

**Proceedings of the DoD Symposium**

**“Evolution of Military  
Medical Entomology”**



**Annual Meeting of the  
Entomological Society of America  
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# Preface

From the Director

For the past several years, the Armed Forces Pest Management Board (AFPMB) has organized a symposium on some aspect of military entomology at the annual meeting of the Entomological Society of America. The 2008 meeting was held in Reno, Nevada and our symposium was held on the 16<sup>th</sup> of November.

The theme of the symposium was “Evolution of Military Entomology”. Our idea was to show how the discipline of military medical entomology, along with some aspects of public health evolved. Our speakers agreed in advance to provide manuscripts for publication and the result is this AFPMB Technical Bulletin.

Gary Miller and Peter Adler start us off with a look at conditions during the Civil War, when there were no medical entomologists. Civil war diaries contain many references to nuisance insects but there was, as yet, no connection to disease transmission. Next, CDR (ret) Joe Conlon traces the real origins of our profession during the Mexican-American War and WWI. As Joe says in his title, it was our ‘coming of age’. COL (ret) Gene Gerberg presents an entertaining account of his activities during WWII, especially dealing with bed bug infestations (and the problems are *still* with us!)

COL Bill Sames and co-authors have contributed a meticulous review of entomological issues encountered during the Korean conflict, in which many preventive medicine units served. CAPT (ret) Lance Sholdt gives an entertaining account of serving with the Marines during the Vietnam War. Of particular interest are his ‘lessons learned’ and some of the difficulties of trying to practice preventive medicine in the field.

Vector control during Operation Restore Hope in Somalia is the focus of the article by COL Steven Horosko. As the author states in his concluding sentence, “preventive medicine support, at any level, in the absence of command emphasis will fail”. Our Air Force colleagues, Maj Mark Breidenbaugh and Lt Col Terry Carpenter discuss the evolution of the aerial spray capability of that service. LCDR Brian Prendergast then provides a glimpse of life aboard a Navy hospital ship during a humanitarian mission.

MAJ Kendra Lawrence discusses how military research in vector control is flexible in its approach to problem-solving, and finally, LCDR Craig Stoops shares his adventures while working on the President’s Malaria Initiative in Africa.

My personal thanks go to LTC Jamie Blow, Chief of AFPMB’s Operations Division for organizing the symposium and pursuing the manuscripts for this publication. She did a great job, as you are about to see. Also, Dr. Rich Robbins of AFPMB’s Information Services Division contributed his great editorial talents. Thank you, Dr. Robbins. Also, I thank the authors for following through on providing us with their manuscripts.

If you would like to learn more about AFPMB, please visit our website at [afpmb.org](http://afpmb.org). Also, we will post these papers as pdf documents on our website as well.

On behalf of the authors and the staff at AFPMB, I hope you enjoy reading this Bulletin and would appreciate any feedback you might have.

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## “...drenched in dirt and drowned in abominations...”: Insects and the Civil War

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Human history has recorded innumerable conflicts. The massing of humanity, poor sanitary conditions, and disease are among the many factors that take their toll during wars. However, the role that insects play in these conditions has often been overlooked by historians, despite the pivotal role that insects have played. The American Civil War (1861-1865) was not exempt from the influence of insects.

The Civil War represents a unique part of American and world history. As the last major war before the proof of the germ theory, it was also a time before the proof of arthropods as vectors of disease agents. A terrible price was paid as a consequence of ignorance. Among the estimated 620,000 deaths, nearly twice as many soldiers died from disease as did in battle. Many of these disease-related deaths had an insect element.

Confederate and Union armies were among the most literate combatants in history. More than 90% of white Union soldiers and more than 80% of Confederates could read and write.<sup>1</sup> Soldiers and their families, sensing the historical importance of the war, preserved many of those personal accounts and reminiscences. These accounts were often laced with references to insects. Perhaps no one said it better than Civil War veteran Wilbur F. Hinman when he wrote, “Among the memories of the war few are more vivid than those of the numerous little pests that, of one kind or another, day and night, year in and year

out, foraged upon the body of the soldier.”<sup>2</sup> In addition, the Civil War was the first extensively photographed war. This photographic legacy provides a wonderful glimpse of the activities of soldiers, their lives, and the conditions that were conducive to the superabundance of insects.

### **In the Absence of Military Entomologists**

No military entomologists existed during the Civil War. Indeed, there were few entomologists anywhere. The first state entomologist (Asa Fitch) and the first federal entomologist (Townend Glover) had been appointed only seven years earlier, in 1854. However, in the absence of military entomologists, other resources served to handle the insect-related issues. These included the Medical Corps (including regimental surgeons), the Quartermaster Corps, the U.S. Sanitary Commission and the U.S. Christian Commission, sutlers, and the individual.

Some of the roots of preventative medicine can be traced to the U.S. Sanitary Commission, an official agency commissioned by the U.S. government early in the war. It grew out of concern for the deplorable conditions being witnessed. A civilian organization, the Commission was divided into three main departments: the Preventive Service or Sanitary Inspection, the Department of General Relief, and the Department of Special Relief. Particularly noteworthy was the task of the inspectors of

Preventive Service to be attentive to the "...chance of danger from change of climate, from exposure, from malarious causes, from hard marching, or from any failure of supplies or transportation."<sup>3</sup> Many of these elements had a direct connection to insects. Under such vigilance, some conditions did improve but the task was daunting.

### **Setting the Stage**

Writings of the Civil War contain a wealth of information about the various arthropods encountered. For the soldier in the field, it wouldn't be long until they realized they would be fighting more than a human enemy. The historian for the 7<sup>th</sup> Rhode Island summarized the full wrath of insects and their brethren in his bivouac: "By evening many tents were up and the camp was in fair condition, but great was the complaint concerning vermin. It seemed as though all the insect life of the entire region had congregated here in anticipation of a glorious picnic. Necessarily our apartments were kept wide open, hence they were free to all comers. Ants built catacombs beneath our couches, land crabs burrowed up through the fungus-grown floor to inspect our resting places, woodticks climbed the tent-walls, whence they could select the most favorable lodging place, flies covered our food as with sackcloth and endeavored to rob us even of its scantiness, mosquitoes of unrivaled force and ferocity plied their lancets with merciless vigor, and, when their appetite were appeased, rested on the ridgepole and mockingly barked at their victim until he went to sleep, great hairy spiders built nests in the peak, strange things whizzed and buzzed and boomed through the darkness, anon dropping on our faces with a sharp thud as if shot or

alighting with sticky feet reluctant of dislodgement. All night long there was a rustling and a crackling of well-nigh every type of winged and creeping abomination that earth produces."<sup>4</sup> While not up to the standards of modern entomology, the participant's descriptions are vivid enough to give us an understanding of the arthropods with which they were contending. We determined that the main arthropods referenced can be divided into the following groups: flies (filth and biting), lice, fleas, bees and ants, beetles, bedbugs, and chiggers, ticks, and spiders. For the purposes of this presentation, flies and lice are the main focus.

The arthropods encountered at a new bivouac were soon accompanied by others that were associated with camp untidiness. The presence of many insect pests was directly related to camp hygiene or of its absence. A British observer resolved that he would be, "...drenched in dirt and drowned in abominations..."<sup>5</sup> Steward Marshall Brooks best summarized the situation: "Few recruits bothered to use the slit-trench latrines (and those who did usually forgot to shovel dirt over the feces) and most urinated just outside the tent - and after sundown, in the street. Garbage was everywhere, rats abounded, and dead cats and dogs turned up in the strangest places. The emanations of slaughtered cattle and kitchen offal together with the noxious effluvia from the seething latrines and infested tents produced an olfactory sensation which has yet to be duplicated in the Western Hemisphere."

"As for water - and seldom was there enough - any source would do in the early camps. Frequently, it was so muddy and fetid the men held their

noses when they drank the stuff. In many instances, the heavy rains washed fecal material directly into the supply, with disastrous consequences.”<sup>6</sup>

Such situations combined with large entourages of military animals exacerbated conditions. This was a war before high mechanization. Horses and mules provided the means for much of the non-rail transportation. The numbers are staggering by today’s standards. For example, Grant’s Wilderness Campaign in 1864 began with 56,499 mules and horses.<sup>7</sup> As the beef was supplied on the hoof, the cattle train that followed was estimated between 8,000 and 10,000 head.<sup>8</sup> Considering the amount of manure produced from these animals, it was a filth fly smorgasbord. A Virginia private elaborated in his diary: “Dec. 3, 1863...On rolling up my bed this morning I found I had been lying in - I won’t say what - something though that didn’t smell like milk and peaches”<sup>9</sup>

### **Filth Flies**

Filth flies are a medically important group of insects because of the role they play in the transmission of disease agents. Feeding freely on human food and excrement, they are structurally well adapted for the transmission of pathogens that cause cholera, diarrhea, dysentery, and typhoid. As early denizens of the camps, the flies multiplied in the squalid conditions. Early in the war, a Confederate elaborated on the dipteran cohabitants in his camp, “When we open our eyes in the morning we find the canvas roofs and walls of our tents black with them [flies] ... It needs no morning reveille then to rouse the soldier from his slumbers. The tickling sensations about the ears, eyes, mouth, nose, etc., caused by the microscopic feet and inquisitive

suckers of an army numerous as the sands of the sea shore will awaken a regiment of men from innocent sleep to wide-awake profanity more promptly than the near beat of the alarming drum.”<sup>10</sup> Union soldiers fared no better. A member of the 72<sup>nd</sup> Indiana Volunteer Infantry described the fly conditions at his camp by writing, “The deluge of rain which had fallen in the 10 days past had soaked the ground until the whole face of the earth was a reeking sea of carrion; in many places, as we walked over the ground, we could hear and see the sputtering water through which the noxious gases arose to high heaven, blending a thousand filthy smells into one, which no christian olfactory could withstand. Countless thousands of green flies flitted about with nasty, lazy drone, like the hum of a thousand spindles. These flies were constantly depositing their eggs on the ground, on the leaves, on everything - which the broiling sun soon hatched into millions of maggots, which wiggled until the leaves and grass on the ground moved and wiggled too; and in a short time they hatched into flies and added to the swarms in the air, and laid more eggs, &c. We are willing to risk our reputation as a faithful recorder of historic facts in saying that we have seen acres and acres of ground covered with leaves that were in a constant quiver from the motions of the maggots that infested them.”<sup>11</sup>

Diarrhea and dysentery were by far the most common sicknesses in both Union and Confederate armies. Although flies probably were not involved in every enteric disease, there is little doubt they contributed to the prominence of such ailments. Whether soldiers called it the “quickstep” or the “alvine flux,” diarrhea and dysentery were the Civil War’s greatest cause of

common misery. Symptoms of dysentery and diarrhea presented themselves as more than an occasional case of loose bowels; one soldier noted that his bowels moved 18 times in three hours while he was on as Corporal of the Guard. Union records list more than 1.7 million cases of dysentery and diarrhea, maladies that took the lives of nearly 60,000 soldiers.<sup>12</sup> The suffering from these diseases was especially bad in prisons. Of 12,462 deaths recorded at Andersonville, 5600 (45%) were attributed to diarrhea and dysentery.<sup>13</sup> Confederate prisoners also suffered; of the nearly 41,000 Rebels held in the North, dysentery and diarrhea took 6,000 lives.

“Curative” measures for dysentery and diarrhea ran the gamut from flannel body bandages, growing a beard, wearing stomach belts, or drinking whisky. Medical doctors prescribed lead acetate, sulfuric acid, calomel (a mercury compound), and silver nitrate. Such prescriptions only worsened matters. However, doses of opium or belladonna were therapeutic.

The omnipresent fly also presented a problem in open wounds of the soldiers. Eggs deposited by flies hatched quickly and the injured area soon teemed with maggots. Union doctors removed the maggots with chloroform but at least one Confederate doctor used maggot therapy to remove the decayed tissue associated with hospital gangrene. J. F. Zacharias, a surgeon in the Confederate army wrote, “During my service in the hospital at Danville, Virginia, I first used maggots to remove the decayed tissue in hospital gangrene and with eminent satisfaction. In a single day, they would clean a wound much better than any agents we had at our command. I used them afterwards at various places. I am sure I

saved many lives by their use, escaped septicemia, and had rapid recoveries.”<sup>14</sup> Besides their efficiency, the maggots also excrete allantoin, a chemical compound that aids the digestion of necrotic tissue and thus promotes new tissue growth. However, maggot therapy works best under sterile conditions -- a rare situation during the Civil War, given the lack of understanding of germs.

### **Mosquitoes**

No story of insects in the Civil War could be complete without referring to the biting flies -- especially mosquitoes, biting midges, and black flies or buffalo gnats. Of the biting flies, mosquitoes probably had the greatest impact on soldiering during the Civil War. Mosquitoes played two roles in the Civil War, one a nuisance, the other deadly. As phlebotomists par excellence, they were annoying pests. If they were infected with one of the microorganisms that causes disease, their bites could lead to debilitation or death. Called “gallinippers” by the soldiers, mosquitoes were considered by some Confederates to be a greater nuisance than Yankee bullets.<sup>15</sup>

The puddles in the camps on the Peninsula, the trenches at Petersburg, the ditches at Vicksburg – all would have provided attractive breeding areas for mosquitoes. Camp life also produced an excess of breeding habitats such as sinks and water-filled pots and barrels that complemented the natural breeding sites. The standing water was often full of “wiggletails” and “wrigglers” – terms the soldiers used to describe the larval mosquitoes. A Confederate soldier in York Co., Virginia, testified that he “drank more mud and wiggle tails than water.”<sup>16</sup>



Figure 1. Trenches near Petersburg attest to both prime breeding habitats for mosquitoes and the filthy conditions. (Library of Congress)

Mosquito abatement was virtually non-existent. Some units were issued mosquito bars but unless the netting was secured correctly, they were ineffectual. Others relied on smoky fires or smudges. One soldier groused, “Mosquito bars and smoke of camp-fires were only slight protection.”<sup>17</sup> Many soldiers depended on tobacco smoke as a deterrent. A Captain tormented by mosquitoes while writing up his company books employed tobacco smoke to his advantage. He bought a box of cigars and had the enlisted men come into the tent, smoke the cigars and puff the smoke while he finished his task.<sup>18</sup> The viler the tobacco, the better it was for repelling mosquitoes. Most soldiers had to endure the ravages until cooler weather brought change.

Of the diseases borne by mosquitoes, malaria ranked highest. Malaria was termed “simple intermittent fever” by the medical professionals, but the soldiers referred to the malady as ague or “the shakes.” Malaria was so prevalent in some camps that a standard greeting was “Have you had the

shakes?”<sup>19</sup> More than 1.3 million cases and 10,000 deaths from malaria were recorded in the Union Army.<sup>20</sup> Fully one quarter of all illness reported in the Union Army was malarial in character.<sup>21</sup> Treatment for malaria reflected a time of heavy dosing. Pills of mercury, turpentine, carbonate of ammonia, tonic, and brandy represented some of the cure-alls. Nevertheless, an effective drug -- quinine -- was available for prevention and cure of the disease. Union armies used more than 19 tons of quinine sulfate during the war.<sup>22</sup> However, the Northern blockade of the Confederacy made this drug difficult to obtain in the South, which led to quinine smuggling and a black market. Prices of \$400 to \$600 and even \$1,700 an ounce were recorded late in the War.<sup>23</sup> Because a Confederate private was paid only \$18 a month in nearly worthless script, the price became prohibitively expensive.



Figure 2. A hospital ward in Washington, D.C. was photographed with mosquito netting draped around the beds. (Library of Congress)

## Lice

Introductory books in entomology describe the basis for louse infestations: “People who bathe and change clothes regularly seldom become infested with lice, but when they go for long periods without doing so and live in crowded conditions, lousiness is likely to be prevalent.”<sup>24</sup> Such a description was certainly fitting for the Civil War. The participant could have suffered from any one or all the lice that infest humans: the body louse (*Pediculus humanus humanus* L.), the head louse (*Pediculus humanus capitis* DeGeer), and the crab or pubic louse (*Phthirus pubis* [L.]). The vast majority of references were to body lice.

Lice were known by a number of names: bluebellies, rebels, tigers, Bragg’s body-guard, soldier’s body-guard, zouaves, graybacks, vermin, travelers, cattle, and livestock.<sup>25</sup> The term used most commonly by both Yank and Reb was “grayback”. Rare individuals claimed not to have had lice.<sup>26</sup> However, lice were so common that it would have been unusual for an enlisted man or an officer not to harbor them. They permeated nearly every aspect of a soldier’s life to the point that they even filled his dreams. A Yankee prisoner wrote, “Had a funny dream last night. Thought the rebels were so hard up for mules that they hitched up a couple of grayback lice to draw in the bread...”<sup>27</sup> A veteran summarized his opinion of the ubiquitous louse, “Like death, it was no respecter of persons. It preyed alike on the just and the unjust.”<sup>28</sup> Many soldiers certainly sheltered a healthy colony of lice. An orderly of one company officer picked 52 graybacks from the shirt of his chief at one sitting.<sup>29</sup>

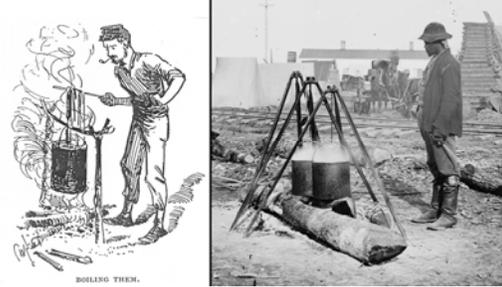


Figure 3. Delousing included several techniques such as boiling clothes. Finding a receptacle big enough for the job often meant the company’s cook pot served double duty. (Illustration from Billings 1887; photograph from Library of Congress)

Delousing or “skirmishing” as it was called took up a good portion of free time. It also served as time for socializing while the individuals methodically inspected the seams and folds of their clothing. Numerous skirmishing techniques were employed. Often the graybacks and nits were simply crushed between the thumb and finger but, quicker methods also were used when available. These included painting the seams of the clothing with “blue ointment” (a mercury compound), singeing clothing over a campfire, or boiling, beating, and scrubbing it. A Yankee prisoner elaborated on the singeing procedure: “One of the most effectual ways of doing this [singeing] was to turn the garments wrong side out and hold the seams as close to the fire as possible, without burning the cloth. In a short time the lice would swell up and burst open, like pop-corn. This method was a favorite one for a reason other than its efficacy: it gave one a keener sense of revenge upon his rascally little tormentors than he could get in any other way.”<sup>30</sup> The boiling method also could be effectual -- if one could find enough water or a receptacle big enough. To this means, the company cook pot would

serve to boil shirts.<sup>31</sup> However, the residue left in the pots was another formula for intestinal distress.

