2003

Seasonal Prevalence of Mosquitoes Collected from Light Traps in Korea (1999-2000)

Kim Heung Chul
5th Medical Detachment (PM), 168th Medical Battalion, 18th Medical Command, US Army, mosqkim@hanmail.net

Kwan Woo Lee
5th Medical Detachment (PM), 168th Medical Battalion, 18th Medical Command, US Army

Robert S. Richards
5th Medical Detachment (PM), 168th Medical Battalion, 18th Medical Command, US Army

Sonya S. Schleich
5th Medical Detachment (PM), 168th Medical Battalion, 18th Medical Command, US Army

William E. Herman
5th Medical Detachment (PM), 168th Medical Battalion, 18th Medical Command, US Army

See next page for additional authors

Authors
Kim Heung Chul, Kwan Woo Lee, Robert S. Richards, Sonya S. Schleich, William E. Herman, and Terry A. Klein

KOREAN JOURNAL OF ENTOMOLOGY
Vol. 33, No. 1, pp. 9～16, March 2003

Seasonal Prevalence of Mosquitoes Collected from Light Traps in Korea (1999−2000)

KIM, Heung Chul*, Kwan Woo LEE, Robert S. RICHARDS, Sonya S. SCHLEICH, William E. HERMAN and Terry A. KLEIN[1]

5th Medical Detachment (PM), 168th Medical Battalion, 18th Medical Command, US Army, APO AP 96205−5247

[1]*Preventive Services Directorate, 18th Medical command, US Army, APO AP 96205−0684*

ABSTRACT **Adult mosquito collections were conducted from 1999 through 2000 at 29 US military installations located in six provinces in the Republic of Korea (ROK). Adult mosquitoes were collected in New Jersey light traps from 15 May to 15 October each year. Adult mosquito surveillance was conducted to determine the appropriate time for pesticide applications at each of the Army installations. A total of 68,051 and 62,526 adults were collected in 1999 and 2000 respectively, comprising 53,983 (79.3%) females and 14,068 (20.7%) males in 1999, and 50,274 (80.4%) females and 12,252 (19.6%) males in 2000. A total of 19 species from 7 genera were collected. The most common species collected were *Anopheles sinensis* (34.2%), *Culex tritaeniorhynchus* (29.4%), *Aedes vexans nipponii* (18.2%) and *Culex pipiens* (16.8%). *Anopheles sinensis* were collected at the same level while *Culex tritaeniorhynchus* decreased by 6.2% in 2000. The weekly population densities for some species were variable for each of the years, apparently as a result of changing weather conditions.**

Key words : Light trap, Seasonal prevalence, *Anopheles sinensis*, Trap index (TI), Korea

The Entomology Section, 5th Medical Detachment (MED DET) (Preventive Medicine) (PM), in coordination with the Department of Public Works (DPW), 8th US Army−Engineers, conducted annual mosquito surveillance programs at US military installations in the Republic of Korea (ROK) in accordance with Army Regulation (AR) 40−5 (Department of the Army, 1990). Mosquito populations and species distributions throughout the ROK, especially vector species, is of primary importance to US and ROK militaries since each expends substantial amounts of manpower and pesticides for mosquito control to reduce potential health risks to military personnel.

Currently, the primary mosquito−borne disease of greatest concern in the ROK is malaria. Malaria was regarded as officially eradicated in the ROK, until its reintroduction in 1993. Since the first case of *vivax* malaria was reported in 1993 (Chai et al., 1994), malaria continued to increase in the northwestern area of Gyeonggi Province along the demilitarized zone (DMZ) (Lee et al., 1998, 2002). Most US military installations and training sites are located adjacent to rice paddies that are not under the jurisdiction of the US or ROK Armies. These mosquito habitats include rice paddies, parsley fields, ground pools, sewage and drainage ditches, culverts and irrigation ponds that are located mainly off the military installations. These habitats infrequently occur on military installations except during the rainy season. In addition to larval habitats, many of the rural installations are near swine and dairy farms that attract numerous mosquitoes.

