0.3에서 2.3마리 였다.

가장 높은 群集密度를 나타낸 時期는 1989年을 세외하고는 7月 初旬에서 下旬이었으며, 그 密度는 369.0에서 2,540.7마리였다. 그 後 점점 減少하여 12月 初旬부터는 採集할 수 없었다.

採集된 모기 중 吸血率은 5月 0-2.5%, 6月 0.8-4.5%, 7月 0.5-2.5%, 8月 0.2-3.5%, 9月 0-4.2%, 10月 0-3.0%였다.

夜間活動性은 20-22時 사이에 가장 旺盛하였으며, 그 後 점차 減少하다가 23-01時 사이에 다시 增加하였다.

빨간 집모기 幼蟲은 4種의 有機燐劑에 對하여 높은 抵抗性을 나타내었다.

有機燐劑中 malathion와 diazinon에 대하여서는 LC_{50}値가 各各 0.090-0.345ppm, 0.075-0.150ppm, fenitrothion과 fenthion에 대한 LC_{50}値는 感受性 種의 LC_{50}値 보다 各各 2.8-53.2倍, 11.7-15.8倍 이었다.

昆蟲 飼育室 內에서 빨간 집모기, 慶山 種의 生命表 特性에서 平均壽命은 암컷은 30.32 ± 11.74日이었고 숫컷은 25.83 ± 13.19日이었으며, Net reproductive rate는 28.6, generation time은 20.5日이었다.