Additionally, the hot water could shrink woolen clothing to an unwearable size.

Lice were not without redeeming value. As a topic of conversation, soldiers would sometimes compare captured graybacks. Several Confederates claimed they caught lice embellished with the letters C.S. (Confederate States) and I.W. (In for the War).<sup>32</sup> For soldiers, probably the greatest source of entertainment (and at least some income) that involved lice centered on the louse races. Wagers were placed on louse races, where the arena was often a mess plate. Sam Watkins described one of these events among his fellow Confederates, “The boys would frequently have a louse race. There was one fellow who was winning all the money; his lice would run quicker and crawl faster than anybody’s lice. We could not understand it. If some fellow happened to catch a fierce-looking louse, he would call on [Fred] Dornin for a race. Dornin would come and always win the stake. The lice were placed in plates – this was the race course – and the first that crawled off was the winner. At last we found out D’s trick; he always heated his plate.”<sup>33</sup>

Soldiers endured their associations with the louse until the muster out. There is little doubt that the life cycle of the omnipresent louse was intertwined with the daily life of the Civil War soldier. What remains a mystery is why neither Confederate nor Federal (nor corresponding civilians) ever suffered extensively from louse-borne typhus. The conditions certainly seemed rife for such an epidemic. With the exception of a possible outbreak of asymptomatic

typhus in Willington, NC, the disease never really materialized.<sup>34</sup>

## Conclusion

This subject not only underscores the hardships and misery that Americans on both sides had to endure, but it also highlights how far we have come in medical entomology and preventative medicine over the past century and a half. It also reminds us how much has not changed since 1861.

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<sup>31</sup> Billings, op. cit., p 88

<sup>32</sup>Wiley, B. I. 1994. op. cit., p. 250

<sup>33</sup> Watkins, S. R. 1999. *Co. Aytch or , A side show of the big show*. Inge, M. T. (ed.) Plume, Penguin Putnam, Inc., New York, NY p. 39 [274 pp.]

<sup>34</sup> Humphreys, M. 2006. *A Stranger to Our Camps: Typhus in American History*. *Bulletin of the History of Medicine* 80(2): 269-290

## **Military medical entomology during the Mexican-American and First World Wars: A coming of age**

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An inchoate appreciation for the profound impacts poor field sanitation exacted on troop strength and morale during the Civil War led to the establishment of the US Sanitary Commission in 1861. Even so, a full

realization of the critical role sanitation and insect control play in the prevention of communicable diseases had to await the birth of medical entomology brought about by the brilliant discoveries of pioneers in tropical medicine decades

later. Indeed, the Spanish-American War reemphasized that we had not learned our lessons in exposing immunologically naïve troops to exotic diseases and those caused by poor sanitation, and enormous numbers of communicable disease casualties were the predictable results. In time, improved weaponry and a realistic appreciation for the force-multiplicative capabilities of proper field sanitation and hygiene tilted casualty totals in favor of disease forever thereafter.

### **The Beginnings**

This is not to say that a connection of insects with disease hadn't been previously entertained. Doctor John Crawford of Baltimore published some ideas on the possible association of mosquitoes with malaria in 1807 (Bryan et al. 2004). Doctor Josiah Nott had expressed similar ideas in 1848 in South Carolina (Chernin 1983). It was in the late 19<sup>th</sup> century, though, that the connection between insects and certain diseases began to take shape. In 1882 an English expatriate physician, Albert Freeman Africanus King, read a paper "Insects and Disease - Mosquitoes and Malaria" before the Washington Philosophical Society. In the paper, Dr. King listed 19 reasons why he believed malaria was transmitted by mosquitoes. The paper was subsequently published in the *Popular Science Monthly* in September 1883 but drew little interest because of King's reputation as a scientific gadfly. This was not helped by his insistence that malaria could be controlled in Washington DC by erecting mosquito netting to the height of the Washington Monument around the entire city (Daniels 1950).

Prior to our understanding of the role of insects in disease transmission with the findings of Smith, Ross and Manson,

a number of interesting entomological observations were contributed by military medical officers as a result of epidemiological investigations. Differential attack rates for yellow fever among blacks (10.7% fatality rate) and whites (31.6% fatality rate) in the military led to increased study of the disease. Impetus was also gained from deaths due to yellow fever after the Civil War. For instance, 27 fatalities due to yellow fever were recorded from Fort Jefferson in Florida in 1867, while another 13 fatalities occurred at the same base in 1873. A total of 12 soldiers died at Fort Barrancas in Pensacola in 1869 (Sternberg 1899). A survivor of that epidemic, George M. Sternberg, was eventually assigned to the Havana Yellow Fever Commission and became extremely influential in the growth and maturation of military preventive medicine in later years<sup>5</sup>.

### **Spanish-American War**

The Spanish-American War, involving only 118 days of hostilities, nonetheless graphically demonstrated the consequences of inadequate medical resources, particularly in preventive medicine, on troop health in garrison settings. The rapid mobilization of forces strained medical assets and resulted in significant morbidity due to typhoid in garrison settings. The force structure figures below reflect a dramatic increase in troop concentrations occurring in an extremely brief period.

#### **Force Structure**

1. April 1898 - 28,183 officers and enlisted men.
2. May 1898 - 163,592
3. July 1898 - 265,629
4. August 1898 - 272,618, peak army strength

Vector-borne disease casualties were of little significance during the conflict, but commanders were clearly concerned about exotic diseases affecting troops if deployed for extended periods. In July, immediately after the Battle of Santiago, Theodore Roosevelt wrote: “If we are kept here it will in all human possibility mean an appalling disaster, for the surgeons here estimate that over half the army, if kept here during the sickly season, will die.”

The most serious confrontation with communicable disease occurred at Camp Wickoff, a temporary Federal demobilization and quarantine camp for troops returning from Cuba. The camp, named for Col. Charles Wikoff (22nd Infantry, killed at El Caney), was established in August-September of 1898 in the vicinity of Fort Pond Bay, Montauk Point. The site was selected for its proximity to rail and deep-water anchorage, and because it was believed prevailing offshore winds would hinder spread of tropical diseases to the civilian population. In excess of 20,000 returning soldiers were brought in by ship during the August to October timeframe, and 275 perished from typhoid as a result of grossly inadequate sanitation facilities. In fact, regiments in all of the stateside camps suffered 20,738 cases of typhoid fever, resulting in 1,590 fatalities. Typhoid fever accounted for 87% of all deaths attributable to disease (2957 – compared to 332 combat fatalities) during and after the conflict (Gibson 1958).

Investigations into the causes of this level of communicable disease were initiated on the orders of then Surgeon General George Sternberg. The so-called Reed-Vaughan-Shakespeare Typhoid Board eventually concluded that flies

were a major culprit in the spread of the disease (Reed et al. 1940). At the same time, SG Sternberg established other boards to study infectious disease in the Philippines (plague) and Cuba. The value of these boards in expanding our knowledge of communicable disease spread was duly recognized and eventually resulted in Sternberg establishing the Medical Reserve Corps – out of which specialists in disease transmission and control could be drawn (Bayne-Jones 1968).

### **Integrated Vector Control – Havana**

I have purposely avoided addressing the immensely important discovery of *Aedes aegypti* as the vector of yellow fever because the subject requires in-depth treatment well beyond the scope of this paper to attribute it due respect. Nonetheless, William Crawford Gorgas, when appointed Chief Sanitary Officer of Havana, Cuba, accepted the evidence provided by the Reed Commission that the mosquito, *Stegomyia fasciata* (*Aedes aegypti*), was the sole transmitter of yellow fever and immediately began preparations to rid the city of yellow fever. He was aware also of the recently proven transmission of malaria in man by anopheline mosquitoes and used this information to strengthen his case for comprehensive vector control within the city limits.

The military aspect of Gorgas’ control measures cannot be over-emphasized. Gorgas enjoyed the full support of General Leonard Wood, Governor General of Cuba, and used this relationship to its full advantage in devising and implementing control measures. Upon Wood’s declaration of martial law, Dr. Gorgas divided Havana into 20 districts and assigned teams of sanitation officers to each sector. The

inspectors were placed in charge of so-called “Stegomyia Brigades.” These units provided mosquito control services to those areas reporting yellow fever cases. Initially, Gorgas issued orders to the general public of Havana to oil or screen their barrels of drinking water. All cases of yellow fever were required to be immediately reported to American authorities. Upon receiving the report, sanitation officers from the applicable Stegomyia Brigade were sent to the victim’s house to begin fumigation, sealing the house and burning pyrethrum to kill any mosquitoes inside.

Ultimately, he drove yellow fever out of the city. During his first year of control measures, approximately 300 deaths in Havana were due to yellow fever. After 26 September 1901, there were no further cases. This was the first triumph over an insect-borne disease of man based upon bionomics of the vector and knowledge of the cycle of the parasite – although conceived by a military physician, not an entomologist. This also provided the basis for the integrated vector control techniques we utilize to this day.

Gorgas further utilized the military paradigm in his 10-year battle against vector-borne disease in the Canal Zone. The Stegomyia Brigade concept proved so successful that Ronald Ross discussed the initiation of organized mosquito control brigades in a technical manual he developed during his later years lecturing on applied vector control (Bayne-Jones 1968). Despite the lack of full understanding and opposition of the project engineers, Gorgas succeeded in freeing the Canal Zone of yellow fever in two years; the final indigenous case occurred there in May 1906. Malaria was also greatly reduced by instituting a variety of large-scale integrated anti-

mosquito measures, such as ditching, draining, larviciding, fumigating, and screening. Colonel Gorgas claimed that during the construction of the Panama Canal the Sanitary Department, which he headed, had saved 71,370 human lives and the prevention of a vast amount of disability from sickness. He did not fully disclose his methodology for arriving at this number, but it is clear that his control strategies saved an enormous number of lives, time and money (Gorgas 1903).

### **World War One**

Here again, rapid mobilization of troops overwhelmed resources to properly house them and resulted in enormous numbers of disease casualties. Of the 112,422 deaths recorded, 56,206 were from disease. A total of 33,062 of these occurred stateside, while 23,144 occurred in the expeditionary forces (Duncan 1914). This was attributed to poor sanitation and overcrowding. The lessons of the Spanish-American War had not been entirely ignored, as there was a rudimentary program available for pest control training. Unfortunately, malaria (truthfully, as it turned out) was not considered a serious threat in France and areas of Europe in 1914. Thus, little attention was given to the protection of troops from mosquitoes, lice and other pests overseas. Ironically, extensive drainage programs were carried out at training camps stateside in the southern states, with over 3 million dollars expended. This was an enormous sum of money at the time and underscores the emerging realization of the toll mosquito-borne diseases could exact on forces preparing for war. Unfortunately, entomologists did not always supervise the drainage schemes. Furthermore, they were not considered overly successful

since 9,617 cases of malaria were reported among troops in training camps during this period, resulting in a total of 115,000 man-days lost from training. In point of fact, there were several entomologists and biologists on duty in the armed forces during WWI. Herms and Van Dyne were commissioned in the Sanitary Corps and worked on entomological problems (Dews et al. 1960).

Interestingly, as the war increased demand for agricultural products, agricultural pest control assumed a greater importance. Large troop concentrations, food shortages, poor sanitation and epidemics became not just public health, but military problems also. Indeed, chemical warfare and pest control industries created tools used by each other. There is little doubt that World War I stimulated the creation, growth and linkage of military/civilian chemical capabilities, transforming the United States into a world chemical power. It can be said that chemical warfare capability and vector control co-evolved to meet the needs of the war machine. Gas and explosive (explosives use picric acid, a process that produces paradichlorobenzene) production stimulated an enormous amount of research into organic chemistry that spun off into products to combat cotton pests. This was further pushed as prices rose precipitously on cotton due to war demand.

The military mindset continued to exert its influence over pest control during this period, reflecting the dominant role played by the military in the evolution of means to control vector populations. During this war period, our culture even began using military metaphors for pest control. The August 1915 edition of *Living Age Magazine*

contained an article in which it was stated “We shall conquer if we realize in time the seriousness of this war against the arthropod; as no doubt we shall get the better of the Teuton and Magyar if we brush aside half measures.” Also at this time, Dr. Stephen Forbes, an entomology professor at the University of Illinois and president of the Entomological Society of America, was quoted in a 1917 Chicago Herald article entitled *Fifty Billion German Allies Already in the American Field* as saying “In wartime the US needs carefully planned campaigns run by organized communities, participated in by everyone as to be available, directed by experts and financed as far as is necessary by the state.” The military paradigm, the result of 20 years of research and applied vector control, had finally taken root in the American psyche.

Troops engaged in trench warfare in Europe were often infested with lice. There was no satisfactory way of controlling the lice. Methods recommended included the Serbian Barrel, dry heat, fumigation and hand collecting. The treatments were difficult to apply in the field and had no residual effect. Little or no emphasis was placed on the control of flies, roaches, bed bugs, chiggers, ticks, and insects infesting food supplies. As stated by L. O. Howard, “They did not stop to think of the very great importance of insects in the carriage of certain diseases, the ease and frequency of such transfer becoming intensified wherever great bodies of men are brought together, as in great construction projects, and especially in great armies. They did not realize, entirely aside from the special diseases of this character met with by the troops in Africa, Mesopotamia and in the

region of Salonika, that even upon the western front, in a good temperate climate, warfare under trench conditions was rendered much more difficult by reason of the prevalence of trench fever which investigations during the latter part of the war showed to be carried by the body-louse.” (Howard 1919).

The tactical stalemate resulting in trench warfare caught both sides woefully unprepared. The allied expeditionary force actually preferred attack, and thus had no provision for long-term supply of its troops. This had disastrous consequences. Doctrine evolved to plan baths for troops every 10 days. Fires were forbidden. As a result, troops huddled for warmth, facilitating the transfer of body lice. Robert Graves, in his autobiography “Good-bye to All That,” put it humorously: “We once discussed which were the cleanest troops in the trenches, taken by nationalities. We agreed on a descending-order like this: English and German Protestants; Northern Irish, Welsh and Canadians; Irish and German Catholics; Scots; Mohammedan Indians; Algerians; Portugese; Belgians; French. We put the Belgians and French there for spite; they could not have been dirtier than the Algerians and the Portugese.” (Graves 1960). J.R.R. Tolkein, an infantryman who spent a great part of the war in the trenches, remarked that the scene depicted in his novel *The Two Towers*, where the protagonist Frodo looks into the swamp water and sees the faces of corpses, is taken directly from his experiences with dead comrades in the trenches.

A good deal of literature is available on the effects of louse-borne typhus on strategy and tactics on both sides during WWI, and I shall not treat it in any depth here. It appears that Allied/German

soldiers in the trenches of the Western Front were as universally lousy as their colleagues in the East but did not suffer louse-borne typhus. Cogent explanations are few, but the Central Powers, realizing that a typhus fever epidemic introduced with troops transferred from the East could easily lose them the war, took the utmost precautions to avoid this. Troops were deloused whenever they fell back from the front lines. Evidently the louse-borne typhus epidemic that cost the Prussians the War of the Austrian Succession during the siege of Prague (1742) taught them a lasting lesson.

While typhus did not make itself known to any great degree in the Western trenches, a separate louse-borne disease, trench fever, caused considerable morbidity. Discovered in 1915, trench fever had disappeared by 1918, having infected over 800,000 allied soldiers, resulting in an enormous number of man-days lost.

Louse control measures available to the infested troops were crude at best. Treatments were extremely varied and of marginal effect. Naphthalene, creosote, iodoform (NCI) powder or paste, proprietary mercury preparations (Indian troops preferred this method) and sulfur bags (2” square, preferred by South African troops) were but a few of the controls used. Infested clothes were treated with either dry or wet heat.

It is clear that sanitation standards attendant to trench warfare were inadequate. Nonetheless, efforts were made to address the shortfalls at both the command and small unit levels. Hans Zinsser, a professor of bacteriology and immunology successively at Stanford, Columbia, and Harvard Universities, rose to the directorship of communicable disease control and prevention activities

in the American Expeditionary Forces in France during World War I. While serving as a Sanitary Inspector of the Second Army at that time, Zinsser published a general order on "Sanitation of a Field Army," formally establishing acceptable public health practices designed to lower communicable disease incidence in the expeditionary forces. After the war, he wrote a delightful book, "Rats, Lice and History," detailing vector-borne disease impacts on military operations and societies in general, that remains the foremost work on the subject.

Zinsser pursued his career in preventive medicine after the war and served as a consultant to the Surgeon General on the subject for several years afterward. Under his wise and experienced tutelage, medical doctrine in the United States military began to reflect the integrative nature of preventive medicine, compelling practitioners to embrace a number of varied disciplines to ensure more efficient and long-term public health outcomes. Dr. Zinsser wrote: "Just as the laboratory is of partial efficiency only in hospitals if the bacteriologist is unfamiliar with the cases in the wards, so in armies the laboratory service cannot be entirely efficient unless the laboratory officer is trained in and in touch with the epidemiological data. For this reason, the Sanitary Inspector of the Army, who should be capable of acting as an adviser to medical officers and sanitary inspectors of the several troop units, should be a man not only trained in practical sanitation but one who at the same time is familiar with the facts of epidemiology, the methods of making epidemiological surveys, and can handle a laboratory for the control of

communicable diseases as an important tool of his profession." (Zinsser 1919).

### **Between Hostilities**

Realizing the critical nature of timely environmental health interventions upon full force mobilization, the National Defense Act of June 4, 1920 established the Sanitary Corps Reserve as an on-call cadre of sanitation expertise, stating that "...there be organized under the Medical Department for the period of the existing emergency a sanitary corps consisting of commissioned officers." The sanitary corps would primarily be staffed through assignment or appointment of Medical Reserve Corps officers. Dr. William Herms was the first entomologist commissioned in the Sanitary Corps reserve. Dr. Herms noted that 6-8 entomologists and parasitologists in the Sanitary Corps were assigned to "malaria drainage detachments," comprising about 300 officers and men. The work of the entomologists in these detachments was integrated with that of the sanitary engineers.

Herms further stated "This background of military experience, particularly in the Medical Department of the Army, together with some early experience as an infantryman, no doubt, caused me to give emphasis to medico- military problems in my course in "Medical Entomology" particularly from 1919 on. Many of my former students now on duty as sanitary officers in World War II have reminded me of this and have expressed approval." (Herms 1945). In recognition of its manifest contributions to troop health and morale, entomology was listed as one of the professional interest groups in the Sanitary Corps in Army Medical Bulletin No. 21 (1927).

Only 14 entomologists eventually took advantage of the opportunity

afforded. These were called to duty early in WWII and formed the nucleus from which developed the greatly expanded services of entomologists in WWII.

