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MEDICAL DEPARTMENT
UNITED STATES ARMY
IN WORLD WAR II

MEDICAL DEPARTMENT, UNITED STATES ARMY

PREVENTIVE MEDICINE IN WORLD WAR II

Volume VI

COMMUNICABLE DISEASES

Malaria

Prepared and published under the direction of
Lieutenant General LEONARD D. HEATON
The Surgeon General, United States Army

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The volumes comprising the official history of the Medical Department of the United States Army in World War II are prepared by The Historical Unit, United States Army Medical Service, and published under the direction of The Surgeon General, United States Army. These volumes are divided into two series: (1) The administrative or operational series; and (2) the professional, or clinical and technical, series. This is one of the volumes of the latter series.

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Foreword

This volume of the official history of the Medical Department, U.S. Army, in World War II concerns malaria, from the standpoint of the preventive medicine efforts which were undertaken, both in the United States and in oversea theaters, during the period in which the United States was engaged in war against the Axis Powers. It is a comprehensive story written in the main by authorities in malariology, particularly in the fields of survey and control. The authors, themselves, were intimately associated with the work which is related within these pages—work which required a highly technical knowledge of the subject; work which required the training of hundreds and thousands of other officers and men: work which required staff coordination at the highest as well as at lowest unit command levels: work which was hot, dirty, wet and which many times involved the dangers inherent in combat itself. It was in the latter areas that prevention and control were not only most difficult to carry out, but for which the dire necessities of control were so obvious.

During the peacetime years immediately before World War II, the Army Medical Department was generally alert to the problem of malaria and the potential noneffectiveness which could arise from this disease. Relatively small numbers of troops, however, were subjected to this danger—mainly in the Panama Canal Zone, Puerto Rico, the Philippine Islands, and the Southeastern United States. In these areas, a small group of Medical Department personnel, working with command support and to some extent with local civilian public health authorities, had reduced the malaria attack rates among the military personnel and the American civilian employees to a low level. Individual malaria discipline, as it was called, supported by improved, strict, and adjunctive sanitary measures on military posts and surrounding areas, was effective. Army admission rates for malaria dropped from 130 per 1,000 per year in 1900 to about 4.6 in 1938. For example, aggressive control measures in the Panama Canal Department had reduced the rate for primary and recurrent cases in U.S. Army personnel to a satisfactory low just before World War II. Extensive malaria surveys had been conducted in the Philippines prior to the war by medical personnel of the Army in conjunction with the Rockefeller Foundation. Even on Bataan, the vector had been identified and the incidence of malaria in the native population had been determined. Unfortunately, because of the lack of public health funds, little or no control measures on Bataan had been effected before the war. This, as discussed in chapter IX, was later to contribute to a military catastrophe.

The conditions and environment of a relatively static garrison life of an army in peace time are much different from those imposed by war. In the former, an orderly approach can be made to sanitation control and prevention of disease, such as malaria. In war, this setting changes abruptly and rapidly, and there arise many uncertainties, not the least of which are imposed upon us by the enemy, foreign and unknown terrains, climatic conditions to which our troops are unaccustomed, the various mores of Allied as well as hostile nationals, the great variances in global personal and public health standards, and many such other problems. In the control of malaria, which alone caused 500,000 hospital admissions in World War II, there were paramount obstacles to be attacked and surmounted.

From the earliest days of the entry of the United States in World War II, in addition to the physical conflict in which the Army was engaged, there was also this constant battle at home and overseas between the Army and the causative agent of malaria and the mosquitoes which spread the parasites from man to man. As with bullets and high explosives, there was with malaria no respect for rank, color, sex, creed, or ethnic origin.

