MOSQUITO CONTROL ACTIVITIES OF THE U. S. ARMED FORCES IN THE REPUBLIC OF VIETNAM *

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INTRODUCTION. Mosquito control as a weapon against disease has been of great importance to many military campaigns and perhaps never more so than in the present operation in the Republic of Vietnam. The problems of application have been more difficult and frustrating, because of the nature of the war itself, and the inaccessible location of most of the significant disease sources. Much has been written regarding the absence of definable combat fronts and the unpredictable nature of guerrilla tactics, and these conditions affect mosquito surveillance and control as well as all other aspects of the campaign. This discussion is concerned primarily with experience in the First Corps Area of the Republic of Vietnam where major responsibility for mosquito control was assigned to the U. S. Marine Corps and Navy. The other three corps areas comprise the southern three-quarters of the RVN and are the responsibility of the U. S. Army. The same basic problems are encountered and the mosquito control activities of personnel in each area have been similar.

MOSQUITO BORNE DISEASES. Mosquito borne diseases, with the exception of malaria, have not been as serious in Vietnam as had been expected. Dengue and encephalitis are present but little or no filariasis or hemorrhagic fever has been reported.

Dengue. Although dengue was frequently diagnosed clinically by medical officers, only eight military cases were reported officially in I Corps during 1966. Very few actually showed an antibody rise between acute and convalescent sera diagnostic for dengue. Its presence has been reported in other parts of Vietnam by USAID officials and the U. S. Army. The amount of illness diagnosed as "fever of undetermined origin" exceeds that of confirmed malaria, and Army authorities have estimated that one-third or more of this may be dengue. If this is dengue it appears to be much milder than that encountered in World War II. However, the vectors of the disease, *Aedes aegypti* and *A. albopictus* are found commonly throughout the country.

Japanese B. Encephalitis. The picture for Japanese B. encephalitis (JBE) is not entirely clear. USAID health officials reported that the French showed serological evidence of the disease in their troops, but AID had no case data prior to June 1966. Over a 4-year period 400 cases of encephalitis or encephalomyelitis have been observed in the civilian population around Quang Ngai. These cases occurred predominantly in the 4–10 year age group from rural areas and there was a mortality rate of about 80 percent, (Stockard, 1966). Additional evidence of viral encephalitis, possibly JBE, was obtained when a total of 60 or more cases of viral meningoencephalitis with one death was reported from military personnel in I Corps through November 1966. The incidence went from 2 in June to 22 in July, 10 in August and fell to 5 in September and October. Preliminary serological tests were run on paired sera of 15 of these meningoencepha-

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litis patients; 9 of the 15 had significant rises in titer in hemagglutination-inhibition tests to JBE.

Since these findings are preliminary it cannot be said for certain that JBE virus is the causative agent, (Preventive Medicine Unit, Naval Support Activity, Da Nang, 1966). However, if it is not JBE, then it is probably due to a virus closely related to it. Medical officers have reported that clinically most of the cases have been milder than typical JBE. With the presence of the reported vectors, *Culex tritaeniorynchus, C. gelidus* and *C. pipiens quinquefasciatus* in the country, likelihood for more cases of JBE or JB-like encephalitis seems very high. All three mosquitoes were found very commonly throughout the delta and coastal areas.

Malaria. Malaria and its control are now the most important disease problems occurring in Vietnam. The existence of drug resistant *Plasmodium falciparum* has been well established. By far the greatest proportion of malaria cases diagnosed in Vietnam is due to falciparum malaria. Figures on the exact total number of all malaria cases to date since the buildup are not available but it undoubtedly exceeded 10,000 for U. S. and Korean forces alone by the end of 1966.

The malaria eradication program in RVN followed the standard pattern of residual DDT spraying of houses, malaria smear collections and mass use of antimalarial drugs. This program became ineffective after 1963 because of the war. The Malaria Control Service reported that the Viet Cong made a special target of control spray crews by destroying vehicles, equipment and supplies, and killing personnel (RVN, 1963).

