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Late season commercial mosquito trap and host seeking activity evaluation against mosquitoes in a malarious area of the Republic of Korea

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Abstract: Field trials evaluating selected commercially available mosquito traps variously baited with light, carbon dioxide, and/or octenol were conducted from 18-27 September 2000 in a malarious area near Paekyeon-ri (Tongil-Chon) and Camp Greaves in Paju County, Kyonggi Province, Republic of Korea. The host-seeking activity for common mosquito species, including the primary vector of Japanese encephalitis, *Culex tritaeniorhynchus* Giles, was determined using hourly aspirator collections from a human and propane lantern-baited Shannon trap during hours when temperatures exceeded 15°C. The total number of mosquitoes and number of each species captured during the test was compared using a block design. Significant differences were observed for the total number of mosquitoes collected, such that, the Mosquito MagnetTM with octenol > Shannon trap > ABC light trap with light and dry ice > Miniature Black Light trap (manufactured by John W. Hock) ≥ New Jersey Trap > ABC light trap with light only. Significant differences in numbers collected among traps were noted for several species including: *Aedes vexans* (Meigen), *Anopheles lesteri* Baisas and Hu, *An. sinensis* Weidemann, *An. sineroides* Yamada, *An. yatsushiroensis* Miyazaki, *Culex pipiens pallens* Coquillett L., *Cx. orientalis* Edwards and *Cx. tritaeniorhynchus*. Host-seeking activity for most common species showed a similar bimodal pattern. Results from these field trap evaluations can significantly enhance current vector and disease surveillance efforts especially for the primary vector of Japanese encephalitis, *Cx. tritaeniorhynchus*.

Key words: Korean mosquitoes, Japanese encephalitis, light traps, *Anopheles sinensis*, *Anopheles yatsushiroensis*, *Culex tritaeniorhynchus*, attractants

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INTRODUCTION

Adult mosquito trap collection efficacy of selected commercially available mosquito traps and attractants were evaluated in a rice field habitat in a malarious area near the Demilitarized Zone (DMZ) at CP Greaves (US military installation) and Paekyeon-ri (Tongil-Chon), Paju County, in Northern Kyonggi Province, Republic of Korea (ROK). This study is a continuation of trap evaluations conducted during June 2000 (Burkett et al., 2001) but excludes commercially unavailable mosquito traps, and those considered unsuitable for routine use for the US military mosquito surveillance program in the ROK. Moreover, only small numbers of *Culex tritaeniorhynchus* Giles, the primary vector of Japanese encephalitis virus (JEV) in Korea, were captured during the June trials, thus preventing an evaluation of trap efficacy against this medically important mosquito. Populations of *Cx. tritaeniorhynchus* in this area of Korea historically remain low until mid-July (Kim et al., 1995, 1997, 1999).

Other mosquito trapping studies have been conducted in the ROK (Lee et al., 1984; Lee and Ree, 1991; Joo and Kang, 1992; Yang and Yu, 1992; Shim et al., 1997; Kim et al., 1999, 2000; Strickman et al., 2000) with many focusing almost exclusively on the trapping results and population dynamics of *Cx. tritaeniorhynchus* (Self et al., 1973; Joo and Wada, 1985; Baik and Joo, 1991; Shim et al., 1990). Most of these investigators used New Jersey (NJ) light traps, black light traps, livestock-baited window traps, and/or human/livestock landing collections. An organized, ROK-wide vector surveillance program was implemented in 1969 and 1974 by the Korean Ministry of Health and Social Affairs and the US Army (Lee et al., 1971; Ree et al., 1973; Lee et al., 1984), respectively.

The poor condition of specimens collected from the NJ or other non-selective light traps often results in inaccurate species identification of morphologically similar malaria or arbovirus vectors. Additionally, the relatively small numbers of mosquitoes captured with these traditional light traps precludes adequate sample sizes for determining malaria and/or arbovirus infection rates. This is the second in a series of reports concerning the effectiveness of selected modern mosquito trap designs and attractants against currently used older techniques for medically important mosquitoes in the ROK. Additionally, hourly host-seeking activity of the commonly captured mosquitoes was recorded to identify periods of greatest human exposure to host-seeking mosquitoes.

