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Seasonal Prevalence of the Vector Mosquitoes of Japanese Encephalitis Virus in Kyungpook Province, Korea

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INTRODUCTION

The ecology and epidemiology of vector mosquitoes of Japanese encephalitis virus (JEV) through laboratory and field studies in Japan and eastern Asia have been carried out extensively, and a great deal of work has been conducted on the ecology of *Culex tritaeniorhynchus* in Japan, as was reviewed by Suzuki and coworkers(1967), but only a few studies on vector mosquitoes in Korea have been published.

From his studies on the seasonal prevalence of mosquitoes in Korea, Kobayashi(1929) reported for the first time that *Anopheles sinensis* was the most predominant species between July and August, and that biting habits of this species appeared to be active throughout the whole night, but were more active during darkness, after sunset to midnight.

Little work on the vector mosquitoes was done before the end of World War II, although *C. tritaeniorhynchus* was thought to be the main vector of JEV in Korea because the species is the main vector in Japan, according to extensive studies of a period of over six years by Scherer and coworkers(1959).

After the Korean War, studies on vector mosquitoes have been conducted by Lee(1966) in Seoul area, Self and coworkers(1973) in Pusan, Seoul and Sintain areas, Ree and coworkers(1975) in Pohang area, and Frommer and coworkers(1977 and 1979) in U.S. military installations located in Korea.

In the recent study, the distribution and abundance of mosquitoes collected from U.S. Army compounds throughout the Republic of Korea using New Jersey light traps have been reported by Lee and coworkers(1984).

Kyungpook Province is situated in the southeast portion of Korea, and is under the influence of a typical east-coast continental climate.

Every year a few cases of JE in this Province have been reported. However, studies on the vector mosquitoes of JEV have not been undertaken in the Province because of the lack of attention given to the problem of mosquito-borne diseases.

The present study attempts to estimate the population density and seasonal prevalence of vector mosquitoes and obtain informations concerning the prevention of human JE infections.

* This survey was supported by a grant from the Ministry of Education, Republic of Korea, and the results were presented at the spring meeting of the Korean Society for Parasitology (1985).

GEOGRAPHICAL CONDITIONS OF STUDIED AREAS

Two areas in Kyungpook Province were selected as present study stations.

1. Keimyung University training farm in Kyungsan county was the main study area for this year: It is located about 15 kilometers E. S.E. of Taegu city, situated on a low hill studded with copse, orchards, small rice fields and several swamps(Fig. 1).

The farm covers an area of 234,711 square meters and consists of pasture, animal shelters, vinyl houses and human dwellings.

Large numbers of cattle, pigs, fowls, dogs, sheep and deer are raised in this farm but there are no wild animals which could be important as hosts of vector mosquitoes.

2. Sopyung village in Ankang town: This situated about 80 kilometers E.S.E. of Taegu city, about 20 meters above sea level, and surrounded by rice paddies.

The village of Sopyung is composed of some

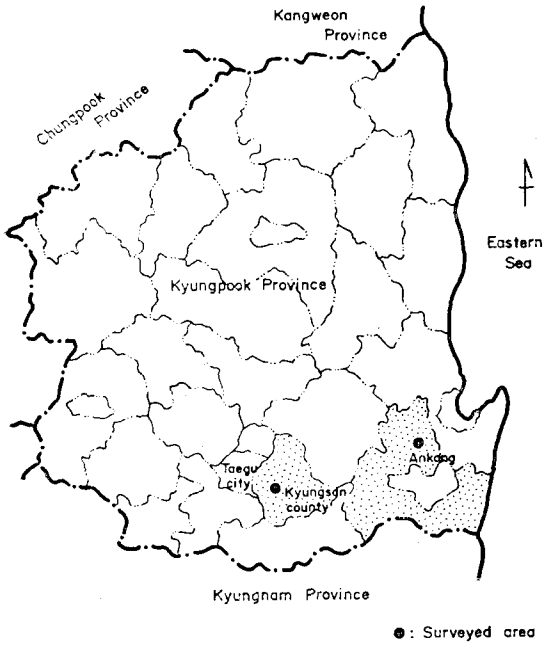

Fig. 1. Surveyed areas in Kyungpook Province, Korea.

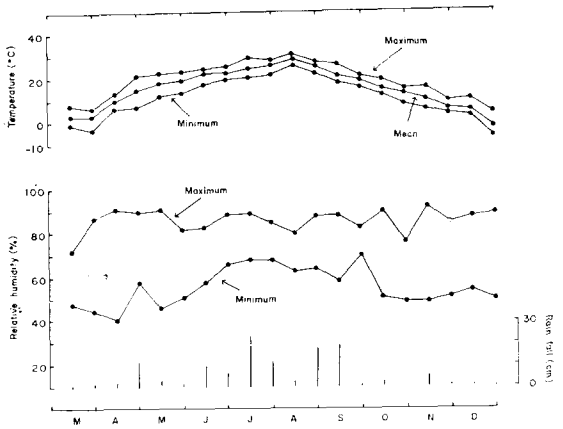

Fig. 2. Fortnightly mean, maximum and minimum temperature, relative humidity and total rain fall(cm) reported by Regional Meteorological Centre in Taegu, Korea during 1984.