Civilians deemed expert in sanitation, sanitary engineering, bacteriology, or other sciences related to sanitation/preventive medicine, or possessing other knowledge of special advantage to the Medical Department, such as medical entomology, were also to be identified as ready reserve assets.

A direct result of the experiences gained in tropical medicine and hygiene during the First World War was the founding and expansion of schools of public health in the United States. The students trained at these institutions eventually formed the basis for medical entomology practice during WWII.

The first school of training in public health and preventive medicine in this country was the Army Medical School, reflecting a profound appreciation for the critical nature of force readiness and the force-multiplication attributes of environmental health.

Shortly thereafter, a school of sanitarians at the Massachusetts Institute of Technology was initiated as a result of Sedgwick's epidemiological investigations in the 1890's. This merged with Harvard University in 1913, forming the Harvard-MIT School of Public Health, and became the first civilian school of public health in the United States. It was reorganized in 1918 and named the Harvard University-Massachusetts Institute of Technology School of Public Health. In 1922, the school was separated from MIT and thereafter has been designated the Harvard School of Public Health.

The Johns Hopkins University School of Hygiene and Public Health was formed and began operations in 1918. In

succeeding years, these were followed by schools of preventive medicine and public health at six more universities.

## Conclusion

An appreciation of the profound impacts vector-borne diseases exert on immunologically naïve populations, gathered through experience and research accomplished, in large part, by specialists from military preventive medicine units, laid the foundation for organized military entomology programs that have demonstrably saved thousands of lives in exotic locales during wartime (Bayne-Jones, op.cit. p. 157). The exigencies of warfare, determined as they are by troop health and morale, inexorably drove military doctrine toward inculcation of unit specialists in sanitation and, eventually, medical entomology. The process of recognizing the impact of communicable disease on force readiness was, in retrospect, slowed by a paucity of information tying disease to specific vectors. However, military medical personnel were - and remain - at the cutting edge of tropical medicine.

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## Entomologists in World War II

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After World War I, the War Department provided for the commissioning of entomologists in the Army Organized Reserve as Sanitary Corps Officers. In 1940, the Army Surgeon General realized that the U.S. could be drawn into a world conflict and began to organize the Medical Department to support this effort. It was recognized that the prevention and control of malaria in posts in the Southern states and in possible overseas areas was one of the principal problems facing the military buildup. In considering the control of malaria in the Southern states, it was recognized that an extensive mosquito control program would have to be implemented. The fourteen entomologists in the Organized Reserves were ordered to Active Duty in 1941 and assigned to military installations in the South, where malaria was a potential hazard to service members. The government decided that more entomologists would be needed to control disease-carrying insects at and around training camps and appointed Dr. George Bradley of the United States Department of Agriculture (USDA) to the task. Dr. Bradley was transferred to the U.S. Public Health Service (USPHS) and commissioned a Colonel. He hired 6 young entomologists, including me and T.E. McNeel, as his assistants. Three of us were eventually commissioned as First Lieutenants in the USPHS. Dr. Stan Freeborn later joined the group and was also commissioned as a Colonel in the USPHS. In November 1941, we were assigned to work at the USDA

laboratory in New Smyrna Beach, Florida, where we intensively studied mosquito taxonomy, biology, and control. On December 8, 1941, Dr. Bradley told us that we would now be working exclusively on malaria. Our group was designated Malaria Control in War Areas (MCWA), and our job was to control mosquitoes within a one mile perimeter of any military establishment. At the same time, great strides were being made by the USDA in the development of pesticides and insect repellents. This combined control program was so successful that malaria was not a serious hazard to Service members in the United States.

By 1943, there were 723 entomologists in the military; the Army commissioned 240 and the Navy 118. Most of the newly commissioned entomologists were eventually assigned to overseas theaters: the South Pacific for malaria control, and the European theater for typhus control. The Army Medical Department organized Malaria Survey Detachments that consisted of an entomologist, a parasitologist and 11 enlisted men, and Malaria Control Detachments that consisted of a sanitary engineer and 11 enlisted men. As of February 1944, there were 35 Malaria Survey Detachments and 65 Malaria Control Detachments.

In 1941, the Naval Medical Department established the Hospital Volunteer Specialist Group [H-V(s)], and two Navy entomologists, LTJG William Lawler and LT Paul Woke, were commissioned. By the end of

WWII, there were over 200 commissioned entomologists in the Navy. Ensign Ken Knight was the first Navy entomologist to work in a combat zone when he and a team were sent to an island in the New Hebrides, where the Marines were being devastated by malaria, and reduced the malaria rate to essentially none. The Pacific Theater provided a cornucopia of arthropod-borne diseases that had a significant impact on fighting forces. The Navy, Army and Allies combined control and prevention efforts to meet the challenge. The Navy Division of Preventive Medicine developed field laboratory teams, designated Navy Epidemiology Units, to fight malaria. In 1944 the Division of Preventive Medicine was responsible for the guidance of 122 of these units. Navy entomologists also served in the South Pacific, Burma, India, North Africa, Caribbean, Central America and Europe. Two Navy entomologists lost their lives in WWII: LT William Gordon was killed by mortar fire during the invasion of Los Negros, in the Admiralties, on March 5, 1944, and LT John Maple died in an airplane crash while directing an aerial spray operation on Okinawa in April 1945.

Following WWII, only a handful of entomologists remained on active duty, with most officers reverting to inactive status. In the Navy, the H-V(s) sections disappeared, with only the Malaria and Mosquito Control Unit at the Naval Air Station (NAS) Banana River, Florida, remaining. It eventually moved to NAS Jacksonville and is now designated as the Navy Entomology Center of Excellence. In the Army, the Sanitary Corps became the Medical Service Corps and the Army Air Corps was established as the Air Force.

During WWII, the military had a total of 771 specially trained personnel combating malaria, typhus, tsutsugamushi fever, and other arthropod-borne diseases. Obviously, malaria was one of the most important diseases that military entomologists had to control. General McArthur said "...for every division I have fighting the enemy, I must count a second division in the hospital with malaria and a third division convalescing from this debilitating disease." In addition to combating malaria and other arthropod-borne diseases, nuisance insects were causing morale problems. The greatest nuisance insect problem was caused by bed bugs at bases in the U.S.

At the request of the colonel in charge of the Sanitary Corps, I left the USPHS and was commissioned a 2LT and given orders to report to Camp Lee, Virginia. Upon my arrival, the Camp Surgeon told me the bed bug situation was so bad that a Congressional investigation was being organized. He assigned me to clean up the problem and told me to consult with the camp engineer to find out what was currently being done. All the bedding was being placed in a 1941 semi-mobile sterilization unit and the bed springs were dipped in a vat of some insecticide (Figure 1).



**Figure 1:** Sterilizing bedding (Top) and dipping bed frames in insecticide (Bottom).

While this was being done, the barracks were inspected, and the web equipment, knapsacks, belts, etc., were examined and found to be heavily infested with bedbugs. Web equipment harbored both eggs and adults, and gas masks were often heavily infested (Figure 2).



**Figure 2:** Bed bugs in protective mask carrier and web gear.

This allowed for a quick reinfestation of the beds. Spraying the walls with a hand sprayer using pyrethrum was not very efficient. It was determined that all of these measures were not resolving the bed infestations due to the heavy infestation of the field equipment and other items in the barracks.

We concluded that fumigation would be necessary to penetrate all the cracks and crevices, and treat all the field equipment left in the barracks. Before fumigation was approved, the building was inspected by representatives of the Camp Surgeons Office in order to

determine the abundance of bed bugs and whether local control measures would prove effective (Figure 3).



**Figure 3:** 2LT Eugene Gerberg conducting barracks inspection for bed bugs and pointing out bed bug excretion on sheets.

Bed sheets were examined for bed bug excretions and blood stains. After a building was approved for fumigation, it was made airtight by wedging the windows shut. The louvers were sealed with Kraft or roofing paper (Figure 4). When all the preparations were completed, guards were placed outside at the doors to ensure that no one entered during the inspection, and an officer inspected the building to make sure that no one was inside (Figure 5).



**Figure 4:** Wedging the widows shut (top) and sealing the louvers (bottom).

Once the building was verified as vacant, the gas fumigant was spread by two men wearing gas masks, supervised by an officer. The fumigant used was Zyklon Discoids, which came in a special container that required a unique tool to open. Each discoid was about the size of a beer coaster and was flipped out of the can onto the floor (Figure 5). One man and the officer went to the top floor and opened the can, discoids were flipped out, and the men moved back toward the exit. When the top floor was done, the process was repeated on the bottom floor.

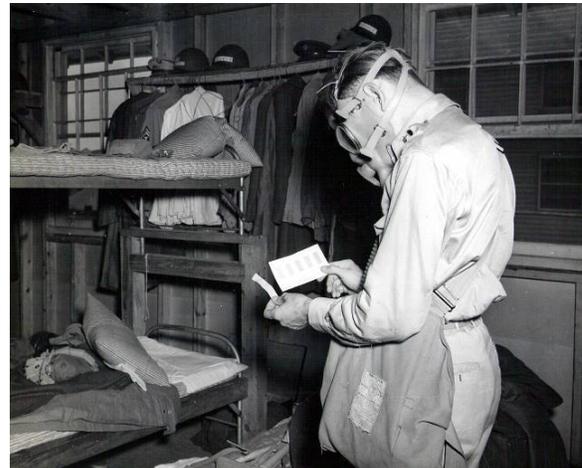


**Figure 5:** Final inspection of barracks. Note can of Zyklon Discoids in the middle of floor (top); spreading the Zyklon Discoids (bottom).

Upon completing both floors, the two enlisted men and the officer left the building, barring the door and posting warning signs (Figure 6). An armed guard was posted and NO ONE was allowed to enter the building. After at least 24 hours, the doors were opened to begin airing out the building. Men in gas masks entered, unsealed the windows and opened them to allow the building to be completely aired out. Before anyone was allowed to return to the building, the area was tested with methyl orange paper to determine

whether hydrogen cyanide gas (HCN) was present in dangerous concentrations (Figure 6).

Thousands of dead bed bugs were found in fumigated buildings. A total of 700 buildings were fumigated and the problem was solved. It was determined that the cracks and crevices of the buildings provided excellent harborage. The use of wooden bedsteads and the practice of hanging web gear and other field equipment on the beds exacerbated the problem.

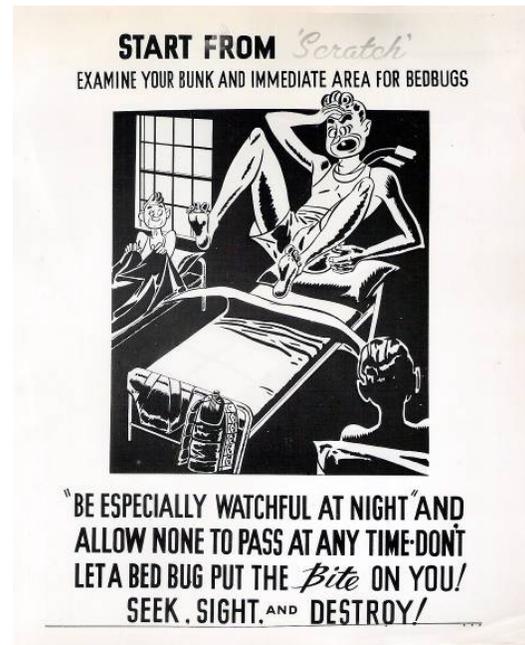
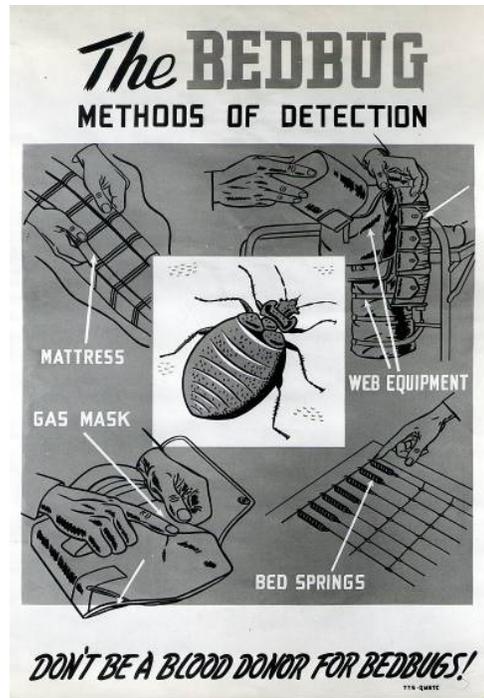


**Figure 6:** Sealing building and posting warning sign (top)s. Testing for the presence of HCN prior to allowing personnel back into building (bottom).



**Figure 7:** New metal bed frames with modifications to allow stacking (top), and simple devices for hanging field gear on walls (bottom).

Metal bed frames replaced the wooden frames, and simple hangers were developed to hang field gear, helping to reduce the problem (Figure 7). An educational campaign was also undertaken using posters to point out methods of detection and eradication (Figure 8). This was before the advent of DDT, which later proved to be quite successful in controlling bed bugs.



**Figure 8:** Educational posters on bed bugs.

## Entomological Issues during the Korean War, 1950-1953

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To understand entomological issues during the Korean War, one must first know something about Korea and the cultural and political situation during that period. Korea is a peninsular country that over the centuries has periodically been occupied by China or Japan. These occupations had a detrimental effect on the country because human and material resources were routinely stripped from the peninsula. The occupations and subsequent national freedom led to a strong sense of national pride in the Korean people and a not inconsequential xenophobia.

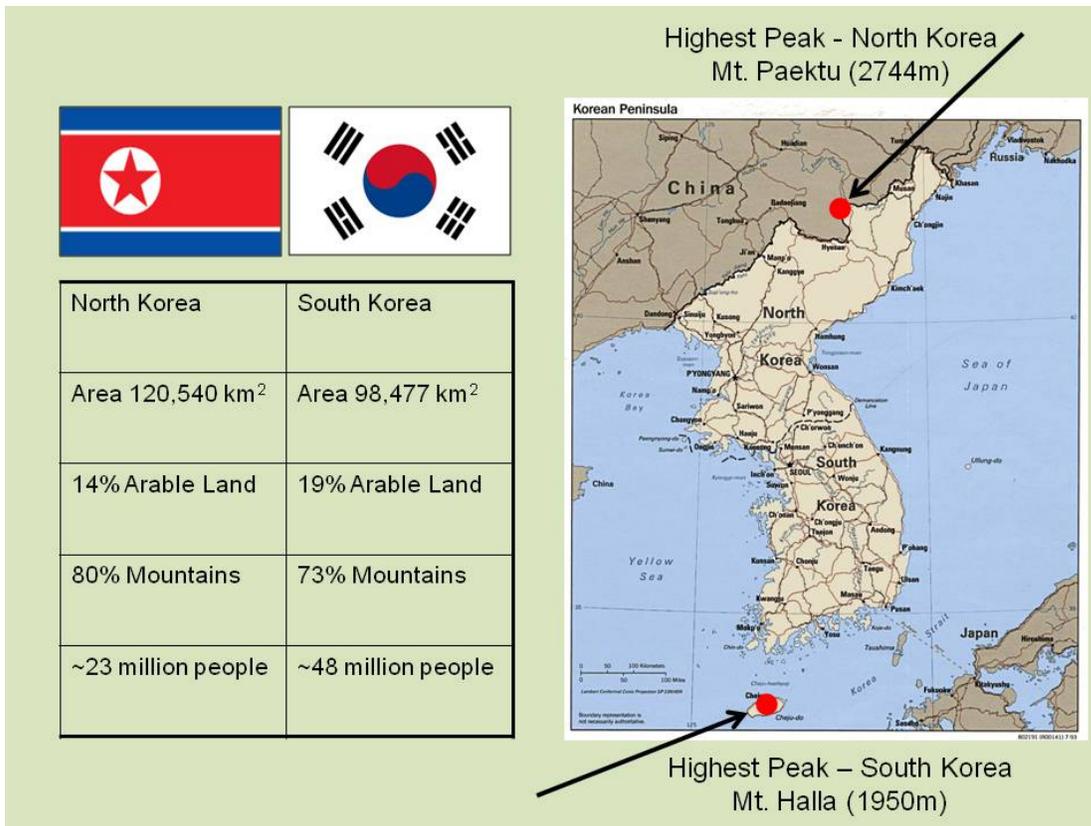
The Japanese occupation from 1910-1945 differed only in its magnitude. Koreans were enslaved and forced to work in war factories or other menial positions. The country experienced widespread deforestation at the hands of the occupiers, and the little wood that remained was gathered for cooking and heating. The widespread loss of forest cover led to landslides and flooding during the summer monsoons.

On September 2, 1945, the Japanese surrendered to the Allied Forces onboard the USS Missouri in Tokyo Bay. This signified the end of World War II and the beginning of the Allied occupation of northeast Asia. By prior agreement with the Union of Soviet Socialist Republics (USSR), Korea was split into two halves along the 38<sup>th</sup> parallel; the northern half became the Democratic People's Republic of Korea (North Korea) with USSR oversight, and the southern half became the Republic of Korea (South

Korea) with United States (US) oversight. North Korea and South Korea are about the size of the states of Pennsylvania and Illinois, respectively, are 70-80% mountainous, and have less than 20% arable land; in 1950, their respective populations were estimated to be 23 and 48 million people (Fig. 1).

In 1949, the US considered South Korea an independent country that no longer needed the presence of US occupation forces, so US forces withdrew from Korea to established bases in Japan. North Korea, still backed by the USSR, took the US withdrawal as indifference to the region and decided it was time to forcibly reunite the country.

On June 25, 1950, North Korean artillery began firing south and North Korean troops began their invasion of South Korea. President Truman protested this action and ordered US military intervention; the United Nations (UN) considered North Korea's action an act of aggression, and sixteen nations under the auspices of the UN joined the ROK in expelling the aggressors. US troops stationed in Japan sprung into action but were too few to stop the North Korean military surge. Within months, the North Koreans occupied almost all of South Korea except for an area in the southeast around the city of Pusan, with the outer boundary referred to as the Pusan perimeter. The stalling action by UN forces allowed sufficient troops and equipment to enter the Pusan perimeter, and a UN offensive action was imminent.



**Figure 1:** Geographic information and map of North and South Korea.

After breaking out of the Pusan perimeter, General Douglas MacArthur implemented a surprise attack on September 15, 1950 at Inchon, a port city to the west of Seoul, effectively entrapping the North Korean Army and cutting off their supplies. Many North Koreans surrendered; the rest began an immediate and rapid retreat. By December 1950, UN forces had pushed the North Korean Army to within a few miles of the Chinese border. China then entered the war on the side of North Korea, and millions of Chinese soldiers marched into North Korea, pushing the UN forces south. Eventually, the war settled around the 38<sup>th</sup> parallel, and on July 27, 1953, an armistice was signed and a demilitarized zone established to create a buffer between

the opposing forces. Numerous hostile actions have since been documented, underscoring the reality that South Korea and its allies are still not at peace with North Korea.

