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Population dynamics in vector mosquitoes of Japanese encephalitis in Kyungpook, Korea*

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Introduction

Since Sabin et al.(1947) first reported on the isolation of JE virus among the American military personnels in the Kunsan area, and since the occurrence of a large nation-wide epidemic JE among the residents in 1949, many investigators have made studies on the epidemiology of JE in Korea (Duel et al., 1950. Hullinghorst et al., 1951. Chang et al., 1959. Kono and Kim, 1969; Kim, 1975. Chun, 1975. Kim, 1986), and on the bionomics of vector mosquitoes (Lee et al., 1969; Shin et al., 1971. Ree et al., 1973; Self et al., 1973; Mathis and Joliver, 1974. Pae et al., 1976. Frommer et al., 1977 & 1979. Lee et al., 1984. Joo and Wada, 1985; Baik and Joo, 1991).

As a result, Japanese encephalitis is one of serious arbovirus infections in human beings, with high mortality in Korea and other counrties, transmitted by mosquitoes, of which *Cx tritaeniorhynchus* is the most important throughout the areas of JE distribution.

Few works on the vector mosquitoes were done in Korea before the end of the World War II, although the *Cx tritaeniorhynchus* belonging to the genus *Culex* was thought to be the principal vector mosquito of JE virus because the mosquito species is the main vector in Japan, Taiwan, Thailand, Singapore and India, etc. After the Korean War, the *Culex* mosquitoes have been considered as the primary target to investigate in order to provide information for the control of JE in Korea by many investigators.

Kono and Kim (1969) summarized the epidemiological features on JE in Korea from 1949 to 1966; Kim(1986) reported that the annual incidence of JE in 1982 were unusually high, a total of 1, 197 with a mortality rate of 3.1; Joo and Wada(1985) studied the seasonal prevalence of the vector mosquitoes of JE in Kyungpook Province.

Recently, the seasonal prevalence and population dynamics of *Cx tritaeniorhynchus* in relation to the epidemics of JE, and ecology of these vector mosquitoes in Kyungpook Province, Korea (Baik and Joo, 1991) suggested that the population density of *Cx tritaeniorhynchus* in the Province was decreasing over the seven-year from 1984 to 1990. This study has been proceeded as a part of our investigation in the epidmiology and control of JE, since *Cx. tritaeniorhynchus* was found to play as the main vector of JE prevalent in Korea and other countries. The present paper represents the data on seasonal variation and population density of adult and larval mosquitoes collected from Kyungpook Province, from 1991 to 1993.

Materials and Methods

Surveyed areas: Kyungpook Province is situated in the southeast part of the Korean peninsula,

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* The results of this study were presented at the 35th annual meeting of the Korean Society for Parasitology(1993).

having an area of 19,700 square kilometers Two areas, Keimyung University training farm in Kyungsan county, and the Agricultural research farm in Kyungpook provincial office of Rural development in the northern district of Taegu city, were selected as this survey's stations (Fig.1) The more detailed geographical conditions of surveyed areas were presented by Baik and Joo (1991)

Meteorological Data Meteorological data for the period of the present survey was provided by the Taegu branch of the Korea Meteorological Agency

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. Mosquitoes collected at each station were counted by species.

Indices of mosquito abundance: In order to compare the annual abundance of *Cx tritaeniorhynchus*, mean percent index (MPI) which was proposed by Maeda et al. (1978), was used.

Human baited trap In order to determine the relative numbers and species of mosquitoes which were attracted by human beings, human baited traps were performed as follows: One man was allowed to lie on the floor of a tent 2.6×2.0m and 1.5m in height. An open window 2.0×1.5m permitted entry of mosquitoes

All mosquitoes biting or attempting to bite were collected between 19:00 and 06:00 hours on one night in August in 1990, July in 1992 and in 1993

Dissection of mosquito All of the mosquitoes biting or attempting to bite were collected either on the skin with a sucking tube or with on insect net, and killed with ethyl ether. They were transferred into a glass tube and kept in an ice box until they were individually identified and dissected in the laboratory. Dissection of the mosquito specimens were made usually in the next morning.

After each mosquito was identified and numbered, it was transferred on a slide glass with a drop of 0.6% saline solution They were examined for the determination of the ovarian age Records were made for each mosquito whether it was nulliparous or parous, and if parous the number of follicular relics was determined

Collection of resting mosquitoes In order to determine the resting places of mosquitoes in daytime, oral aspirators and hand nets, about 40cm 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.

Collection of larvae In order to estimate the species and density of mosquito larvae and pupae, 30 fixed rice paddies were dipped from April to October at one week intervals in 1991-1993. The dipper was 15cm in diameter and 5cm in depth with a wooden handle of 60cm in length At the outset a collector stood at a point on the side of rice paddies, and took a dip on the water surface, which was thought to be most favorable for the breeding of the larvae and pupae within the reach of the dipper. In each rice paddies, the dipping was made ten times which was thought to be necessary to determine the distribution pattern of the numbers of mosquito larvae in a rice paddy. The total number of mosquito larvae in the study areas was estimated according to the methods described by Wada and Mogi (1974).

