기 생 충 학 잡 지 제 30권 제 4호
The Korean Journal of Parasitology
Vol. 30, No. 4, 329-340, December 1992

Epidemio-entomological survey on malarial vector mosquitoes in Kyongbuk, Korea*

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Abstract: In order to determine population dynamics of *Anopheles sinensis*, a survey based on average number of female mosquitoes per trap-night was carried out during the period of 5 years from 1987 to 1991. *A. sinensis* first appeared between the 2nd and 20th April, and were trapped in large number between the 5th and 12th July. The number of trapped mosquitoes began to decrease from mid-August, and a few were collected until mid-November, each year. The average number of *A. sinensis* in July was 542.6 per trap-night in 1987, but in 1989 increased abruptly to 1,331.4, and then decreased to considerably lower levels, 271.9 in 1990 and 372.1 in 1991. The nocturnal activity of *A. sinensis* to attack humans was found to become active in the early night, and it was gradually decreasing at mid-night, however, then slightly increasing toward dawn. The immature stage of *A. sinensis* in the rice paddies was first found in the correlation pattern with peak adult densities in early July. The highest larval density of *A. sinensis* in the study area was $21,226\times10^3$ in early July 1990. The larval *A. sinensis* showed high resistance level and resistance ratios against 3 kinds of organophosphorous compounds, diazinon, malathion, and fenitrothion, but low resistance against fenthion. The present results indicated that the population density of *A. sinensis* in Kyongbuk area is decreasing over the five-year from 1987 to 1991.

Key words: *Anopheles sinensis*, seasonal prevalence, population dynamics, Kyongbuk Province.

INTRODUCTION

Malaria due to *Plasmodium vivax* had been one of the most important and widely spread protozoan diseases in Korea. After the beginning of the New Community project in the third "Five-year economic development plan" in 1972, the Korean Government 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, reformation of land, improvement of agricultural technique, and intense use of agricultural chemicals. However, increased rice production inevitably resulted in the expansion of mosquito larval habitats, and introduced important changes in the agroecosystems which would influence the distribution and abundance of mosquitoes. Furthermore, rice paddies also produced important vectors of malaria and Japanese encephalitis.

Recently Joo and Wada (1985) conducted the seasonal prevalence and population density of vector mosquitoes in Kyongbuk Province. Every year a few cases of malaria in Korea have been

* This study was supported in part by NON Directed Research Fund, Korea Research Foundation, 1991 and presented at the Spring meeting of the Korean Society for Parasitology (1991).

noted, although the innate cases of malaria are said to have disappeared in Korea since 1980, it was considered to be due to lack of attention given to the problem of mosquito borne diseases. Kyongbuk Province is situated in the south-eastern part of Korea, and some endemic foci of malaria in northern counties of the Province were found during a malaria survey in 1960~1962. The present study attempts to estimate the population dynamics of vector mosquitoes in Kyongbuk Province from 1987 to 1991, and to estimate the present status of malaria infections among residents in the former endemic area.

MATERIALS AND METHODS

Surveyed areas: Kyongbuk Province is situated in the southeast part of the Korean peninsula, having an area of 19,700 square kilmeters. Three areas, Keimyung University training farm in Kyungsan-gun, the Agricultural research farm in Kyongbuk Provincial office of Rural development in the northern district of Taegu city, and Yeongpung-gun county in the northern Kyongbuk Province, were selected as the survey stations (Fig. 1). The more detailed geographical conditions of surveyed areas were presented by Baik and Joo (1991) and Lee *et al.* (1986).

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 1.5 m 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 *A. sinensis*, mean per cent index (MPI) which was proposed by Maeda *et al.* (1978) was used.