40 households and about 200 residents, and has several cowsheds and piggeries, of which one was selected as mosquito study station.

The study areas are under the influence of a typical continental climate of the eastern coast affected by both high atmospheric pressure from the cold continent and low one from the Pacific Ocean in the summer season.

Therefore, seasonal fluctuation of air temperatures and precipitation, which is of fundamental importance to understand the dynamics of mosquito populations, is very large.

Meteorological data in this study are based on Monthly Reports of the Taegu branch of the Korea Meteorological Agency(Fig. 2).

MATERIALS AND METHODS

The following methods were used mainly for the collections and observations of the mosquitoes in the study areas.

Light traps: In order to observe the seasonal prevalence of the vector mosquito populations, light trap collections were performed as follows: These light traps were located at two sampling spots, the piggery A and the human dwelling B.

A light trap was fixed at 1.5m above the ground at a trapping spot, and operated from dusk to dawn on one-night per week schedules.

Human baited traps: In order to determine the relative numbers and species of mosquitoes which were attracted by human beings, human baited traps were performed as follows: A man was allowed to lie on the floor of a room 2.2× 2.0 meters and 2.5 meter in height. An open window 1.5×1.0 meter permitted entry of mosquitoes.

All mosquitoes biting or attempting to bite were collected between 19:00 and 06:00 hours on one-night per month schedules.

Collection of resting mosquitoes: In order to determine the resting places of mosquitoes in day-time, oral aspirators and hand nets, about 40cm in diameter, made of fine mosquito netting were used to catch adult mosquitoes resting in the human and animal shelters.

Sorting and counting of mosquito specimens: All the mosquito specimens were individually examined for species under a stereomicroscope and counted.

Collection of larvae: The mosquito larvae were collected from their breeding places by means of a short-handled dipper 15cm in diameter and were identified for species as by Tanaka and coworkers (1979).

RESULTS

Table 1 presents the numbers and species of mosquitoes collected by various methods in Kyungpook Province, and indicates that four genera and fourteen species were collected and identified.

The relative prevalence of various species of mosquitoes in the Kyungsan county and Ankang town, Kyungpook Province are indicated in Table 2.

The 34,571 mosquitoes identified in Kyungsan county were derived from collections by the light traps, from the human dwellings, and from the animal shelters at the animal breeding farm of Keimyung University.

It may be noted that *C. tritaeniorhynchus* comprised approximately 45.0 per cent of the total number, that *C. pipiens pallens* came next with approximately 34.0 per cent, and *A. sinensis* were approximately 19.0 per cent of the total.

The percentages of the remaining six species were very low.

However, quite a different distribution of various species of mosquitoes was encountered in Ankang town, in which JE had been reported in the past, as shown by this survey.

Of the 13,075 mosquitoes identified, *A.*

Table 1. Species of mosquitoes identified in Kyungpook Province (1984)

Species
Anopheles sinensis Wiedemann
Anopheles sineroides Yamada
Aedes vexans nipponii (Theobald)
Aedes albopictus (Skuse)
Aedes hatorii Yamada*
Aedes togoi (Theobald)
Culex pipiens pallens Coquillett
Culex pipiens form molestus Forskal
Culex vagans Wiedemann
Culex tritaeniorhynchus Giles
Culex orientalis Edwards*
Culex halifaxii Theobald*
Culex hayashii hayashii Yamada*
Armigeres subalbatus (Coquillett)

* These were collected mainly as larvae

Table 2. Relative prevalence of various species of mosquitoes by light traps in two localities of Kyungpook Province, Korea(1984)

Species	Kyungsan county		Ankang town	
	No. collected	% to total	No. collected	% to total
A. sinensis	6,529	18.9	9,908	75.8
A. sineroides	118	0.3	32	0.2
A. vexans nipponii	261	0.8	10	0.08
A. albopictus	48	0.1	0	0
C. pipiens pallens	11,875	34.3	73	0.6
C. vagans	174	0.5	11	0.08
C. tritaeniorhynchus	15,516	44.9	3,027	23.2
C. orientalis	20	0.06	0	0
A. subalbatus	30	0.09	13	0.01
Total number of all species	34,571		13,075	

Table 3. Number of the *Culex tritaeniorhynchus* collected by two light traps (1984)