Malaria control became, therefore, one of the major concerns of The Surgeon General and of the entire Medical Department, and it remained one of high priority throughout the war. In order to plan for and successfully implement the plans for the war against malaria, it was not only necessary to understand the basic facts of malaria epidemiology, but it was likewise necessary to understand the basic clinical considerations. Additionally, knowledge of the strategic concepts and plans and the place and timing of future tactical operations had to be gained. It was necessary to develop and evaluate medical intelligence on diverse and little-known areas of the world. Competent personnel had to be obtained to devise and direct the overall malaria program, and other trained personnel had to be located and dispatched to implement the program in the field. Training schools had to be established for officers as well as for enlisted men. The procurement of supplies and equipment and their shipment to appropriate destinations were of the utmost importance. It was necessary to organize and train special malaria survey and control units and to arrange for their movement and employment consistent with their mission. It was likewise necessary to orient and educate commanders at all levels with the need for control measures and malaria discipline for, obviously, command support is a must in any such undertaking. Where commanders understood the dangers involved and the methods by which these dangers could be overcome, the health of the troops was preserved—one might say in direct proportion to the command support given to the effort. For the troops, training programs and training media had to be prepared and presented, for as always, much of any success or failure depends upon the knowledge and motivation of the individual soldier. Not the least of the elements of necessity that arose was the time, effort, and money which was devoted to research in the field of antimalarial drugs, insecticides, larvicides, and repellents. This went into high gear by mid-1943, and the cooperative efforts of the Army and Navy, other Federal agencies, and civilian medical schools, industrial firms, research institutes, and other private health organizations were a causative factor in the final success of the malaria program. In all of these endeavors, every effort was made to keep our Allies informed of the technical progress and so provided an exchange of pertinent information and experience. Major benefits accrued for all concerned.

As Dr. Paul F. Russell points out in chapter I, the greatest advances made in malariology during World War II were in the development and use of synthetic antimalarial drugs and residual insecticides. We learned to use Atabrine. Research into and clinical studies of other antimalarial drugs were made during and continued after the war and have resulted in even newer and more useful drugs. From the standpoint of the new insecticide, DDT, many trials were conducted. Large quantities were produced, distributed, and used in all theaters with outstanding success. The research, development, clinical study, and application of these products during the war was a massive joint effort by military and nonmilitary personnel, by Government and civilian agencies, with a great pooling of resources and cooperative spirit.

As one reads this book, one can but be impressed with the tremendous number and scope of malaria surveys which were conducted by the various Medical Department survey units which were located eventually in every appropriate theater of operations, as well as in certain areas of the United States. These officers and men, under adverse conditions, steadfastly and unrelentingly studied and reported on the characteristics of the area where they were located, whether in South or Central America, Africa, Italy, Burma, or some strategically located island in the far reaches of the Pacific. Physiography, climate, native population, general health situations, habits, and distribution of the mosquito vectors were included. Basic knowledge and facts were sought and obtained. Based upon this information, malariologists, epidemiologists, entomologists, malaria control units, and combat and service troops, employing their individual and collective efforts and facilities, strove to improve malaria prevention. The Army Air Forces cooperated by providing personnel and airplanes by which the spraying of large areas of terrain was accomplished. In many areas, this proved of inestimable assistance.

Many practical lessons learned from these war experiences are included within the pages of the various chapters of this volume. A few of the more pertinent are: The need for malaria control enlightenment of line commanders; the requirement for utilization of medical supervision of, and didactic malaria control training for, all troops regardless of branch or service; the relative emphasis to be placed upon environmental control measures vis-a-vis the personal measures of the individual soldier, including suppressive medication; the use of special malaria control organizations; and the place and responsibilities of the malariologist in the overall medical framework and organization.

In discussing these and other matters, the authors—as one might expect—have been somewhat repetitious. In order that the individuality of the authors' presentations might remain, the editors have intentionally permitted such repetitions to stand. There were other reasons, also. No two areas were exactly alike. Conditions of combat, terrain, environment, personnel, supply, and other factors were dissimilar. And, individual interests of participating personnel, as well as readers, in reality dictated the individual approach.