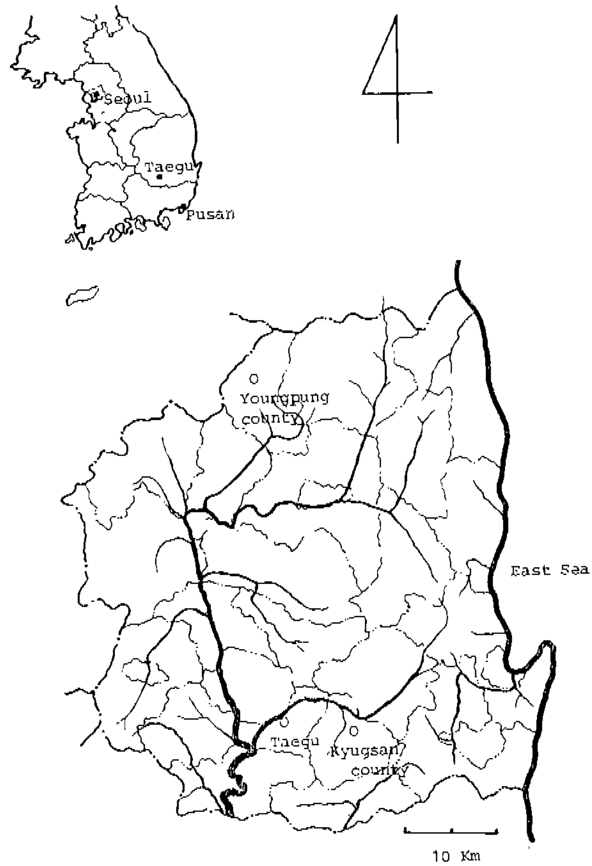

Fig. 1. Surveyed areas (O) in Kyongbuk Province, Korea.

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

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 was 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 the number of follicular relics was determined. After this, all of the other body parts, especially salivary glands, were examined for malarial infections.

Collection 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 of 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 1989 ~1991. The dipper was 15 cm in diameter and 5 cm in depth with a wooden handle of 60 cm 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).

Insecticide susceptibility test: In order to estimate insecticide resistance on *A. sinensis*, blood-fed females of *A. sinensis* were collected 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±1°C and 70~80% 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 described 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.

Parasitological survey: Thick and thin blood films were made for the determination of the incidence and densities of species of malaria parasites among residents aged from 1 to 70 living in northern parts of Kyongbuk Province.

Blood films were fixed in methanol and treated with 4% Giemsa stain for 30 minutes. Thick film fields were examined microscopically (1000 ×) for the presence of malarial parasites. Parasite densities were recorded as the number of parasite per 200 white blood cells.

RESULTS

The five years' observation of the earliest dates in which *A. sinensis* begin to be collected by light traps and air temperature and humidity at that time in Kyungsan-gun, Kyongbuk

Table 1. Five years' observations of the earliest dates *Anopheles sinensis* begin to appear in Kyungsan-gun Kyongbuk Province, Korea, together with meteorological data

Year	Earliest date when mosquito appeared	Temperature (Range °C)	Humidity (%)	Averge No./trap-night
1987	April 2	3.3~16.1	55	0.3(1/3)*
1988	April 20	5.9~13.0	61	0.3(1/3)
1989	March15	4.8~16.1	46	0.3(1/3)
1990	April 11	7.7~24.3	52	1.0(3/3)
1991	April 3	2.4~19.6	45	0.3(1/3)

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

Table 2. Dates of peak population of *Anopheles sinensis* and meteorological data at that time

Year	Dates of peak population	Temperature (Range °C)	Humidity (%)	Average No./trap-night
1987	July 9	21.7~34.8	59	1,247.0 (3,741/3)*
1988	July 6	20.5~24.6	70	1,109.3 (3,328/3)
1989	July 5	18.6~28.4	69	3,495.0(10,485/3)
1990	July 12	24.3~31.2	76	518.3 (1,555/3)
1991	July 18	20.2~23.0	85	730.7 (2,192/3)

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

Province, Korea is presented in Table 1. *A. sinensis* were first collected in the light traps from 1987 to 1991 in April, between the 2nd and 20th days, but on March 15 in 1989. At that time the air temperature ranged from 2.4~24.3°C and humidity from 45~61 per cent. The average number of *A. sinensis* per trap-night was from 0.3 to 1.0.

Table 2 lists the dates of peak population of *A. sinensis* collected in the surveyed area and the meteorological data at that time. The highest population density of *A. sinensis* was observed during the period from early July to mid-July in every year. The air temperature was between 18.6 and 34.8°C, and the relative humidity from 59 to 85 per cent. The maximum number of *A. sinensis* in 1987 was 1,247 per trap-night. The number decreased to 1,109.3 in 1988, abruptly increased to 3,495 in 1989, decreased again to 518.3 in 1990.

Table 3 shows the dates *A. sinensis* were not collected in the surveyed area according to the years studied. *A. sinensis* was not observed during the period from late October to mid-November. The air temperature at that time ranged from 2.6~24.6°C and humidity from 39 to 70 per cent.