By the spring of 1965 when U. S. Marines began to take up positions in the northern quarter of the Republic of Vietnam, mosquito control had ceased for all practical purposes. Residual spraying of houses was restricted to limited numbers in the secure coastal areas where malaria incidence had never been high. Lysenko (1965) has noted that French medical officers as far back as the end of the nineteenth century recognized that the territory of Vietnam is not homogeneous for malaria. For example, in North Vietnam the Red River delta, the maritime plains and the high mountains have been practically free of malaria while the infection rate in the foothills and medium elevation mountainous areas is extremely high. Similarly in South Vietnam the coastal plain and much of the delta has little or no malaria while there are numerous hyperendemic foci scattered throughout the interior.

Lysenko divides North Vietnam into four malariogenic zones based on topographical features which in turn determine the distribution and abundance of *Anopheles minimus.* He concludes that the medium-elevation mountain-and-river zone is an independent malaria zone where all human settlements are intensive and constantly active foci and implies that *minimus* is the only significant vector. Malaria in the other zones (low mountain-and-river, hill-and-river, and plateau) is hypoendemic and is dependent upon periodic importation of the carrier and sources of infection from hyperendemic foci. Military experience in the northern part of South Vietnam since July 1965 supports this concept basically. However, there is considerable evidence that, given the presence of an adequate parasite reservoir, *Anopheles* species other than *minimus* are responsible for maintenance of transmission.

ORGANIZATION FOR A CONTROL PROGRAM. The Marines began their development of the Da Nang, Hue-Phu Bai and Chu Lai enclaves in March and April 1965. Serious deficiencies in vector control resulted from lack of pesticides, equipment and adequately trained personnel. Fortunately these deficiencies were not followed by any significant amount of illness because of the low level of vector-borne diseases in the localities where personnel were concentrated at that time.

A survey of the situation during July

1965 by the senior author resulted in recommendations for a vector surveillance and control program. Special emphasis was placed on the need for the collection and interpretation of entomological and epidemiological data in order to define high-risk areas and provide priorities for control operations. A prime control measure for implementation by the III Marine Amphibious Force was outlined under the heading, *Personal Protection and Malaria Discipline*. This included command directives, education and regular unit inspections to check on use of suppressive drugs, repellents and bed nets. It was also recommended that helicopter insecticide dispersal units be obtained as soon as possible and that the Armed Forces Pest Control Board coordinate plans to obtain field trials of mosquito control by low volume dispersal of insecticides in selected areas of Vietnam. Other recommendations were made for the revision of tables of allowance and cataloguing of pesticides and equipment, and greater emphasis on the training of technical personnel.

U. S. Navy preventive medicine components (G–17 and G–18) began to arrive in Da Nang during July 1965 and were assembled to form a Preventive Medicine Unit under the Naval Support Activity. A vector control component (G–19) was soon added which provided valuable assistance in the form of supplementary supplies, maintenance and repair of equipment, training, and direction of large scale operations, including helicopter dispersal. Although disease outbreaks of all types were investigated, the control of malaria became the single most important function of the Naval Preventive Medicine Unit.

DISTRIBUTION OF MALARIA IN RVN. One of the most important and successful activities of the Unit has been the epidemiological follow-up of malaria cases which was organized and carried out by the Officer in Charge, LCDR P. F. D. Van Peenen, MC USN and the epidemiologist LT W. T. Adams, MC USNR. A number of techniques were employed to define the hyperendemic areas and insofar as possible to pinpoint the origin of each infection. These included: patient interviews, review of battalion command records showing company and platoon movements, determination of lengths of exposure to infection, and location of probable origin of infection by map grid coordinates. The end result was the identification of problem areas by months indicated by colored pins on large area maps. Much of the data became available too late for use in current operations but it will be of great value in guiding control programs during 1967.

The non-homogeneity of malaria in Vietnam has made the use of incidence rates for comparisons between units or time periods rather meaningless. For example, some satisfaction might be taken from the reported 9 percent rate for French troops in 1953 as compared with an approximate 2 percent incidence in U. S. forces in 1966. However this would be unjustified without information as to the numbers exposed in specific locations. Overall Marine rates have been considerably lower than Army rates but again this comparison is meaningless when complete information on the population at risk and degree of risk in specific areas is not available.