Yu and Kim (1989) provided valuable data on some biological agents used to control larvae. However, the use of biological and chemical agents by the Korean public and Public Health officials to control larvae is limited. Therefore, the development of an effective means for controlling adult mosquitoes on military installations is the primary focus of the US military mosquito control program. The 5th MED DET instituted a “Trap Index” that establishes a baseline for initiating/conducting pesticide applications when numbers of female vector mosquitoes captured in a New Jersey (NJ)

* Corresponding author
E−mail: mosqkim@hanmail.net, Tel: 82−0505−725−1500

light traps exceed the threshold (Yi et al., 1988). Although this method is associated with many inaccuracies, it serves as a valuable operational tool to reduce pesticide usage and environmental exposure. Pest control personnel (DPW) at selected US installations operate the NJ light traps, collect captured insects, and forward them by postal service to the 5th MED DET for identification. Based on population densities of vector/nuisance species, the 5th MED DET recommends whether pesticide application is warranted within two days after the samples are received.

The purpose of this paper is to present additional scientific data that increases our current knowledge of the seasonal abundance and geographical distribution of selected mosquito species captured at US military installations in the ROK. The recent outbreak of malaria in Korea is a reminder of the importance of maintaining this historical record of vector populations and seasonal trends.

MATERIALS AND METHODS

Seasonal distribution and abundance of mosquitoes were obtained from mosquitoes collected using New Jersey light traps installed at 22 US Army and 3 Air Force installations and 2 training sites, and CDC light traps baited with CO_2 (dry ice) at two Air Force installations (Gunsan and Osan Air Bases) throughout the ROK. The traps located in 6 provinces and operated by local pest control personnel DPW, 8th US Army-Engineers. Whenever possible, the light trap sites were selected at least 100 m from the nearest external light sources and 25-50 m away from multistory buildings. New Jersey light traps used a 25-watt, white frosted light bulb and were set approximately 1.5 meters above the ground surface. CDC light traps at Gunsan and Osan Air Bases were hung from a tree about 1.5 m above the ground and baited with CO_2 provided by dry ice in an insulated, one-liter jug with an open pour spout. A piece of dichlorvos-impregnated plastic was placed in the light trap collection jars to kill the mosquitoes. The traps were operated between the hours of dusk and dawn (6:00 p.m. to 8:00 a.m.) 1-4 times weekly and the samples collected the morning after capture. The collected adults were sent to the 5th MED DET, and identified under the dissecting microscope according to standard keys (Tanaka et al., 1979; Lee, 1998). Based on current evidence, *Anopheles sinensis* and *An. lesteri* cannot be separated morphologically and are therefore included as *An. sinensis* group. *An. yatsushiroensis* are included with *An. pullus* group for similar reasons. Light trap indices represented the average number of female mosquitoes collected per trap night. Negative results (i.e., nights when traps were operated but no female mosquitoes collected during severe weather conditions, etc.) were not always reported when samples were sent for identification.

Table 1. Number of mosquitoes collected at installations for each area with New Jersey light traps and CDC light traps baited with CO_2 (dry ice) during 1999 and 2000

Area	1999						2000					
	No. traps	Female	Male	Total	Trapnights	TI*	No. traps	Female	Male	Total	Trapnights	TI*
Dongducheon	8	1323	1046	2369	240	5.51	8	3837	3883	7720	344	11.15
Munsan	4	11312	3818	15130	148	76.43	5	20059	2823	22882	171	117.30
Uijongbu	4	1053	565	1618	160	6.58	4	831	396	1227	132	6.30
Seoul	8	478	220	698	144	3.32	4	384	275	659	78	4.92
Suwon	3	663	619	1282	105	6.31	3	651	321	972	111	5.86
Osan**	4	1387	1	1388	28	49.54	4	379	34	413	64	5.92
Pyongtaek	7	20413	4435	24848	280	72.90	7	6821	2588	9409	308	22.15
Chuncheon	3	202	255	457	93	2.17	2	173	379	552	108	1.60
Wonju	2	489	110	599	46	10.63	2	221	70	291	38	5.82
Gunsan**	5	3766	12	3778	60	62.77	4	5644	5	5649	78	72.36
Gwangju	5	11237	2115	13352	128	87.79	5	11047	1367	12414	170	64.98
Daegu	3	171	150	321	43	3.98	3	69	19	88	33	2.09
Waegwan	2	1443	664	2107	64	22.55	2	140	83	223	66	2.12
Busan	3	46	58	104	72	0.64	3	18	9	27	93	0.19
Total	61	53983	14068	68051	1611	33.51	56	50274	12252	62526	1794	28.02