MATERIALS AND METHODS

A 7 x 7 Latin square design was initially employed to evaluate the effectiveness of selected traps and attractants for mosquito surveillance and/or control. Unfortunately, a malfunctioning Mosquito Magnet™ treatment (without octenol) prevented us from analyzing the data as a Latin Square design. Instead, trap and day effects were evaluated using a two-way ANOVA (SAS Institute, 1995). Trap data were transformed to $\log_{10}$ (x + 1) prior to analysis. Multiple comparisons were made using the Ryan-Einot-Gabriel-Welsh multiple range test ($\alpha = 0.05$).

The mosquito trap evaluation field trial was conducted during 18-26 September 2000 from 1800 to 0700 h. The position of each trap was changed nightly so that each trap would occupy every position durig each of the test periods. After each trap night, mosquito collections were placed in shipping containers over dry ice and transported to the 5th Medical Detachment Entomology Laboratory where they were counted and identified using keys specific to Korean mosquitoes (Lee, 1998). As in Burkett et al. (2001), *Anopheles* species were separated and sent to the Armed Forces Research Institute of Medical Sciences (AFRIMS), Bangkok, Thailand, to determine malaria infection rates [Enzyme Linked Immunosorbent Assay (ELISA)]. Culicine mosquitoes were separated by species, placed in cryovials (30/vial), and then shipped on dry ice to the US Army Medical Research Institute of Infectious Disease (USAMRIID) for virus isolation. Both of the latter studies will be reported separately.

Table 1. Description of mosquito traps and attractant combinations

Trap type	Man	Light	CO_2	Octenol[c]	Manufacturer
Shannon Trap	Yes	Yes	Yes	No	—
ABC Light Trap	No	Yes	No	No	American Biophysics Crop (TRAPKIT1)
ABC Light Trap	No	Yes	Yes[a]	No	American Biophysics Corp (TRAPKIT DI)
Mosquito Magnet™	No	No	Yes[b]	Yes	American Biophysics Corp (Pro Model)
Mosquito Magnet™ [d]	No	No	Yes[c]	No	American Biophysics Corp (Pro Model)
New Jersey Light Trap	No	Yes	No	No	John W. Hock, Model 1112
Black Light (UV) Trap	No	Yes	No	No	John W. Hock, Black Light Trap, Model 1212

[a]Source of CO_2, dry ice.
[b]Source of CO_2, propane gas.
[c]Octenol cartridge (OCT1, American Biophysics Corp).
[d]Not included in analysis because of trap malfunction.

7 x 7 Rice Field Trapping Study

As with the June trials (Burkett et al. 2001), tests were conducted in approximately 4 hectares of terraced rice fields (N 37°54′, E 126°43′) adjacent and northeast of Camp Greaves (US Army installation) and west of Tongil-Chon near the DMZ, ROK. Traps were positioned either on elevated walkways separating terraced rice fields, or in small woodland clearings (mixed deciduous and coniferous forest with underbrush) adjacent to the rice fields. One hundred meters or more separated the traps. The field trial trap and attractant combinations are shown in Table 1.

The Mosquito Magnet™ (Pro Model, American Biophysics Corp, East Greenwich RI) uses a similar counter flow technology to capture insects. Propane gas supplied by 20 lb tanks powered the fan motors, produced heat, and generated CO_2 (a by-product of combustion). Otherwise, it was operated (including the OCT1, octenol cartridge) per manufacturers instructions. The trap hung from a wheeled stand that placed the opening 60 cm above the ground. As with the other traps, the Mosquito Magnet was operated nightly from 1900-0600 and shut off during the day. Collection nets from all the traps were emptied and replaced daily. Although not used in the analysis due to malfunction, data from the Mosquito Magnet treatment without an octenol cartridge are reported. The ABC light trap (TrapkitDI) with dry ice, and ABC light trap (Trapkit1, American Biophysics Corp., East Greenwich, RI) using light only were operated as outlined in Burkett et al. (2001). Traps were hung from tripods constructed from aluminum tent poles so that the light sources were approximately 60 cm from the ground. The ABC traps were used as received from the manufacturer and included a standard CM-47 bulb, and 3 diameter, 4-bladed fan inserted into a plastic housing and covered with a rain guard. The dry ice-baited ABC light trap had an insulated container above the rain guard to hold the dry ice. In order to save battery power, both traps were operated with light set to flicker (32.5 Hz). Studies show that the ABC light traps are representative of other typical CDC-type traps. Likewise, a NJ light trap (Model 1112, John W. Hock, Gainesville, FL) was set up as in the June study; however, power was provided using a portable 110 V electric generator (Powermate Pulse Plus 1750, Coleman Company Inc., Wichita, KS). Mosquitoes captured in the NJ light trap were not captured alive and therefore not processed for arbovirus isolation studies.