Date of mosquito collection		Light trap A		Light trap B	
		Female	Male	Female	Male
May	30	0	0	0	0
June	7	0	0	0	0
	14	0	0	0	0
	20	7	1	0	0
	28	8	0	2	0
July	5	11	3	13	1
	11	9	2	10	0
	20	169	5	45	3
	26	396	8	113	14
August	4	424	30	156	18
	10	736	21	357	11
	16	813	43	275	38
	22	1,784	48	287	13
	28	4,394	42	374	62
September	4	1,824	14	289	5
	11	635	19	90	7
	17	178	10	33	5
	23	104	3	17	2
	30	19	0	20	1
October	3	2	0	1	1
	13	0	0	0	0
	19	0	0	0	0
	26	0	0	0	0
November	3	0	0	0	0

Remark: Light trap A; Piggery
B; Human dwelling

sinensis was the most abundant species, being constituted in 75.8 per cent, followed by *C. tritaeniorhynchus* (23.2 per cent), and *C. pipiens pallens* (0.6 per cent).

The seasonal prevalences of *C. tritaeniorhynchus* collected by the light traps are summarized in Table 3 and illustrated by Fig. 3.

In general, *C. tritaeniorhynchus* was collected in five months, from June to October in 1984.

The numbers of this species collected by traps were approximately equal in mid-July and in late-September between the two sampling spots, the piggery and human dwelling.

In the periods from July 11th to September 30 th, the numbers of *C. tritaeniorhynchus* collected

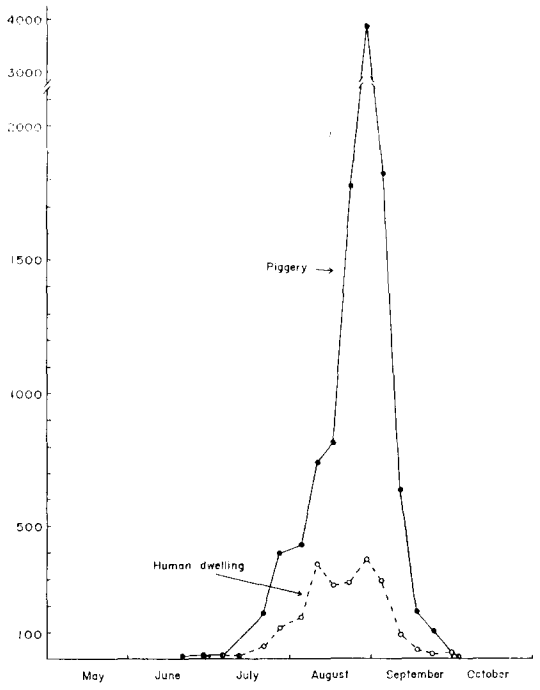

Fig. 3. Seasonal changes in the number of *Culex tritaeniorhynchus* collected by light traps in Kyungpook Province, Korea, 1984.

at the human dwelling was about one-third or one-fourth of those at the piggery in every survey night.

C. tritaeniorhynchus began to appear from June 20th, and peak in its distribution was found on August 28th. There was a gradual decrease from mid-September, with a very small number of them collected until early October, in both traps.

The first appearance of male *C. tritaeniorhynchus* was observed on June 20th in the light trap A, and on July 5th in light trap B.

The seasonal prevalence of the three mosquito species by the average numbers collected in each decade are summarized in Table 4 and illustrated in Fig. 4.

Of the three species of mosquitoes collected by the light traps, female *C. tritaeniorhynchus* was the most commonly found mosquito, being found in 36.7 per cent, followed by female *C. pipiens pallens* in 28.1 per cent.

Table 4. Seasonal prevalence of three main mosquito species by the average numbers collected each decade with light traps in Kyungpook Province, Korea(1984), together with meteorological data

Period	No.		Temperature (Range C)	Humidity (Range %)	*Anopheles sinensis*	*Culex pipiens pallens*	*Culex tritaeniorhynchus*
May	Ⅲ	1	11.3~23.6	56~82	2.0	3.0	0
June	Ⅰ	2	17.9~25.1	58~83	5.5(2.0)*	85.0(21.5)	0
	Ⅱ	6	21.9~25.0	60~86	5.0	433.5(53.5)	1.2(0.2)
	Ⅲ	3	19.9~25.8	66~89	70.7(5.7)	407.7(230.0)	4.7(1.0)
July	Ⅰ	3	21.2~29.9	68~89	259.0(96.3)	1,039.0(682.3)	9.7(4.3)
	Ⅱ	6	20.9~28.6	68~86	384.3(48.3)	375.3(200.3)	60.8(6.0)
	Ⅲ	4	23.4~28.9	68~85	404.8(32.8)	554.5(258.0)	214.0(16.5)
August	Ⅰ	8	27.8~31.6	61~78	268.3(44.0)	225.8(25.5)	209.1(10.0)
	Ⅱ	4	24.8~31.1	63~83	106.8(15.0)	91.5(17.5)	348.0(11.3)
	Ⅲ	8	23.0~27.9	64~88	212.0(13.3)	236.3(17.0)	1,008.4(19.4)
September	Ⅰ	4	19.6~27.6	58~88	52.5(5.8)	107.5(8.3)	528.3(4.8)
	Ⅱ	8	19.0~22.2	65~83	50.0(4.8)	77.3(20.0)	104.6(5.2)
	Ⅲ	8	16.3~21.9	70~83	12.8(3.0)	46.3(17.5)	20.1(0.8)
October	Ⅰ	4	13.3~20.1	51~90	1.0(0.3)	8.8(7.3)	1.8
	Ⅱ	8	15.2~18.0	65~81	0.3	3.8(1.8)	0
	Ⅲ	4	9.3~16.7	49~76	0 (0.3)	0.3(0.5)	0
November	Ⅰ	4	9.4~16.9	44~90	0	0.5	0
Total		85			6,525(1,619)	11,875(6,243)	15,516(465)
Ratio %					15.5(3.8)	28.1(14.8)	36.7(1.1)