The seasonal prevalence of *A. sinensis* collected by light traps are summarized in Table 4. In general, *A. sinensis* was collected in 8 months, from April to November in every year studied, but 9 months in 1989. In 1988, the average number of *A. sinensis* females per trap-night in April was 0.1, it increased to 0.7 in May, 128.8 in June, and reached the maximum number, 537.6 in July. In August, the average

Table 3. Dates of disappearance of *Anopheles sinensis* and meteorological data

Year	Date of disappearance of mosquito	Temperature (Range °C)	Humidity (%)
1987	November 19	2.6~13.0	39
1988	November 9	5.6~21.7	60
1989	November 15	4.7~14.2	64
1990	October 21	9.1~24.6	70
1991	October 31	9.2~19.3	64

number decreased to 74.3, in September 60.6, in October 2.4, and in November 0.1. The general patterns of seasonal prevalence of *A. sinensis* in the other years are similar to those for 1988, but the pattern of monthly change in 1989 is dissimilar to those for 1988. In 1989 *A. sinensis* first appeared in mid-March, it subsequently increased and reached a maximum of 1,331.4 in July.

In August the number abruptly decreased to 48.6, and in September the number increased again to 121.1. There was a gradual decrease from October, with a very small number of them until mid-November in the traps.

The results of relative abundance and MPI calculation for *A. sinensis* in successive years after 1987 are shown in Table 5 and illustrated by Fig. 2. It was found that the total number of *A. sinensis* progressively increased during the initial three years from 1987 to 1989. A marked decrease in MPI was obtained in 1990 and 1991.

Table 6 shows the results of the number of total and engorged female *A. sinensis* by light traps collected at three locations during 5 years from 1987 to 1991. The overall rate of engorgement, as calculated by dividing the number

Table 4. Seasonal prevalence of *Anopheles sinensis* by the average number collected each traps during 5 years

Year	Average number of female mosquitoes per trap-night								
	March	April	May	June	July	August	September	October	November
1987	0	0.1	0	108.2	542.6	50.8	18.1	0.4	0.1
1988	0	0.1	0.7	128.8	537.6	74.3	60.6	2.4	0.1
1989	0.2	0.7	2.5	401.0	1,331.4	48.6	121.1	4.2	0.1
1990	0	0.6	1.9	89.4	271.9	180.8	84.3	0.2	0
1991	0	0.3	1.3	151.3	372.1	44.1	73.0	6.3	0

Table 5. Relative abundance of *Anopheles sinensis* population in successive years after 1987

Year	At the 3-stations located in suburban areas	
	Total No. collected	Mean per index
1987	10,242	100.0
1988	11,383	125.1
1989	21,241	175.2
1990	7,248	71.2
1991	6,591	67.8

engorged with the total, which reflect the efficiency of blood-sucking activity on *A. sinensis* in 1990 were in the order of 62.7 per cent on cow-stall, 43.7 per cent on piggery, and 1.3 per cent on human dwelling. The general patterns of engorgement rates in the other years are similar to those for 1990, but in 1989 are dissimilar.

The monthly fluctuation in the blood-sucking

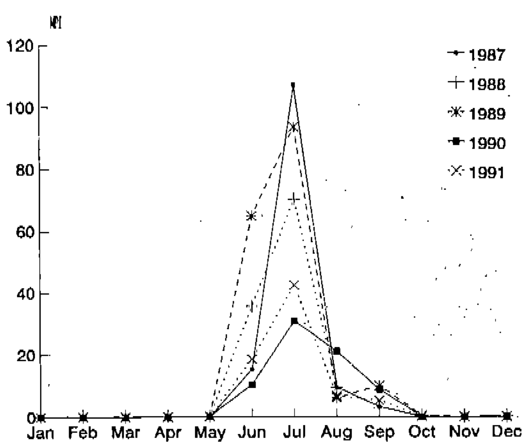

Fig. 2. Annual prevalence of *Anopheles sinensis* as shown in MPI calculated from the data of mosquito collection at 3 stations.

rate of *A. sinensis* is listed in Table 7. The blood-sucking rate varied greatly by different month in every year. The rate was 10.5~44.8 per cent in June, 8.2~58.7 per cent in July, 12.9~42.5 in August, and 9.2~48.3 per cent in September, although the rate decreased in October, it was kept on the level of 5.0 per