A miniature black light (UV) trap (Model 1212, John W. Hock, Gainesville, FL) was used for one of the treatments. An internal transistor ballast is used to drive a blue-black light (wavelength not provided) tube. Otherwise, this light trap operates like other CDC-type light traps (e.g., a 3″ diameter, 4 bladed fan inserted into a plastic housing and covered with a black plastic rain guard).

Human landing/biting collections were not made during this investigation. As a substitute, human host-seeking/attractant collections were conducted using mouth

Table 2. Mosquito species composition and back-transformed means for variously baited commercially available mosquito traps

Species	Magnet+Oct.	Magnet-Oct.[b]	Shannon	AB+dry ice	UV Trap	New Jersey	AB+light	P Value
Total mosquitoes	936.3 (A)[c]	234	228.6 (B)	20.0 (C)	2.8 (D)	4.2 (D)	0.4 (E)	0.0001
An. lesteri	1.1 (A)	0.41	0.67 (AB)	0.0 (B)	0.1 (B)	0.0 (B)	0.0 (B)	0.006
An. sinensis	35.5 (A)	8.1	14.1 (B)	0.74 (B)	0.43 (B)	1.1 (B)	0.0 (B)	0.0001
An. sineroides	0.22 (AB)	0	0.35 (A)	0.0 (B)	0.0 (B)	0.0 (B)	0.0 (B)	0.03
An. yatsushiroensis	2.9 (A)	0.7	2.9 (A)	0.0 (B)	0.0 (B)	0.0 (B)	0.0 (B)	0.01
Ae. vexans[a]	276.5 (A)	109.4	158.7 (A)	7.9 (B)	1.8 (B)	0.57 (B)	0.1 (B)	0.0001
Cx. pipiens pallens	0.5 (B)	3.4	0.64 (B)	6.2 (A)	0.22 (B)	0.22 (B)	0.0 (B)	0.0001
Cx. orientalis	0.0	0	0.43	0.17	0	0.51	0	0.09
Cx. tritaeniorhynchus	564.0 (A)	91.1	35.1 (B)	3.9 (C)	0.1 (C)	0.84 (C)	0.3 (C)	0.0001

[a]Significant day effect ($p < 0.05$).

[b]Values not included in analysis due to trap malfunction.

[c]Means within each row having the same letter are not significantly different [$P < 0.05$; Two-way ANOVA and multiple domparison (Ryan-Einot-Gabriel-Welsh Multiple Range Test) performed following $\log_{10}(x+1)$ transformations].

Table 3. Hourly mean (± SEM) number of mosquitoes, by species, collected for Shannon trap collection in a rice field habitat (n = 7 nights)

Species	1800	1900	2000	2100	2200	2300-0400[a]	0400	0500	0600
Total mosquitoes	78.7 ± 30.0	157.0 ± 60.0	71.4 ± 33.0	27.4 ± 12.0	16.3 ± 7.0	N.D.[b]	7.5 ± 3.0	18.3 ± 8.0	13.9 ± 6.0
Ae. vexans	56.2 ± 20.0	127.0 ± 51.0	50.0 ± 26.0	20.1 ± 10.0	12.2 ± 7.0	N.D.	5.5 ± 2.0	11.7 ± 5.0	6.9 ± 2.0
An. lesteri	0.2 ± 0.0	0.3 ± 0.0	0.3 ± 0.0	0.1 ± 0.0	0.0 ± 0.0	N.D.	0.0 ± 0.0	0.1 ± 0.0	0.0 ± 0.0
An. sinensis	2.3 ± 0.0	6.6 ± 1.0	2.3 ± 0.0	1.1 ± 0.0	1.3 ± 0.0	N.D.	0.5 ± 0.0	2.3 ± 1.0	0.6 ± 0.0
An. sineroides	0.0 ± 0.0	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.0	N.D.	0.0 ± 0.0	0.1 ± 0.0	0.0 ± 0.0
An. yatsushiroensis	0.3 ± 0.0	3.7 ± 1.0	0.4 ± 0.0	0.1 ± 0.0	0.2 ± 0.0	N.D.	0.3 ± 0.0	0.4 ± 0.0	0.0 ± 0.0
Cx. orientalis	0.0 ± 0.0	0.1 ± 0.0	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	N.D.	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Cx. pipiens pallens	0.5 ± 0.0	0.4 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	N.D.	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Cx. rubensis	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.3 ± 0.0	0.0 ± 0.0	N.D.	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Cx. tritaeniorhynchus	18.7 ± 12.0	17.7 ± 7.0	18.3 ± 10.0	5.3 ± 2.0	2.5 ± 1.0	N.D.	1.2 ± 0.0	3.6 ± 2.0	6.4 ± 5.0