Remark: No. : Times of collection in the respective decades.
Ⅰ : First decade, Ⅱ : Middle decade, Ⅲ : Last decade of the month
* : Number in parentheses means the average number of males.

Table 5. The results of overnight mosquito collections on human baits on two nights, July 17~18 and August 3~4, 1984 in Kyungpook Province (1984)

Hour	Human baits			
	*C. trit.**	*C. p. pallens*	*A. sinensis*	Others**
July 17~18				
19:00~20:00	0	0	14	5
20:00~21:00	3	0	18	7
21:00~22:00	1	0	63	2
22:00~23:00	1	0	216	0
23:00~24:00	7	2	298	0
24:00~01:00	12	1	391	0
01:00~02:00	8	7	269	0
02:00~03:00	8	7	328	0
03:00~04:00	7	4	185	0
04:00~05:00	4	0	62	2
05:00~06:00	0	0	3	0
Subtotal	51	21	1,847	16
August 3~4				
19:00~20:00	3	0	2	1
20:00~21:00	10	0	12	0
21:00~22:00	18	1	29	0
22:00~23:00	8	4	17	0
23:00~24:00	15	4	18	0
24:00~01:00	17	0	26	0
01:00~02:00	11	0	7	0
02:00~03:00	6	3	12	0
03:00~04:00	3	0	9	0
04:00~05:00	6	0	1	0
05:00~06:00	0	0	0	3
Subtotal	97	12	131	4

* *C. trit.* means *C. tritaeniorhynchus.*
** Others include *C. vagans, Aedes vexans nipponii* and *A. subalbatus.*

Male *A.sinensis* and male *C. tritaeniorhynchus* were less prevalent, 3.8 per cent and 1.1 per cent, respectively.

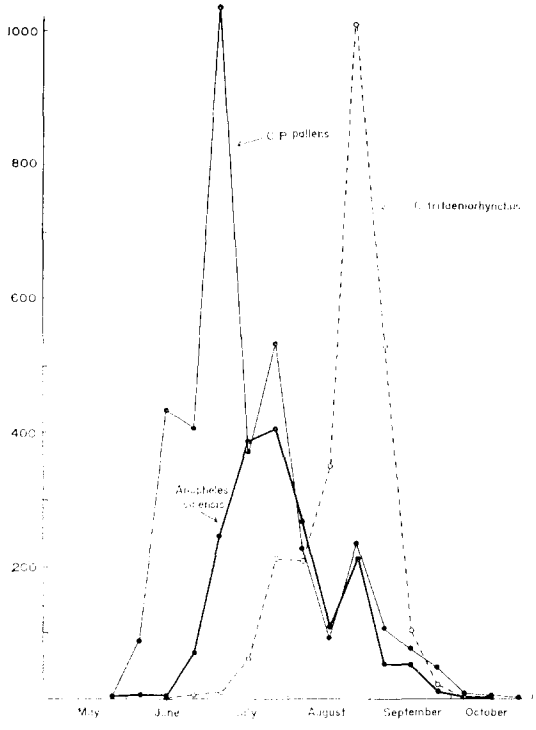

Fig. 4. Seasonal prevalence of *Culex pipiens pallens*, *Culex tritaeniorhynchus* and *Anopheles sinensis* collected by light traps in 1984.

The general pattern of seasonal prevalence of the principal mosquito species during the year were found to differ essentially according to the species.

C. tritaeniorhynchus first appeared in mid-June, and trapped in large numbers during the periods from mid-August to early September, showing a simple sharply pointed one-peaked curve, while *C. pipiens pallens* was found to be active through almost the entire season showing irregular curves with several peaks.

The trend of seasonal distribution of *A. sinensis* was similar to that of *C. tritaeniorhynchus*, but the earliest dates of appearance and disappearance differed from that of *C. tritaeniorhynchus*.