It is necessary to examine each focus of endemicity separately to obtain a reliable picture of the malaria situation. The areas of I Corps in which U. S. forces are concentrated include the three enclaves, Da Nang, Phu Bai and Chu Lai, and from July 1966 the area south of the Demilitarized Zone (DMZ), based at Dong Ha. Malaria cases by month for these areas are shown in Table 1.

The incidence for the Da Nang area has been relatively insignificant although the population at risk has been much larger than in the other enclaves. The terrain is typical of the coastal plain consisting largely of rice paddies with interspersed estuaries, rivers, and small farms. Most of the 19 cases from Da Nang ap-

TABLE 1.—I Corps—Malaria cases by month for 1966.

	Total	Da Nang	Phu Bai	Chu Lai	South of DMZ	Other
Jan.						
Feb.	76	?	12	18–?	..	46*–?
Mar.						
Apr.	50	?	35	9–?	..	6–?
May	81	2	3	10	..	66**
Jun.	69	..	10	30	..	29**
Jul.	73	3	4	47	10	9**
Aug.	142	0	5	54	73	10**
Sep.	153	3	0	51	66	2
Oct.	193	7	0	114	102	1
Nov.	81	2	0	40	39	0
Dec.	68	1	0	52	9	6
	986	18	69	425	299	175

* Mostly from inland operations.
** Mostly from Thanh Tan Valley.

pear to have originated in perimeter areas rather than in the main base complex.

At Phu Bai the foothills are much closer to the base area. The rolling hills are covered with dense but low scrub and numerous streams, small rice paddies and seepage areas occur in the valleys. Malaria attack rates have been higher than in other enclaves but the smaller population at risk makes the total considerably less. The majority of the 69 cases from Phu Bai during 1966 originated at only two locations. Twenty cases resulted from one village during a 2-weeks' occupation for an annual rate of 570/1000 and most of the others from a battalion headquarters position in the foothills. There was a significant reduction in malaria from the Phu Bai enclave during the remainder of 1966 with no cases reported in Marines during the last 4 months. Insecticide applications by helicopter were initiated in May but it appears that there was also a considerable reduction in personnel at risk throughout the area; therefore there is insufficient evidence to make a positive claim that the absence of malaria was an effect of the insecticide applications.

Another area of high malaria was revealed by a battalion of Marines while deployed for about 3 months in the Thanh Tan Valley 5 miles north of Hue. The attack rate for the period of exposure was approximately 360/1000/annum. This is a foothill zone very much like the Phu Bai area.

A base was established at Dong Ha in July to support the extensive operations to the west between Route 9 and the DMZ. Dong Ha is located in the coastal plain and its relationship to the foothills is quite similar to the situation at Phu Bai. Several marine battalions were involved in hard fighting in an area extending about 20 miles inland and north to the DMZ. The key position in this area, nicknamed the "Rockpile," is located at the confluence of five valleys. Topography of this area is best described as a medium elevation mountain-and-river. About 300 cases of malaria were reported from operations in this area during the last half of 1966 (Table 1, South of DMZ). As expected, few if any of these could be shown to have originated at the main Dong Ha base. One battalion showed an attack rate of 956/1000/annum and several others average about 300/1000/annum during operations near the "Rockpile." There is every indication that the great majority of the cases which occurred during the remainder of 1966 originated in the medium elevation terrain just south of the DMZ.

The bulk of the military population at Chu Lai was located in permanent camps

along the coast and very little malaria occurred in these locations. A major portion of the 425 cases from Chu Lai listed in Table 1 originated from semi-permanent battalion positions in the foothill zone just west of the north-south highway or from patrol or sweep operations beyond the outer perimeter.

The most significant conclusion suggested by Table 1 is that more than two-thirds of the malaria cases during 1966 in I Corps appear to have originated at relatively few hyperendemic foci.