In this great effort toward the eradication of malaria, resulting as it has in an improvement in mankind's environment, the Medical Department of the Army takes natural and justifiable pride in the role which it played on the antimalaria team during the war. Nowhere was its mission, "to conserve the fighting strength," more typified and of more importance than in the minds, souls, and bodies of the thousands of its dedicated officers and men wherever they were engaged in the battle against malaria. To these, our country and our Armed Forces are ever grateful.

LEONARD D. HEATON,
Lieutenant General,
The Surgeon General.

Preface

A momentous chapter in the history of wars is the story of the devastations caused by malaria. Man has struggled under the ravages of this disease and many other incapacitating and lethal illnesses transmitted by insects, mites, and ticks, diseases which seem to be especially destructive in wartime. For example, as Dr. Russell has stated in the first chapter of this volume, from 9 July to 10 September 1943, during the active campaign in Sicily, malaria was responsible for the hospitalization of 21,482 American soldiers as contrasted with 17,375 hospitalized because of wounds inflicted by the German-Italian forces. Since most of those infections were with *Plasmodium vivax*, many relapses occurred in the crucial spring of 1944, and so deprived the American forces of valuable manpower.

World War II saw great advances in military preventive medicine and in particular in the control of malaria. The effort is by no means finished however, and certain lessons that were learned in World War II can be helpful in guiding our preventive programs in the future. Probably the most important lesson to be learned is that effective malaria control in military operations in malarious areas will fail unless the line commanders at all echelons are specifically malaria conscious. Clearly, the control of malaria and other arthropodborne diseases is not a task that the Army Medical Service can undertake alone. There must be education and training of both medical and line officers toward a definite understanding that control of these diseases is a broad military problem with immediate application to actual striking power. Malaria discipline is necessary to an army's success in many areas of the world.

The experiences of World War II have shown that control of malaria cannot be really effective without a special military control organization, which must actively and continuously function and give full and undivided attention to the problem.

The volume presents the story of the difficulties as well as the triumphs in the constant fight against malaria during World War II. Each author is a specialist who has written from the vantage point of his own close experience. Thanks are extended to the authors for their willingness to undertake this task of writing, which has meant long hours of work snatched from busy schedules. Each chapter has been reviewed by one or more experts who have advised the authors as to scope, coverage, and technical accuracy. Thanks are expressed for this valuable help to: Dr. Justin M. Andrews, Col. Samuel C. Dews, Dr. Elliston Farrell, Col. Hugh R. Gilmore, Jr., Mr. William A. Hardenbergh, Prof. John M Henderson, Brig. Gen. Earl Maxwell, the late Dr. Maurice C. Pincoffs, Dr. Earle Rice, Capt. James S. Sapero, U.S.N., Mr. Millard E. Smith, Dr. Alan Stone, Col. William S. Stone, and Dr. Stanley F. Yolles.

As in the case of the previous volumes of the Preventive Medicine series, members of the Advisory Editorial Board have been closely associated with the planning, writing, and preparation of the volume. Grateful thanks are tendered to Dr. Stanhope Bayne-Jones, Chairman of the Board, for his careful review of every chapter. Dr. Paul F. Russell, the member of the Advisory Board with special concern for the subject matter of this volume, has been consulted in all phases of its preparation. Dr. Russell has participated significantly in the selection of authors and has corresponded with them as to content and presentation. He has scrutinized each manuscript meticulously and has advised in numerous technical details. The editors, authors, and readers of this volume owe a particularly warm debt of gratitude to Dr. Russell.

The editors are grateful for this opportunity of thanking the President, Chancellor, Comptroller, and other officers of the Medical College of Virginia whose cooperation has made possible the work of the editorial office at the Medical College under contract with the Office of The Surgeon General.

It is a privilege for the editor of the Preventive Medicine series to record here his cordial thanks to Col. John Boyd Coates, Jr., MC, USA, Editor-in-Chief of the History of the Medical Department, U.S. Army, World War II, of which this series is a part. The comprehensive history of the Medical Department, under Colonel Coates' inspired and competent direction, will stand as a major contribution to medicine. Colonel Coates has continued to expedite the publication of these volumes so that they may be available as soon as possible. He and his staff have produced books of high quality in both appearance and content.