Results

The three years' observation of the earliest dates when *Cx tritaeniorhynchus* began to be collected by light traps and the meteorological data at that time in Kyungsan county are shown in Table 1. From 1991 to 1993, *Cx tritaeniorhynchus* firstly began to be collected in June, between the 3th and the 17th. At that time the air temperature ranged from 17.4 to

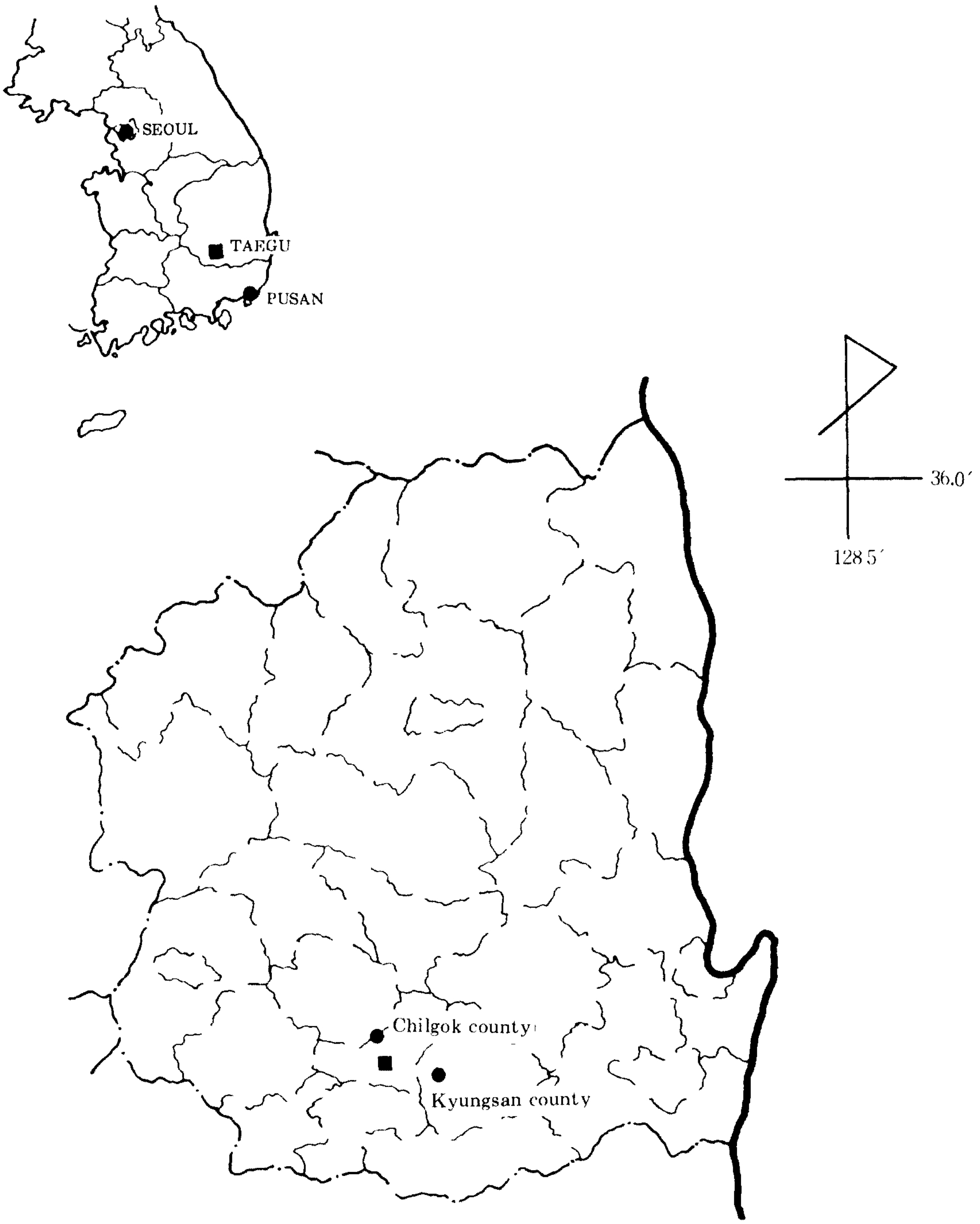

Fig. 1. Surveyed areas(●) in Kyungpook Province, Korea

26.0℃ and relative humidity from 71 to 71 per cent. The average number of *Cx. tritaeniorhynchus* per trap-night was from 0.3 to 1.0.

Table 2 shows the dates of peak population of *Cx. tritaeniorhynchus* and air temperature and humidity at that time. The highest population density of *Cx. tritaeniorhynchus* from 1991 to 1993 was encountered in early August, between the 5th and the 9th. The air temperature was between 21.9 to 25.2℃ and humidity from 82 to 85 percent. The maximum number of *Cx. tritaeniorhynchus* in 1991 was 178.0 per trap-night. The number increased to 255.7 in 1992 and then decreased to 115.0 in 1993.