The situation outside of the I Corps area during 1966 was similar but on a larger scale. There were numerous endemic foci which consistently produced very high malaria rates while many extensive areas of the country remained malaria-free. In the highlands west of Qui Nhon total malaria cases in Korean forces during 1966 exceeded that for the entire I Corps area. The Ie Drang Valley between Pleiku and the Cambodian border is probably the most hyperendemic area yet encountered in the Republic of Vietnam. Every operation conducted in this valley has resulted in very high malaria attack rates. A 10-day sweep in August 1966 produced 485 cases representing 20 percent morbidity for a rate which in less than 2 months would have given 100 percent infection. Another unit averaged 10 cases per day in September even though it was on the new suppressive drug, DDS (diaminodiphenylsulfone).

The pattern of ever-increasing transfers of parasite reservoirs from hyperendemic, independent, malaria foci to all parts of Vietnam and beyond became obvious during 1966. Montagnard refugees and large numbers of Vietnamese Army personnel brought into the Duc My-Lam Son area from all over Vietnam for training undoubtedly played a major part in the high malaria incidence which developed there during the last half of the year. Fifteen cases occurred in Korean personnel during October at Chu Lai less than 2 weeks after transfer from their division headquarters more than 200 miles to the south. There were over 200 cases on Con Son Island during May and June where prior to 1966 only a few had been reported. This abrupt development of a malaria problem suggests the introduction of a substantial reservoir in the several thousand prisoners transferred to the island in recent years.

Two cases of introduced autochthonous malaria occurred in civilians who had never left Guam in November 1966 and were traced to two U. S. Army Guamanians on leave from Vietnam.

VECTOR SURVEILLANCE. The necessity of obtaining good information on species present, abundance, breeding sources and habits in order to conduct an effective program is obvious to all mosquito control workers. This was the primary mission of the entomology section of the PMU.

The problems associated with establishing a unit in a war zone were for the most part the same as those encountered in similar campaigns of the past. Although entomological investigations began immediately, building a firm base of operations overshadowed all initial activities. The greater part of the first 6 months in the country were taken up with overcoming such basic inadequacies as lack of suitable laboratory facilities, basic equipment, keys to the mosquito fauna, shortage of personnel, and lack of experience. Despite these difficulties, considerable information on mosquito bionomics was obtained.

Some twelve genera and 76 species, or about 45 percent of the mosquito fauna known to occur in South Vietnam, were encountered in I Corps and significant information on bionomics was obtained (Santana *et al.*, 1966).

Anopheles minimus minimus is historically the most important single malaria vector throughout most of southeast Asia. It has been reported that in Vietnam malaria occurs wherever it is found while the species is rare in non-malarious areas (Morin, 1935), (Toumanoff, 1936), (Lysenko, 1965). In China *A. minimus* is extremely anthropophilic and endophilic

and according to Ho Ch'i, its sporozoite rate is the highest of all *Anopheles*. It is extremely susceptible to household residual spraying and has been virtually wiped out in areas where this program has been in effect for several years (Ho Ch'i, 1965). *A. minimus* larvae have been collected in small numbers at Lang Vie, the Rockpile, in the hills west of Chu Lai and in the Qui Nhon area. It has rarely been taken in the night-biting collections even in areas where malaria attack rates for military personnel were high. This may be explained by its strongly endophilic habits.

Anopheles balabacensis balabacensis is exophilic and is probably an even more efficient vector than *A. minimus* (Scanlon and Sandhinand, 1965) but fortunately its distribution range is limited in I Corps. It is likely that *A. balabacensis* will be found in areas with high attack rates, such as forested localities near the Rockpile or in the Ie Drang Valley, but collections in these areas as yet have not been made or had not been reported by the end of 1966.