*TI (Trap Index)-average number of female mosquitoes per trap night
**CDC light trap baited with CO_2 (dry ice)

RESULTS AND DISCUSSION

A total of 68,051 and 62,526 mosquitoes were captured during 1,611 and 1,794 trap nights using 56−61 New Jersey and CDC light traps during 1999 and 2000, respectively. Similarly for 1999 and 2000, 79.3% (53,983) and 80.4% (50,274) females were collected, respectively (Table 1). Nineteen mosquito species from 7 genera were collected and identified (Table 2). The most abundant and widely distributed species were members of the *Anopheles sinensis* group Wiedemann, *Culex tritaeniorhynchus* Giles, *Aedes vexans nipponii* (Theobald) and *Culex pipiens* Coquillett. *Culex pipiens* consists of two subspecies, *Cx. pipiens pallens* and *Cx. pipiens molestus* that cannot be differentiated morphologically and are thus included together.

Members of the *An. sinensis* group were the most abundant species and accounted for 34.3% and 34.2 % of the mosquitoes collected during 1999 and 2000, respectively (Table 2). The majority of this species (69.4%) were collected from Gyeonggi Province, particularly from Munsan (38.3%) and Pyongtaek (31.1%) (Table 3). During May, populations of this species fluctuated (Table 4), but by June populations steadily increased (29.8% of total catch). *An. sinensis* populations normally peak during July (50.1%) and declined in August (33.0%) and September (26.4%) when *Cx. tritaeniorhynchus* popula-

Table 2. Total number and percentage of mosquitoes by species collected from New Jersey light traps and CDC light traps baited with CO_2 (dry ice) during 1999−2000

Species	1999	2000
Aedes albopictus	23 (< 0.1)	29 (< 0.1)
Aedes esoensis	−	1 (< 0.1)
Aedes vexans nipponii	9,832 (14.5)	13,911 (22.3)
Ochlerotatus dorsalis	72 (0.1)	136 (0.2)
Ochlerotatus koreicus	20 (< 0.1)	12 (< 0.1)
Ochlerotatus togoi	4 (< 0.1)	−
Anopheles lindesayi	1 (< 0.1)	−
Anopheles pullus	68 (0.1)	108 (0.2)
Anopheles sinensis	23,309 (34.3)	21,406 (34.2)
Anopheles sineroides	113 (0.2)	15 (< 0.1)
Armigeres subalbatus	40 (< 0.1)	49 (< 0.1)
Culex bitaeniorhynchus	37 (< 0.1)	73 (0.1)
Culex mimeticus	−	4 (< 0.1)
Culex orientalis	197 (0.3)	100 (0.2)
Culex pipiens	11,904 (17.5)	10,018 (16.0)
Culex tritaeniorhynchus	22,042 (32.4)	16,355 (26.2)
Culex vagans	38 (< 0.1)	216 (0.4)
Coquillettidia ochracea	18 (< 0.1)	13 (< 0.1)
Mansonia uniformis	333 (0.5)	80 (0.1)
Total	68,051 (100.0)	62,526 (100.0)

Table 3. Geographical distribution of mosquito species collected on U.S. military installations using light traps in Korea, 1999−2000

Species \ Site	Dongducheon	Munsan	Uijongbu	Seoul	Suwon	Osan*	Pyongtaek	Chuncheon	Wonju	Gunsan*	Gwangju	Daegu	Waegwan	Busan	Total
Aedes albopictus	3	1	7	3			1			34	2		1		52
Ae. esoensis		1													1
Ae. vexans nipponii	1851	14131	520	214	435	84	6028	16	237	22	172	1	32		23743
Ochlerotatus dorsalis		2	1							205					208
Oc. koreicus	4	1	22	5											32
Oc. togoi										4					4
An. lindesayi	1														1
An. pullus	23	110	2	1	10	2	18		3	3	4				176
An. sinensis	1858	17135	1075	180	683	58	13893	157	488	546	7040	42	1554	6	44715
An. sineroides	9	29	5		2		55		3	3	21		1		128
Ar. subalbatus	38	18	14				3			3	2	2	9		89
Culex bitaeniorhynchus	8	35	1	14	1		18			26	7				110
Cx. mimeticus	4														4
Cx. orientalis	35	62	87	26	6	1	59	4	8		6		3		297
Cx. pipiens	5869	2371	938	653	761	1625	1702	750	124	3029	3551	244	283	22	21922
Cx. tritaeniorhynchus	354	4052	156	242	307	26	12316	60	27	5252	14936	119	447	103	38397
Cx. vagans	32	61	17	15	33	5	26	22		18	24	1			254
Coquillettidia ochracea				1	1		20			8	1				31
Mansonia uniformis		3		3	15		118			274					413
Total	10089	38012	2845	1357	2254	1801	34257	1009	890	9427	25766	409	2330	131	130577
Total species found	14	15	13	12	11	7	13	6	7	14	12	6	8	3	19