The dates when *Cx. tritaeniorhynchus* was not collected are listed according to the year studied in Table 3. *Cx. tritaeniorhynchus* was not observed from the area in mid and late October. The temperature of the air at that time ranged from 8.6 to 21.0℃ and humidity ranged from 54 to 69 percent.

Table 4 summarizes the seasonal prevalence of *Cx. tritaeniorhynchus* collected by light traps. In general,

Table 1. 3 years' observations of the earliest dates *Culex tritaeniorhynchus* begin to appear in Kyungsan county, together with meteorological data

Year	Earliest date when mosquito appeared	Temperature (Range ℃)	Humidity (%)	Average No./ trap-night
1991	June 3	17.2-20.8	86	0.3(1/3)*
1992	June 17	17.4-26.0	71	0.3(1/3)
1993	June 2?	18.3-27.3	80	1.0(3/3)

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

Table 2. Dates of peak population of *Culex tritaeniorhynchus* and the meteorological data at that time

Year	Dates of peak population	Temperature (Range ℃)	Humidity (%)	Average No./ trap-night
1991	August 9	20.0-21.5	85	178.0(534/3)*
1992	August 5	21.9-25.2	82	255.7(767/3)
1993	August 25	31.9-24.5	79	115.0(345/3)

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

Table 3. Dates of disappearance of *Culex tritaeniorhynchus* and the meteorological data

Year	Date of disappearance of mosquito	Temperature(Range ℃)	Humidity(%)
1991	October 17	11.7-21.0	54
1992	October 21	8.6-20.1	69
1993	October 6	16.3-17.9	63

Table 4. Seasonal prevalence of *Culex tritaeniorhynchus* by the average number collected in each trap during 3 years in Kyungsan county, Korea

Year	Average number of female mosquito per trap-night				
	June	July	August	September	October
1991	0.8	28.5	65.5	44.3	1.5
1992	0.1	38.5	164.1	80.2	0.8
1993	0.7	13.1	46.1	33.8	0

Cx tritaeniorhynchus were collected in five months, from June to October in every year. In 1992, the average number of female *Cx tritaeniorhynchus* per trap-night in June was 0.1, it increased to 38.5 in July, and reached its maximum number, 164.1 in August. In September the average number decreased to 80.2, in October to 0.8, and none was collected in November. The general pattern of monthly changes of *Cx. tritaeniorhynchus* per trap-night in the other years is similar to those for 1992.

The results of relative abundance and MPI calculated for successive years after 1991 are shown in Table 5 and illustrated by Fig.2. This expression is useful for showing annual pattern of mosquito prevalence from the data of collection

Table 5. Relative abundance of *Culex tritaeniorhynchus* population in successive years after 1991

Year	At the 3-stations located in suburban areas	
	Total No. collected	Mean percent index
1986*	2,398	100.0
1991	1,871	65.5
1992	3,760	175.4
1993	1.087	45.6

* Data of standard year reported by Baik and Joo (1991).