[a]Collections were not conducted from 2300-0400 since temperatures dropped below 15°C.

[b]N.D.: Not Done.

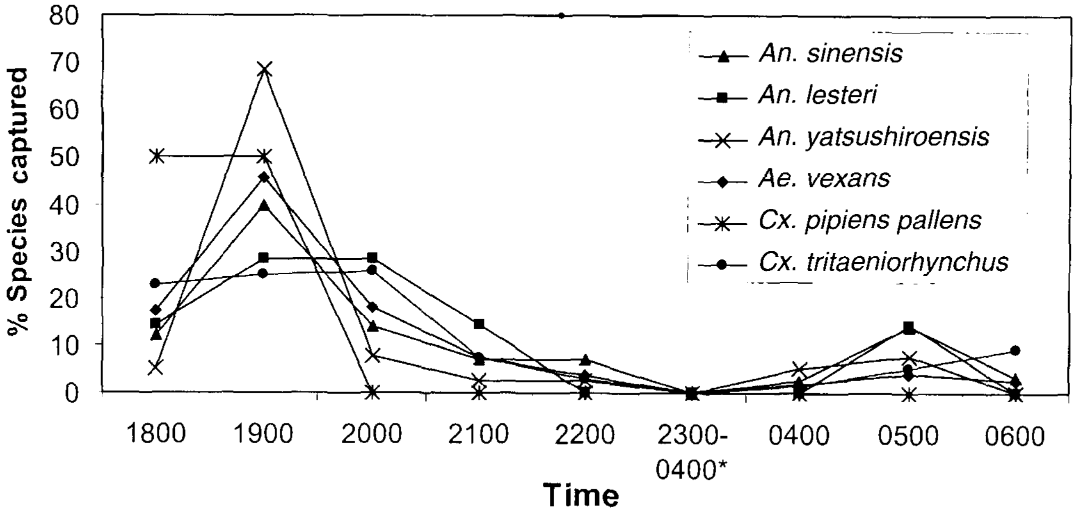

Fig. 1. Relative percent composition of hourly aspirator collections for common mosquito species captured at a human and propane lamp-baited Shannon trap. n = 7 nights. Mosquitoes were not collected from 2300-0400 when temperatures were > 15°C.

aspirators from a 6 x 4 x 6 white cotton Shannon-type trap (Service 1993) baited with two human collectors and a propane lantern (Model No. 5152D700T, Coleman Company Inc., Wichita, KS) placed about 40 cm from the ground. A 20-cm gap at the bottom of the trap allowed mosquitoes to enter the trap. Two groups of two collectors each manned the trap. Groups were rotated throughout the test to reduce collection bias. Mosquitoes landing on the outside or inside of the Shannon trap in a screen-topped pint carton at hourly intervals. Collections were not done between 2300 and 0400 hours because mosquito activity was low when nightly temperatures dropped below 15°C. At the termination of each hour/ collection period, mosquitoes were placed in a cooler. At the end of the daily collection, each carton was placed on dry ice and transported to the 5th Medical Detachment, Yongsan, Korea.

A Shannon trap was set up and the specimens processed as described in Burkett et al. (2001). Collections were not done between 2300 and 0400 hours because mosquito activity was low when nightly temperatures dropped below 15°C. As with the June study, two human collectors and a propane lantern placed about 40 cm from the ground were used as the primary attractants. A 20 cm gap at the bottom of the Shannon trap allowed mosquitoes to enter the trap. Two groups of two collectors manned the trap during the collection period. Mosquitoes landing on the inside and outside of the Shannon trap were mouth aspirated and placed in screened-topped pint cartons and processed similarly to other specimens.