*CDC light trap baited with CO_2 (dry ice)

Table 4. The number of mosquitoes collected monthly at New Jersey light traps and CDC light traps baited with CO_2 during 1999–2000

Species	May	June	July	August	September	October	Total
Aedes albopictus	2	3	10	27	7	3	52
Ae. esoensis		1					1
Ae. vexans nipponii	3163 (77.2)	5940 (37.3)	8087 (21.9)	3286 (8.5)	2229 (7.2)	1038 (26.1)	23743 (18.2)
Ochlerotatus dorsalis	22	61	6	88	3	28	208
Oc. koreicus	1	11	9	5	6		32
Oc. togoi		4					4
An. lindesayi					1		1
An. pullus		37	99	21	19		176
An. sinensis	216 (5.3)	4738 (29.8)	18476 (50.1)	12745 (33.0)	8199 (26.4)	341 (8.6)	44715 (34.2)
An. sineroides	2	27	57	26	16		128
Armigeres subalbatus		3	17	28	31	10	89
Culex bitaeniorhynchus		1	6	34	38	31	110
Cx. mimeticus				4			4
Cx. orientalis	1	18	115	86	65	12	297
Cx. pipiens	540 (13.2)	4757 (29.9)	8336 (22.6)	3974 (10.3)	3169 (10.2)	1146 (28.8)	21922 (16.8)
Cx. tritaeniorhynchus	2 (<0.1)	92 (0.6)	1585 (4.3)	18086 (46.8)	17264 (55.5)	1368 (34.4)	38397 (29.4)
Cx. vagans	146	107		1			254
Coquillettidia ochracea		1	10	11	9		31
Mansonia uniformis	1	107	48	228	29		413
Total	4096 (100.0)	15908 (100.0)	36861 (100.0)	38650 (100.0)	31085 (100.0)	3977 (100.0)	130577 (100.0)

tions increased (46.8–55.5%). Although *An. sinensis* population decreased in August and September, it still remained the second most abundant species (Table 4). *An. sinensis* is often found associated with *Cx. tritaeniorhynchus*, breeding in such habitats as ground pools and stream margins on US military installations, and rice paddies, marshes, parsley fields, ground pools and irrigation ditches adjacent to the installations. During 1999, torrential rains caused flooding in northern Gyeonggi Province in late July and typhoon Olga hit Cheju Island and the western part of the Korean peninsular hard. Continued heavy rains during early August resulted in the Imjin River flooding beyond its banks into houses and farmyards, especially in the areas of Munsan and Dongducheon. The NJ light traps were not operated during the first two weeks of August due to extensive flooding and adverse weather conditions in this area. Flooding later resulted in the expansion of larval habitats for malaria vectors that corresponded to the appearance of increased numbers of mosquitoes. Correspondingly, malaria cases increased as a result of greater exposure to mosquitoes since many people were forced to live outdoors due to the destruction of their homes.

Culex tritaeniorhynchus was the second abundant species accounting for 32.4% of the total number of mosquitoes captured in 1999 and 26.2% in 2000 (Table 2). Unlike *An. sinensis*, the majority of the specimens collected were captured in the southern part of the ROK (Gwangju, Gunsan and Pyongtaek) (Table 3). *Culex tritaeniorhynchus* made its first appearance in May (<0.1%) and was collected in increasing numbers in July (4.3%) and trapped in large numbers during the period from August (46.8%) through September (55.5%). There was a sharp decrease from October (34.4%), with small numbers collected during late October (Table 4). Lee and Ree (1991) studied the fluctuations of mosquito population densities of 7 different species collected at 18 different locations in Chollabuk Province from 1985 through 1990. In this report, the *Cx. tritaeniorhynchus* population densities showed large annual changes for different localities. Of concern are virus isolations made from *Cx. tritaeniorhynchus* where 14 pools of 4,281 mosquitoes were positive for Japanese encephalitis virus. Studies are being conducted to identify relative rates of mosquito infections from selected sites near US military installations (Turell, personal communication).