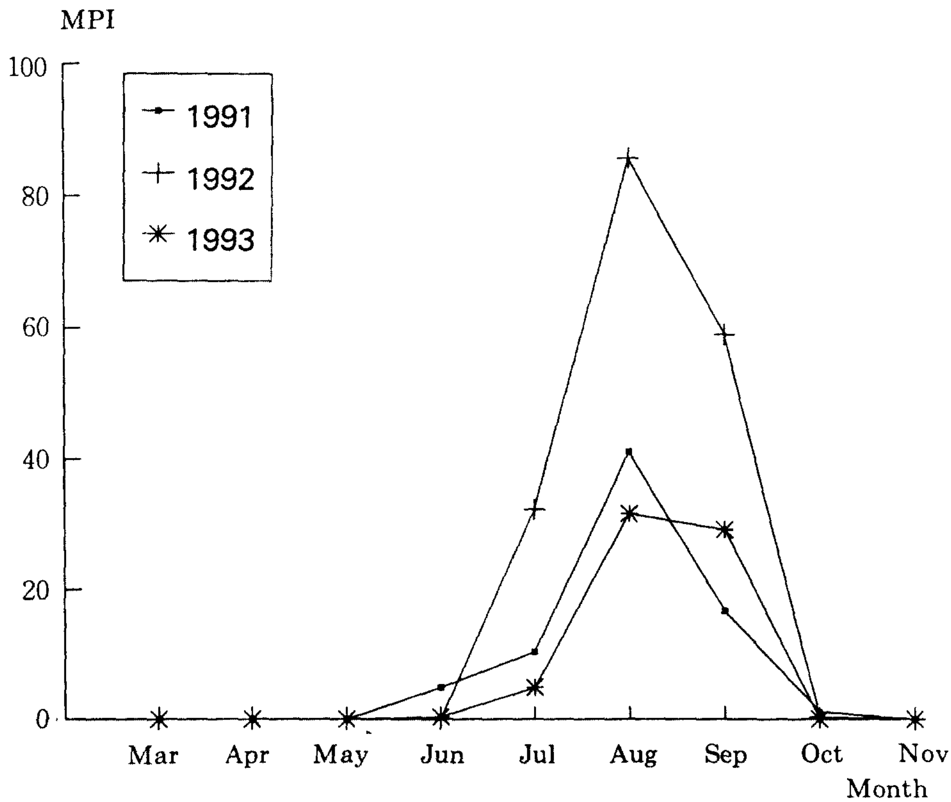

Fig. 2. Annual prevalence of *Culex tritaeniorhynchus* as shown in MPI calculated from the data of mosquito collection at 3 stations.

at several stations.

Table 6 shows the numbers and percentages of engorged female *Cx. tritaeniorhynchus* collected by light traps at three localities during three years, from 1991 to 1993. The overall rates of engorgement which reflect the blood－sucking activity of *Cx tritaeniorhynchus* in 1992 were in the order of 60.2 percent on the cow－stall, 32.6 percent on the piggery, and 14.6 percent on human dwelling.

The general patterns of engorgement rates, as calculated by dividing the number engorged with the total, in the other years were similar to those for 1992

In Table 7, the monthly fluctuations in the blood－sucking rate of *Cx tritaeniorhynchus* are listed according to the year studied. The rate was 31.9 to 36.6 percent in July and 47.4 to 59.2 percent in September. Although the rate decreased in October, it was kept on the level of 40 9－50.0 percent.

The number of total and engorged female *Cx tritaeniorhynchus* collected with light traps and on human baited method are listed by the order of the date in Table 8.

Cx tritaeniorhynchus attempted to feed from 19 00 onward, and the number of the mosquitoes showed two peaks, one between 21 : 00 and 22 : 00, and another between 01 : 00 and 02 00 on July 29－30 in 1992.

In the trend of nocturnal activity of *Cx tritaeniorhynchus*, on becoming dark, they become very active, gradually decreasing in activity towards midnight, but slightly increasing towards dawn. The hourly distribution of *Cx tritaeniorhynchus* is not apparent at the human baited trap, because of a very small number collected. The overall rate of engorgement at three observations on the pigs was from 21.3 percent in July 20－30, 1992 to 31 4 percent in August 14－15, 1991, with an average of 23.4 percent.

The total number of *Cx tritaeniorhynchus* caught in each hour for all the successive collections, their cumulative number and cumulative percentage distributions are shown in Table 9 and illustrated by Fig.3. The cumulative percentage distribution of the number of mosquitos collected at hourly intervals derived from the grand total is roughly on a sigmoid curve, from this figure it is shown that about 50.0 percent of *Cx tritaeniorhynchus* attacking pigs in a night can be collected before 23 . 00 p.m, or about 70.0 percent can be collected with seven hours' work from 20 00 p.m. to 03 . 00 a.m Thus, these results indicate that in making comparative studies of the mosquito population between different localities or by season

Table 6. Comparison of total and engorged number of *Culex tritaeniorhynchus* collected by light traps at Piggery A, Cow－stall B, and House－dwelling C during 3 years, 1991－1993

Year	Location	No. collected	No. engorged(%)
1991	A	619	228(36.8)*
	B	1,187	433(36.5)
	C	65	9(13.8)
	Subtotal	1,871	670(35.8)
1992	A	1,579	515(32.6)
	B	1,901	1,144(60.2)
	C	280	41(14.6)
	Subtotal	3,760	1,700(45 2)
1993	A	583	235(40.3)
	B	446	192(43.0)
	C	58	9(15.5)
	Subtotal	1,087	436(40.1)

* Number in parentheses means the percentage of engorged females.

Table 7. Monthly fluctuation of total and engorged number of *Culex tritaeniorhynchus* collected by light trap (1991–1993)

Month	1991		1992		1993	
	No. collected	No. engorged	No. collected	No. engorged	No. collected	No. engorged
June	9	0	1	0	10	7(70.0)
July	314	116(31.9)*	577	211(36.6)	118	23(19.5)
August	982	223(22.7)	1,969	879(44.6)	553	228(41.2)
September	544	322(59.2)	1,203	570(47.4)	406	178(43.8)
October	22	9(40.9)	10	5(50.0)	0	0(0.0)

* Number in parentheses means the percentage of engorged females.