RESULTS

7 x 7 Rice Field Trapping Study

A total.of 13,068 mosquitoes were collected among rice paddies during the 7 trap night trial period. Back-transformed means, p-values, and significant differences for the common species collected are shown in Table 2. As noted in the table, there were significant day effects for *Aedes vexans* and the total number of mosquitoes collected. Significant differences in the total number of mosquitoes captured were found for different traps and attractant combinations (p = 0.0001) and among species [*An. lesteri* (p = 0.006), *An. sinensis* (p = 0.0001), *An. sineroides* (p = 0.03), *An. yatsushiroensis* (p = 0.01), *Aedes vexans* (Theobald) (p = 0.0001), *Culex pipiens pallens* Coquillett L. (p = 0.0001) and *Cx. tritaeniorhynchus* Giles (p = 0.0001)]. Overall, the greatest numbers of *Anopheles* species and *Ae. vexans* were captured with the Mosquito Magnet and Shannon traps. The Mosquito Magnet was the most effective trap for collecting *Cx. tritaeniorhynchus*, capturing more than 15, 140, and 650 times as many mosquitoes as the Shannon trap, dry ice-baited ABC traps and NJ traps respectively. Conversely, the ABC light traps baited with dry ice captured significantly more *Cx. pipiens pallens* than the other traps.

Aedes albopictus (Skuse) [8], *Ae. alboscutellatus* (Theobald) [3], *Ae. lineatopennis* (Ludlow) [3], *Culex bitaeniorhynchus* Giles [3], *Cx. rubensis* Sasa and Takahasi [6], and *Mansonia uniformis* (Theobald) [4] were not collected in sufficient numbers for analysis (totals in [ ]).

Shannon Trap

A total of 2,631 mosquitoes were collected in the Shannon trap. Hourly arithmetic means with standard errors for each of the common species are shown in Table 3. No mosquitoes were captured prior to 1800 or after 0700. Overall, *Ae. vexans* (279±106) was the most abundant species collected by Shannon trap, followed by *Cx. tritaeniorhynchus* (70±32), *An. sinensis* (16±3.4), *An. yatsushiroensis* (5.4±2.4) and *An. lesteri* (1.0±0.5). An average of $\leq$ 1 mosquito/night of the other species was captured at the Shannon trap (Table 3). More (though not significant) *An. sineroides* and *Cx. pipiens pallens* were captured with the Shannon trap than with the Mosquito Magnet. The relative percentage of each of the common species captured each hour (n = 7 nights) is shown in Fig. 1. All mosquito species showed a similar host-seeking activity pattern peaking between from 1800-2000. A second small peak was observed between 0500-0600 hours for most species. A small peak was observed for *Cx. tritaeniorhynchus* between 0600-0700 hours.

DISCUSSION

A paucity of reported mosquito-borne diseases among ROK/US military personnel and civilians living in Korea from the 1970s through the mid-1990s provided little impetus for government health, research or military organizations to revamp waning mosquito/vector surveillance that constitute an important part of their respective disease surveillance programs. The antiquity of current mosquito surveillance programs in the ROK prompted an evaluation of newer and potentially more effective surveillance strategies (Burkett et al., 2001). Additional evaluations for selected traps were performed for late season mosquitoes (specifically, *Cx. tritaeniorhynchus*) to (1) compare their collection efficacy and (2) provide information for there suitability for both detection of malaria and virus infected mosquitoes.

Starting in 1993, autochthonous malaria (*Plasmodium vivax*) reemerged along the DMZ, and quickly spread through the civilian and military communities to become a primary health threat in Kangwon and Kyonggi Provinces bordering the DMZ (Kho et al., 1999; Ree, 2000). Prior to 1993, few authorities considered the reemergence of malaria in the ROK a reasonable possibility. Similarly, the incidence of human cases of Japanese encephalitis (JE) has largely disappeared from the ROK since the mid 1980's. Historically, JE had been one of the most important diseases in Korea with several thousand cases reported annually up until 1968 and hundreds per year up through the mid 1980's (Sohn, 2000). Through a combination of childhood vaccinations, improved public health and living conditions, insecticides, decreases in vector populations/habitat, vaccination of breeder pigs and improved production methods, the incidence of JE in the ROK decreased from > 18.5/100,000 in 1964 to < 0.02/100,000 over the past 3 decades (Baik and Joo, 1991; Sohn, 2000). In spite of consistent annual JE IgM seroconversions observed in blood from slaughtered pigs throughout the ROK (Self et al., 1973; Sohn, 2000), immunization for JE is not currently required for most US soldiers deployed to Korea. This policy is primarily based on the lack of confirmed JE cases reported for American soldiers deployed to Korea since the 1960's. While transmission may occur, it is estimated that only 1/200 to 1/1,000 infections result in apparent disease. As to whether the lack of JE cases in American soldiers has been due to implemented personal protective measures or whether soldiers have just been lucky is subject to debate. High vector populations (Kim et al., 1995, 1997, 1999) on military installations, extensive outdoor training requirements, low herd immunity for US military personnel, high rates of swine JE seroconversions and incidence of JE virus in mosquito populations should theoretically result in at least periodic symptomatic cases of JE in US soldiers deployed to Korea.