Korea was an agrarian society and infrastructure throughout the country was minimal in 1950. There were no highways until 1966, and much of the population still lived in traditional Korean housing. The aftereffects of WWII left the people impoverished and struggling to reestablish their lives with few resources and threats of catastrophic disease. The Korean War severely aggravated the problems for Koreans, many of whom were rendered homeless or displaced by combat actions (Figure 2). Disease was rampant during



Millions of Koreans were displaced and homeless

In 1950, 50,000 civilian smallpox cases (12,000 died), S. Korea

In 1951, 90,000 civilian typhoid cases (20,000 died), S. Korea

In 1950-1, 38,000 civilian typhus cases (5,000 died), S. Korea



**Figure 1:** Displaced Koreans and combat actions suffered from disease and environmental exposure. Photos: US Army. (Disease data per Long 1954)

this period, with high morbidity and mortality due to smallpox, typhoid, typhus, other diseases, and harsh environmental conditions.

Living conditions for military personnel were generally open and makeshift. Soldiers were exposed to environmental extremes, and arthropod and rodent interactions were common (Figure. 3). For example, during the winter of 1950-1951, intense cold led to over 5,000 frostbite injuries in US forces (Shaver 1962). Arthropod-borne diseases (louse-borne relapsing fever and typhus, Japanese encephalitis, vivax malaria, and epidemic hemorrhagic fever) threatened all civilian and military populations.

Louse-borne diseases were holdovers from WWII and rapidly expanded as displaced Koreans relocated to crowded areas with inadequate hygiene and sanitation opportunities. Louse-borne typhus is estimated to have caused 32,000 cases and 6,000 deaths in South Korean soldiers and civilians. No US cases were reported in Korea; one occurred in Japan (Long 1954, Pruitt 1954).

Lice also affected prisoner of war (POW) camps and were of great concern at the Koje Island POW camp along the southern coast of South Korea. North Korean POWs were kept at this location, and a 10% DDT dust was used as the louse control agent. Over time, the DDT treatments did not appear to have an effect



Field living conditions were generally in-the-open and make-shift

Exposure to arthropods and rodents was common

5000 US frostbite casualties in winter of 1950-1951



**Figure 2.** Examples of field living conditions for military personnel. Photos: US Army.

on the lice, and an investigation of the problem was initiated (Military Entomology Information Service 1965). Military entomologists suggested that the lice had become resistant to DDT and requested a new insecticide (Hurlbut 1960). However, authorities in the US felt that DDT was adequate and that the problem lay in its application or in a bad batch of the chemical (Dews 1960).

Fleet Epidemic Disease Control Unit No. 1 planned and conducted tests to evaluate DDT efficacy and louse Army and Navy entomologists from the 37<sup>th</sup> Preventive Medicine (PM) Company, the 297<sup>th</sup> PM Survey Detachment, and the resistance. (Figure 4). DDT was tested for its efficacy against *Culex pipiens* larvae (mosquito species), killing them at

one part per 2 million. The DDT met expectations of efficacy, and a mass delousing ensued (Curtin 1953, Dews 1953).



**Figure 3:** Lt. Nibley (USA) and CDR Hurlbut (USN) check Korean subject's DDT armband as part of test for louse resistance to DDT. Photos: US Navy.

For the resistance test, South Korean soldiers were employed and an arm band was placed on each arm of the shirtless volunteers (Figure 5). One arm band was treated with 10% DDT while the other was left untreated. Lice were placed under each arm band and counted at 24 and 48 hours. No difference was observed between the treated and untreated arm bands, which strongly suggested louse resistance to DDT. The US authorities approved the use of a new insecticide, lindane, which provided effective louse control.



**Figure 5:** Republic of Korea Soldiers volunteered as subjects for the DDT and body lice test of CDR H.S. Hurlbut, 7 April 1951. Photo U.S. Navy

Implementing the use of lindane at the Koje Island POW camp was a challenge. POWs, who were accustomed to standing in long lines to be treated with ineffective DDT, had no faith that the new product would be any better and many refused to go for treatment. On the first day, some POWs submitted to treatment; once they saw how well lindane worked, word quickly spread, and the rest of the camp complied (Dews 1960). In a short time, the louse infestation on Koje was brought under control.

Japanese encephalitis, a viral mosquito-borne disease, was also of concern because 300 cases had occurred in US military personnel between August and October 1950. Little was known about this disease, so blood sera from 210 of these cases were sent to the 406<sup>th</sup> Medical Laboratory at Camp Zama, Japan, to determine its etiology.

Vivax malaria, a parasitic mosquito-borne disease, was of great concern, with infection rates of 8.3, 3.2, and 1.9/1000/year for 1951, 1952, and 1953, respectively (Cowdrey 1990). Acute and latent forms of the disease were expressed. Soldiers affected with the acute form showed disease symptoms within two weeks of exposure and became medical liabilities in Korea. Those affected with the latent form showed disease symptoms months to a year later. Because deployments to Korea were 19 months or less, many soldiers returned home with inactive latent malaria parasites in their liver. Later, when the disease appeared in these soldiers, health authorities became concerned that malaria would reestablish itself in the US. Chloroquine was the chemoprophylaxis of choice, but it only suppressed blood parasites and did not affect the parasitic liver stage.

Primaquine, which killed the liver parasite, was approved for use during this period, thus reducing latent cases and relieving concerns about reintroducing malaria into the US (Coatney et al. 1953, Hunter 1953, Archambeault 1954, Marshall 1954, Pruitt 1954, Brundage 2003).

Epidemiological studies were conducted in South Korea to determine the malaria infection rate of Korean civilians (Murdoch and Lueders 1953, Marshall 1954)(Figure 6), and military entomologists (Army, Air Force, Navy)



**Figure 4:** Left: R. I. Thomas, HM1, observed by Chief D. B. Webb, continues his testing of possible malaria subjects, Koje Island, 9 Apr 1951. Right: CWO R. S. MacDonough and CDR H. S. Hurlbut inspect stagnant pool somewhere in Korea for mosquito larvae, no date. Photos: US Navy.

were instrumental in preventing the disease through the application of pesticides by ground and air, and through advocating the use of uniforms treated with repellents (M-1960 contained 30% 2-butyl-2-ethyl-1,3-propanediol for protection against mosquitoes and biting flies, 30% N-butylacetanilide for ticks, 30% benzyl benzoate for chiggers and fleas, and 10% of an emulsifier, Tween 80 [polyoxyethylene ether of sorbitan monooleate])(Gupta et al. 2003).

Epidemic hemorrhagic fever (now known as hantavirus) was a viral disease of great importance. Over 3,000 UN soldiers were affected, with an initial mortality rate of 14.6% that was reduced to 2.7% as medical providers learned more about the management of this infection (Pruitt 1954). However, very little was known about this disease, so studies began in earnest to understand its etiology and how to control and/or prevent it. Studies of Japanese literature suggested this was the same disease encountered by Japanese military forces in Manchuria during their 1938-1940 campaign, and notes from the Japanese experience were useful (Katz 1954,

Traub et al. 1954). Studies of the agent were confounded because it had been observed that application of the repellent M-1960 appeared to reduce epidemic hemorrhagic fever rates, suggesting that a vector was involved in the transmission cycle (Traub 1954). Initially thought to be a vector-borne disease with a rodent reservoir, all potential vectors (mites, mosquitoes, black flies, and fleas) were studied (Traub et al. 1954). In 1976, the virus was isolated from the black-striped mouse, *Apodemus agrarius* (Lee et al. 1978), and named Hantaan virus after the Hantaan River where it was first isolated.

During the war, many rodents were live-captured to study hantaviral and other diseases, but live traps were in short supply and those that were available were quickly acquired by others for personal use (Applewhite 1953). Therefore, soldiers of the preventive medicine detachments improvised and built traps from beer cans and mouse snap-traps, both of which were abundant (Bevier 1953). These “Beer Can Traps” were made by cutting off the top of the can and affixing the mouse trap to the open end, with the

trigger extending into the can. A flat piece of metal was placed over the wire “snap” loop so that once the trap was triggered, the loop covered the open end of the can and trapped the rodent.

During WWII, scrub typhus was feared more than malaria in parts of Southeast Asia, but only 8 UN soldiers acquired the disease during the Korean War even though thousands of cases were diagnosed in the civilian population (Ley and Markelz 1961). Similarly, tick-borne disease was not a factor, as ticks were uncommon and very few soldiers complained of tick attachment (Traub 1954). The lack of trees and leaf litter may have limited the habitats capable of supporting ticks that parasitize humans.

A history of entomology during the Korean War would not be complete without discussing the contributions of the 406<sup>th</sup> Medical Laboratory, Camp Zama, Japan. The 406<sup>th</sup> served as the primary laboratory supporting entomological studies throughout the war, and entomologists in Japan worked closely with entomologists stationed in Korea. The laboratory conducted epidemiological, virological and entomological studies on arthropod- and rodent-borne diseases, and provided mounted specimens to US and regional museums (US Army 1953). Arthropods studied and mounted included mosquitoes, black flies, filth flies, mites, lice, and fleas. In addition, birds and small mammals were studied and mounted. The laboratory expanded to meet its research demands, and many Japanese joined the staff. Some of the new employees were sympathetic to Communism, a situation that caused friction subsequently (Lockwood 2009).

During the winter of 1950-1951, reports of massive disease outbreaks in

the North Korean military and among civilian and Chinese military populations were received. These reports also stated that the North Korean authorities were doing nothing to mitigate the problem. Several reports claimed that the “Black Death” was spreading throughout North Korea. Black Death to US medical personnel meant flea-borne plague, *Yersinia pestis*. If UN forces were to move north in the spring, they would encounter this disease and needed to be prepared. To validate the reports, the US sent COL Crawford F. Sams into North Korea to investigate. COL Sams infiltrated North Korea near Wonsan and determined the disease to be hemorrhagic smallpox, not plague. US military personnel were vaccinated against smallpox, with the result that only 4 soldiers developed the disease during the war (Waldo 1955). However, the North Korean civilian population suffered tremendously and its population dropped from 11 to 3 million people (Sams 1998).

In the spring of 1951, North Korea and China accused the US of engaging in biological warfare and cited multiple examples of attacks with a variety of arthropods (Collembola, crickets, Plecopterans, etc.) and small rodents (moles) harboring disease (Lockwood 2009). The Communist sympathizers within the 406<sup>th</sup> Medical Laboratory claimed that the US was conducting biological warfare studies using arthropods and rodents. To most people, these accusations seemed ludicrous because the supposed vectors were not known to transmit disease to humans, and research on how to prevent, treat, and control a disease is not the same as biological warfare studies. The Communists also claimed that the US protection given to Japanese scientists

(who practiced biological warfare during WWII) in exchange for their secrets was further evidence that the US was engaged in biowarfare. A team of “experts” sympathetic to the Communist cause was sent to investigate. Their report condemned the US, but upon questioning, the team admitted that they never saw the evidence; their report was based exclusively on what they had been told or shown by the North Koreans and Chinese. The report caused more controversy but was considered biased.

The US denied all allegations concerning the use of biological weapons, pointing out that disease was already rampant in both Koreas and without medical intervention many people would fall ill and die. Two recent books (Lockwood 2009, Endicott and Hagerman 1998) provide insights on this issue, as well as references to other books, literature, and documentation.

Entomologists from the Army, Air Force, and Navy served during the Korean War. Army entomologists served on the 8<sup>th</sup> Army Surgeon’s Staff and in the Preventive Medicine Company and Survey Detachments. LTC Samuel O. Hill (Fig. 7a), of the 8<sup>th</sup> Army Surgeon’s Staff, was the first entomologist to enter the combat zone (Bunn and Webb 1961). He was later replaced by LTC Samuel C. Dews (Figure 8), who served in this position for the remainder of the war. In a 1953 report, LTC Dews reported that 38 entomologists served in Korea during the war, but Bunn and Webb (1961) reported 65 entomologists; the difference may lie in the numbers who served in units only (38) versus those who served in units plus those who were conducting

research (65). Traub et al. (1954) is an example of those involved in research. Further studies are needed to determine exact numbers. Lieutenant Carlyle Nibley Jr. (Figure. 4) and Captain Robert Altman (Figure. 7b) served in Korea, and many of authors listed in the reference section of this paper also served. In 1954, COL (ret.) Harold D. Newson and LTC (ret.) Alexander A. Hubert served in Korea (Newson and Hubert, personal communication).

The 37<sup>th</sup> Preventive Medicine (PM) Company and 10 different PM Detachments saw service during the Korean War (Table 1). In 1950, two types of detachments existed and were in the middle of a name change. Malaria Control Detachments were redesignated as PM Control Detachments and Malaria Survey Detachments were redesignated as PM Survey Detachments. Two sanitary engineers typically served in the PM Control Detachments, whereas an entomologist and a parasitologist served in the PM Survey Detachments. Nine enlisted personnel were assigned to each of these detachments (Curtin and Spitzer 1953).

In September 1950, the 38<sup>th</sup> and 207<sup>th</sup> PM Survey Detachments were moved from Japan to Korea and were the first two detachments deployed to the war zone. Seven PM Control Detachments served in Korea and one served in Japan for the duration of the war. Similarly, three PM Survey detachments served in Korea and one served for the duration in Japan. Table 2 provides a summary of the entomological work performed by the PM Survey Detachments.



**Figure 5:** Left: Opened ramp of USS LSIL 1091 with LTJG G.P. Miller and LTC Sam Hill, 26 Mar 1951. Right: L-R, CPT James B. Butler MC, USN, CPT Robert Altman, 37<sup>th</sup> PM Company, 8<sup>th</sup> Army, 1LT Lindenberg, CWOHC MacDonough on a mountain overlooking Kojedo bay, 20 Mar 1951; Photos: US Navy.



**Figure 6:** Members of the Preventive Medicine Division, Medical Section, HQs, Eighth US Army Korea. L/R: LTC Edward C. Mulliniks, Asst Chief, PM; 1LT David L. Griffith, Public Health Education Officer; MAJ Morris Krasnoff, Sanitary Engineer; CDR Leonard M. Schuman, Cold Injury Team and Consultant; LTC Irvine B. Marshall, Chief, PM Division; LTC Samuel C. Dews, Entomologist; CPT Ralph Takami, Medical Intelligence Consultant, Jan 1952. Photo: US Army.

**Table 1.** Preventive Medicine units that served in Korea or Japan, 1950-1954.<sup>1</sup>

Unit <sup>2</sup>	Date served in War	Country	Activation/inactivation
6 <sup>th</sup> PM Survey	Mar 1950-Dec 1954	Japan	activated Feb 1952, inactivated Oct 1954
10 <sup>th</sup> PM Control	Jul 1951-Dec 1954	Korea	activated Feb 1952,
17 <sup>th</sup> Malaria Survey	Jan 1950-Jul 1950	Japan	Inactivated Jul 1950
37 <sup>th</sup> PM Company	Fall 1950	Korea	
38 <sup>th</sup> PM Survey	Jan 1950-Aug 1950	Japan	
38 <sup>th</sup> PM Survey	Sep 1950-Dec 1954	Korea	Inactivated Sep 2007
78 <sup>th</sup> PM Control	Apr 1953-Dec 1954	Korea	inactivated after Dec 1954
118 <sup>th</sup> PM Control	Jan 1950-Dec 1954	Japan	
151 <sup>st</sup> PM Control	Feb 1952-Oct 1954	Korea	activated Feb 1952, inactivated Oct 1954
152 <sup>nd</sup> PM Control	Nov 1951-Dec 1954	Korea	activated Feb 1952
153 <sup>rd</sup> PM Control	Feb 1952-Dec 1954	Korea	activated Jan 1952, inactivated Jan 1955
154 <sup>th</sup> PM Control	Jan 1952-Oct 1954	Korea	inactivated Nov 1954?
155 <sup>th</sup> PM Control	Jan 1952-Oct 1954	Korea	inactivated Nov 1954?
207 <sup>th</sup> PM Survey	Jan 1950-Aug 1950	Japan	
207 <sup>th</sup> PM Survey	Sep 1950-Dec 1954	Korea	
219 <sup>th</sup> PM Survey	Jan 1952-Dec 1954	Korea	activated Jan 1952, inactivated after Dec 1954
406 <sup>th</sup> General Lab	Jan 1950-Dec 1954	Japan	

<sup>1</sup>Data derived from US Army Directory and Station Lists for the Korean War period.

<sup>2</sup>Except for the 37<sup>th</sup> PM Company and 406<sup>th</sup> General Laboratory, all units are detachments with the 17<sup>th</sup> Malaria Survey Detachment being inactivated before the name was changed to PM Survey Detachments.

**Table 2.** Identifications and miles travelled by the 219th Preventive Medicine Survey Detachment, 1 Mar-15 Sep 1952. <sup>1</sup>

Total identifications made	73,152
Mosquito larvae	35,152
Mosquito adults	30,195
Mites	4,212
Lice	2,206
Fleas	91
Rats	779
Other mammals	337
Travel miles logged	36,718

<sup>1</sup>Data from Curtin and Spitzer (1953).

## Army Aerial Spray Mission

- Army used L-13 and OH1/L-19 aircraft for aerial spraying, because these smaller aircraft could go into small valleys where the larger USAF aircraft could not go.



L-13 Grasshopper (Convair)  
photo: Heritage Flight Museum



OH1/L-19 Bird Dog (Cessna)  
photo: GlobalSecurity.org

**Figure 7:** Aircraft used by the US Army to control mosquitoes and filth flies during the Korean War.

While most Army vector control missions were ground based, it became necessary for the Army to engage in aerial spray missions in the narrow, small valleys where the larger US Air Force aircraft could not go. The Army modified the L-13 and OH1/L-19 aircraft (Figure 9) for aerial spraying and sprayed DDT for the control of mosquitoes and filth flies (Harder 1953a, b).

Navy entomologists primarily served in the port cities that were feeding Korea with essential supplies, equipment, and troops. They were also essential to vector control at the Koje Island POW camp and during malaria epidemiological studies around port cities. At present, we believe six Navy entomologists served during the Korean War, with CDR H. S. Hurlbut (Figure 10a) confirmed as being present because

he wrote about his experiences and appears in photographs. Many of Hurlbut's photos include CWO R. S. MacDonough (Figure 10b), but we have not determined the latter's association with entomology.