The authors and editors have again greatly relied upon the services of the Medical Statistics Division of the Office of The Surgeon General. Mr. E. L. Hamilton, Chief, Mr. A. J. McDowell, Assistant Chief, and Mr. M. C. Rossoff, Assistant Chief, Statistical Analysis Branch, have not only provided essential data but have also checked and reviewed all statistical information in this volume. Their contribution has been a substantial one. The Scientific Illustration Division, Medical Illustration Service, Armed Forces Institute of Pathology, under the direction of Mr. Herman Van Cott, prepared the illustrations for this volume. Maps were prepared by Miss Elizabeth P. Mason, Chief, Cartographic Section, and Miss Jean A. Saffran, Cartographic Draftsman, of the Special Projects Branch, The Historical Unit.

The editors gratefully acknowledge the assistance of Mrs. Elaine R. Stevenson, Publication Editor of the Editorial Branch, The Historical Unit, who performed the manuscript editing and prepared the index for this volume.

EBBE CURTIS HOFF, Ph. D., M.D.

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CHAPTER I

Introduction

Paul F. Russell, M.D., M.P.H., Sc. D.

> But, as to public matters, it is clearly in military service that the ravages made by the diseases of malaria have been frequent, serious, and often ruinous: while if those have sometimes been inevitable, they have much too often been the results of neglect, or of what should be called ignorance * * *—MACCULLOCH, 1829.

At first, in this series on the history of preventive medicine in the U.S. Army in World War II, it was planned to include in one volume accounts of all the arthropodborne diseases that afflicted our troops throughout the world. But because of the size, scope, and attractiveness, as well as the importance of the manuscripts prepared by malariologists with wartime experience, the editors decided to devote an entire volume to malaria and a subsequent volume to be entitled "Arthropodborne Diseases Other Than Malaria." This volume will include accounts of some 15 diseases spread by mosquitoes, mites, ticks, lice, and fleas.

The following chapters tell the story of the life and death battling that went on continuously at home and overseas during World War II between the U.S. Army and the plasmodia of malaria together with certain species of *Anopheles* mosquitoes that spread the parasites from man to man. In many engagements, arthropodborne diseases, especially malaria, sent more soldiers to hospital beds than did the armies of the Axis with all their guns, planes, and tanks. For example, as noted in chapter V (p. 362), from 9 July to 10 September 1943, during the fierce Sicilian campaign, there were 21,482 hospital admissions for malaria compared with 17,375 battle casualties. Because most of the infections were with *Plasmodium vivax*, there were many incapacitating relapses during the spring of 1944, a time when every man was badly needed at Cassino and Anzio.

Naturally, malaria control became one of the main concerns of the Preventive Medicine Service of the Office of The Surgeon General. The importance in the Army's final conquest of malaria in World War II of the massive and steadily maintained primary administrative attack, initiated by Brig. Gen. James S. Simmons, and fully supported by The Surgeon General and by the Chief of Staff of the Army, can hardly be overemphasized. Details have been given by Hardenbergh [1] and by McCoy (see chapter II).

[1] Hardenbergh, William A.: Control of Insects. *In* Medical Department, United States Army. Preventive Medicine in World War II. Volume II. Environmental Hygiene. Washington: U.S. Government Printing Office, 1955, pp. 179–232.

This power of the mosquito to knock out our soldiers was particularly manifest in the South and Southwest Pacific. I shall not forget Gen. Douglas MacArthur's statement to me in May 1943: "Doctor," he said, "this will be a long war if for every division I have facing the enemy I must count on a second division in hospital with malaria and a third division convalescing from this debilitating disease!" The general was not at all worried about defeating the Japanese, but he was greatly concerned about the failure up to that time to defeat the *Anopheles* mosquito. Thanks to this understanding of the power of the *Plasmodium*-arthropod axis and thanks to the superb attack on these enemies by American and Australian antimalaria personnel, as recounted in chapters III and X, U.S. Forces from mid-1943 onward waged a fast and successful war through some of the most malarious areas on earth.