The results of the numbers and species of mosquitoes which fed or attemped to feed on the human being from 19:00 until 06:00 on July 17~18, and August 3~4 in 1984 are shown in Table 5 and illustrated in Fig. 5.

Table 6. Hourly night catches of mosquifoes by light traps off cow baits, in two nights, July 17~18 and August 3~4, 1984 in Kyungpook Province (1984)

Hour	Light traps			
	C. trit.	*C. p. pallens*	*A. sinensis*	Others**
July 17~18				
19:00~20:00	1	0	30	0
20:00~21:00	55	4	474	3
21:00~22:00	17	3	451	1
22:00~23:00	48	0	127	0
23:00~24:00	18	0	518	0
24:00~01:00	21	3	539	0
01:00~02:00	16	0	572	0
02:00~03:00	45	0	822	0
03:00~04:00	88	0	1,365	0
04:00~05:00	3	2	300	2
05:00~06:00	0	0	7	0
Subtotal	312	12	5,805	6
August 3~4				
19:00~20:00	11	0	12	1
20:00~21:00	7	0	34	3
21:00~22:00	2	0	85	3
22:00~23:00	18	5	26	0
23:00~24:00	5	1	10	0
24:00~01:00	12	4	41	0
01:00~02:00	0	0	36	0
02:00~03:00	3	0	38	0
03:00~04:00	0	0	25	0
04:00~05:00	1	0	8	1
05:00~06:00	0	0	0	4
Subtotal	59	10	315	12

* *C. trit.* means *C. tritaeniorhychus.*

** Others include *C. vagans*, *A. vexans nipponii* and *A. subalbatus.*

Six species, *A. sinensis*, *C.pipiens pallens*, *C. tritaeniorhynchus*, *C.vagans*, *Aedes vexans nipponii*, and *Armigeres subalbatus*, were collected.

Among these species, *A. sinensis*, *A. vexans nipponii*, and *C. tritaeniorhynchus* attempted to feed from 19:00 onward, but *A. subalbatus* bit before 21:00 and after 04:00 a.m. The hourly distributions of these mosquitoes were all different.

The peak number of *A. sinensis* on human

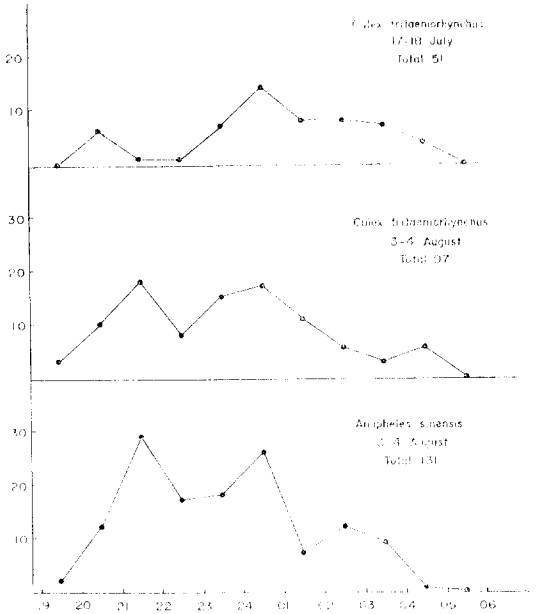

Fig. 5. Biting rhythm of *Culex tritaeniorhynchus* and *Anopheles sinensis* as observed by the number of mosquitoes biting on human beings.

beings was 391 between 24:00~01:00 on July 17~18, and 29 between 21:00~22:00 on August 3~4, but *C. tritaeniorhynchus* showed two peaks, one between 21:00~22:00 and another between 24:00~01:00 on August 3~4.

C. pipiens pallens was distributed nearly constantly between 23:00~04:00, and *A. vexans nipponii* disappeared after 22:00.

Hourly catches of mosquitoes by light traps were made at the Kyungpook Province on two nights, July 17~18 and August 3~4 in 1984.

The total numbers of mosquitoes by species and hour are tabulated in Table 6.

The trend of nocturnal activity of *C. tritaeniorhynchus* and *A. sinensis* is roughly summarized as follows: On becoming dark *C. tritaeniohynchus* and *A. sinensis* become very active, gradually decreasing in activity towards midnight, however, slightly increasing towards dawn.

COLLECTIONS OF LARVAL POPULATIONS

These surveys were made on various species of larval mosquitoes which are found in certain breeding places in Kyungpook Province.