The Korean War was the Air Force's first war as a separate service. To meet the needs for aerial spray missions, the Air Force activated the 1st Epidemiological Flight in May 1951. The mission was flown on 17 June (Muchmore and Read 1953) and the first season was completed on October 8, 1951 (Nowell 1954, Lumpkin and Konopnicki 1960). The Air Force used a variety of aircraft for the aerial spray mission: C-40, C-46, C-47, L-20, L-5, and the T-6. Aerial spray missions commonly targeted mosquitoes and filth flies to reduce disease affecting military and civilian populations. A DDT oil solution of 20% was commonly sprayed.

At the time of this writing, we are unable to determine which Air Force entomologists served in Korea, even though we have an extensive list of those who served in that capacity.



**Figure 8:** Top: CDR H. S. Hurlbut moves mosquito from collecting vial prior to examination, 3 Apr 1951. Bottom: CWO MacDonough dips stagnant stream for mosquito larvae, 1 Apr 1951. Photos: US Navy.

During the Korean War, the word “Mosquito” with a capital “M” referred

not to an insect but to an airplane (Futrell 1983). The T-6 “Texan” was used as a Forward Air Controller, and it was commonly called the “Mosquito” by its pilots and ground crew (Fig. 11). Two theories have been advanced for this moniker. The first postulates the use of the call sign “Mosquito” as in “Mosquito 1, this is “Mosquito 2, over.” Pilots and ground crews apparently liked this call sign and began calling the T-6 the “Mosquito” (Futrell 1983). An alternative explanation is that North Korean and Chinese prisoners called this aircraft a mosquito (Mogi in Korean) because they associated its buzzing around with the “bites” (bombs) that followed shortly thereafter (Morris 1997).

Much work remains to be done before we have a clear picture of military entomology during the Korean War. References for this presentation came from the US Army Center of Military History, Fort McNair, DC; the US Army Institute of Military History, Carlyle, PA; entomological, scientific and tropical medicine journals of the period (e.g., *Mosquito News*, *Am J Hyg*); collections of unpublished documents on file at the Armed Forces Pest Management Board ([www.afpmb.org](http://www.afpmb.org)); books written about the Korean War; and Internet searches on subjects or people who may have served during that era.



## The “Mosquito”

- Formerly called the T-6 Texan
- Popular name of “Mosquito” derived during Korean War
- “Mosquito” used as Forward Air Controller aircraft

**Figure 9:** The T-6 Forward Air Controller aircraft earned its common name "Mosquito" during the Korean War.

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## **Entomology with the U.S. Marines in Vietnam— Some Lessons Learned**

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The following is a discussion of the entomology-related activities of the 1st Marine Division in the Republic of Vietnam during 1968. It is based on the author's experiences as the first medical entomologist to be assigned to the Division's Preventive Medicine Section since its deployment to Vietnam in 1964.

The 1st Marine Division's area of responsibility during 1968 was in the I Corps Tactical Zone, the northernmost corps area in Vietnam. The majority of the troops were concentrated from Hue to about 25 miles south of Danang. The area was primarily coastal and foothill terrain consisting largely of rice paddies interspersed with estuaries, rivers and small farms. Units were also deployed to mountainous areas (medium elevation and rivers) near the Demilitarized Zone (DMZ). Potential disease vectors, particularly mosquitoes, were found in abundance in certain of these areas, and malaria, dengue, encephalitis, plague, scrub typhus and filariasis represented a potential threat to combat readiness and effectiveness.

While disease vector control was of utmost importance, control measures were often frustrated by the inaccessible location of vector breeding sources and the very nature of the war. The latter includes the effects of the so-called Tet Offensive, a series of surprise attacks by the Viet Cong (VC) and the North Vietnamese Regular Army (NVA) beginning 31 January 1968. Under orders to "crack the sky and shake the earth," the offensive consisted of three phases, the last of which ended on 23

September 1968. Of the over 58,000 troops killed in action (KIA) during the Vietnam war, almost 30% occurred during 1968. The difficulties working in areas of high disease incidence were made all the more challenging by this significant increase in combat intensity.

### **Preventive Medicine Section**

The Preventive Medicine Section (PMS) was a general support element responsible to the Commanding General for supervising the preventive medicine program of the 1<sup>st</sup> Marine division. The PMS was located in Danang under the technical control of the Division Surgeon. It received its administrative and logistical support from the 1<sup>st</sup> Medical Battalion.

The primary focus of the PMS was directed toward the more complex health problems beyond the technical capability of individual commands. This included the provision of epidemiological, laboratory and entomological services, assisting in the detection and elimination of direct and potential health hazards and providing training and indoctrination of personnel in the principles and practices of field preventive medicine.

The Table of Organization (T.O.) for PMS staff included one environmental Health Officer as OIC, one assistant OIC, three Environmental Sanitation Officers, one Medical Entomologist, 15 Preventive Medicine Technicians (PMT's) and three Laboratory Technicians. Several staff, including the entomologist, were frequently

temporarily assigned duty (TAD) to forward PMS detachments in Phu Bai and An Hoa.

Working for the Division Surgeon but receiving logistical and administrative support from the Company Medical Battalion (CO MedBN) was a challenge at times. The PMS operated without assigned vehicles and drivers for the first eight months of the year until these assets were assigned directly to the PMS. Essentially, the staff had to “thumb rides” to outlying units using already overtaxed ground and air assets. This was often unacceptable when trying to respond to the urgent needs of outlying commands. PMS personnel were continually “borrowed” to stand watch and perform other non-related functions. Much of this was related to a lack understanding and appreciation of the PMS’s mission.

#### **Entomology Branch**

An Entomology Branch of the PMS was organized and staffed with the entomologist and four enlisted Preventive Medicine Technicians who were responsible for vector surveillance, vector control, rodent control, and epidemiology. A laboratory was established for the identification of disease vectors, particularly mosquitoes.

Initial inspections revealed that vector control in 1st Division units was largely inadequate due to a general lack of equipment, supplies, and trained personnel. Most unit corpsmen were found using 5-20% DDT for all of their vector and pest problems, few had a working knowledge of proper control techniques, and many did not have adequate equipment to accomplish control. To correct these conditions: (1) a training course was established to train corpsmen from each marine unit in the fundamentals of vector control; (2)

entomological surveys were made regularly to determine potentially active problem areas and make recommendations for their control or elimination; (3) control operations were accomplished when necessary; (4) handouts on vector control, malaria and malaria discipline were written and distributed to all units; and (5) assistance was rendered to all commands in the acquisition of proper equipment and supplies as needed.

#### **Vector-Borne Diseases**

**Malaria.** Malaria was the most important vector-borne disease found in Vietnam. Approximately 1,200 cases of malaria were reported for the 1st Marine Division during 1968, representing about 25,000 days of hospitalization. Of that total, about 60% were falciparum malaria, 22% were vivax malaria, < 1% were malariae malaria, 5% were mixed infections, and 13% were undetermined infections.

Locations in I Corps with the highest malaria incidence rates were the interior highlands, including Khe Sanh and Ca Lu (April through July), and An Hoa (July through November). The Happy Valley, Elephant Valley, and Antenna Valley areas were secondary sources throughout the year. Relatively few cases occurred in the cities, coastal plains or foothill areas such as Danang, Phu Bai, and Chu Lai.

Malaria contracted by military personnel was probably acquired outdoors rather than indoors, primarily from the exophilic species *Anopheles aconitus*, *An. maculatus*, *An. jeyporiensis candidiensis* and, in some areas, *An. balabacensis*. Secondarily it may have been acquired from *An. minimus*, and *An. sinensis*, the most common *Anopheles* found in Vietnam.

The endemicity of malaria varied widely in time and space. This was probably due to the large, mobile parasite reservoir (NVA, VC & local populations), occurrence of drug-resistant falciparum malaria, the lack of complete information on the population at risk and degree of risk in specific areas, and factors that influenced mosquito abundance (e.g., breeding sources, available harborages, flight ranges).

**Fevers of Undetermined Origin (FUO's) and Dengue.** Military medical personnel had a general lack of knowledge and experience with infectious diseases in the area and their manifestations in non-immune adults. As a result, the clinical diagnosis of FUO's was a major problem confronting physicians serving in Vietnam. The vectors of dengue, *Aedes aegypti* and *Ae. albopictus*, were commonly found in the area, and many FUO's may have been a mild form of dengue. In any case, the true incidence of the disease was unknown at the time.

**Japanese B Encephalitis.** Less than 40 1st Division personnel were diagnosed with a Group B arbovirus infection through hemagglutination-inhibition tests. Depending on the clinical picture, some of these were most likely Japanese B and the others probably due to one of the dengue viruses. The vectors *Culex tritaeniorhynchus*, *C. gelidus* and *C. pipiens-quinquefasciatus* were commonly encountered in larval and adult surveys in the Phu Bai, An Hoa, and Danang areas. Light trap collections of the first two species were heaviest during the months of July through November in Danang.

**Filariasis, Scrub Typhus & Plague.** Filariasis and plague occur in Vietnam,

but the actual incidence rate in US Marine personnel during 1968, if any, was not available at the time. About 22 cases of scrub typhus occurred in 1<sup>st</sup> Division units from the Hoi An and An Hoa areas.

### **Mosquito Surveillance**

A primary function of the Entomology Branch was mosquito surveillance. This proved to be a frustrating experience in many ways. Surveys could be accomplished with relatively little difficulty in base camp areas, which were usually at low risk for malaria. In highly malarious regions, such as the foothills and mountains, these activities were often impossible for security reasons and inaccessibility.

**Larval Surveillance.** Larval surveys were conducted at all units in the Danang, Phu Bai, Gia Le, Chu Lai, and An Hoa areas in order to identify and eliminate breeding sites in or near the cantonments. Pre-surveys and post-surveys were made in conjunction with ground and aerial spray missions, and additional surveys were conducted throughout the countryside to obtain biological data and to build up a reference collection.

**Adult Surveillance.** Adult surveillance utilizing mosquito light traps was conducted throughout the year in the Danang area and for part of the year in the Phu Bai and An Hoa areas. Populations were high during the periods prior to and following the monsoon season, and low during the monsoon months and some of the hot, dry summer months. Similar indices would probably be found in the foothill and mountain regions. The location of light traps was often a challenge. Their use in the "bush" was not feasible for security reasons, lack of power sources, and the

possibility of being booby-trapped. Even in relatively secure base camp areas, they could seldom be hung in the most ideal location because the white light could act as a “beacon” to the enemy. Vandalism was often encountered, and one trap was rendered inoperative by a 122 mm rocket.

Day and night mosquito-bite counts were conducted when 1st Division troops moved into new areas such as Phu Bai and An Hoa. Bite counts were useful for obtaining data about the biting habits of important species and determining if any primary vectors were prevalent in an area. They could only occasionally be conducted at units located in very hostile areas because there was seldom any way to effect control, and the risks involved were difficult to justify. During one night at An Hoa, bite counts were suspended after the use of a red-lens flashlight still provoked enemy fire. On another occasion, an all-night bite count was conducted at the Liberty Bridge combat base. The mosquito populations were so high that only the lower part of one leg could be exposed in order to keep up with the numbers biting.

Surveys conducted in the countryside were especially enjoyable due to the interest and participation of the villagers—particularly the Vietnamese children. Whether mosquitoes, leeches or general insects were being collected, the kids were always eager to help. They became very adept at handling a dipper or collecting net and, at times, outdid the professionals. Cards printed in Vietnamese were carried that explained what was being done and why.

### **Mosquito Control**

Mosquito control in 1st Marine Division units consisted essentially of attempts to control the secondary vectors

of malaria, the vectors of dengue and encephalitis, and pest mosquitoes in relatively secure base camp areas. The major malaria and mosquito problems were associated with observation posts, Combined Action Program (CAP) units, night patrols, and larger units operating in the foothills and mountain regions. These areas were usually too insecure or too inaccessible for ground equipment, and no aerial dispersal systems were available that could be flown in such a manner as to avoid hostile fire.

**Ground Control.** In base camp areas, breeding was usually limited to artificial containers during the summer months and to small areas of standing water during the winter months. Fire barrels were frequent offenders, and recommendations included screening or covering and the addition of diesel fuel. Attempts were made to eliminate artificial containers, such as C-ration cans, shell casings, clay pots, unused fighting holes and bunkers, barrel rim tops and tires, all of which commonly contained breeding mosquitoes. Areas with standing water within or adjacent to camps were drained or filled. If source reduction was not possible, then the areas were usually treated with 2% Fenthion granules applied with back-pack mister-dusters.

Based on light trap counts and complaint calls, adulticiding operations with trailer-mounted, military cold foggers were conducted at all units accessible by road. Hand compressed sprayers, back-packs and buffalo turbines were used for making residual applications of malathion to bunkers, hootches, and vegetation where resting mosquitoes were found. Pyrethrum aerosol dispensers were recommended for space treatments inside bed nets,

tents and buildings at night to eliminate resting adults.

**Aerial Dispersal.** During the year, the U. S. Air Force Special Aerial Spray Flight Team (Ranch Hands) operated one C-123 aircraft for the aerial dispersal of insecticide for all of South Vietnam. Through coordination with the Preventive Medicine Unit, Naval Support Activity (PMU, NSA), about one flight each month was flown in the Danang and Phu Bai areas. Low-volume dispersal of 57% or 95% malathion was used. Light trap counts in treated areas usually dropped by 60 to 80 percent and remained so for 5-10 days. The use of a low-flying C-123 over insecure territory was considered an unacceptable risk, and requests for missions in such areas were never approved.

GRANDAP units developed by the Navy Disease Vector Control Center (DVCC) in Jacksonville, Florida, were operated by the PMU (NSA) in HU-34 helicopters. These were deployed on four occasions in the Hue-Phu Bai area, dispersing a total of 14,000 pounds of 2% Fenthion granules for larviciding effect. Adequate coverage was seldom achieved due to the difficulty in getting pilots to treat the breeding sites thoroughly and equipment malfunctions. Because of the vulnerability of low-flying aircraft to hostile fire, no missions were flown in insecure areas of the 1st Division.

During November, a commercial aerial dispersal unit called the HUSS (Helicopter Underslung Spray System) was evaluated in the Danang area. The HUSS was a self-contained unit that operated from a pendant attached to a helicopter. Mechanical problems were encountered and there were difficulties in obtaining aircraft and pilots to fly the spray missions. In one instance, the pilot

“accidentally” hit the quick release button and the unit detached, falling 150 feet into the South China Sea.

Aerial dispersal by helicopter was useful for controlling vectors and pest mosquitoes in secure base camp areas. However, it was not the answer to the problems encountered in hyperendemic areas, where vulnerability to enemy fire prevented rotary-winged aircraft from flying grid-pattern swath widths in the "small arms envelope" of 0-1500 feet. Small payload and poor availability of helicopters limited regular applications needed to effect control. In addition, the assignment of adequate helicopter pilots, technical direction and crews was seldom possible because of the demands of combat operations.

### **Malaria Discipline**

The difficulties in eliminating vectors in highly malarious areas, the mobile and often rapid pace of military operations, and the realities of tactical and logistical limitations underscored the importance of individual Marines protecting themselves. This included the use of personal protective measures, such as chemoprophylaxis, insect repellents, bed nets and protective clothing. Unfortunately, these measures were not always employed to maximum effectiveness.

The utilization of personal protective measures or "malaria discipline" was monitored in the 1st Division by making regular malaria discipline surveys at all units and conducting nearly 1,000 interviews on malaria and non-malaria patients. The results of the interviews revealed serious deficiencies, including the failure to take chemoprophylaxis and apply repellents regularly and correctly.

**Command support.** Consistent and vigorous command emphasis on

preventive measures is critical to a malaria discipline program. Messages prepared by the OIC, PMS, were distributed through the Commanding General as needed. They stressed the CG's concern regarding the high incidence rates and directed that steps would be taken to improve malaria discipline at all levels. Such support proved invaluable when dealing with some commands.

**Chemoprophylaxis.** Based on interviews of 674 malaria patients, 16% complained about the non-availability of suppressive drugs and 21% complained of adverse side effects. About 60% admitted not taking the C-P tablet regularly during their tour, usually missing more than once and some for six months or longer. Patients were, of course, reluctant to admit any laxity in their chemoprophylaxis.

The reasons given for not taking the tablet were varied and at times amusing. Some said they simply forgot or it was not available. Others complained of adverse side effects such as diarrhea, headaches, stomach cramps, nausea or dizziness. One individual complained that the pill made him burp for several hours after ingestion. A few insisted that the pills actually gave them malaria.

The administration of the tablet was a problem at some units. At base camps, roster systems with follow-ups of absentees were established. But it was the troops in the field that most often missed taking the tablet.

Recommendations were made that the unit corpsman be responsible for carrying an adequate supply, dispensing them to the men in their unit and ensuring that they swallowed the pill.

It was difficult to determine what percentage of patients contracted falciparum malaria because of a laxity in

chemoprophylaxis or because of the presence of drug resistance. At the time, it was generally believed that the C-P tablet was 60% to 80% effective against falciparum strains and 100% effective against vivax malaria (except in cases of high parasitemias).

**Repellent.** Based on interviews with 674 malaria patients, 22% said repellent was not available, 49% did not use repellent regularly or properly, and 21% disliked the standard issue repellent for a number of reasons. Non-availability of repellent was a problem at times; however, the lack of repellent was not the primary reason for the failure to use it regularly. Even when an adequate supply was available, it was usually applied when pest mosquitoes were abundant in the early evening hours and was not reapplied during the night when *Anopheles* mosquitoes were active (particularly after 2000 hours). Even when used regularly, most individuals failed to apply it to areas where clothing fits tight against the skin, enabling mosquitoes to bite through the layers.

A small percentage would not use repellent, believing, falsely, that the Viet Cong could detect the odor. A few stated that they seldom used it because mosquitoes never bothered them or that they were "too tough" to need protection. Some disliked it because it caused burns or skin irritations or because it "smelled bad," left an oily sensation on the skin or "didn't taste good." Repellent purchased through local exchanges was believed to be significantly better than the standard military issue. About 60% of the Marines interviewed were unaware that using repellents could protect them from dengue, encephalitis and filariasis.

**Bed Nets.** In base camp areas where pest mosquitoes were abundant and

annoying, bed nets were in general use. In the field, where protection from *Anopheles* bites was vital, bed net use was seldom feasible because of the combat situation. Even in base camps, many complaints were received that the nets were too hot and impeded quick retreat to bunkers during a mortar or rocket attack.

**Protective Clothing.** During the extremely hot, humid summer months, it often seemed unrealistic to expect troops in the field to always keep their sleeves rolled down, blouses buttoned and trousers bloused during the hours after dusk or when entering dark jungle areas. In many cases, minimal clothing was being worn anyway and PMS emphasized covering all exposed areas with repellent and wearing as much protective cloth as feasible.