Surveys conducted in I Corps areas where military malaria attack rates have been high have not shown a significant *A. minimus* population, and *A. balabacensis* was not found at all. This raises the question as to which vectors are responsible. *A. jeyporiensis candidiensis* is often referred to as an important primary or secondary vector in Vietnam, and this species has been taken frequently in most areas where malaria cases have occurred. *A. maculatus* and *A. aconitus* have also been reported as potential or secondary vectors in Vietnam. All three have been taken in larval surveys and light traps from endemic areas but *A. aconitus* has been found more frequently than others in the Chu Lai area. Navy entomologists, medical officers and technicians made night-biting collections from themselves during 1965 and 1966 in I Corps. Data are available from 18 locations representing 80 hours on 31 nights. The following consolidation shows numbers of significant *Anopheles* species collected in localities with low to high malaria rates compared with those from which no cases were reported.

	Malaria Present	Malaria Absent
minimus	0	0
balabacensis	0	0
jeyporiensis candidiensis	6	0
maculatus	9	0
aconitus	9	0
philippinensis	3	3
sinensis	28	30

Several diverse items of information developed during the past year and a half suggest that *A. aconitus* may be a very important vector of exogenous malaria. In July 1966, the Army 20th Preventive Medicine Company found 3 out of 20 dissections of *A. aconitus* from Con Son Island positive for sporozoites or oocysts. Sixty-eight specimens of *A. aconitus* were taken in human biting collections in 4 nights, of which only 10 were indoors. In September oocysts were found in 3 of 20 *A. aconitus* collected in the Duc My area (Willman, 1966). During 1966 the U. S. Army Medical Component, SEATO Laboratory entomologists also found *A. aconitus* specimens from Thailand positive for malaria parasites (Gould, 1966).

No references to *A. aconitus* as a primary vector of malaria in Vietnam have been found and *A. maculatus* and *A. jeyporiensis candidiensis* are usually reported as secondary to *A. minimus*. However, the ecological changes brought about by the war situation are fully compatible with a shift in relative importance from the strongly endophilic *A. minimus* to these more exophilic species. The provision of large numbers of human hosts in feral environments, together with an absence of large animals, would provide an ideal situation for transmission of malaria by normally zoophilic and exophilic vectors.

Anopheles sinensis is the most common *Anopheles* in Vietnam, particularly in the coastal plain. Despite the presence of large populations of this species, malaria

rates have remained very low. Presumably this is due to its inefficiency as a vector and the small parasite reservoir which has prevailed in the coastal parts of Vietnam. Certainly it has been responsible for endemic *vivax* malaria in many countries of Asia and for temporary outbreaks in plain and delta regions of North and South Vietnam. The efficiency of *A. sinensis* as a vector of *falciparum* malaria is unknown. As the reservoir in U. S. and allied forces builds up with continued introduction from the interior we may expect increased transmission in the coastal plains by *A. sinensis* unless effective control of this species is obtained. Continued high incidence of malaria during the closing months of 1966 and the increasing percentage of vivax may be an indication of future trends.

CONTROL

Mosquito control by military units in Vietnam falls into three categories: Personal protection, adult and larval ground control operations and aerial dispersal. Personal protection includes the use of repellents, nets and screens, and protective clothing, and in the case of malaria the use of chemoprophylaxis. Thus far repellents and suppressive drugs have been the only practical measures which could be used in the advanced combat-type situations where most of the malaria has originated. Serious deficiencies in application have reduced effectiveness greatly, probably by at least one-half. These deficiencies are primarily due to drug resistance, failure to use repellents and antimalaria tablets, and at first nonavailability of repellents to some units.

ANTI-MALARIAL DRUGS. The existence of a large amount of drug resistance has been conclusively demonstrated by clinical experience in several military hospitals. A study of 80 cases of *falciparum* malaria in personnel from Vietnam by CDR. F. M. Barnwell at the Naval Hospital, Guam from September through November 1966 suggests that the problem of drug resistance may be far more serious than yet realized. Only 3 of the 80 patients were returned to duty as cured despite treatment regimens which included one or more of the usual medications, chloroquin, pyrimethamine, quinine, sulfa and DDS, and the experimental Fanasil. Total relapses under eight different treatment regimens ranged from 88 to 100 percent. It should be emphasized the relapse rate includes all individuals with parasitemia whether or not clinical symptoms were present. One of the most interesting findings was the very high percentage of asymptomatic parasitemias and the benign nature of the symptoms when present. In fact, 21 patients admitted to the hospital by transfer from Southeast Asia with diagnoses other than malaria were found to have positive smears. Other military hospitals have not encountered such high relapse rates, but significant amounts of asymptomatic malaria have been noted in several unit surveys by the U. S. Army WRAIR Unit at Saigon.