Culex pipiens mosquitoes are frequently collected, widely distributed, and composed of two subgenera,

Table 5. Trap Index (TI)* for mosquitoes collected in New Jersey light traps and CDC light traps baited with CO_2 during 1999 and 2000

Species	Sites	May		June		July		August		September		October	
		1999	2000	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Aedes vexans nipponii	Munsan	46.6[#]	59.5	27.8	64.2	21.8	80.1	17.5	24.9	13.1	16.7	42.1	4.3
	pyongtaek	12.8	1.8	10.0	1.5	16.2	10.3	16.2	5.7	9.3	1.7	4.4	0.04
	Gunsan**	0.0	0.0	0.3	0.3	0.1	0.0	0.0	0.4	0.0	0.0	0.0	0.0
	Gwangju	0.2	0.1	0.1	0.7	0.2	1.0	0.0	0.3	0.2	0.5	0.0	0.1
Anopheles sinensis	Munsan	4.2	3.9	17.1	19.3	54.3	62.1	26.7	116.6	43.3	62.5	2.3	2.2
	pyongtaek	0.1	0.1	10.1	0.6	65.5	17.3	51.0	24.8	31.0	7.2	1.3	0.3
	Gunsan**	0.0	0.0	2.0	0.0	14.3	0.0	7.3	6.1	0.4	5.8	0.5	0.4
	Gwangju	1.0	0.2	43.2	5.1	62.6	52.2	22.5	11.3	14.8	6.1	0.4	1.2
Culex pipiens	Munsan	1.7	0.7	2.3	2.1	4.5	1.8	2.9	2.0	7.6	2.2	4.8	1.8
	pyongtaek	0.5	0.2	2.2	0.6	4.0	0.8	2.6	1.0	2.7	0.7	1.9	0.7
	Gunsan**	0.0	11.9	40.3	19.4	22.2	16.6	19.7	35.4	0.4	15.3	2.0	2.2
	Gwangju	17.3	2.4	22.2	8.5	16.0	33	8.8	1.1	4.7	1.6	4.7	2.5
Culex tritaeniorhynchus	Munsan	0.0	0.0	0.0	0.0	1.1	0.3	35.0	18.6	54.7	18.5	7.4	0.8
	pyongtaek	0.0	0.0	0.1	0.0	5.3	0.4	99.4	19.7	84.1	17.9	4.8	3.5
	Gunsan**	0.0	0.0	3.2	0.0	7.1	0.2	97.7	109.2	15.4	51.1	6.5	1.6
	Gwangju	0.0	0.1	0.8	0.1	17.2	16.1	91.4	106.9	109.2	117.4	3.1	7.0

*Average number of female mosquitoes per trap night
**CDC light trap baited with CO_2 (dry ice)
[#]The figures bold-faced represents the higher TI of the year

Cx. pipiens pallens and *Cx. pipiens molestus*, in the ROK. *Culex pipiens* comprised 17.5% and 16.0% of all specimens collected in 1999 and 2000, respectively (Table 2). It is a domestic mosquito, often associated with unsanitary conditions, breeding in stagnant water with high organic content (e.g., sewage ditches and pools of water), and frequently entering houses. It is probably the mosquito that most often bites humans in urban settings in the ROK. Based on light trap collections peak populations are bimodal occurring in June and October (Table 4).

Aedes vexans nipponii accounted for 18.2% of the specimens collected during both years (Table 2). In the ROK, this mosquito develops in rice paddies, ground pools and ponds in association with *An. sinensis* and *Cx. tritaeniorhynchus*. This species, although widely distributed throughout the ROK, was collected mostly in the northern part of Korea (Munsan, 59.5% of total catch). During mosquito surveillance with light traps at 25 sites from 1969–1971 in the ROK, Ree et al. (1973) reported the association of *Ae. vexans nipponii* with other species (e.g., *An. sinensis* and *Cx. pipiens*) and related seasonal population densities. Also, during 2000, a Tahyna-like virus (Bunyaviridae) was isolated from 1 pool of 4,334 mosquitoes. More work is being conducted to determine the specific virus and if infections result in human disease (Turell, personal communication).