**Malaria Discipline Lectures.** It was soon obvious from the malaria interviews and discussions with troops in the field that a great deal of ignorance existed concerning malaria as a disease and its prevention. Many had little or no idea of how the disease was contracted, and some actually believed it was from drinking "bad" rice paddy water. One malaria patient insisted that he had never been bitten by mosquitoes but noted that "I was bitten by a snake once." Clearly, guidance was needed to help separate fact from fiction.

Most Marines received some level of malaria discipline training in the United States before coming to Vietnam; however, less than 40% received such indoctrination while in the country. To establish a better educational program, a field guide on malaria and malaria discipline was developed and distributed to all commands, and assistance was given in establishing malaria discipline programs. Monthly malaria discipline

visits were made at all units to help promote the continuation of these programs.

**Malaria Reporting.** While visiting outlying units experiencing high incidence rates of malaria, it was discovered that little or no feed-back was being received regarding the actual number of cases they had each month. Most also had little idea of the real status of their malaria discipline programs. Battalion and Regimental Surgeons frequently complained that recommendations to their commanding officers for reducing malaria rates were often poorly received because they had no data "on paper" to back them up. Beginning in June, a monthly report was sent by the PMS through the Division Surgeon to each Regiment and Separate Battalions. The reports listed the number of cases that occurred in the unit along with a discussion of their weak areas in malaria discipline (based on malaria interviews).

### **Significant Pests**

During the year, 233 pest control operations were conducted at outlying units on request. Of that total, 39% were for filth flies, 19% for mosquitoes, 16% for rodents, 14% for cockroaches, 8% for ants, 3% for termites, and 1% for stored product pests. Because of transportation problems, even the simplest of these operations often required a half day or longer to accomplish. In addition, many units became completely reliant on the PMS and would not make even basic corrections of discrepancies themselves. The PMS was not designed as an on-call pest control company, but it endeavored to help individual units handling their own routine problems when trained

personnel and appropriate supplies were aboard to do so.

**Filth Flies.** Infestations of filth flies were the most common problem encountered at the typical mess hall. The primary nuisance was the ubiquitous House Fly (*Musca domestica*); the Old World Secondary Screwworm (*Chrysomia megacephala*) was a secondary pest. The control of flies in Vietnam was complicated because much of the breeding came from nearby villages where flies had easy access to animal feces and garbage. This was true also of Vietnamese dumps, which were poorly operated and maintained.

While the greatest percentage of flies found inside a mess hall could be excluded by good screening and close-fitting doors, the exclusion of flies was a constant battle. Part of the problem was due to the temporary nature of the buildings, heavy usage, exposure to extremes in weather, and occasional 122 mm rockets. Typically, screening was torn or rotten and needed to be replaced, doors were ill-fitting and often propped open during the day, and entrance holes in the bulkheads and overheads needed patching. Correction of these discrepancies was the obvious solution to the problem. It was not so obvious to some commanders who instead insisted that the areas should be sprayed once a day and were, in some cases, requiring their personnel to do so.

Initial inspections at outlying units revealed that many were using, or had on hand, a variety of unauthorized concentrated pesticides. During the year, over 350 gallons of concentrated malathion, chlordane, dieldrin, DDT and lindane were confiscated. At one motor pool, for example, several gallons of 57% malathion were discovered. Upon inquiry, a staff sergeant replied that they

had run out of engine oil and were using "that other stuff" instead.

As needed, residual treatments with 0.5% Diazinon were applied to areas where flies were found resting. Dry baits and fly cords were tried, but a water bait gave better results. The technique consisted of cutting sponges to fit a specimen cup containing a solution made by mixing 3 ounces of DDVP and 3 pounds of sugar in 1 gallon of water. When placed in strategic locations, it was not uncommon to find the cups covered with dead flies within a few hours.

Breeding within the cantonments was usually located in burn-out barrels and effluent from the galley. In this modern conflict, the old-style military head (sitting over a pit) was improved by placing one half of a 55-gallon barrel filled with 3 inches of diesel oil under each hole. Every morning, these were removed, additional fuel added, and the fecal matter burned off. If the contents were not adequately burned or, worse yet, not burned at all, the resulting fly breeding was intolerable. Additional problems were created when barrels leaked on the deck or ground or when someone neglected to replace barrels that had been removed. Unfortunately, Marines did not always look before they sat.

Ideally, effluent from the galley should be disposed of by piping it through a grease trap and into a soakage pit or leaching field. Grease traps often failed and had to be replaced because they were designed to last only six months. During heavy rains, drainage systems commonly backed up and flooded the area with organic matter. In some cases, soakage pits were not utilized and the effluent was simply piped directly to the perimeter.

Regardless of the source of the problem, whenever effluent soaked into the soil it became an excellent breeding source for filth flies.

Other problems included the storing of wastes in garbage cans without lids (even though lids were often stacked neatly nearby), rusting cans sitting directly on the ground where organic matter leaked into the soil, or the garbage not being collected often enough.

Garbage at most cantonments was collected by the Vietnamese. Units in the bush, however, did not have this service and had to dispose of their own. Sanitary landfills were the basic recommendation in these cases. Due to the lack of proper equipment and a reticence by some commands to designate personnel to be responsible for the landfills, few units ever achieved a completely satisfactory method of waste disposal.

At one combat base, the fly infestation was so heavy that it was difficult to eat in the mess hall without ingesting one or two. Not only was garbage scattered throughout the dump site but raw feces were also being dumped in the area. When space treatment was accomplished using Dyna-Fog 70 units, the operators literally became black with flies as horrendous numbers were stirred up by the fog. Foggers were loaned to outlying units with serious fly or mosquito problems. This practice was eventually discontinued because the foggers were abused in most cases and two were permanently damaged. One was even returned with the insecticide tank filled with white enamel paint.

**Graves Registration.** An unpleasant but indispensable job of the PMS was the treatment of bodies at Graves Registration after they had been exposed

in the field for several days. In advanced stages of decomposition, they were often heavily infested with fly larvae and carrion beetles. The most effective method of treatment was the application of 1/3 gallon of 0.5% DDVP in water to each body bag. The Vapona effected rapid kill and, due to its short residual life, left little danger of contamination after 24 hours.

**Rodents.** Several species of rats and mice are found in Vietnam. The Roof Rat (*Rattus rattus*) was the most common species but the Norway rat (*Rattus norvegicus*) was prevalent in the port cities. During the year, 757 rodents were trapped by the PMS or received from outlying units for disposition. Of the total, 39% were Norway Rats, 42% were Roof Rats, 8% were Polynesian Rats (*Rattus exulans*) and the remainder (11%) were mice (*Mus musculus*), shrews (*Tupaia* spp.), mongoose (*Herpestes* spp.) and Bandicoot Rats (*Bandicota indica*).

Most cantonments experienced rodent problems but they were seldom of major importance except in rat bite cases (which necessitated an individual taking 14-21 of the painful rabies shots). Recommendations for control included the elimination of all unnecessary food and harborages available to rodents and the institution of trapping and poisoning programs.

Snap or break-back traps were never as profitable as live traps. Some of the larger rats were able to survive and escape snap traps, so they were seldom used. Live trapping was also preferred because it afforded the opportunity to establish ectoparasite indices. (Live traps were available on the local market for 50 cents each). For bait, peanut butter or sardines wrapped in a 2x2 gauze square consistently gave good results. On

occasion, two and even three rats were caught at the same time.

Unique problems were associated with trapping. Traps were often stolen or trampled, or the animal was released. Some Marines poured lighter fluid or DEET repellent on the trapped animal, applied a match, and then released the burning victim to watch it run off. In one instance, a near catastrophe occurred when the blazing creature ran into an ammunition bunker.

The use of anticoagulant baits was not particularly successful. The dry rolled oats carrier was probably a poor competitor against other readily available foods (particularly for the 5-7 consecutive days required for the animal to obtain a lethal dose). In cases of heavy rat infestations, poison bait torpedoes of zinc phosphide, hamburger, corn meal and salad oil or zinc phosphide and peanut butter were made up and dispensed. Generally 60-90% of the bait was taken and good control obtained. Cards printed in Vietnamese and explaining the purpose of the baits were distributed to any Vietnamese personnel working in a treated area.

Of the 550 rodents combed for ectoparasites, less than 2% harbored fleas, all of which were identified as the Oriental Rat flea (*Xenopsylla cheopis*). About 10% were found infested with various species of mites.

**Lice.** All three species of human lice are known from the Republic of Vietnam (RVN). Body and head lice (*Pediculus humanus*) were occasionally reported to the PMS but never confirmed. Crab louse (*Phthirus pubis*) infestations were not common and usually involved isolated cases that were easily controlled. The most memorable case began when an urgent message was

received by the Division Surgeon (with a copy to the Navy Surgeon General) in February, requesting immediate insecticide and dispersal equipment to control a “widespread body louse infestation in the bunker complexes” at Con Thien. The Tet offensive had just begun, the complex was under repeated attacks, and the PMS was not permitted to visit the area. Attempts to make direct contact by phone were unsuccessful. Due to the urgency of the message, 200 pounds of lindane and malathion dust and proper dusting equipment were dispatched to Con Thien. A few weeks later, it was learned that the situation had been blown out of proportion and involved only two individuals infested with crab lice.

**Cockroaches.** At least slight infestations of cockroaches could be found in most mess halls during sanitation surveys. With few exceptions, the species involved was the German Cockroach (*Blattella germanica*). On occasion, the American Cockroach (*Periplaneta americana*) was also found.

**Termites.** Except when termite nests were uncovered by personnel digging bunkers or tearing down old buildings, most complaint calls concerning these insects were received when swarms appeared during June and July. Termite damage could be found in most of the older buildings, which was not surprising since neither the lumber nor the ground was treated in the construction of these “temporary” structures.

**Ants.** During the summer months, complaints were commonly received concerning ant infestations in living quarters. Exposed food and drink were the usual attractant, and the practice of eating inside hootches was discouraged.

**Stored Product Pests.** Only three complaints were received concerning infestations of stored product pests. In two instances, hominy grits were involved and in the third, several sacks of flour. In all cases, the infestations consisted of the Red Flour Beetle (*Tribolium castaneum*) and the Saw-toothed Grain Beetle (*Oryzaephilus surinamensis*).

**Blister Beetles.** Meloid beetles were not common; however, several cases of contact dermatitis caused by a small staphylinid beetle (*Paederus* spp.) were encountered during the year. The vesicating fluid secreted by this insect produced lesions similar to those occasionally caused by DEET insect repellent. Lesions from the repellent were usually limited to the antecubital fossi, while those from the beetle could be found anywhere on the body and were usually "streak-like" in appearance.

**Bed Bugs.** Complaints of bed bugs were seldom received. A Vietnamese orphanage in Chu Lai was found heavily infested but nothing like it was ever encountered on marine cantonments. In one instance, bed bugs (*Cimex hemipterus*) were found in a military head where they were reportedly biting personnel on the legs while they sat. Proper control techniques were explained and a hand compressed sprayer with ready-mixed insecticide was provided to the responsible corpsman. It was learned later that the problem was simply resolved by pouring diesel fuel on the structure and burning it down.

**Other Arthropods.** The *Scolopendra* genus of centipede found in Vietnam is the large tropical variety that attains lengths of up to 16 inches. These were commonly encountered in bunkers and stacks of lumber and, while known

to inflict a painful bite, they were not considered deadly. While few cases of envenomization were reported during the year, an encounter with one in a dark bunker was a memorable experience for even the toughest marine.

Scorpions are common throughout RVN but no cases of envenomization were reported during the year. A few mess halls experienced heavy infestations of spiders but generally they were only a minor nuisance. The large tarantula-like spider of the genus *Felenocosmia* was occasionally encountered but no bites were reported.

Black Widow Spider (*Latrodectus mactans*) infestations were encountered in several bunkers at the Force Logistics Command (FLC). Presumably, they were imported with gear shipped from CONUS. The NSA Hospital admitted several patients during the year with apparent spider bites in which necrosis was prominent about the bite site. The species of the spider involved was unknown.

**Snakes.** Of the few snake bite cases reported, all were from nonpoisonous species or from the common and militantly defensive Bamboo Viper (*Trimeresurus* spp.). The Bamboo Viper has a hemotoxic venom that is only weakly toxic to humans, and its bite seldom involved more than localized swelling and pain.

A reptile case built by Public Works enabled the PMS to keep several live snakes on display. These were usually the common species of *Natrix* and Bamboo Vipers. In April, a 4 1/2-foot Vietnamese Rock Python (*Python molurus*) was given to the PMS by a SeaBee Unit (MCB-1). Subsisting on a rich and plentiful diet of rats, she increased her length to well over seven feet by the end of the year. "Pythias"

soon became famous in her own right, and it was not uncommon to find an audience of 20 or more personnel (including visiting VIP's) intently watching her kill and devour her victims. Many also nervously held her for pictures to send home. In only one instance did she mistake her handler's hand for a rat, causing some hurt pride but no physical damage. (Pythias was eventually donated to the Steinhart Aquarium in San Francisco).

The live snake and lizard collection and the arthropod and general insect collections that were on display did much to enhance public relations and increase understanding of the PMS and its mission. It also afforded an opportunity to "sell" preventive medicine and explain the functions and programs of the Section. This helped dispel the idea that PMS was just "the guys that chased bugs and inspected heads."

### **Summary of Lessons Learned**

1. Personal protective measures become especially crucial when combat intensity and absence of definable combat fronts preclude use of ground and aerial dispersal.

2. For personal protective measures to be significantly effective requires a high usage rate of repellents and suppressive drugs, a low drug failure rate, continuing education, and aggressive monitoring of compliance.

3. Aerial spray operations fell short of expectations due to limited payload, the vastness of the areas needing treatment, a lack of pilots and aircraft, equipment malfunctions and hostile fire.

4. Operational research on new skin and clothing repellents and suppressive drugs needs priority emphasis.

5. Being under the technical control of the Division Surgeon but receiving all administrative and logistical support from the CO, 1<sup>st</sup> Medical Battalion, was at times unsatisfactory (e.g., this situation resulted in a lack of dedicated vehicles and drivers for eight months).

6. Initially, serious deficiencies in pest and vector control existed because combat units deployed without adequate supplies and equipment.

7. Aggressive and consistent command support is critical to the success of malaria discipline programs.

8. Basic training of medical department personnel in vector surveillance, vector control and malaria discipline should be done in CONUS, not in the combat theater.

9. Medical intelligence needs to be more current and accurate, especially for countries where we may be involved in future conflicts or in rendering humanitarian assistance.

10. Receiving contingency experience (e.g., disaster relief, humanitarian assistance) during peacetime would better prepare military entomologists for deployment to a combat zone.

11. Urgent requests that seem bizarre (e.g., "widespread body louse infestations in the bunker complexes" at Con Thien) often are, and the true nature of the problem needs to be determined or verified before drastic action is taken.

12. When immediate survival is threatened, concern about a malaria attack and proper use of personal protective measures is often a low priority.

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## Vector Control During Operation Restore Hope - Somalia

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### Introduction

During the early stages of Operation Restore Hope, three U.S. Army preventive medicine detachments were deployed to Somalia to counter the disease and non-battle injury threat to deployed forces. The activities of these units are discussed, with an emphasis on the entomology detachment. The preventive medicine (PVNTMED) threat facing deployed forces was considerable and probably greater than that encountered in any recent operation, including Operations Iraqi Freedom and Enduring Freedom. This threat is discussed, as are the methods used by the PVNTMED detachments to counter the threat. Vector control and pest management operations of the entomology detachment are highlighted, and how they related to the health and comfort of deployed personnel. These operations ranged from routine mosquito surveillance to large-area vector-control missions using a helicopter-slung pesticide dispersal unit. A variety of "lessons learned" are also discussed, focusing on Individual and company-level PVNTMED measures.

United States forces deploying to Somalia during Operation Restore Hope encountered significant disease and environmental health risks. The disease threat was assumed to be greater than that encountered during any recent military operation, including Operation Desert Shield/Storm. Due to the high heat of the dry season, and given that most personnel deployed during the winter months in the U.S., heat-related

injuries were thought to be the most immediate risk to soldiers deploying to Somalia. Food- and waterborne diseases (including acute diarrheal diseases, typhoid and paratyphoid, hepatitis A and E, enteric protozoal diseases, and cholera) also provided significant disease risks, followed by malaria and arboviral fevers. Other health risks were attributable to poor sanitation, indiscriminate disposal of wastes, lack of public health infrastructure, and other concerns such as vehicle accidents and poisonous plants and animals.<sup>1</sup>

The initial challenges facing U.S. Army forces were to prepare safe areas for newly arriving forces, obtain safe water supplies, and control potential vector insects. Many of the areas occupied by our forces had been devastated. In industrial areas hazardous chemicals were spilled or left in damaged containers. Potable water was a critical commodity during the early phases of the deployment. Wells and distribution systems had been destroyed by looting and vandalism. Local water supplies were heavily contaminated by bacteria, and the mineral contents generally exceeded U.S. military field water-quality standards for consumptive uses.

During the initial deployment of U.S. Marines, selected U.S. Army forces, and U.S. Navy medical personnel had the vector control/preventive medicine responsibility for deployed forces. As U.S. military involvement increased in early January 1993, three U.S. Army preventive medicine detachments

deployed to Somalia. The "hand-off" of theater responsibility for preventive medicine from the Navy to the Army occurred on approximately February 1, 1993. The 485th Medical Detachment (Entomology) from Fort Polk, Louisiana, the 61st Medical Detachment (Sanitation) from Fort Campbell, Kentucky, and the 224th Medical Detachment (Sanitation) from Fort Hood, Texas, constituted the Army's echelon III and echelon IV (combined) preventive medicine/vector control capability. These detachments each had approximately 11 soldiers and similar preventive medicine (PVNTMED) capabilities. The 62nd Medical Group from Fort Lewis, Washington, provided command and control for all three detachments.

Initially, the mission of U.S. forces was limited to securing the food distribution system for relief organizations (i.e., ports of entry, warehouses, and convoy routes). Humanitarian assistance was to be left to the various international relief organizations

already in country. Therefore the mission of preventive medicine units was to maintain the health of U.S. forces and not to restore the non-functioning public health system of Somalia. The purpose of this presentation is to present information concerning the activities of deployed U.S. Army preventive medicine detachments during Operation Restore Hope, focusing primarily on pest and vector control operations. Much of this presentation was previously published in the *Journal Military Medicine* in 1996.<sup>2</sup>

## **Field Preventive Medicine Overview**

Throughout history, non-battle losses have played a significant role in the outcome of military operations. Prevention of disease and non-battle injury (DNBI) by reducing the medical threat to deployed forces is the objective of preventive medicine. To counter the DNBI threat, the U.S. Army established levels (echelons) of field preventive medicine responsibilities, ranging from individual preventive medicine measures (PMM) to specialized preventive medicine units. Individual PMM included drinking sufficient volumes of water at frequent intervals, using insect repellents and netting properly, consuming food and water only from approved sources, and taking appropriate chemoprophylaxis.