Duplication and confirmation of the Guam findings will be necessary before concluding that they signal the future development of a widespread condition. However, biologists who are familar with the history of insect and bacterial resistance to chemicals will recognize a pattern and, given the mass use of antimalarial drugs throughout Southeast Asia, will not find such a development illogical.

The CDC reports a ninefold increase over 1965 in the number of malaria cases of military origin with onset in the U. S. through October 1966. The cumulative total for malaria with onset in the U. S. as of December 31 is given as 517. It is not known whether these resulted because of failure to maintain the chloroquin-primaquin prophylaxis for the required 8 weeks after leaving a malarious area, or because of drug resistance, or both.

REPELLENTS. The lack of repellents was certainly an important factor in many units during the first year. However, the conclusion that non-availability was the primary cause of failure to use repellent would be a mistake. Assurance of a

plentiful supply would not solve the problem in itself because it is quite evident that even when repellent was on hand it was used for the most part only when pest mosquitoes were abundant. Numerous night-biting collections have demonstrated that the *Anopheles* vectors are most active after 2100 hours. The bite of the *Anopheles* is hardly noticed by most people even when awake. An abundance of pest mosquitoes just after sunset will cause a run on the repellent supply, whereas when pests are not annoying there is no concern or even realization that *Anopheles* mosquitoes are present, and very little use of repellent.

Another factor which has limited use of repellent has been the unfounded, but widespread rumor that the Viet Cong could detect the odor. Special forces and Marine trainees have actually been told by their instructors that they should not use repellents for this reason. Fortunately, timely, controlled tests at the U. S. Army Medical Component, SEATO Laboratory and by the USDA at Gainesville showing that the odor of the standard repellent cannot be detected unless it is within 12 inches of the nose, have provided information to combat this fallacy.

Other considerations which may explain in part the failure to utilize personal protection methods more fully are inadequate education and an indefinable attitude sometimes referred to as "combat fatigue." There is no doubt that more training in malaria discipline can and must be accomplished at all levels and that continued emphasis on command responsibility is essential. It is also a fact that an undetermined number of personnel, particularly during or after long and repeated exposure to conditions where immediate survival is at stake, have little concern about a possible malaria attack.

GROUND CONTROL OPERATIONS. While aerial treatments are sufficiently hampered by hostile action, ground treatments are precluded by it. Some "Secure" areas where ground treatments have been employed have had pretty small perimeters, it is true, but the security is a necessary prerequisite to ground actions. This has meant that in some places adulticiding, without larviciding or source reduction of any nature, has been the method of the limited choice; use of large equipment, such as turbines, has been confined to roads with good, solid foundations beneath them and good drainage.

Fortunately, some ground equipment has fitted this specialized situation. The most useful, probably, is the back-pack, engine-driven mist and dust blower, with which a very considerable coverage can be effected in areas accessible only on foot. A non-thermal fog generator, which was developed by the military, has been an effective area treatment tool, even though it is trailer-mounted.

There is now being built up in each major area a nucleus of engineer personnel, trained in the proper use of both large and hand-operated equipment and coordinated closely with medical department surveys of breeding sources and population levels. The problem, therefore, is principally centered about the protection of the patrol, the civic action detail and similar isolated units or individuals, operating away from the camps and military enclosures.

AERIAL DISPERSAL. It was obvious as early as July 1965 that conventional ground control methods would not be applicable to a majority of situations where malaria was likely to be most prevalent. Therefore recommendations were made for the provision of a helicopter capability as soon as possible as well as for field trials in RVN of the low volume dispersal concept.