Table 6. Comparison of total and engorged number of *Anopheles sinensis* collected by light traps at piggery A, cow-stall B, and house-dwelling C during five years, 1987 ~1991

Year	Location	No. collected	No. engorged(%)
1987	A	3,492	1,034(29.6)*
	B	5.206	2,016(38.7)
	C	1,544	90 (5.8)
	Subtotal	10,242	3,140(30.7)
1988	A	4,632	535(11.6)
	B	4,274	1,540(26.0)
	C	2,477	41 (1.7)
	Subtotal	11,383	2,116(18.6)
1989	A	4,258	1,384(32.5)
	B	15,286	940(6.1)
	C	1,697	55 (3.2)
	Subtotal	21,241	2,379(11.2)
1990	A	2,847	1,243(43.7)
	B	3,355	2,103(62.7)
	C	1,046	14 (1.3)
	Subtotal	7,248	3,360(46.4)
1991	A	3,276	1,544(47.1)
	B	3,121	2,004(64.2)
	C	1,163	9 (0.8)
	Subtotal	7,560	3,557(47.1)

* Number in parentheses means the percentage of engorged females

Table 7. Monthly fluctuation of total and engorged number of *Anopheles sinensis* collected by light trap(1987~1991)

Month	1987		1988		1989		1990		1991	
	No. collected	No. engorged (%)	No. collected	No. engorged (%)	No. collected	No. engorged (%)	No. collected	No. engorged (%)	Nol collected	No. engorged (%)
Mar.	0	0	0	0	2	0	0	0	0	0
Apr.	1	0	1	0	7	0	5	2(40. 0)	3	0
May	0	0	11	0	38	7(18. 4)	23	3(13. 0)	19	2(10. 5)
Jun.	1, 298	136(10. 5)	3, 090	336(10. 9)	4, 812	878(18. 2)	1, 073	316(29. 5)	1, 815	813(44. 8)
Jul.	8, 112	2, 886(35. 6)	6, 451	1, 510(23. 4)	14, 645	1, 198 (8. 2)	3, 263	1, 917(58. 7)	4, 093	2, 297(56. 1)
Aug.	609	98(16. 1)	892	115(12. 9)	596	140(23. 5)	1, 870	795(42. 5)	661	148(22. 4)
Sep.	217	20 (9. 2)	909	155(17. 1)	1, 090	154(14. 1)	1, 012	489(48. 3)	876	290(33. 1)
Oct.	4	0	29	0	50	2 (4. 0)	2	0	93	7 (7. 5)
Nov.	1	0	0	0	1	0	0	0	0	0

Table 8. The results of overnight *Anopheles sinensis* collection by light trap in a pigsty and on human baits(1990)

Hour	July 27~28		August 13~14		August 30~31	
	Light trap	Man	Light trap	Man	Light trap	Man
19 : 00~20 : 00	10 (4)*	0	13 (3)	0	22 (2)	0
20 : 00~21 : 00	50 (7)	0	136(28)	0	123 (75)	1
21 : 00~22 : 00	40(10)	3(1)	38(11)	3	29 (12)	1
22 : 00~23 : 00	17 (8)	0	19 (8)	6(2)	13 (4)	2
23 : 00~24 : 00	8 (2)	1	15 (4)	2	4 (1)	1
24 : 00~01 : 00	10 (2)	10	10 (3)	1	8 (3)	3
01 : 00~02 : 00	14 (6)	3	8 (1)	3	4	3
02 : 00~03 : 00	11 (2)	0	8 (1)	2	2	2
03 : 00~04 : 00	18 (5)	5	9 (1)	5	3	0
04 : 00~05 : 00	7 (1)	3	13 (1)	3	12 (5)	0
05 : 00~06 : 00	0	0	9 (3)	0	8 (3)	0
Table	185(47)	25(1)	278(63)	25(2)	228(105)	16
Temperature(°C)	33. 0~26. 1		33. 9~24. 1		30. 8~25. 0	
Humidity(%)	43~88		30~80		52~88	

* Number in parentheses means number of engorged female mosquitoes.

cent.

The data shown in Table 8 represents the biting rhythm of *A. sinensis* by light trap collections in a pigsty and on human baits through the night at interval of one hour. The biting activity was continued throughout the night.