Similar to the problem of distinguishing closely related *Anopheles* species discussed in Burkett et al. (2001), many of medically important *Culex* species are also morphologically similar and relatively difficult to accurately identify. Trapping relatively undamaged specimens that preserve key identification characteristics of collected mosquitoes is an important characteristic of trap design. Similar to the previous study by Burkett et al. (2001), the Mosquito Magnet traps captured significantly larger numbers of undamaged and living mosquitoes when compared to those captured in the NJ and even the CDC/ABC style light traps where mosquitoes are often damaged when forced through high-speed fan blades.

With few exceptions (notably *An. lesteri* and *An. yatsushiroensis*), other light trap studies in the same Korean province (Sasa and Sabin, 1950; Ree et al., 1969; Ree et al., 1973; Frommer et al., 1979; Lee et al., 1984; Shim et al., 1997; Kim et al., 1995, 1999, 2000; Strickman et al., 2000) found mosquito species composition and relative seasonal abundance consistent with those of our study. Many of the same trends observed in the June trials (Burkett et al., 2001) were again evident in this study where mosquito numbers differed significantly among trap design ranging from < 1 per trap-night for the ABC trap using only light as an attractant to > 900 per trap-night for the Mosquito Magnet trap with octenol. The only mechanical trap that captured significantly more mosquitoes of a particular species than the Mosquito Magnet baited with octenol was the ABC light trap baited with dry ice that captured significantly more *Cx. pipiens pallens* than the other traps. As noted by Burkett et al. (2001), capture rates for both *Cx. pipiens pallens* and *Cx. orientalis* were significantly decreased for traps baited with octenol during the June trials.

During the June trials (Burkett et al., 2001), significantly more *An. yatsushiroensis* and *Ae. vexans* were captured in the Shannon trap than the Mosquito Magnet. Conversely, these trials showed the Mosquito Magnet captured significantly more *An. sinensis* and *Cx. tritaeniorhynchus* than the other traps including the Shannon trap. Agreeing with Slaff et al. (1983) and Acuff (1976), the ABC light trap baited with dry ice captured significantly more mosquitoes than the NJ or UV light traps. The ABC trap using only light again performed poorly, capturing < 1 mosquito per trap-night. No significant differences in the total number of mosquitoes collected or for any of the species were observed between the UV and the NJ light traps. This is important, as the UV trap is portable, battery operated, and desirable for operation in remote sites. The UV traps could serve as a viable trap substitute for NJ light traps or where CO_2 (dry ice or gas cylinder) or propane, is unavailable.

The use of octenol as a mosquito attractant has been well documented (Kline, 1994). The malfunction of the "octenol-less" Mosquito Magnet that would occasionally quit operating during the trap night was unfortunate, as the antagonistic/synergistic response to octenol for *Cx. pipiens pallens* and *Cx. tritaeniorhynchus* could not be conclusively determined and was not included in the statistical analysis. Even so, 10 times as many *Cx. pipiens pallens* were collected in the Mosquito Magnet without octenol, agreeing with the results observed in the June field trials. Conversely, far more *Cx. tritaeniorhynchus* were collected in the Mosquito Magnet with octenol suggesting a potential synergistic octenol affect for this species when used in combination with carbon dioxide. This finding agrees with those of Vythilingam et al. (1992) who captured greater numbers of *Cx. tritaeniorhynchus* in CDC light traps baited with CO_2 and octenol when compared to CO_2 baited traps without octenol. A synergistic response was not noted for any of the other captured species. Based on surveillance requirements, octenol may not be recommended for use if *Cx. pipiens pallens* or other repellent species are targeted. Octenol's potential synergistic activity may be beneficial for maximizing collection numbers of *Cx. tritaeniorhynchus* for JE infection rates and virus isolations. The synergistic/repellent characteristics of octenol-baited traps for mosquito species in Korea should be further investigated, especially since the Mosquito Magnet without octenol malfunctioned, eliminating any possibility of direct comparison during this trial.