The Navy Bureau of Medicine and Surgery arranged for two helicopter dispersal equipment experts to report to the Preventive Medicine Unit, Naval Support Activity, Da Nang, in order to train vector control personnel and aircraft crews in the use of HIDAL (conventional liquid dispersal) and HIDAF (fog). Mr. David

L. Hayden and Mr. Willie V. Weeks of the Navy Disease Vector Control Center, NAS, Jacksonville, arrived at the end of November and a helicopter dispersal capability was established by 15 December.

Pre- and post-treatment data from larval dipping stations were used to evaluate effectiveness of HIDAL in Chu Lai area when operations began in February 1966. The survey data demonstrated excellent control of larvae but it has not been possible to prove that there was a similar effect on malaria rates because of several unknown factors such as seasonal incidence, population at risk, delayed incubation period, etc. The small payload and limited helicopter availability prevented the regular applications to sufficiently large areas which would have been required to demonstrate effective control of malaria. Nevertheless, there were definite indications that rates were reduced in treated zones at both Chu Lai and Phu Bai. The most serious weakness of the HIDAL system is the small payload and necessity to restrict operations to fully secured areas. These deficiencies were responsible for the failure to conduct complete treatments at Chu Lai and at the Rockpile and other high risk areas. The assignment of adequate helicopters, pilots, technical direction and crews was not possible during 1966 because of the demands of combat operations.

The Army has utilized another type of equipment for dispersal of a medium low volume (57 percent malathion at 8 to 13 oz./acre) spray from the HU-1 helicopter. This is a commercial unit which incorporates the tank, pump and booms in one unit and does not require any modifications or attachments to the helicopter. The payload is 4 to 5 times that of the HIDAL but the same vulnerability to enemy fire also prevents its use in combat or insecure zones. Definitive, objective data for evaluation of effectiveness against *Anopheles* species have not been available although subjective observations indicate good results against adult mosquitoes. Results in terms of lower malaria rates in treated areas were also inconclusive as of October 1966.

Attempts to obtain the use of a C-123 aircraft to conduct field trials of ultra low volume applications against *Anopheles* of Southeast Asia were unsuccessful until late in 1966. A capability was finally established in October when the Commander of U. S. Forces in Vietnam requested assistance from the Special Aerial Spray Flight. Major C. W. Marshall, USAF and Major C. T. Adams, USAF on TDY from Langley AFB trained pilots and crews in the conversion of defoliation equipment for insecticide application and in the techniques of low volume applications. One C-123 was assigned for a period of 30 days for the purpose of training and operational trials. Several areas were treated in Vietnam but adequate entomological surveillance facilities which could be used for meaningful evaluation were not available in most locations. One limited study was conducted on Con Son Island where 57 percent malathion at a dosage of 0.5 lb./acre was applied. Data collected under the direction of LTCOL T. E. Blakeslee, U. S. Army indicated very good post spray reduction of both larvae and adult mosquitoes over a 10-day period when compared with pre-spray counts, while counts in untreated areas increased considerably. Evidence of a reduction in malaria attack rates was not expected and was not obtained because of the lateness of the season and short period the aircraft was available.

Plans are being developed for extensive utilization of low volume dispersal by the C-123 during 1967 and strong recommendations have been made to improve facilities and provide more specialized personnel for the collection and analysis of epidemiological and entomological information.

Repeated swath runs in a grid pattern over enemy-held territory present an unacceptable risk even with the C-123. Therefore control in such areas will con-

tinue to be a problem. Some consideration is being given to the possibility of treating such areas by irregular single swaths to reduce vulnerability. An important unknown is how complete coverage must be to reduce vector populations below a critical transmission level. LV dispersal equipment for use on high performance combat aircraft has been under development at the Navy Disease Vector Control Center, Alameda and it is hoped that operational trials in Vietnam will also be possible with this equipment during 1967.

The failure of household residual techniques to control exogenous malaria in RVN and other countries of Southeast Asia as well as the urgency of the malaria problem facing friendly forces, make a comprehensive evaluation of the low volume concept of the utmost importance. Even if low volume applications are proven to be completely effective against *Anopheles* mosquitoes in protected situations, there will be many questions to be answered. There is no prior experience with this method of malaria control on which to determine the frequency of application, most efficient insecticide, selection of target areas and many other problems.