In light trap collection in a pigsty, *A. sinensis* attempted to feed from 19 : 00~20 : 00 onward, and the peak numbers of the mosquitoes showed two peaks, one at 20 : 00~21 : 00 and the other at 03 : 00~04 : 00 in July, and 04 : 00~05 : 00 in August. In human baited trap, the peak

Table 9. Age composition of *Anopheles sinensis* collected in 1990 as determined by the number of follicular relics

Bait	No. dissected	Frequency distribution by the No. of relics				Percent parous (%)
		N*	1	2	3	
Human	67	47	16	4	—	29. 9
Pig	413	201	145	59	8	51. 3

* N means nulliparous.

Table 10. Age structure of immature stages of *Anopheles sinensis* in the study area (1989～1991)

Date	Total No. in the study area at the median age of each stage(×10³)*				
	L1	L2	L3	L4	Pupa
1989					
Jun. 30	745	541	286	64	45
Jul. 7	952	1,408	379	39	58
Jul. 14	2,337	916	329	62	27
Jul. 21	3,890	1,021	596	115	46
Jul. 28	149	251	98	125	10
Aug. 18	85	51	21	83	7
Aug. 25	17	59	17	25	0
Sep. 1	120	144	66	36	9
Sep. 8	18	63	59	89	0
1990					
Jul. 15	—	24	330	118	18
Jul. 22	39	136	613	183	56
Jul. 29	1,055	2,299	1,070	190	105
Jun. 6	5,748	7,387	6,580	1,227	284
Jun. 13	1,498	413	247	164	128
Jun. 19	120	230	268	76	25
Jun. 27	190	251	106	50	15
Aug. 2	63	88	31	27	15
Aug. 10	9	68	26	4	6
Aug. 19	128	18	30	21	12
Aug. 23	43	16	16	11	7
Aug. 30	86	136	131	71	7
Sep. 6	203	74	41	43	13
Sep. 20	12	32	95	25	6
1991					
Jun. 15	443	195	99	53	38
Jun. 21	35	257	585	253	43
Jun. 29	988	1,129	781	274	25
Jul. 4	3,995	2,094	657	96	—
Jul. 10	325	517	74	7.4	—
Jul. 20	489	457	223	37	—
Jul. 27	1,061	430	168	77	4
Aug. 2	74	208	238	22	—
Aug. 7	2,796	480	170	55	—
Aug. 14	1,144	527	104	38	10
Aug. 21	515	493	756	164	42
Aug. 30	982	2,667	360	99	226
Sep. 6	358	382	294	123	92
Sep. 13	3,604	1,232	773	398	175
Sep. 20	1,228	474	306	287	41
Sep. 27	531	199	159	75	39

* Total No. in the study area at the median age of each stage(×10³)=Total No. of each stage in the study area(=Average No. per dip×186×total area with water in m²)/Mean period of the stage at the temperature.

hour of biting differed each month, for example 24 : 00～01 : 00 in July, and 22 : 00～23 : 00 in August, when the temperature was between 24.1 and 33.9°C and the humidity 30～88 per cent in the field.

The age compositions of *A. sinensis* collected by human baited trap are compared with that of a pigsty by pig bait and listed in Table 9. The frequency distribution of the *A. sinensis* by the number of follicular relics counted after their dissection, and parous of both biting collections were relatively low, being found in 29.9 per cent in human bait and in 51.3 per cent in pig bait, respectively.

The age structure of immature stages of *A. sinensis* and the seasonal prevalence of total number of larvae plus pupae in the study area are shown in Table 10.

The highest larval density in cultivated fields was 21,226×10³ on July 6th, 1990. After late September, such densities show a marked decrease and the larvae and/or pupae of *A. sinensis* were rarely found until rice plants were harvested. In practice, the general pattern of the seasonal prevalence in the study area was determined largely by the prevalence in cultivated fields. The total number reached at its yearly peak during the period from late June to mid-July.

Table 11 shows the insecticide resistance levels

Table 11. Resistance levels and resistance ratio of larval *Anopheles sinensis* for tested insecticides(1990)

Insecticides	Resistance level		Resistance ratio
	Kyungsan	Nagasaki*	
O-P compounds			
Diazinon	12.35**	3.16	3.19
Malathion	14.50	3.52	4.12
Fenthion	0.085	0.085	0.68
Fenitrothion	21.50	6.50	3.31
Pyrethroids			
Phenothrin	0.25	—	—
Allethrin	0.94	—	—

* Data reported by Department of Medical Entomology, NIH, Japan.