Though human landing/biting collections were not used in our study per se, human bait was again used as a primary attractant to gather hourly flight information for host-seeking mosquitoes collected at the Shannon trap. In most studies, *Cx. tritaeniorhynchus* is known to be only moderately anthropophilic (Self et al., 1973; Yi and Wildie, 1983; Joo and Wada, 1985). In night landing/biting collections, relatively few *Cx. tritaeniorhynchus* (or *Cx. pipiens*) were attracted to human bait when compared to *An. sinensis*, even though concurrent light trap collections captured roughly equal numbers of these species (Joo and Wada, 1985; Baik and Joo, 1991; Strickman et al., 2000). However, in some ROK localities (Self et al., 1973) *Cx. tritaeniorhynchus* is reported to be the dominant species biting man. If the results of the Shannon trap collection in this study provide some indication of human attractiveness, *Culex tritaeniorhynchus* was only moderately attracted to humans when compared to the large numbers captured by the Mosquito Magnet. The potential lack of anthropophilic behavior in combination with the low symptomatic/asymptomatic virus infection ratios may be the primary reasons why cases of JE have not been reported in recent years for non-immunized US soldier populations in the ROK.

Time of year, weather conditions and other factors are obvious and well documented factors that play significant roles in mosquito diel flight and biting activities. In this study, host-seeking activity for *Cx. tritaeniorhynchus* and other common species demonstrated bimodal activity period from 1800 to 2000 and 0500-0600. The lack of activity throughout the night is most likely due to temperatures dropping below 15°C nightly. While studies show that *Cx. tritaeniorhynchus* is active throughout the night (Joo and Wada, 1985; Baik and Joo, 1991), none of these studies present data later than August. Though the Shannon trap was useful for estimating host-seeking activity for most species, it did not effectively attract *Cx. pipiens pallens* or *Cx. orientalis*. Uniform diel host-seeking activity patterns such as those observed for most species during this late season field trial greatly simplifies the proper timing of ultra-low-volume (ULV) adulticide applications or other management efforts to correspond with those of peak mosquito and human activity.

Based on the seasonal disease risk analysis, the total number of mosquitoes, and/or the number of *Cx. tritaeniorhynchus* collected in NJ light traps, Yi et al. (1988) developed trap indices for implementing mosquito control measures at US military installations in the ROK. A modified trap index of ≥ 25 females/trap/night (1 May to 31 July) and ≥ 10 females/trap/night (1 August to 15 October) is used by US military pest management/preventive medicine personnel before control measures are implemented. An evaluation of the correlation of human disease risk, biting activity and trap collection indices for more efficient Mosquito Magnets or other traps employing counter flow technology for mosquito/vector surveillance at all or select installations (especially in malarious and JEV areas near the DMZ) are required if these traps are employed by the US military. Changing traps to one of the more efficient Mosquito Magnet traps will not solve the present vector-borne disease threat, but would expand the current mosquito/vector surveillance program into a more comprehensive disease surveillance program. Furthermore, their portability and lack of electrical requirements allows for collections during and prior to local field training exercises to develop trends for estimating population densities, malaria and arboviral infection rates, etc., to be used for estimating risk of human disease and implementing vector and disease control strategies.

The unique mosquito fauna of the ROK

make it critical that tests are conducted for local species and not extrapolated from species or populations elsewhere. For example, the anthropophilic behavior of *Cx. tritaeniorhynchus* appears to vary from one locality to another (Joo and Wada, 1985; Self et al., 1973). The characteristics of these new technologies provide many benefits to the currently used mosquito surveillance system, including live collections for arbovirus or parasite detection and isolation, collecting specimens in better condition for more reliable identification, and collecting large numbers of mosquitoes that may effectively reduce biting populations when traps are employed near human activities. Evaluating new designs and technologies where US soldiers are deployed will increase our knowledge of vectors and assist in the development and implementation of vector and disease control strategies. New technologies that are employed in highly portable, effective, and efficient traps should be considered for inclusion as part of the US military mosquito surveillance/control system.

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