Table 8. The results of overnight *Culex tritaeniorhynchus* collection by light trap in a pigsty and human baits

Hour	August 14–15, 1991		July 29–30, 1992		August 18–19, 1993	
	Light trap	Man	Light trap	Man	Light trap	Man
19 : 00–20 : 00	5(1)*	0	1(1)	0	2	1(1)
20 : 00–21 : 00	14(4)	1(1)	12(3)	1(1)	7(2)	5(5)
21 : 00–22 : 00	4(2)	2(2)	49(11)	0	1(1)	2
22 : 00–23 : 00	1(1)	0	7(2)	0	2(1)	1(1)
23 : 00–24 : 00	1	0	8(1)	0	1(1)	1
24 : 00–01 : 00	1(1)	0	13(4)	1(1)	0	1
01 : 00–02 : 00	2(1)	0	13(1)	1(1)	0	1
02 : 00–03 : 00	1	1(1)	12(2)	2(0)	0	0
03 : 00–04 : 00	2	0	8(3)	0	2(1)	0
04 : 00–05 : 00	3(1)	0	6(1)	0	1	0
05 : 00–06 : 00	1	0	7	0	2(2)	0
Total	35(11)	4(4)	136(29)	5(3)	18(8)	12(7)
Temperature(℃)	21.5–27.7		24.7–35.1		20.0–26.8	
Humidity(%)	56–85		43–86		69–91	

* Number in parentheses means number of engorged female mosquitoes.

are useful in saving the labour of a collector.

The grand total of the number of mosquitoes collected in Kyungsan county in 3 nights was 189. The mean time calculated form this data was 11 : 46, and the standard deviation was 2.95 hours. The theoretical numbers per each hour expected from the normal distribution were compared with the numbers observed. The value of chi-square was 131.5338 with the degrees of freedom of 11, and thus the probability was less than 0.005. The results suggest that the biting rhythm of *Cx tritaeniorhynchus* observed under this method takes a pattern significantly different from a normal frequency distribution.

table 10 summarizes the age structure of immature stages of *Cx tritaeniorhynchus* and the seasonal prevalence of the total number of larvae plus pupae in the study area. The highest larval density in cultivated fields was 264×10^3 on August 14th, 1992. After September, such densities decreased and the larvae and pupae of *Cx tritaeniorhynchus* were rarely found until rice

Table 9. Frequency distribution and cumulative percentage of *Culex tritaeniorhynchus* collected by light trap at hourly intervals at Kyungsan county (1991−1993)

Time of collection	Freq*	Cumulative No	Cumulative %	Z	P	F	(f−F)²/F
1700−1800	0	0		−1.85	0.0322	6.0858	6.0858
1800−1900	0	0		−1.52	0.0321	6.0669	6.0669
1900−2000	8	8		−1.18	0.0547	10.3383	0.5289
2000−2100	33	41	21.69	−0.84	0.0814	15.3846	20.1696
2100−2200	54	95	50.26	−0.50	0.1081	20.4309	55.1558
2200−2300	10	105	55.56	−0.16	0.1279	24.1731	8.3099
2300−2400	10	115	60.85	0.18	0.1350	25.5150	9.4342
2400−0100	14	129	68.25	0.52	0.1271	24.0219	4.1811
0100−0200	15	144	76.19	0.86	0.1066	20.1474	1.3120
0200−0300	13	157	83.07	1.20	0.0798	15.0822	0.2875
0300−0400	12	169	89.42	1.54	0.0533	10.0737	0.3683
0400−0500	10	179	94.71	1.87	0.0311	5.8779	2.8908
0500−0600	10	189	100.00	2.21	0.0171	3.2319	14.1735
0600−	0				0.0136	2.5704	2.5704
Total	189				1.000	189.0000	131.5338

Note The mean and the standard deviation of the Table were calculated from the frequency distribution by the class interval of an hour.
Mean±SD=11 46±2.95 hours

Table 10. Age structure of immature stages of *Culex tritaeniorhynchus* in the study area (1992)

Date	Total No. in the study area at the median age of each stage (X10⁵)*				
	L1	L2	L3	L4	Pupae
1992					
Aug. 7	16	11	27	16	2
Aug. 14	4	115	107	20	18
Aug. 21	0	86	99	11	6
Aug 28	24	24	24	38	14
Sep. 4	0	69	53	51	8
Sep. 18	47	72	21	10	12
Sep. 25	19	52	0	0	11

* Total No. in the study area at the median age of each stage ($X10^5$)=total No. of each stage in the area(=Average No. per dip×186×Total area with water in m^2)/Mean period of the stage at the then temperature. Ten−day average temperature were used here.