Company-level PMM included forming, equipping, and training a unit field sanitation team. This team, which comprised a trained non-commissioned officer and soldier, was responsible primarily for conducting individual PMM training, monitoring the status of unit PMM (water disinfection, food service sanitation, latrine construction, etc.), and conducting limited arthropod and rodent control. In essence, this team advised the small-unit commander in all areas of field preventive medicine.

The next level of preventive medicine support (echelon II) was at the division or separate brigade. The preventive medicine section of the medical battalion or main support battalion provided services including identification of the preventive medicine threat and problems, and training of unit field sanitation teams.

At echelons III and IV (combined), additional PVNTMED support was provided by small, mobile PVNTMED detachments. During the early 1990s, there were two types of Army

PVNTMED detachments: the Medical Detachment, Preventive Medicine (Entomology) and the Medical Detachment, Preventive Medicine (Sanitation). The common mission of both detachments was to provide PVNTMED support and consultation in the areas of entomology, DNBI prevention, field sanitation, sanitary engineering, and epidemiology. Both detachments had similar capabilities; however, the entomology detachment had the additional capability of providing area vector control using truck-mounted and helicopter-slung pesticide-dispersal units. The echelons of field preventive medicine in the Army today remain essentially the same, but the Army has transformed the two types of PVNTMED detachments and merged their capabilities into a single unit - the Medical Detachment (Preventive Medicine).

#### **Activities of PVNTMED Detachments**

Peak U.S. forces strength in theater reached approximately 20,000 by the end of January 1993. The largest concentration of personnel was in Mogadishu, with various levels of troops in Baidoa and Bardera to the west and in Kismayu in the south. Theater responsibility for PVNTMED was divided among the three detachments, with the exception that the 485th, being the only entomology unit, had theater-wide responsibility for area vector control. During the deployment, PVNTMED detachments spent approximately 80% of their duty time providing general PVNTMED support and 20% on arthropod surveillance and control.

One of the major challenges facing the PVNTMED detachments was that the majority of the Army's company-

sized units had deployed with poorly trained and equipped field sanitation teams (FSTs). For example, out of 17 units evaluated by the 485th Medical Detachment in the early stages of the deployment, only 3 had fully functional FSTs. As the PVNTMED detachments had to undertake various unit FST responsibilities (e.g., training unit personnel, providing FST supplies, conducting unit-level cockroach and rodent control, inspecting unit water supplies), their ability to provide echelon III and IV support was significantly hampered.

Typically, a PVNTMED detachment's daily activities would include sending out a pair of two-vehicle, four-man teams to supported units. The purpose of the visits was to inspect company- or unit-level PMM, which would include inspecting the unit food service facility, waste disposal operations, and chlorine levels in unit water trailers/blivets. Each unit was visited/inspected weekly. In addition, PVNTMED personnel took water samples from water distribution sites and conducted bacteriological and chemical analyses. They also routinely tested samples of bottled water coming into the theater.

#### **Vector Control/Pest Management Operations**

The threat to deployed forces in Somalia from arthropod-borne and other animal-associated diseases was significant. Mosquito-borne diseases, such as malaria and dengue, accounted for a large number of cases of arthropod-borne illnesses.<sup>2,3</sup> However, endemic illnesses transmitted by or associated with filth flies, sand flies, ticks, fleas, and domestic animals also were potential threats.

Given the lack of current or reliable vector and epidemiological data on Somalia, it was important for the PVNTMED detachments to determine which vector species were present. This was not an easy task, because accurate and usable arthropod Identification materials (i.e., keys) were nonexistent. Additionally, no field rapid diagnostic tests or assays had been developed, or none were available to the detachments during the deployment to determine whether collected arthropods were infected with disease-causing organisms.

### **Mosquito-Borne Diseases**

Malaria (*Plasmodium falciparum* and *P. vivax*), transmitted by *Anopheles gambiae* sensu lato and *A. junestus* mosquitoes, was the most important vector-borne disease faced by deployed forces. From December 1992 to September 1993, 48 cases of malaria were diagnosed among U.S. personnel in country. The majority of these cases were from personnel stationed in the southern riverine areas of Bardera and Jilib. Subsequently, 79 malaria cases were described in U.S. Army soldiers returning to Fort Drum, and another 112 cases were reported from U.S. Marines returning from Somalia.<sup>4,5</sup>

Dengue, transmitted primarily by *Aedes aegypti* mosquitoes, was also present and diagnosed in many cases in which an identified etiology of fever was not present. Forty-one cases of dengue were diagnosed in U.S. personnel in Somalia during 1992-1993.<sup>3</sup> A variety of arboviruses and filarial parasites are also known to occur in Somalia; however, only one case of Sindbis and two cases of West Nile fever, both viral diseases, were confirmed among deployed U.S. forces.<sup>4</sup>

There are many mosquito surveillance techniques described in the literature; however, under the constraints of deployment in the austere environment of Operation Restore Hope, options were limited. Both adult and larval mosquito surveys were conducted, but only in areas that were relatively secure tactically, and where mosquito control measures could be employed. Solid-State Army Miniature mosquito light traps were the primary means used to collect adult mosquitoes. Even though these light traps are questionably effective in collecting anophelines, they were the only practical means of adult mosquito surveillance available. These traps were the sole adult mosquito surveillance items included in the authorized equipment of PVNTMED detachments. Depending on the numbers of mosquitoes collected, light traps were usually employed once a week at selected sites.

By the time the Army assumed the PVNTMED responsibilities from the Navy in early February, the apparent number of mosquitoes biting troops in most areas, excluding the southern riverine areas, was reduced. This was due primarily to the dry season and was reflected in the low numbers of adults collected during surveillance activities.

Personal protective measures used against mosquitoes included activities such as applying skin repellent (diethyltoluamide), treating uniforms with permethrin, and sleeping under bed nets. Command emphasis on these measures was very good overall. However, one U.S. Marine infantry battalion suffered a serious outbreak of vector-borne illness due to a lack of attention to these measures. The battalion was deployed in the town of Bardera, along the Jubba River in the

southern region of Somalia. The unit arrived around the last week of December, and by the end of January more than 60 marines (approximately 8% of the battalion strength) had developed febrile illness and the majority of these had been medically evacuated. As of January 25, the Joint Forward Laboratory in Mogadishu had confirmed 16 cases of malaria and 22 cases of dengue. An additional 19 cases were also believed to be dengue fever.

An investigation of the outbreak and questioning of the patients revealed that mosquito discipline was generally poor. Approximately 40% of the sick marines admitted that they never used skin repellent, and only 20% always used it. Additionally, very few marines used bed nets while sleeping, especially while bivouacked in the town close to the river.

As a result of the vector-borne disease outbreak at Bardera, the Marine Forces Surgeon requested mosquito control assistance from the Army Entomology Detachment. Two aerial pesticide spray missions were conducted by the 485th Medical Detachment in Bardera during the first and last weeks of February. These missions were the first time the Army's new Pesticide Dispersal Unit-Helicopter Slung (PDU) was used in a contingency operation.

Aviation support for the missions was provided by the 159th Air Ambulance Company in the form of UH-60 MEDEVAC helicopters. Applying pesticides is doctrinally not a correct mission for MEDEVAC assets; however, the commander of the Marine's aviation assets on-site at Bardera refused to fly the mission due to his unfamiliarity with the equipment. The Army MEDEVAC flight crews also had no experience with the PDU, but given

the need for the mission they were willing to work with the entomologists and PVNTMED technicians and train with the equipment.

Coordination with the local population before the missions was carried out by an Army Civil Military Operations Team and an Army Special Forces PSYOPS Team, which announced our intentions over loudspeakers, from the ground and air, immediately before each mission. Due to mission constraints and the problems associated with collecting adult mosquitoes described above, there were no statistically significant mosquito collection data to support the claim that the aerial spray missions were successful. However, these missions were deemed successful for two reasons: (1) given the way the missions were conducted and the environmental conditions at the time, adult mosquito mortality of some degree was certainly achieved; and (2) the morale of the soldiers and marines in the vicinity was noticeably improved after each mission. Additionally, given the visibility and apparent priority allotted the missions, the general awareness of the mosquito/arthropod threat was increased, and probably the use of personal protective measures (repellents, bed nets, etc.) was as well. Another aerial spray mission was conducted in Jilib, also in the southern riverine area of the country, and was equally successful.

Truck-mounted aerosol-generated ultra-low-volume equipment (AGULVE) pesticide dispersal units were used for more routine area mosquito control missions. Most of these missions took place at troop concentration sites in Mogadishu. Given that it was the dry season, these control operations were

normally needed only once each week in most areas.

### **Filth Flies**

Somalia is highly endemic for *Escherichia coli* diarrheas, various enteric viruses, typhoid and paratyphoid fevers, salmonellosis, shigellosis, giardiasis, and helminthiasis.<sup>6,7</sup>

Epidemics frequently occur as a result of the extremely poor sanitation conditions. The fecal-oral route is the normal mode of transmission for these illnesses, and house flies and other filth flies have been implicated in amplifying outbreaks.

Overall, theater diarrheal rates remained extremely low, usually below 1% per week.<sup>8</sup> This low rate, significantly lower than that experienced during Operation Desert Shield/Storm, was directly attributable to the fact that U.S. forces had complete control of all food and water. Additionally, all units in general practiced excellent field sanitation, including screening latrines and using handwashing stations. A few *Shigella* cases were diagnosed, but investigations revealed that no common source or person-to-person transmission occurred. As a result, flies were believed to be responsible for the transmission.

Practicing good sanitation and using fly bait with the pesticide methomyl were successful in controlling filth flies. Small amounts of the bait would be placed adjacent to but away from troop areas, attracting flies that would feed on the bait and rapidly die. Filth fly control was monitored during the weekly PVNTMED inspections of each cantonment area. A more interesting problem was caused by a different type of fly, the "tumbu fly" (*Cordylobia anthropophaga*). This fly is known to cause myiasis, which is an invasion of

the body by fly larvae. Of the thousands of troops deployed to Somalia, only five U.S. personnel were diagnosed with tumbu myiasis. However, once knowledge about this fly became widespread, no animal - insect, reptile, or mammal - seemed to raise as much excitement and concern.

### **Sand Fly-Borne Diseases**

Visceral leishmaniasis occurs in isolated areas of focal endemicity in Somalia, and a variety of sand flies have been incriminated as vectors.

Surveillance for sand flies was conducted by PVNTMED personnel in a manner similar to that employed for mosquitoes. Light traps were used, along with castor oil-coated papers (sticky traps) placed in the openings of termite mounds and animal burrows. From January through March, sand fly numbers were usually very low.

However, in Afgooye, about 30 km north of Mogadishu, large numbers of sand flies were collected. This area was previously a botanical garden and was occupied by a U.S. Army military police company. The area was surrounded by a high wall and was adjacent to a river. As such, it was an ideal breeding site for sand flies.

The AGULVE truck-mounted sprayers were used to control the sand flies at this site as well as the mosquitoes. The pesticide used for mosquito control (malathion - ULV) was also effective against sand flies.

### **Other Arthropod Pests**

Cockroaches, centipedes, bees, and wasps were the other arthropods most encountered by U.S. personnel and for which PVNTMED detachments received requests for control. Cockroaches, even though not directly associated with

disease transmission, are known to carry a wide variety of pathogenic organisms and seemed to thrive everywhere.

Centipedes ranging in length from 10 to 20 cm were also very common in many areas where U. S. personnel were bivouacked. Centipedes feed mainly on insects, killing their prey by means of poison claws or pincers. Most centipedes are nocturnal and they like to hide during the day in dark places, such as inside boots or under items on the floor or ground. As a result, many unwary soldiers were bitten by not watching where they put their hands and feet. The good news was that the centipedes most often encountered were not highly venomous - the pain resulting from these bites was similar to that of a bee sting for most people.

Control of cockroaches and centipedes, along with other ground-crawling arthropods such as spiders, was accomplished using the pesticide chIorpyrifos (Dursban) applied with 2-gallon hand-held sprayers. These sprayers could be stocked, along with the pesticide, by Army company-sized units for their FSTs as previously discussed. Since so few units had these items, however, the PVNTMED detachments had to provide this service as well. For units fortunate enough to be bivouacked under cover with concrete floors, one treatment with Dursban would last about 3 weeks.

Honey bees also occasionally caused problems around troop areas. The variety of honey bee found in Somalia tends to be more aggressive than the domestic varieties found in the U.S. The venom is no more toxic than that in U.S. species, but the bees tend to sting more readily and in greater numbers. Most of the requests for assistance came when a

colony or hive of bees was found near troop living/working areas.

The same pesticide used for cockroach control was also used to control bees. A hydraulic sprayer, with its pressure-spray capability, was used in many cases to reach areas inaccessible to a 2-gallon sprayer. This sprayer is operated from the back of a truck and during the 1990s was found only in the Entomology Detachment.

### **Rats**

Commensal rats are usually present wherever humans are found, and Somalia was no exception. The characteristics of a disaster area - poor sanitation, temporary shelters, garbage/waste accumulation - all made for an abundant rat population. For example, many of the buildings at the Mogadishu University complex were so heavily infested with rats that when U.S. forces began occupying the buildings it was common for one to look down the cracks between any of the walls and see a few pairs of eyes looking back. Upon awakening in the mornings, soldiers would frequently see rat droppings around their cots.

Rats are responsible for spreading a number of diseases, either directly by contamination of human food with their urine or feces, or indirectly by diseases transmitted by rodent fleas and mites (rat-bite fever, leptospirosis, murine typhus, and plague).

The PVNTMED detachments put out large numbers of poison bait boxes, snap traps, and live traps to control the rats cohabitating with our soldiers. Traps, poison bait, and instructions for constructing bait boxes were also distributed to various units in most compounds. These materials should also

have been stocked by each company-sized unit for their FSTs.

### **Domestic Animals**

Stray cats and especially dogs were also a common site around troop concentration areas. As rabies is endemic to Somalia, in addition to many tick- and flea-borne diseases, these animals presented a significant health risk.

Even when constantly warned to have no contact with animals, soldiers will invariably provide food, water, and attention to stray dogs and cats. This behavior encourages strays to remain in the area, and soon the animal numbers rise, increasing the chance of someone getting bitten or scratched. When stray dogs became habituated to an American compound, and efforts to entice them away were unsuccessful, stronger measures were taken. This usually meant shooting the animals and removing the carcasses.

Goats were also frequently found wandering around inside our compounds. In addition to being infested with the same types of ticks and fleas found on dogs, Q-fever and anthrax are also potential byproducts of cohabitating with these animals. Efforts to rope these animals and remove them from the area were usually successful.

### **Conclusion**

The success of the PVNTMED effort during Operation Restore Hope is difficult to quantify. Given the infectious diseases and environmental health risks in Somalia, the disease threat to U.S. forces was probably greater than that encountered in any recent operation. Fortunately, this was recognized by medical planners prior to the deployment and plans were made

accordingly. During the initial phase of the operation, the Navy provided the PVNTMED support to deployed forces. By the end of January, the Air Force component was in theater, along with three Army PVNTMED detachments. Based on the number of deployed forces, this body of PVNTMED professionals was doctrinally more than three times what was required. Additionally, the Department of Defense medical intelligence community provided some excellent information for field forces in the form of booklets and guides. A guide that was especially valuable for the soldiers “on the ground” was distributed by the U.S. Army Medical Research and Development Command: “Sustaining Soldier Health and Performance in Somalia: Guidance For Small Unit Leaders.” Information in this format has been used successfully in many similar deployments since, including current operations in Iraq and Afghanistan.

The lack of field rapid diagnostics available to the PVNTMED detachments significantly hampered their ability to accurately assess the vector-borne disease threat facing deployed forces. Field assays enable PVNTMED personnel to determine what arthropod species are actually infected with disease-causing organisms, and allow the limited vector control assets to pinpoint the source of the threat.

A valuable lesson learned by deployed Army units is how important the unit field sanitation team can be to the unit, not only by preventing disease but by doing things and providing materials to make the troops more comfortable. Given the current trend of humanitarian assistance and disaster relief operations, field preventive

medicine is becoming increasingly important.

Overall, command emphasis and personal attention to preventive medicine measures such as drinking sufficient water, utilizing insect repellents, and consuming food and water only from approved sources was excellent. Unfortunately, some commanders failed to support PVNTMED and their units suffered as a result, despite the large PVNTMED presence in theater. Preventive medicine support, at any level, in the absence of command emphasis will fail.

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## The Evolution of the Air Force Aerial Spray Capability

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The Air Force, first under the Army Air Corps, and later as a separate service, has engaged in aerial spraying since the inception of the technique. Aircraft were used as early as 1919 for making surveys of potential mosquito breeding habitats. Aerial dusting was undertaken at Mound, Louisiana, and in 1927 at Quantico, Virginia (Lumpkin & Konopnicki, 1962). However, it was not until 1931 that the first successful liquid spray by means of aircraft for mosquito control occurred (Ginsburg 1931). The variety and modifications of military aircraft used in both experimental and operational aerial spraying have been extensive. One example is a wind-driven propeller assembly that was modified for the Piper cub (L-4). This assembly produced approximately 50 pounds per square inch of pressure that forced the liquid pesticide through six spray nozzles mounted on the lower trailing edge of a hopper clamped to the lower longerons of the fuselage. In 1946 the Army Air Forces Board modified this same equipment for use in the L-5 aircraft (Nowell 1954).

The original concept of aerial spraying in the military service was primarily for the control of mosquito populations and mosquito-transmitted diseases. DDT powders and sprays proved to be excellent control agents when used to combat fly populations and, after a period of time, aerial spraying was utilized to control both fly and mosquito populations in all combat theaters. Consequently, these repeated DDT applications resulted in some

insecticide resistance in local pestiferous fly populations.

Experience gained in 1945 indicated that successful aerial spraying required technical supervision in the preparation of projects as well as the selection of planes and spray equipment (Nowell 1954). Therefore, the War Department updated policy for aerial spraying, which included a review of all projects by entomologists and a single agency of the Army Air Forces to conduct spray operations. Subsequently, the Special DDT Flight was created at Greenville AAB, South Carolina, in 1946 but was soon transformed to the Special Aerial Spray Flight (SASF) in 1947 and moved to Langley AFB, Virginia, when the Air Force separated from the Army to be a distinct service (Dowell 1965).