** Number means LC_{50} value in ppm.

of larval *A. sinensis* for one generation in the laboratory from collections in Kyongsan-gun and compared with those of susceptible laboratory strains. The larval *A. sinensis* were highly resistant to malathion and dizainon, the LC_{50} values being 14. 50 ppm for malathion and 12. 35 ppm for diazinon, but only low resistance was indicated in larval *A. sinensis*, LC_{50} value being 0. 085 ppm for fenthion. The LC_{50} values to malathion and fenitrothion were about 4. 12 and 3. 31 times as high as those of susceptible strain.

DISCUSSION

In the survey on Anopheline mosquitoes in Korea, with a consideration of their importance as malaria vector, Kobayashi(1929) examined many specimens of the adult and larval mosquitoes collected from various localities, and reported for the first time that the principal vector of malarial parasite was *A. sinensis.*

A study of Yamada(1936) reported that among the blood meals of *A. sinensis* collected from animal sheds, 82. 5 per cent fed on cows and none in man, however, among those collected in human dwellings and railway station in Seoul, 54. 8 per cent and 80. 3 per cent fed on man, respectively, and Yokoo(1944) reported that the seasonal prevalence of *A. sinensis* first appeared in late March and they trapped large numbers during the period from late June to mid-July. He also stressed that *A. sinensis* seemed to serve as a vector of setariasis of domestic animals in Korea. Whang(1962) found that Anopheline mosquitoes began to appear from April or May and disappeared in October each year. He also commented that Anopheline mosquitoes had a mainly zoophilic habit, and since its man-biting rate was rather low, it would cause a low infection rate of malaria. Seasonal fluctuation in numbers of *A. sinensis* have been reported previously, but 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 18. 6 and 34. 8°C and the humidity 59～76 per cent. The earliest date of appearance and disappearance in this survey was in mid-March or early and mid-Apri and in late October or mid-November each year. The main factors contributing to the earliest time of appearance and the change in the density of the *A. sinensis* each year were considered to be breeding sites such as rice paddies and swamps, *etc.*, rainfall, temperature and humidity, *etc.*

The seasonal prevalence of *A. sinensis* has been shown usually in the number of *A. sinensis* 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 *A. sinensis.* On the basis of this point, the mean per cent index (MPI), being calculated from the totals of vector mosquito collections at stations in comparison with those in the standard year, were used for the comparison of the annual abundance of vector mosquitoes. The results shown in Table 4 and Table 5 indicated that a marked decrease in MPI was obtained in 1990～1991, and accompanied with a decrease in the number of mosquitoes. Although the main reasons for the decrease in population levels of vector mosquitoes are not readily apparent, it is considered to be due to the intermittent irrigation or early planting of rice plants, extensive uses of chemical insecticides and herbicides in farming, high temperature and small precipitation, livestock and natural enemies and the reduction of rice paddies by urbanization.

In this survey, *A. sinensis* blood feeding success observed sometimes a reflection of mosquito abundance. *A. sinensis* abundance during 1989 was greater than in other years observed, and the same relationship held true for the number of engorged mosquitoes collected during those years. However, monthly engorgement success was not always linked to overall mosquito collected abundance. In 1989, *A. sinensis* was most abundant in July, but engorgement of female *A. sinensis* had the highest rate in August. The results of a monthly fluctuation of engorged number of *A. sinensis* during the period from 1987~1991 indicated that blood feeding was significantly associated with rainfall. In the biting rhythm of *A. sinensis* in this survey, this species appeared to be active throughout the whole night, but was more active during darkness, after sunset to mid-night. At that time the temperature was between 24.1 and 33.9°C and the humidity 30~88 per cent. In the present study the nocturnal periodicity activity of the female *A. sinensis* was not always similar by collection methods on the same night.

Although the environmental factors such as temperature, light, humidity, *etc.*, should be important in determining the attraction of mosquitoes, this data can not be explained fully only by the hourly changes of these factors when the collection was made. Further work along this line is needed.

Ree *et al.* (1967) reported for the first time that of 7,517 dissections of *A. sinensis*, only one specimen was found to be naturally infected with the sporozoite in August, 1962. They also commented that the abundance of Anopheline mosquitoes did not always seem to coincide with the incidence of malaria.