Nearly all of the chapters that follow were written soon after the war by men who took an active part in the struggle. Place names, epidemiological facts, and authors' titles appear as they existed during the period of World War II. The authors have not glossed over early mistakes and omissions which permitted malaria rates in U.S. Forces to climb, at times, to such appalling heights as 2,700 per 1,000 on Efate, in the second month of occupation; 1,781 per 1,000 on Guadalcanal, in November 1943; 4,000 per 1,000 at Milne Bay, in late 1942; and the fact (as noted in chapter IX) that malaria hastened the surrender on Bataan. Each author has attempted to give an accurate account of the difficulties and the errors—and of the ways in which these were overcome. There are valuable lessons in these chapters, published not merely for the record but in the hope that some of the pitfalls may be avoided in the future, although perhaps one is unduly optimistic to believe that the lessons of one war are ever remembered in the next. That memory is a sieve has been demonstrated over and over again with regard to military malaria control. Quoting Macculloch,[2] "* * * and still it would seem, as if fatal, that the wisdom and experience of one generation should be forgotten by the next, that peace should extirpate the knowledge that had been gained in war * * *."

MALARIA IN PAST WARS

For centuries, it has been recognized that there must be command responsibilities if preventive measures against disease are to be successful in military forces. In 1764 for example, John Pringle noted the fact in the preface of his classical book on diseases of the army that he was writing "for the information of officers as well as physicians."[3] Both in his preface and in the text, he wrote that "the prevention of diseases cannot consist in the use of medicines, nor depend upon anything a soldier shall have it in his power to neglect, but

[2] Macculloch, John: Malaria; an Essay on the Production and Propagation of This Poison and on the Nature and Localities of the Places by Which It Is Produced: With an Enumeration of the Diseases Caused by It, and of the Means of Preventing or Diminishing Them, Both at Home and in the Naval and Military Service. Philadelphia: Thomas Kite, 1829.

[3] Pringle, John: Observations on the Diseases of the Army. 4th edition. London: A. Millar, 1764.

upon such orders as shall not appear unreasonable to him, and such as he must necessarily obey." In 1910, Col. C. H. Melville,[4] professor of hygiene, Royal Army Medical College, London, wrote for Ronald Ross a chapter on malaria prevention in war. In this, he commented that as regards antimalaria measures: "A specially selected medical officer should be placed in charge of these operations with *executive* and *disciplinary powers*, a step that has proved to be so effective by the officers of the U.S. Army in Cuba and elsewhere."

It is a simple truth that, in an army, discipline is as important in fighting disease as in fighting the human enemy. But this seemingly obvious fact was almost completely forgotten in the early months of World War II when there was often what Macculloch referred to in 1829 as "a contempt and an incredulity respecting malaria." The attitude of all too many command officers was at first similar to that reported of a general officer in a highly malarious area who, at a time when some 40 percent of his forces were already ill with malaria, resented all suggestions of malaria prophylaxis and said that if one had to play with mosquitoes in wartime that person should go back to Washington and stop bothering him while he was so busy getting ready to fight the Japs. Unfortunately, before his forces did any fighting at all, they were ignominiously routed by anopheline mosquitoes and were all evacuated to a rear area for malaria therapy and convalescence.

Most line officers and all too many medical officers at the beginning of World War II were ignorant about malaria and its potential for disrupting military operations. This was understandable in newly recruited personnel but hard to excuse in regular officers presumably trained to fight in any part of the world. For the history books are full of examples of malaria's military power. As Melville wrote: "The history of malaria in war might almost be taken to be the history of war itself, certainly the history of war in the Christian era." He mentioned the fevers in the French and Austrian armies in the Italian campaigns of 1859 and the disastrous Walcheren Expedition a century earlier in the Low Countries when the British were conquered by malaria before a battle could be fought. Melville commented on the 1864 West African campaigns as follows: "It can scarcely be called a war, as an enemy was never seen, or a grain of powder expended; our troops were defeated by disease, much of which was preventable." Then, there was the French campaign in Madagascar in 1895 when there were 13 deaths in action and over 4,000 deaths "due almost entirely to malarial fevers and their sequelae."