SUMMARY

1. Malaria is by far the most important mosquito-borne disease affecting personnel of the Armed Forces in the Republic of Vietnam. The total number of confirmed cases in U. S. Forces in less than two years has exceeded 10,000.

2. The distribution of malaria in RVN is highly discontinuous. Incidence is very low in most of the coastal plain, the cities and delta, whereas in parts of the foothills and highlands the attack rate has attained the equivalent of 100 percent infection in 2 months for small units. A very high percentage of the malaria has originated in combat, patrol and outpost situations where conventional mosquito control operations have not been possible.

3. Most of the military malaria is contracted outdoors rather than indoors and there is considerable evidence that the endophilic *Anopheles minimus* has not been a significant vector. The exophilic species *A. aconitus, A. maculatus, A. jeyporiensis candidiensis* (and in limited areas, *A. balabacensis*), are believed to be the most important vectors affecting military personnel.

4. The application of personal protection control methods has not been adequate. Anti-malarial drugs have not provided satisfactory control primarily because of resistance, and repellents have not been used consistently by personnel during exposure in high risk areas. There is evidence of a marked increase in the prevalence of strains of *falciparum* malaria resistant to *all* anti-malarial drugs.

5. The extraordinary amount of personnel movements is causing a redistribution of malaria from the hyperendemic foci of the interior to all parts of RVN and beyond. Wherever suitable vectors occur malaria has increased as new reservoirs are established. At least two cases of autochthonous malaria introduced from Vietnam have occurred on Guam. A major portion of the 517 cases of imported malaria reported in the U. S. during 1966 originated in Vietnam.

6. Conventional mosquito control methods for larviciding and adulticiding are being applied extensively in all the major enclaves and secure permanent bases. This program will assist greatly in the control of mosquito-borne encephalitis and dengue in these areas. It will also assist in preventing secondary vectors, particularly *A. sinensis* from entering the malaria reservoir.

7. A limited capability for low volume dispersal of insecticide by aircraft has been established recently in RVN. Efforts are being made to obtain Department of Defense support of a high priority for development of this technique and its evaluation as a malaria control method during 1967.

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NOTE: The majority of sources consist of unpublished, mimeographed reports, personal communications and observations, and unclassified official reports. These sources are not listed but may be obtained on request to the authors.

BIOLOGY OF *CULEX TARSALIS* DURING THE SPRING SEASON IN OREGON IN RELATION TO WESTERN ENCEPHALITIS VIRUS [1]

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The western encephalitis (WE) and St. Louis encephalitis (SLE) viruses are maintained by cyclic transfer of virus between *Culex tarsalis* and avian hosts during the summer months in the western United States, but it is not known how the viruses survive the winter period when mosquitoes are inactive. The vector overwinters as the hibernating adult female and can carry WE virus for several months during the winter (Bellamy, Reeves, and Scrivani, 1958). The virus has been isolated from *C. tarsalis* in California during all months except December (Reeves, Bellamy, and Scrivani, 1958), and *C. tarsalis* has, therefore, been suspected of maintaining WE virus through the winter. However, most evidence indicates that *C. tarsalis* or other mosquitoes are not the winter reservoir for WE virus in northern areas (Bennington, Sooter, and Baer, 1958; Rush, Brennan, and Eklund, 1958; Rush, Kennedy, and Eklund, 1963a, 1963b) and that mosquitoes become infected after they emerge from hibernation. Rush *et al.* (1963a) reported evidence that *C. tarsalis* did not acquire virus immediately after it left its winter habitat and postulated that it acquired virus later in the spring.

The virus transmission cycles that occur each summer would be impossible if the vector did not feed regularly on infected and susceptible hosts at some time earlier in the year. In the spring and early summer the number of mosquitoes and rate of blood feeding constantly increase and mosquitoes are increasingly exposed to potential sources of infection. As a result, conditions become more and more suitable for virus amplification in a mosquito-bird cycle. Isolations of virus from mosquitoes or birds during this

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