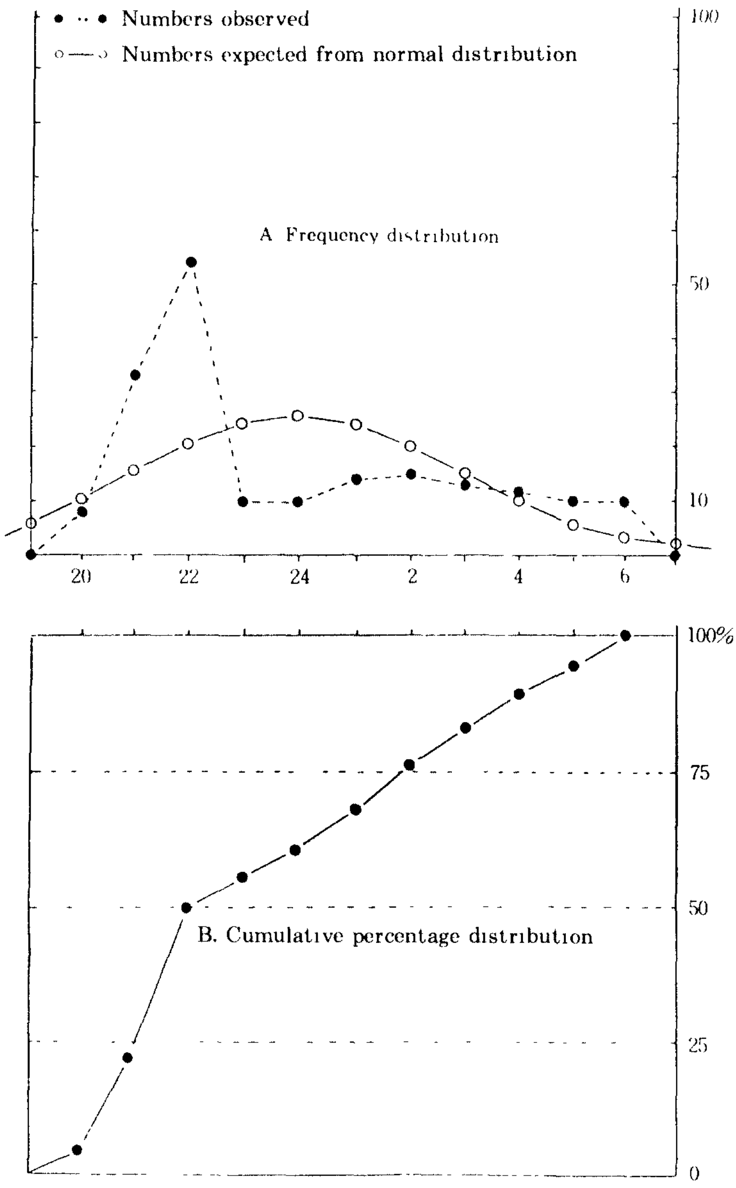

Fig. 3. Total numbers of *Culex tritaeniorhynchus* collected on light trap at hourly intervals at Kyungsan county.

plants were harvested.

Discussion

Since Mitamura et al. (1937, 1938) first reported on the discovery of JE virus from *Cx tritaeniorhynchus* in Japan through experimental and field studies, the neuro-viro-pathoepidemio-entomological studies on the subject of JE and its vector mosquitoes have been carried out by many investigtors in south and east Asia, including China, Indonesia, Malaysia, Korea, Japan and Thailand

As a result, it has become clear that the infection cycle of JE virus is associated with the vector, *Cx tritaeniorhynchus*, and the amplifier, domestic pigs.

The fact that patients with JE are present among the residents in Korea have been known for a long time, and a disease called "Summer encephalitis" or "Encephalitis lethargica" before 1935 is now accepted to be nothing but JE.

Sabin et al. (1947) first confirmed that the virus of JE was widely disseminated in south Korea. They conducted a study of JE in American military personnels stationed in Kusan city of south Korea, and observed four cases of JE during the summer of 1946. At the same time, they also proved the presence of the antibody of JE in native Koreans and of indiginous domestic animals in four different areas of south Korea

In the survey of the vector mosquitoes in Korea, with a consideration of their importance as JE vector, Lee et al. (1969) reported that five strains of JE virus were isolated from *Cx tritaeniorhynchus*, one from *Ae vexans nipponii*, and two from overwintering *Cx pipiens pallens*, and commented that the principal vector of JE in Korea was *Cx tritaeniorhynchus*

A study of Shin et al. (1971) found that *Cx tritaeniorhynchus* was the most prevalent spedies, and next in order were *An sinensis*, *Ae vexans nipponii*, with *Cx pipiens pallens* taking 4th place, and reported that the population density of *Cx tritaeniorhynchus* by month were 0.1% in June, 8 2% in July, 55 2% in August, 36.6% in September and 0 02% in October, respectively Similar results in vector mosquitoes have been obtained by Self et al.(1973), Pae et al. (1976), Frommer et al.(1977,1979) and Lee et al (1984) in some U. S army Compounds, and by Joo and Wada (1985) in Kyungpook Province, Korea. In the general patterns of seasonal prevalence, *Cx pipiens pallens* was found to be active through almost the entire season showing irregular curves with several peaks, while *Cx tritaeniorhynchus* first appeared in mid- June, and were trapped in large numbers during the periods from mid-August to early September, showing a sharply pointed one peak curve. As for *An sinensis*, the trend of seasonal distribution was similar to that of *Cx tritaeniorhynchus*, but the earlist dates of appearance and disapperance differed from that of *Cx tritaeniorhynchus*

Monthly fluctuation in number of *Cx tritaeniorhynchus* have been reported previously, but this is a report on a complete year's collection with one night per week schedules. It seems that the highest population of *Cx tritaeniorhynchus* was clearly observed in August, when the temperature was between 18.2 and 32.4℃ and humidity 63-83 percent. The earlist date of appearance and disappearance in present survey was in early or mid-June and mid or late October each year

The main factors contributing to the earlist time of appearance and the changes in the population density of *Cx tritaeniorhynchus* each year were considered to be due to the changes in the rice culture system and/or rural environment such as water management of rice fields, high temperature and small precipitation, etc., the extensive uses of chemical insecticides in rice farming, livestock and natural enemies, and the reduction of rice fields by urbanization.