As shown below, an attempt has been made to classify larval habitats according to size, degree of persistence of the breeding water and

Table 7. The reported average number per trap-night of *C. tritaeniorhynchus* by month in Korea

Source	Localities	May	June	July	August	September	October	Remarks
Lee *et al.* (1969)	Seoul	0	1.0	11.5	8.3	7.0	0	Results of 1965
Shin *et al.* (1971)	Seoul	0	0.1	15.4	108.6	60.3	0.1	
	Pusan	0	1.2	111.7	745.7	363.7	0.1	
	Suwon	0	0.1	2.1	17.0	2.2	0	
Self *et al.* (1973)	Pusan	0.3	1.0	110.0	375.0	401.0	—	Results of 1971
	Sintain	0	3.0	258.0	25.0	2.0	—	
	Seoul	0	0	16.0	99.0	84.0	—	
Pae *et al.* (1976)	U.S. Army installations and Chinju	—	0.04	2.1	6.6	1.7	—	Results of 1974
	Yosu & Taesungdong	—	0.01	0.4	2.9	2.4	0.3	Results of 1975
Frommer *et al.* (1977)	U.S. Army installations and Cheju city Yosu, Taesungdong	0	0.01	0.9	3.6	1.7	—	Results of 1976
Frommer *et al.* (1979)	U.S. Army installations	0	0	1.1	10.7	5.3	—	Results of 1977
Lee *et al.* (1984)	U.S. Army compounds	0	4.4	253.1	665.5	144.6	4.9	Results of 1979~80
Authors (1985)	Kyungpook Province	0	2.3	96.2	556.6	155.6	0.4	Results of 1984

type of water designated.

A. Large or medium size habitats:

1. Swamps or marshes: The larvae of *A. sinensis* and various *Culex* species, especially those of *C. tritaeniorhynchus* and *C. pipiens pallens* are to be found in them.

2. Streams and rivers: The cool streams at the foot of mountains provide special breeding places for *C. hayashii hayashii*, which in sluggish streams larvae of *C. tritaeniorhynchus*, *C. orientalis* and *A. sinensis* were found.

3. Rain pools and puddles: In rain pools and pools on river banks created by inundation are found the larvae of *C. pipiens pallens*, *C. tritaeniorhynchus*, *A. sinensis* and *A. sineroides*.

4. Rice fields: Relatively large numbers of larvae of *C. tritaeniorhynchus*, *A. sinensis*, *A. vexans nipponii*, and *C. pipiens pallens* were found in this Province.

5. Surface ditches for the evacuation of waste water or for drainage of temporary waters: In ditches with foul water, there are many larvae of *C. pipiens pallens*. Whereas the water is clear and some green algae on the surface *C. tritaeniorhynchus*, *A. sinensis*, and *C. orientalis* may be found.

6. Parsley fields: Relatively large numbers of larvae of *C. triaeniorhynchus*, *C. orientalis*, *C. pipiens pallens* and *A. sinensis* are found.

B. Small well defined habitats:

1. Bamboo holes and tree holes containing rain water larvae of *A. albopictus* are to be found.

2. Rock holes on stream bed containing water constitute special breeding places for the larvae of *A. hatorii*, while tidal pools of salty or brackish water contain the larvae of *A. togoi*.

3. Artificial containers: Containers such as water cisterns, earth pots for storage of water, empty tins and rubber tires have the larvae of *A. albopictus* and *C. pipiens pallens*.

4. Concrete pools: The pools containing water constitute special breeding places for the larvae of *C. pipiens pallens*, *C. halifaxii* and *A. sinensis*, etc.

5. Cesspools: Cesspools containing human and animal excrement provide special breeding places for the larvae of *Armigeres subalbatus*. However, if those contents are diluted by rain water, *C. pipiens pallens* may also breed well.

DISCUSSION

Since describing the establishment of experimental infections of JEV to *C. tritaeniorhynchus* and isolation of the virus from them in nature by Mitamura and coworkers(1937), the ecological, sero-epidemiological and virological studies on the subject of vector mosquitoes have been carried out by many investigators.

As a result, it has been demonstrated that *C. tritaeniorhynchus* plays the important role in transmitting JE virus in the epidemic season.

The seasonal prevalence of the various species of mosquitoes in Japan and eastern Asia was clearly demonstrated by a number of workers, and that of *C. tritaeniorhynchus* was found to show a peculiar sharply pointed curve coincident with the occurrence of the JE among human populations.

The surveyed areas in this study are under influence of a typical east-coast continental climate, and a few cases of JE occurred practically every year.

However, the details of the ecology of various vector mosquitoes have not yet been studied in this Province because of the lack of attention given to the problem of the mosquito-borne disease.

A little factual work on the vector mosquitoes in Korea was done before the end of World War II, although *C. tritaeniorhynchus* was thought to be the main vector of JEV because the mosquito species is the main vector in Japan and eastern Asia.

After the Korean War, the epidemiological and virological studies on the vector mosquitoes in Korea have made remarkable progress through the labors of medical entomologists serving in the U.S. military services.

Members of the 406th Medical General Laboratory U.S. Army in their studies on the isolation

of Japanese encephalitis virus from wild caught mosquitoes in Pusan area in the summer of 1958, found one strain of the virus from *C. tritaeniorhynchus.*

Ten years later, Lee and coworkers(1969) conducted a survey for JEV isolation from mosquitoes collected in Seoul area in the summer of 1965.