The Korean War catalyzed the establishment of the Air Force Medical Entomology career field as the public health threat to troops was quickly realized. A program for aerial spraying in the Korean War was proposed early in 1951 by the 5th Air Force after 355 cases of Japanese B encephalitis and 429 cases of malaria were diagnosed during the last half of 1950 in United Nations Forces. By June, C-46 aircraft began flying operational spray missions over a series of targets on a 21-day treatment interval. These missions were considered highly successful and helped to firmly establish the entomology program in the Air Force. Stateside, the SASF continued the use of the C-47 to spray military installations, such as

Dover AFB in Delaware, to control mosquitoes.

Following the Korean War and continuing through 1973, the Air Force was extremely active in aerial spray operations. The C-123 had been selected as the most versatile aircraft to continue the Air Force spray mission, and methods of dispensing ULV, low volume, and granular sprays were developed (Dowell, 1965). Aerial sprays were conducted in the continental United States, Alaska, Labrador, the Bahamas, Iran, Afghanistan, and several other locations.

By the time of the Vietnam War, the aerial spray mission had developed a sufficient level of importance that the requirement for multiple spray missions was considered justified, and mosquito control and herbicide applications were carried out to protect and aid troops in combat zones. The 'mosquito war' required over 1,300 individual missions and dispensed approximately 1.76 million liters of malathion concentrate (500,000 gallons). This mission, Operation FLYSWATTER (1962-1971), was a significant part of the overall United States preventative medicine program to reduce the number of man-days lost to ground forces due to malaria. Ironically, although the program was widely publicized through both military and civilian in-country channels, the memories of many veterans of the Vietnam War would later confuse exposure to the mosquito insecticide spray missions with the spraying of Agent Orange defoliants. During the Vietnam War, approximately 11 million gallons of Agent Orange were applied by the SASF and several other groups using various aircraft (Cecil and Young 2007). The negative publicity that followed the use of defoliants

tarnished the image of aerial spray operations and began a contraction of the program by the military and the State Department. Executive Order 11850 was signed in 1975, renouncing the use of herbicides during war.

In 1966, an outbreak of St. Louis encephalitis occurred in and around Dallas, Texas. During the course of the epidemic, most of Dallas County was sprayed aurally with an ultra-low-volume, high-concentration malathion mist. Hopkins et al. (1975) stated that "the effects of this treatment cannot be adequately assessed from the human epidemiologic aspect alone, but the spraying clearly reduced the number and infection rate of the vector mosquitoes." Some members of the Public Health Service were apparently so impressed with the results that it was suggested that mosquito densities be only cursorily monitored and aerial sprays used whenever vector mosquitoes threatened public health. These ideas would later be refined to include the principles of integrated pest management (IPM), which dictate ongoing surveillance to track pest and vector levels. This was the first domestic use of military aircraft to interrupt disease transmission by mosquitoes in a civilian population and would serve as a model for future responses following natural disasters.

Following Vietnam, the Air Force aerial spray mission was transferred from active duty to the Air Force Reserve Command (AFRC) on 1 April 1973 and was relocated to Lockbourne AFB, Ohio, later renamed Rickenbacker AFB. The 355<sup>th</sup> Tactical Airlift Squadron (AFRC) gained the mission using UC-123K spray aircraft and an active-duty Air Force entomologist. The Aerial Spray Group's first spray mission took place at Langley Air Force Base on

22 May 1973 to control mosquitoes. The mission remained at Rickenbacker using C-123K's until 1985 when airframes were replaced with C-130E models. The Modular Aerial Spray System (MASS) was developed in 1988 to provide easy configuration changes, making the spray-modified C-130's capable of normal C-130 tactical air/land missions in addition to aerial spray. While the MASS was capable of delivering an impressive spread of application rates, between 0.25 ounces per acre and 25 gallons per acre, the Spray Group lost the ability to dispense granules at this time. The Air Force Aerial Spray Unit was moved to the Unit's current base of operations at Youngstown Air Reserve Station, Ohio, in 1992. Youngstown currently is using C-130H2 model aircraft to conduct aerial spray operations.

In order to train for the wartime tasking of protecting troops from vector-borne illness, the Aerial Spray Unit is involved in a number of pest management programs at military installations around the United States. The majority of these missions focus on mosquito and biting midge control using ULV adulticides and low-volume liquid larvicide sprays in locations from North Dakota, Virginia, and South Carolina to southern Florida. The Unit has also been successful at using herbicides to combat invasive plant species in the United States. Using IPM methods, herbicide sprays have helped reduce the incidence of musk thistle on the Smoky Hill Air National Guard Range, Kansas, and improved native prairie plant species by

reducing competition with cheatgrass on the Saylor Creek Range near Mountain Home AFB, Idaho.

Looking toward the future, the Spray Unit has embraced predictive computer modeling of droplet fate to reduce the risk of off-target pesticide drift. Aircraft are equipped with navigational GPS systems and an integrated droplet fate model. The Unit is also exploring new aerial spray techniques, such as rotary nozzles and high pressure sprays.

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## **Vector Control during Humanitarian Assistance Missions Aboard the U.S. Navy Hospital Ship Mercy**

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The purpose of this presentation is to describe the activities of the Preventive Medicine Department on the U.S. Naval Ship (USNS) MERCY during Pacific Partnership 2008. Pacific Partnership was a humanitarian operation using the USNS MERCY as a platform to provide medical care to people in the Republic of the Philippines, Vietnam, Timor-Leste, Papua New Guinea, and the Federated States of Micronesia. The USNS MERCY visited each host nation for 10 to 14 days in the summer of 2008. During this time, medical providers on the ship saw over 90,000 patients, performed 1,300 surgeries, examined 14,000 dental patients, and conducted 26 engineering projects. The Preventive Medicine (PM) Department generated 26 reports covering all aspects of preventive medicine.

The PM Department conducted several reviews along with public health personnel from the host nations. The mission evolved as we progressed from one country to the next. The first mission site was Catobato City on the island of Mindanao, in the southern Philippines. Due to minimal planning for the preventive medicine function and because of the restrictive security situation, our mission was limited to collecting water samples. PM tested the water for the presence of coliform bacteria and 15 analytes using the Direct Reading Environmental Laboratory (DREL) 5000, from the HACH Corporation. A predetermined sampling plan did not exist. Still, results were

given to local government and Armed Forces of the Philippines personnel for further action.

The Republic of Vietnam would not allow PM personnel to do any work in their country.

In Timor-Leste, a water sampling plan was developed. Samples were taken from five water treatment facilities, where we looked for the full range of analytes. Later, samples were taken from throughout the distribution system, looking only for lead, copper and coliform bacteria, analytes that can show up in water that has been fully treated but subsequently tainted by welds and cross-connections. Water treatment was more than adequate, but there was some contamination throughout the system. PM also provided inspections and recommendations regarding sewage treatment lagoons and a solid waste disposal dump and conducted five occupational safety reviews of industrial facilities.

In Papua New Guinea, PM followed the same water sampling plan. However, the water distribution system was different. We did some additional sampling of large water tanks that also held water for outlying communities. These communities did not have water piped to their homes; instead, they had to get water from the large storage tanks at the edge of Port Moresby's distribution system. Water treatment was very good, but there were problems in the distribution system. Again, PM

reviewed the sewage and solid waste disposal situations. The sewage lagoons were draining into a large freshwater lake. It is unlikely that recommendations to move the facility will be followed. We also worked with Civilian Mariner engineers from the USNS MERCY to fix several broken pieces of equipment at Port Moresby General Hospital. The engineers fixed the ventilation in the tuberculosis lab, making it possible for them to do tuberculosis tests for the first time in several years. The refrigeration in the morgue was also fixed.

In Chuuk State, Federated States of Micronesia, the PM Department reviewed water treatment facilities and sewage lagoons, as well as the solid waste dump. Food service inspections were also done in seven restaurants. PM conducted an epidemiological investigation of persons exposed to an individual with multi-drug resistant tuberculosis. This was a follow-up to an investigation that was started by the U.S. Centers for Disease Control and Prevention. We examined all 33 contacts that the CDC was unable to

locate when they conducted their study a month earlier. Two new cases were found. The engineers fixed several items of equipment at the Chuuk state hospital.

Sewage lagoons are an acceptable way of treating sewage, but in all cases the facilities were too small relative to the use they received. PM recommended dredging the lagoons in order to increase the efficiency of treatment. The dumps were all run very inefficiently. Refuse was scattered and incineration was incomplete. In some cases, people lived in the dumps, surviving off whatever could be salvaged. PM recommended that the solid waste dumps be consolidated and encouraged greater efforts at recycling, moves that would enable the dumps to operate in accord with their design. We also made recommendations to improve the incineration process. Recycling would greatly reduce the volume of waste going into the dumps.

LCDR Prendergast continues to work with medical planners to build on these successes during future missions.

## Current Trends in Vector Control: Adapting to Selective Pressure

Kendra Lawrence  
MAJ, Medical Service Corps, U.S. Army

The mission of the Division of Entomology, Walter Reed Army Institute of Research, is to mitigate the risk posed by arthropods to DoD personnel through its research efforts in personal protective measures (PPMs), surveillance methods, vector identification, and disease diagnostics. The direct threats posed by arthropods are the vector-borne diseases that they may transmit and the potential for allergic reactions and secondary infections from the bites themselves. However, there are also substantial indirect threats in terms of expenditures on medical treatment and medical evacuation, decreased morale, and impacts on mission due to lost manpower days and decreased unit effectiveness. To tackle research needs, the Division of Entomology is divided into 6 departments, each focusing on a different aspect of the overall mission of the division. Research in the Department of Vector Control focuses specifically on PPMs, vector surveillance, and control methods. Our research needs are driven by the experiences and lessons learned from contingency operations that take place all over the world.

Research in vector control evolves as a result of lessons learned and other external factors. For example, the current operational environment has highlighted new needs, particularly with respect to the incidence of leishmaniasis and sand fly fever, sand fly control measures, and noncompliance in using

PPMs. In addition, rapidly changing technologies bring new, innovative products to the forefront that may fulfill mission needs. The Department of Vector Control (and the Division of Entomology) tackles these evolving needs by adopting a multi-faceted approach. We leverage small businesses and the commercial sector to meet our needs through the Small Business and Innovative Research (SBIR) program and various cooperative agreements. We seek early buy-in from our end-user and interested parties, such as the Armed Forces Pest Management Board and Program Executive Office Soldier.

Vector Control has multiple projects in the three research areas: PPMs, vector surveillance, and vector control. In PPMs, current research focuses heavily on a new topical repellent formulation to replace or augment the current DEET-based military repellent; a personal, wearable repellent device that would provide a long-lasting spatial effect; and improved bed nets and bed net materials. In vector surveillance, current projects include a field-deployable CO<sub>2</sub> generator and sand fly attractants. Current vector control projects include a new residual insecticide formulation for hot, desert environments; a rodent treatment and bait box; and barrier treatments and treated flooring to control sand flies. In nearly all of these projects, funding comes from multiple sources and research is accomplished via multiple collaborative partners and agreements

(Cooperative Research and Development Agreements, Material Transfer Agreements). This approach allows us to more effectively conduct research on a greater number of vector control projects and products to fulfill our mission and to meet the needs of U.S. Army entomologists and other DoD personnel in mitigating the risk posed by arthropods and vector-borne diseases.

## President's Malaria Initiative

Craig Stoops  
LCDR, Medical Service Corps, U.S. Navy

### Introduction

Malaria was the single most serious health hazard to Allied troops in the South Pacific area during World War II. It caused up to five times as many casualties as combat. Some 100,000 Allied military personnel contracted malaria in the South Pacific, most more than once. On Guadalcanal, in the Solomon Islands, this disease threatened the success of the military campaign.

Due to the presence of U.S. military personnel around the world and because of our experience with malaria, military entomologists are often expected to confront this and other vector-borne diseases. Although force health protection is our primary mission, many operations are humanitarian in nature and require working with host country ministries of health. These efforts are usually of short duration and range from small-scale control operations designed to prevent epidemics, to training of in-country public health staff.

The background that enabled me to work with the President's Malaria Initiative (PMI) was research that I conducted while stationed at U.S. Naval Medical Research Unit No. 2 (NAMRU-2), located in Jakarta, Indonesia. My first experience with malaria came via Initiative Antimalaria Indonesia (IAMI), which was a project funded by the U.S. Agency for International Development (USAID) to train health workers in the diagnosis and control of malaria. I also participated in several malariometric surveys in support of anti-malarial testing studies being conducted at

NAMRU-2. Additionally, I completed several projects on the bionomics and ecology of *Anopheles* in West Java, Indonesia, and led numerous *Anopheles* surveys throughout the country (e.g., on the island of Simeulue, funded by Save the Children, U.S.).

### President's Malaria Initiative

The PMI is a collaborative U.S. Government effort led by the USAID in conjunction with the Department of Health and Human Services (DHHS), the Centers for Disease Control and Prevention (CDC), the Department of State, the White House, and others. The PMI assists National Malaria Control Programs (NMCPs) in each target country to achieve the President's goal of cutting malaria-related deaths by 50 percent. This goal will be attained by reaching 85 percent of the most vulnerable groups – children under 5 years of age and pregnant women – with proven and effective prevention and treatment tools. PMI funding for fiscal year (FY) 2006 was \$30 million; it rose to \$135 million in FY 2007, will increase to \$300 million in each of FYs 2008 and 2009, and to \$500 million in FY 2010.

The countries that received PMI funds during FY 2006 were Angola, Tanzania and Uganda. In FY 2007 programs in Malawi, Mozambique, Rwanda and Senegal were initiated, and in FY 2008 the PMI launched operations in Benin, Ethiopia (Oromia Region), Ghana, Kenya, Liberia, Madagascar, Mali and Zambia.

There are several strategies employed by the PMI to meet its stated goals: 1) spraying the insides of households with insecticides using indoor residual spraying techniques (IRS); 2) providing Long-Lasting Insecticide-Treated Mosquito Nets (LLITNs); 3) distributing lifesaving drugs based on the country's malaria treatment policy; and 4) supporting preventive treatment of malaria for pregnant women ("intermittent preventive treatment," or IPT).

In 2007 I was assigned to the team that assists Malawi. The team includes members from USAID Washington, USAID Malawi, CDC Atlanta, and US CDC Malawi. Malawi is a country in southeastern Africa with a population of approximately 13.9 million. The life expectancy at birth is 44 years for men and 43 years for women. Fully 100% of the population is at risk for malaria, although it is unknown whether true urban transmission of malaria is occurring in the capital city of Lilongwe or the largest city, Blantyre. The under-5 mortality rate is 120/1000, or approximately 1 in 8 children. Malawi has a National Malaria Control Program that is staffed with very capable and hardworking individuals. PMI is working closely with these dedicated people to develop a Malaria Control Plan that augments rather than duplicates their efforts.

### **Entomology and the PMI**

My focus on the Malawi team is the entomology portion of the program. In Malawi PMI supported the first IRS round in Nkotakota Malawi, covering 28,308 houses. The Ministry of Health National Malaria Control Program in Malawi plans to greatly expand IRS to seven districts, covering 500,000 houses

and an estimated population of 2.5 million people this year. The PMI's role in this expansion of IRS will be to spray the entirety of Nkhotakota District (approximately 53,000 houses). In addition to spraying Nkhotakota district, PMI will continue entomological monitoring and surveillance, including vector assessments and insecticide resistance testing in designated NMCP IRS scale-up districts to monitor the efficacy of both ITN and IRS. The Malaria Operation Plan for Malawi, and those of the other 14 countries covered under the PMI, is posted at <http://www.fightingmalaria.gov/countries/mops/index.html>.

We use several techniques to measure the effectiveness of IRS. Pyrethrum Spray Catches (PSCs), where insecticide is sprayed inside a house and the dead mosquitoes are collected on sheets that cover the floor, have been carried out in sprayed and unsprayed villages and provide a coarse picture of IRS effectiveness. World Health Organization cone bioassays are the standard technique that the PMI uses to determine effectiveness. A colony of *Anopheles gambiae* has been established at the Malaria Alert Center in Blantyre, Malawi, to provide material to carry out the assays. In addition, we have partnered with the Malawi College of Medicine, Malaria Alert Center, in a window exit trap study to measure the bionomics and resistance status of vectors both inside and outside the IRS area.

### **Conclusions**

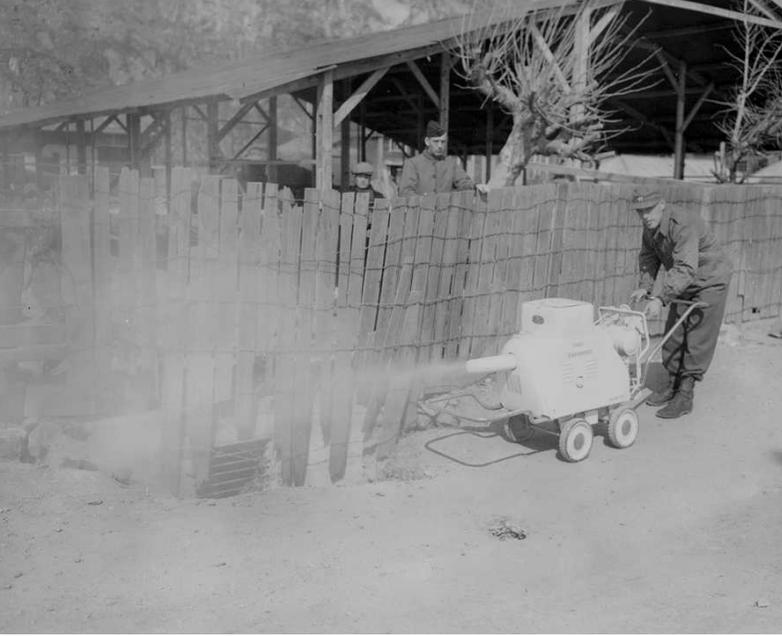
In my opinion, IRS is effective in reducing *Anopheles* numbers, and entomological monitoring is crucial to recognizing the success of the program. With pyrethroids applied to walls and

incorporated into LLITNs, the long-term effectiveness of these chemicals is a concern to control personnel.

Entomological monitoring allows us to measure the length of time that insecticides are effective under local environmental conditions and to recognize insecticide resistance in vector populations.







*These proceedings are dedicated to the Military Entomologists who have served our Military since World War I. Their dedication and commitment to protect Service Members from pests and the diseases they transmit have significantly contributed to the reduction of disease non-battle injuries and increased operational readiness.*



**Delousing operation in Italy, 1944**  
Photo taken by Jack Rosebush (retired Army PMC) while assigned to a photography unit)