As for experiments with Korean *P. vivax*, valuable information was published in Japan by Otsuru (1949) who succeeded in infecting 25.7 per cent of Japanese *A. sinensis* fed on a patient with this parasite. Similar experiments were performed by Ham (1970). He also reported that oocysts were found in 17 per cent of the *A. sinensis* fed on patients.

In the present survey, the population density of *A. sinensis* is was relatively abundant but no infection for the oocysts or sporozoites of *P. vivax* was found among 717 female *A. sinensis* dissected. Such a result seems to be affected by human and socioeconomic factors in relation to the ecology of vector mosquitoes, *i.e.*, the gradual elevation of living standards of the residents, gradual awakening and behavior of the residents to protect themselves from mosquito biting using such preventives as mosquito nets and insecticide sprays. The relatively short period of mosquito season each year may also affect the transmission of Korean *vivax* malaria.

The immature stages of the Anopheline mosquitoes occur in a variety of habitats among which the most important is the rice paddies in Korea. The ecology of this species in various rural and suburban areas in Korea and other parts of the world have been studied by many investigators. Some of their results indicate that the seasonal fluctuation in the larval population densities in paddy water is markedly different from paddies to paddies in the same area and/or from year to year in the same paddies. In the present survey, the total number of larval *A. sinensis* in rice paddies was highest in early July, when the paddies were undergoing rice transplanting, and its number progressively decreased in early August by insecticide sprays. After mid-September, densities showed a marked decrease and both larvae and pupae of the vector mosquitoes were rarely found until rice plants were harvested. A similar result of peak abundance of vector mosquitoes from rice paddies in Kyongbuk Province of Korea was recorded by Baik and Joo (1991) who also reviewed published observations from other parts of the world.

In Korea, *A. sinensis* were always collected from parsely fields and open stagnant but relatively clean water, also in stream pools or sluggish streams near the villages in early April. A study of Whang (1962) reported that only female *A. sinensis* with sperms in the spermathecae hibernated in cellars and animal sheds, *etc.*, because male mosquitoes were not found. Further work along this line is needed. He also commented that *A. sinensis* from various habitats moved progressively in a series of dispersal flights until whole area was finally repopulated by mid-summer each year. From their study on the toxicity of agricultural pesticide applications to several mosquito species in south Korean rice paddies, Self *et al.* (1973) reported that the use of agricultural insecticides had reduced larval populations in rice paddies throughout Korea. On the contrary, Chandler and Highton (1976) and Service (1977) reported an increase in larval densities and adult population, respectively following the application of insecticides to control rice pests in the Kisumu area of Kenya. In both cases these increases were attributed to the suppression of predator populations.

There is evidence that the widespread use of insecticides in agriculture has been responsible for the selection of resistant strains of vector mosquitoes in various parts of the world. In the studies on insecticide resistance of vector mosquitoes in Korea, Lee(1969) reported for the first time that *A. sinensis* as a malaria vector was found to be resistant to dieldrin and susceptible to DDT, but *C. tritaeniorhynchus* was highly resistant to both dieldrin and DDT. Ree *et al.* (1979) reported that the mortality rates of *A. sinensis* on the second days of the treatment were 12 per cent to BPMC, 38 per cent to diazinon, and 10 per cent to fenitrothion. They also commented that this species had developed a high degree of resistance to some insecticides, and that organophosphorous and carbamate insecticides seriously affected the population of other aquatic organisms in the rice paddies besides mosquitoes. In recent years, from their studies on epidemio-entomological survey of Japanese encephalitis in Korea, Baik and Joo(1991) reported that *C. tritaeniorhynchus* had developed high resistance to most of the insecticides as compared with the results of susceptible strains reported by Yasutomi and Takahashi(1987). The results of the present study indicate that the resistance ratio to organophosphorus compounds in Kyungsan colonies of *A. sinensis*, relative to susceptible colonies, were nearly 4 times. Resistance being higher of *A. sinensis* suggests that this is probably related to some difference in the opportunity of contact of the insecticides and fungicides.

In the studies on the *P. vivax* infections among residents in Korea, there have been many investigators since World War II. A study of Paik and Tsai(1963) reported that the number of positive *P. vivax* cases during the period from 1961 to 1962 found in the northeastern area including the four Provinces of Kyongbuk, Kangwon, Kyonggi and Chungbuk comprised 97.3 per cent of all positives.