From their mosquito survey, it was found that *C. pipiens pallens* was the most prevalent mosquito species and next in order were *A. sinensis*, *A. vexans nipponii*, with *C. tritaeniorhynchus* taking 4th place.

They also reported that 5 strains of JE virus were isolated from *C. tritaeniorhynchus*, one strain from *A. vexans nipponii*, and two strains from overwintering *C. pipiens pallens*, and claimed that the main vector of JE virus in its season in Korea was *C. tritaeniorhynchus.*

A study of Shin and coworkers(1971) reported that the population density of *C. tritaeniorhynchus* by month were 0.1 per cent in June, 8.1 per cent in July, 55.2 per cent in August and 36.6 per cent in September, respectively, and also commented that the population densities of *C. tritaeniorhynchus* were remarkably different between urban and rural areas, *i.e.* high population densities in the vicinity of large and newly developing cities, and low prevalence in the rural areas.

Similar results in vector mosquitoes have been obtained by Self and coworkers (1973), Pae and coworkers (1976), Frommer and coworkers (1977), Frommer and coworkers(1979), and Lee and coworkers(1984) in U.S. Army Compounds located in Korea.

In the present study, four genera and fourteen species were collected by the various methods of light traps, human baited traps, resting mosquito collections by nets, and larval collections.

The results in this study are similar to those reported by Shin and coworkers(1971), Pae and coworkers(1976), Frommer and coworkers (1976), and Lee and coworkers(1984).

However, they differ considerably in the number of genera and species of mosquitoes collected, *i.e.*, nine genera and forty-seven species reported by Lee(1971), and eight genera and forty-two species by Chow(1973).

These differences may be due to the collection techniques, geographical variations, or general changes in the population distribution of various mosquito species and the climatic variations.

The results presented in Table 3 indicate the difference in the numbers of the *C. tritaeniorhynchus* collected by light traps between two sampling spots, one piggery and the other human dwelling.

This is corroborated on other studies such as those of Wada and coworkers(1967), who noted that *C. tritaeniorhynchus* is strongly zoophilic and probably to a lesser extent ornithophilic.

When monthly decade light trap collections of *A. sinensis* and *C. pipiens pallens* are compared with those of *C. tritaeniorhynchus*, it was shown that *C. tritaeniorhynchus* represented about 70.0 per cent of the total numbers in mid-August and early September, while *A. sinensis* was only dominant in mid-July and high population of *C. pipiens pallens* appeared during the periods of May and July.

This confirms generally the results of the distribution and abundance of mosquitoes which have been reported in Korea(Table 7).

The results given in Table 5 and 6 indicate that the patterns of nocturnal activity of various species of mosquitoes was not always similar by collection methods even on the same night.

It has been known that environmental factors such as wind-born stimuli, humidity, light, and temperature, *etc.* are essential in determining the attractions of mosquitoes.

Although these factors should be important in determining the attraction of mosquitoes, the present data can not be explained fully only by the hourly changes of these factors because the meteorological conditions were considered nearly the same at least on the same night at the sites, where the collections were made.

In this study, the hourly distribution of the collected females of *C. tritaeniorhynchus* usually

had two peaks, one between 21:00-22:00 and the other between 24:00-01:00 on August 3-4.

This is generally consistent with the results reported by Wada(1966), by Wada and coworkers(1970), and Mogi and coworkers(1979).

It this study, four genera and fourteen species of mosquito larvae collected at eighteen kinds of habitats which classified according to the categories followed by Bates(1949).

In general, it is known that the classification of larval habitats does not always coincide, because the characteristics and the criteria adopted by each investigators are more or less different.

The main breeding sites contributing to peak *C. tritaeniorhynchus* adult densities in this surveyed areas were evidently ricefields, ground pools, puddles and swamps, *etc.*

Similar results in larval collections from the habitats have been obtained by Self and coworkers(1973), and Lee and coworkers(1984).

It was found that seasonal prevalence of *C. tritaeniorhynchus* first appeared in mid-June and were trapped in large numbers during the period from mid-August to early September, showing a simple sharply pointed one-peaked curve, and it is clearly emphasized that the prevention of JE infections is possible with extensive public health education concerning mosquito-borne diseases, early identification of vector mosquitoes of JE virus each year, large-scale aerial insecticidal treatments, and means of anti-mosquito measures directed at killing the engorged mosquitoes in their animal shelters.

SUMMARY

In order to determine the seasonal prevalence and population density of vector mosquitoes in Kyungpook Province, a survey based on average numbers of female mosquito per trap-night, were carried out during the period from May to November in 1984.

Among the 34,571 mosquitoes collected in Kyungsan county in animal shelters and human dwellings by light traps, approximately 45.0 per cent were *Culex tritaeniorhynchus*, 34.0 per cent *Culex pipiens pallens*, and 19.0 per cent *Anopheles sinensis*.