Such consideration was also recognized by Mogi (1978, 1984), Maeda et al. (1978) Baik and Joo (1991), and Joo and Kang (1992).

The seasonal prevalence of *Cx tritaeniorhynchus* has been shown usually in the number of *Cx tritaeniorhynchus* 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 abundance of *Cx tritaeniorhynchus* On the basis of this point, the mean percent index(MPI), being calculated from the totals of vector mosquito collections at stations in comparison with those in a standard year, was used for the comparison of the annual abundance of vector mosquitoes.

A study of Baik and Joo (1991) and our own investigation have conducted vector mosquito surveys with light traps in Kyungsan county, Kyungpook Province, every year starting in 1984. These data are valuable, but are not used for further analysis of the epidemic of JE. However, in these data a remarkable decrease of *Cx tritaeniorhynchus* has been found in recent years and a trend of the decrease in number of this mosquito is likely to be case not only in Kyungpook Province, but also all over Korea. It may be considered that the decrease of *Cx tritaeniorhynchus* is an important factor in the reduction of human JE cases in recent years.

Although the main reasons for the decrease in population density of *Cx tritaeniorhynchus* can hardly be explained, it was considered to be due to the intermittent irrigation or early planting of rice plants made unsuitable conditions for breeding mosquito larvae (Kamimura and Watanabe, 1973), extensive uses of chemical insecticides (Shimada, 1974, Kang and Joo, 1993), and uses of the herbicides such as CNP (p-nitrophenyl 2, 4, 6-trichlorophenyl) and NIP (nitrofen) for rice plant cultivations (Oya, 1972; Shim and Self, 1973, Maeda et al, 1976). Furthermore, such factors as the decrease in rice field areas due to urbanization, improved water management, aerial application of agricultural chemicals, and modernized livestock breeding, have contributed to the reduction of larval vector populations (Mogi, 1984)

In the studies on the characteristics is the chronological biting rhythm of the vector mosquito species, Joo and Wada (1985) reported that the hourly distribution of the female *Cx tritaeniorhynchus* observed by the human-baited collections usually had two peaks, one between 2100 and 2200, and another between 2400-0100 on August 3-4, 1984, and Kang and Joo (1993) in a mosquito survey by light trap and human-baited traps through the night at hourly intervals reported that *An sinensis* appeared to be active throughout the whole night, but was more active during darkness, after sunset to midnight, and at that time the temperature was between 26.9 and 30.1℃ and the humidity 67-76 per cent.

In the present study the nocturnal periodicity activity of the female *Cx tritaeniorhynchus* was not always similar by collection methods on the same night.

Although the environmental factors such as temperature, light, humidity and wind-borne stimuli, etc. should be important in determining the attraction of mosquitoes, present data can hardly be explained by the hourly changes of the factors because the meteorological conditions were considered nearly the same at least on the same night at the sites where the collection was made. Further works along this line are needed.

As also indicated by the previous reports (Sasa et al., 1968; Shin et al., 1971, Baik and Joo, 1991, Kang and Joo, 1993) and our own observations with light traps clearly indicated that *Cx tritaeniorhynchus* with nocturnal biting habits had two peaks in their activities, one soon after the sunset and another during a few hours' period from 2-3 o'clock, though the relative numbers varied by the collections and the highest peak had at different time a night.

Cx tritaeniorhynchus blood success observed in this study was sometimes a reflection of this species abundance. *Cx tritaeniorhynchus* abundance during 1992 was greater than 1991. The same relationship held true for the numbers of engorged female mosquitoes collected in those years. However, daily engorgement success was not always linked to overall mosquito abundance. In this study, *Cx tritaeniorhynchus* was the most abundant in August, but engorgement of female *Cx tritaeniorhynchus* had the highest rate in September each year.

The main factors influencing to the monthly fluctuation of engorged number of *Cx tritaeniorhynchus* during the period from 1991-1993 are not readily appeerent, it is considered to be due to meteorological conditions such as rainfall, relative humidity, and wind, etc., Day and Curtis (1989) in a study of the influence of rainfall on *Cx nigripalpus* blood feeding behaviour in Indian river county, Florida reported that *Cx nigripalpus* abundance and blood feeding behaviour was significantly associated with rainfall. This is very likely in response to the fact that rainfall raises the relative humidity, and relative humidity strongly influences mosquito flight and subsequent host-seeking behaviour (Provost, 1973).