They also commented that almost all localities in the southwestern(plain) area were non-active and retrogressive in malaria occurrence, where malaria transmission was low. In contrast the northeastern(mountainous) area had a rather large number of residual foci where malaria transmission was high.

Whang(1963) reported that of 3,991 smears collected, 13 cases were found to be positive for *P. vivax*, 23 positive for *P. falciparum*, and 1 positive for *P. malariae*. He also commented that *P. malariae* and *P. falciparum* in Korea were not natural infections but resulted through contaminated syringes commonly used among the narcotic addicts. Similar results among narcotics patients in Korea have been obtained by Seo and Rim(1959).

After the beginning of the New Village Movement in the third Five year Economic Development Project, the epidemiological and ecological studies on malaria and its vector mosquitoes in Korea had made remarkable progress through the labors of medical parasitologists, entomologists, and Public Health officials.

As shown in "Yearbook of Health and Social Statistics(1987~1991), the malaria cases reported in and after 1977 were very few and seemed not too significant as a public health problem. The exact cause for the decrease of indigenous malaria in Korea and no Korean *vivax* infection case in 1,546 residents of northern Kyongbuk Province in this survey is not known, but there are several factors possibly being due to control measures against malaria by means of free treatment of patients and drug prophylaxis, and to spraying of insecticides against mosquitoes, cutting down of grass around dwellings, *etc.* In recent years, the number of malaria cases reported in and after 1987 increased and it was estimated that they were mostly imported by Korean businessman or travellers from tropical regions such as Southeast Asia, Africa, America, or other countries.

In practice, many people who recently went abroad for various purposes increased from year to year, and actually many cases of parasitic diseases were imported by people returning to this country from tropical countries. Thus, several reports of imported malaria were published by some investigators of Korea (Ahn, 1983; Soh *et al.*, 1985; Lee *et al.*, 1988; Lee *et al.*, 1990).

As a result, it was expected that the imported malaria again became a public health problem in this country. Consequent upon a thriving international traffic, more than a few persons who travelled or stayed in tropical and/or other countries returned home with malarial infections. Thus the eradication and prevention of exogenous malarial cases seems to be possible with the education of necessity for chemoprophylaxis of persons going abroad in combination with the proper treatment of the malarial cases.

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=國文抄錄=

韓國에 있어서의 말라리아 媒介모기의 疫學的, 媒介動物學的 調査

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慶北地域에 있어서 三日熱 말라리아 媒介모기인 중국얼룩날개모기(*Anopheles sinensis*)의 季節的 出現消長과 群集變動을 糾明하기 위해 1987年부터 5年間 慶山郡 1個所에 誘蚊燈으로 1週日에 한번씩 成蟲을, 1989年부터 3年間 慶北 農村 振興 院附屬農場에서 모기幼蟲을 採集調査하였다. 1987年부터 1991年까지 誘蚊燈에 처음으로 중국얼룩날개모기가 採集되는 날짜는 年度別로 큰 差異를 나타내었으며, 3月 中旬에서 4月 中旬사이에 採集되었고 가장 높은 群集密度를 보인 것은 7月 初旬에서 中旬이었으며, 그 後 점점 減少하여 11月 初旬과 中旬부터는 전혀 採集되지 않았다. 採集된 모기 중 吸血한 個體率은 採集場所別로 差異가 있었으며 그 率은 0.5～67.9%이었다. 중국얼룩날개모기의 採集되는 數는 1987年 이후 增加하여 1989年 가장 많은 數가 採集되었으며, 그 後 급격히 減少하여 1991年에는 가장 적은 數가 採集되었다. 夜間活動性은 22時에서 23時사이에 가장 旺盛하였으며, 그 後 점차 減少하다가 새벽 4～5時에 다시 약간 增加하였다. 중국얼룩날개모기 幼蟲은 6月 中旬에 논에서 처음 發見되었고 그 密度는 7月 初旬 및 中旬에 가장 높았으며, 9月 中旬 이후부터는 그 密度가 현저히 減少하였다. 중국얼룩날개모기 幼蟲은 3種의 有機燐劑에 對하여 높은 抵抗性을 나타내었다. 以上의 成績으로 미루어보아 慶北地域에서 중국얼룩날개모기는 每年 減少되고 있다고 판단된다. **〔기생충학잡지, 30(4):329-340, 1992년 12월〕**