By comparison, distribution of mosquito species in Ankang town, in which Japanese encephalitis had been reported in the past, were quite different and *A. sinensis* was the most abundant species, being constituted in 75.8 per cent, followed by *C. tritaeniorhynchus*(23.2 per cent), and *C. pipiens pallens*(0.6 per cent).

In the general pattern of seasonal prevalence, *C. tritaeniorhynchus* first appeared in mid-June, and trapped in large numbers during the periods from mid-August to early September, showing a simple sharply pointed one-peaked curve, while *C. pipiens pallens* was found to be active through almost the entire season showing irregular curves with several peaks.

The trend of seasonal distribution of *A. sinensis* was similar to that of *C. tritaeniorhynchus*, but the earliest dates of appearance and disappearance differed from that of *C. tritaeniorhynchus*.

The results of hourly catches of mosquitoes by human baited traps have clearly shown the differences in the biting rhythm among the vector mosquitoes of this Province, such as the facts that *C. tritaeniorhynchus* and *A. sinensis* are rather constantly active all through a night with more or less inconspicuous peaks twice a night, while *C. pipiens pallens* exhibits an irregular curve, and the numbers of *A. vexans nipponii*, *C. vagans* and *Armigeres subalbatus* are very small and are not sufficient for estimating the biting rhythm.

Four genera and fourteen species of larval mosquitoes collected from eighteen kinds of habitats which classified according to the categories followed by Bates (1949).

The main breeding sites contributing to peak *C. tritaeniorhynchus* adult densities in this surveyed areas were evidently ricefields, ground pools, puddles and swamps and marshes, *etc.*

Summarizing the results, this study indicated that the highest population density of *C. tritaeniorhynchus* was encountered in late August

and early September, showing a simple sharply pointed one-peaked curve.

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＝國文抄錄＝

慶北地域에서의 日本腦炎 媒介모기의 出現 消長

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1984年 5月부터 11月까지 6個月間 慶北地域에서 出現하는 모기의 種類와 그 生態를 調査함과 아울러, 誘蚊燈에 의한 媒介모기의 季節的 出現 消長을 觀察하였다.

調査 期間中에 採集된 모기의 種類는 4屬 14種이었으며, 其中 *Culex tritaeniorhynchus* Giles(작은 빨간집모기), *Anopheles sinensis* Wiedemann(중국얼룩날개모기), *Culex pipiens pallens* Coquillett(빨간집모기), 3種이 優占種으로 全 採集數의 95.5%를 차지하였다.

地域別로는 慶山郡에서 採集한 모기 34,571마리 중 *C. tritaeniorhynchus*가 44.9%로 가장 많았고, 그 다음은 34.3%를 나타내는 *C. pipiens pallens*였으며, *A. sinensis*는 18.9%로 中間値를 나타내었다.

이에 反하여 腦炎患者의 多發性 地域인 安康邑에서 採集한 모기 13,075마리 중, *A. sinensis*가 75.8%로 가장 많았고, *C. tritaenorhynchus*는 23.2%, *C. pipiens pallens*는 0.6%였다.

調査地域에서 *C. tritaeniorhynchus*를 처음으로 採集할 수 있는 時期는 6月 中旬이었으며, 이 期間中 氣溫은 21.9°C～25.0°C, 濕度는 60～80%, 그 密度(Average number of female mosquito/trap-night)는 1.2마리였다.

*C. tritaeniorhynchus*의 最大 密度時期는 8月 下旬에서 9月 初旬 사이었으며, 그 期間中 氣溫은 23.0°C～27.9°C, 濕度는 64～88%였고, 最大密度는 1,008.4마리였다.

媒介모기의 夜間 吸血 活動性을 알아보기 위해 7月 17～18日과 8月 3～4日 2回에 걸쳐 저녁 19時부터 그 다음날 아침 6시까지 1時間 간격으로 모기를 採集하였다.

*C. tritaeniorhynchus*의 活動이 가장 活潑한 時間은 21時에서 22時, 24時에서 1時 사이였으며, 아침 5時 以後에는 한마리도 採集할 수 없었다.

調査 地域에서 採集한 幼蟲은 飼育室로 옮겨 種을 同定 하였던 바, 4屬 14種이었으며, 每年 社會的으로 問題가 되는 腦炎 媒介種인 *C. tritaeniorhynchus*의 幼蟲棲息處는 畓, 웅덩이, 작은 연못, 늪, 미나리논 및 소택지 등이었다.

以上의 成績으로 미루어 보아 腦炎 媒介 모기, *C. tritaeniorhynchus*는 6月 中旬에 처음으로 出現하며, 8月 下旬과 9月 初旬에 最大 密度를 나타내었고, 10月 中旬 부터는 採集할 수 없음을 알았다.