Table 6. A comparision of the mosquitoes species collected in New Jersey light traps and CDC light traps baited with CO_2 (dry ice) at Osan Air Base, 15 May through 15 Oct, 2000

Species	New Jersey light trap		CDC light trap+CO_2	
	Female	Male	Female	Male
Anopheles sinensis	12	6	5	0
Aedes vexans nipponii	34	25	17	0
Culex pipiens	21	2	262	0
Culex tritaeniorhynchus	4	1	19	0
Culex vagans	5	0	0	0
Total	76	34	303	0

The remaining species of mosquitoes were collected infrequently. The Genus *Ochlerotatus*, was elevated from the subgenus *Aedes* (*Ochlerotatus*), to generic level (Reinert, 2000). Members of the Genus *Ochlerotatus* were collected infrequently in NJ light traps since they are daytime feeders (*Ochlerotatus dorsalis*, *Oc. koreicus*, and *Oc. togoi*). These species are currently considered to be nuisance pests and have not been associated with mosquito-borne diseases, to date, in the ROK.

CDC light traps baited with CO_2 and NJ light traps vary in their attractiveness for capturing selected mosquito species (Burkett et al., 2001, 2002). At and Osan Air Bases, *An. sinensis*, *Ae. vexans nipponii*, *Cx. pipiens* and *Cx. tritaeniorhynchus*

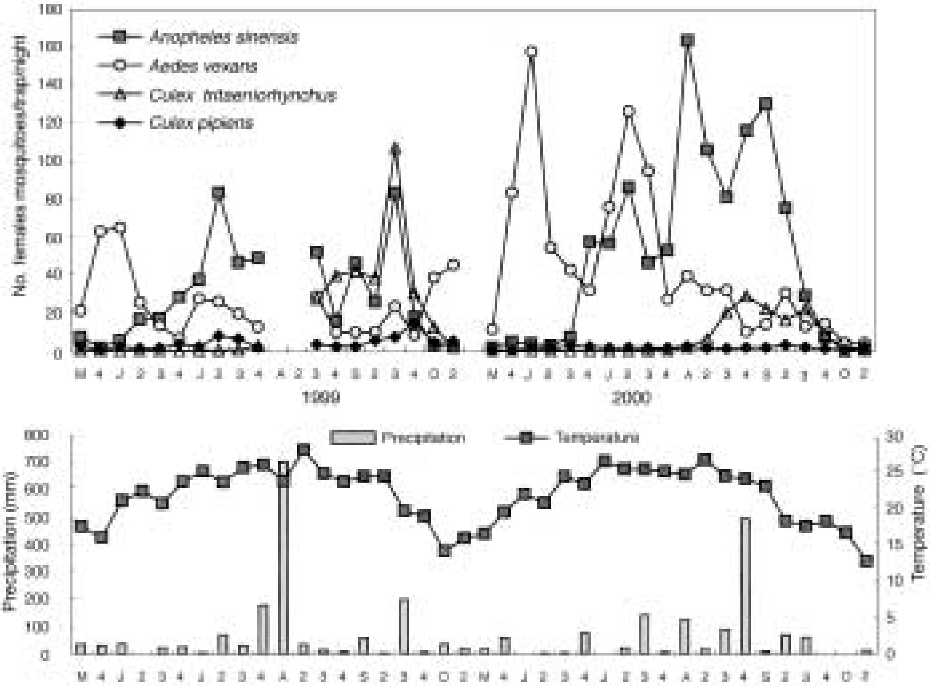

Fig. 1. Seasonal prevalence of *An. sinensis, Ae. vexans, Cx. tritaeniorhynchus* and *Cx. pipiens* collected by New Jersey light traps, Munsan area, Gyeonggi province in 1999–2000.

were collected more 2.75 times more frequently collected in CDC light traps baited with carbon dioxide than in NJ light traps (Table 6). These results are similar to that of Easton et al. (1986) and Acuff (1976) where carbon dioxide baited CDC light traps invariably collected nearly 2 times as many mosquitoes as NJ light traps.

The 5th MED DET developed a weekly “Trap Index” (TI) based on the number of female mosquitoes captured in NJ light traps that is used by other US Army Agencies in other parts of the world. An index of ten females per trap night for malaria vector species, *An. sinensis* or the Japanese encephalitis (JE) vector, *Cx. tritaeniorhynchus*, results in the initiation of control operations from August to October, while 25 female mosquitoes per trap night of these vector species were used during other periods of the surveillance period. Munsan, Pyongtaek, Gwangju and Gunsan areas recorded the highest TI of mosquitoes (Tables 1 and 5). Monthly TIs are reported only to provide an indication of the relative abundance of female mosquitoes occurring each of the months.