Such consideration on the relationship between adult abundance and rainfall has also been recognized by Provost (1973) for *Cx nigripalpus*, by Olson et al. (1983) for *Cx tritaeniorhynchus* and *Cx gelidus*, and by Russel (1986) for *Cx annulirostris*

As for the survey of immature stages of *Cx tritaeniorhynchus*, Mogi(1978) conducted a study of the population dynamics on the mosquitoes in the rice field areas of Nagasaki, Japan, especially on *Cx tritaeniorhynchus*, and reported that the highest average density if *Cx tritaeniorhynchus* larvae plus pupae in uncultivated fields was 5,636 per m^2 on July 25, 1973, and in cultivated fields was 1,169 per m^2 recorded on July 14, 1971 He also stated that active reproduction occurred almost exclusively in July when oviposition and pupation rates were raised greatly by extension of suitable breeding places following transplanting of rice plants.

Baik and Joo (1991) made an epidemio-entomological survey of Japanese encephalitis in Korea, and reported that the density of *Cx tritaeniorhynchus* in rice fields was highest in mid-August, with an average number per m^2 of 14,900.

They also commented that major factors to contribute reproduction of *Cx tritaeniorhynchus* were temperature, precipitation, water management of rice fields, availability of hosts, chemical insecticides and herbicides applied to rice fields, and natural enemies, among which the first two factors were responsible for the yearly change of population size, while the changes of the mean population level was attributable to other four factors which were controlled or influenced by human beings.

From their studies on the Japanese encephalitis vectors in northern Thailand, Somboon et al. (1989) reported that the average numbers of *Cx tritaeniorhynchus* larvae plus pupae per m^2 in rice fields were highest in July when the fields were ploughed, but in the period from transplanting to harvesting, the densities were very low. In the persent survey, the total number of larval *Cx tritaeniorhynchus* in rice fields was highest in mid August, and its number progressively decreased in early September by insecticide sprays. After late September, densities showed a marked decrease and larvae plus pupae of *Cx tritaeniorhynchus* were rarely found until rice plants harvested. Similar results of peak abundance of *Cx tritaeniorhynchus* from rice fields in Kyungpook Province were recorded by Baik and Joo (1991). They also reported that the seasonal fluctuation in the larval *Cx tritaeniorhynchus* population densities in paddy water was markedly different from field to field in the same area and/or from year to year in the same field.

Summary

The seasonal prevalence and population dynamic of *Cx tritaeniorhynchus* in relation to the epidemic of Japanese encephalitis, and the biological and ecological studies of this vector mosquitoes in Kyungpook Province, Korea were made during the period 3 years from 1991 to 1993.

The peaks in the population densities of *Cx tritaeniorhynchus* as measured by light trap collections on one night per week schedules, occurred during the period from early August to mid-August, showed a simple sharply pointed one-peaked curve. There was a gradual decrease from mid September, with a very small number of them collected until late October in every year.

Cx tritaeniorhynchus with nocturnal biting habits had two peaks in their activities, one soon after the sunset and another during a few hours' period from 2-3 o'clock, though the relative numbers varied by the collections and the

highest peak had at different time a night.

The total number of larval *Cx tritaeniorhynchus* in rice fields was highest in mid August, and its number progressively decreased in early September by insecticides sprays. After late September, the larval *Cx. tritaeniorhynchus* was rarely found until rice plants harvested.

The present results indicated that the population density of *Cx tritaeniorhynchus* in Kyungpook Province was decreasing over a period of 3 years from 1991 to 1993.

Key Words Population dynamics, vector mosquito, Japanese encephalitis, Kyungpook Province, *Culex tritaeniorhynchus*, seasonal prevalence, light trap, human-baited trap

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=국문초록=

慶北地域에 있어서 日本腦炎 媒介모기의 群集變動

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慶北地域에 있어서 日本腦炎媒介모기, 작은 빨간 집모기의 季節的 出現 消長, 群集變動과 生物生態學的 調査를 하기 위하여 1991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함과 아울러 慶北農村 振興院 附屬農場에서 모기 幼蟲 分布狀을 觀察하였다.

작은 빨간 집모기의 最大 密度時期는 8月 初旬에서 中旬사이 였으며, 그后 점점 減少하여 11月 初旬에서는 採集되지 않았다.

작은 빨간 집모기 夜間 活動性은 저녁 9~10時 사이에 가장 活潑하였으며, 그 后 漸次 減少하다가 새벽 1~2時에 다시 若干 增加하였다.

작은 빨간 집모기 幼蟲은 8月 中旬에 그 密度가 가장 높았으며, 最高群集密度는 $1m^2$ 當 平均數는 264×10^3이었다. 9月 下旬 以后부터는 그 密度가 顯著히 減少하였다.

以上의 成績으로 미루어 보아 작은 빨간 집모기는 8月 初旬에서 中旬사이에 最大密度를 나타내었으며, 每年 減少되고 있다고 判斷된다.