The Western Corridor, including Munsan and a number of army installations and training sites, reported the highest numbers of malaria patients among US military personnel. During 1999, the TI for *An. sinensis* was 27.7 compared to 2000 where the TI for the Munsan area was >2 times greater (57.4). The higher rates during 2000 are due, in part, to failed light trap collections and extensive flooding and high winds throughout Korea during the first two weeks of August as a result of typhoon Olga in 1999. Typhoon Olga had a greater impact on *An. sinensis* population densities with light trap collections accounting for only 36.3% of the total catch compared to 2000 where *An. sinensis* accounted for 48.9% of the total catch. According to Lee and Ree (1991), the usual weekly fluctuation pattern of *An. sinensis* includes a first peak during the last week of June and first week of July and a second peak during the fourth or fifth week of August. As shown in Figure 1, the pattern of seasonal abundance in 1999 was unusual. The population density of *An. sinensis* increased rapidly during the second week of July to 83.4 females/trap night (first peak) and decreased during the third and fourth week of July to 46.8–49.0 females/trap night. A late second population peak was observed during the third week of September (83.4 females/trap night) (Fig. 1). The seasonal pattern in 2000 was different, due to the early occurrence of the hot season, with a small peak during the second week of July (86.5 females/trap night) and high densities sustained during the forth week of July. The highest peak occurred in the first week of August (164.3 females/trap night) after the wet monsoon season. During the second and forth week of August population densities decreased to 81.3−116.6 females/trap night. Population densities reached the third peak during the first week of September (130.9 females/trap night) following heavy rains with a sharp decrease in capture rates from late September as a result of earlier than usual cooler temperatures. These results are variable and more closely coincide with mosquito surveillance conducted during 1997 and 1998 (Kim et al., 2000, 2001). During 1999, two *An. sinensis* were positive for malaria antigen, one collected at CP Howze and the other at CP Bonifas (Panmunjom). During 2000, more than 26,000 *Anopheles* were assayed and none were positive for malaria parasites (Coleman et al., 2002).

Weather patterns vary throughout the Korean Peninsula and weather conditions may have a greater impact for some areas, affecting population densities and peaks. Mosquito surveillance provides the basis for mitigating mosquito control measures as population densities change. The effects of these measures, however, were not taken into account in this report, and may have impacted on seasonal peak population densities. However, recent preliminary data indicates that Ultra Low Volume (ULV) fogging had little effect on numbers of mosquitoes collected in Mosquito Magnets® or in human landing counts in the Munsan area (unpublished data).

Standard practices to determine the effect of pest control measures based on pre− and post−surveillance have not been done. Mosquito surveillance that determines the effectiveness of control measures must be instituted for an effective malaria control program and are currently included in the US Forces Korea malaria plan. The 18th Medical Command, in collaboration with Korea National Institute of Health, is working hard to develop an effective and efficient mosquito surveillance and abatement program that will benefit both the US military and ROK counterparts. Results for mosquito surveillance activities will continue to provide the basis for modification of the vector control plan to reduce vector populations and thus providing more protection to US military, civilians and Korean counterparts at US military installations and training sites.

ACKNOWLEDGEMENT

We sincerely thank Ms. Yi, Song−Chu, 8th US Army Command Entomologist, for providing guidance and logistical support for the 8th US Army mosquito surveillance program. We all thank all the 8th US Army pest control personnel and 5th MED DET personnel that made this program work by conducting mosquito surveillance. We also express our gratitude for Air Force personnel that conducted mosquito surveillance on their installations and provided the mosquitoes for identification.

REFERENCES

Acuff, V.R., 1976. Trap biases influencing mosquito collecting. *Mosquito News* **36**(2): 173−176.

Burkett, D.A., W.J. Lee, K.W. Lee, H.C. Kim, H.I. Lee, J.S. Lee, E.H. Shin, R.A. Wirtz, H.W. Cho, D.M. Claborn, R.E. Coleman, and T.A. Klein, 2001. Light, carbon dioxide, and octenol−baited mosquito trap and host−seeking activity evaluation for mosquitoes in a malarious are of the Republic of Korea. *J. Am. Mosq. Control Assoc.* **17**(3): 196−205.

Burkett, D.A., W.J. Lee, K.W. Lee, H.C. Kim, H.I. Lee, J.S. Lee, E.H. Shin, R.A. Wirtz, H.W. Cho, D.M. Claborn, R.E. Coleman, W.Y. Kim, and T.A. Klein, 2002. Late season commercial mosquito trap and host seeking evaluation against mosquitoes in a malarious area of the Republic of Korea. *Korean J. Parasitol.* **40**(1): 45−54.

Chai, I.H., G.I. Lim, S.N. Yoon, W.I. Oh, and S.J. Kim, 1994. Occurrence of tertian malaria in a male patient who has never been abroad. *Korean J. Parasit.* **32**(3): 195−200.

Coleman, R.E., C. Kiattibut, J. Sattabongkot, J. Ryan, D.A. Burkett, H.C. Kim, W.J. Lee, and T.A. Klein, 2002. Evaluation of anopheline mosquitoes (Diptera: Culicidae) from the Republic of Korea for *Plasmodium vivax* circumsporozoite protein. *J. Med. Entomol.* **39**(1): 244−247

Dept. of the Army, 1990. Preventive medicine (AR 40−5). Hqs. Department of the Army, Washington DC. 62 pp.

Easton, E.R., R.S. Coker, and R. Ballinger, 1986. Occurence and seasonal incidence of mosquitoes on Indian reservations in Iowa, Nebraska and South Dakota during 1983. *Am. J. Mosq. Control Assoc.* **2**(2): 190−195.

Kim, H.C., D.A. Strickman, and K.W. Lee, 2000. Seasonal prevalence and feeding activity of *Anopheles sinensis* (Diptera: Culicidae) in the northwetern part of Kyonggi province, Republic of Korea. *Korean J. Entomol.* **30**(3): 193−199.

Kim, H.C., K.W. Lee, M.B. Miller, and D. Strickman, 2001. Seasonal prevalence of mosquitoes collected from light traps in Korea (1997−1998). *Korean J. Entomol.* **31**(1): 7−13.

Lee, J.S., W.J. Lee, S.H. Cho, and H.I. Ree, 2002. Outbreak of vivax malaria in areas adjacent to the demilitarized zone, South Korea, 1998. *Am J. Trop. Med. Hyg.* **66**(1): 13−17.

Lee, J.S., W.G. Kho, H.W. Lee, M. Seo, and W.J. Lee, 1998. Current status of vivax malaria among civilians in Korea. *Korean J. Parasit.* **36**(4): 241−248.

Lee, K.W., 1998. A revision of the illustrated taxonomic keys to genera and species of female mosquitoes of Korea. Department of the Army, 5th Medical Detachment, 168th Medical Battalion, 18th Medical Command, 40 pp.

Lee, S.K., and H.I. Ree, 1991. Studies on mosquito population dynamics in Chollabug−do, Korea (1985−1990). *Korean J. Entomol.* **21**(4): 141−155.

Ree, H.I., L.S. Self, H.K. Hong, and K.W. Lee, 1973. Mosquito light trap surveys in Korea (1969−1971). *Southeast Asian J. Tropical medicine and Public Health.* **4**(3): 328−386.

Reinert, J.F., 2000. New classification for the composite genus *Aedes* (Diptera: Culicidae: Aedini), evaluation of subgenus *Ochlerotatus* to generic rank, reclassification of the other subgenera, and notes on certain subgenera and species. *Am. J. Mosq. Control Assoc.* **16**(3): 175−188.

Tanaka, K., K. Mizusawa, and E.S. Saugstad, 1979. Mosquitoes of Japan and Korea. *Contribution of the American Entomological Institute* **16**: 148−152.

Yi, S.C., T.J. Zorka, and R.S. Edgecomb, 1988. Comparative evaluation of trap index limit to control population. *Korean J. Entomol.* **18**(3): 197−203.

Yu, H.S., and H.C. Kim, 1989. Integrated control of vector mosquitoes with native fishes (*Aplochielus* and *Aphyocypris*) and *Bacillus thuringiensis* (H−14) in natural rice fields of Korea. *Korean J. Appl. Entomol.* **28**(3): 167−174.

(Received 14 January 2003; Acceptded 26 February 2003)