Numerous other examples could be cited, such as that of Macedonia in World War I when malaria immobilized British, French, and German armies for 3 years. On one occasion, when the French commanding general was ordered to attack, he replied: "Regret that my army is in hospital with malaria." Nearly 80 percent of 120,000 French troops in this area were hospitalized with malaria. In an average British strength of 124,000, there were

[4] Melville, C. H.: The Prevention of Malaria in War. *In* The Prevention of Malaria by Ronald Ross. 2d edition. London: John Murray, 1910, pp. 577–599.

162,512 admissions to hospital for malaria during the years 1916 to 1918, in contrast to 23,762 killed, wounded, prisoner, and missing in action. In the spring of 1918, about 25,000 British soldiers were sent home from Macedonia with chronic malaria, and, apart from these evacuees, over 2,000,000 man-days were lost to the British Army in this area in 1918 because of malaria.[5]

BASIC MALARIA EPIDEMIOLOGY

To understand why malaria can so seriously disrupt an army, one must know a few basic principles of malaria epidemiology. For example, except for occasional accidental infections, as by blood transfusion, man acquires malaria only through the bite of an anopheline mosquito. No other genera can transmit the disease, and, in practice only, about 50 of some 200 species of *Anopheles* are closely enough associated with man to be dangerous. Most anophelines feed on animals. There was no malaria in New Caledonia because there were no *Anopheles* mosquitoes there. No malarial infections occurred on the flat coastal plain or mangrove swamp areas of the Philippines because the anophelines in those areas do not feed on man. In the Philippines, malaria is transmitted by a species of *Anopheles* that breeds chiefly in foothill streams.

Secondly, there can be no malaria transmission if there are no malaria parasites in man available to the mosquitoes. For example, there are potent malaria vector mosquitoes in many areas of our Southern States but no malaria transmission because none of the residents has malaria parasites in his blood. When soldiers bivouac in communities where there are parasites in the blood of the residents and vector mosquitoes in the area, it is a foregone conclusion that many of the soldiers without protection will become malarious. This, in turn, will increase the parasite reservoir, and there will be an epidemic among the soldiers unless preventive measures are taken promptly. Another important fact is that anophelines are rarely effective vectors over a radius much longer than a mile and a half. Yet time and time again, troops were allowed to bivouac in highly malarious surroundings when safe locations could have been utilized a mile or two away.

It is also important to know that different species of anophelines have different breeding habits. All develop only in water, but some prefer rice paddies, some pools and puddles, some foothill running streams, some swamps or ponds, some marshes, some wells, some fresh water, some brackish, some sun, and some shade. Therefore, malaria control requires the help of trained entomologists or malariologists who know or can find out the habits of the mosquitoes. For example, on Guadalcanal and in West Africa, where the vectors breed in pools, puddles, and wheel ruts, U.S. Armed Forces created

[5] (1) Russell, Paul F., West, Luther S., and Maxwell, Reginald D.: Practical Malariology. Philadelphia: W. B. Saunders Co., 1946. (2) MacDonald, A. G.: Prevention of Malaria. *In* History of the Great War Based on Official Documents. Medical Services. Hygiene of the War, edited by W. G. Macpherson, W. H. Horrocks, and W. W. O. Beveridge. London: His Majesty's Stationery Office, 1923, vol. II, pp. 189–238.

thousands of breeding places for the local malaria vectors and thus greatly increased the numbers of malaria mosquitoes and so the cases of malaria.

The fact that most anopheline vectors feed only at night is important. In West Africa and elsewhere, U.S. Forces suffered from much preventable malaria by permitting unprotected soldiers to attend night movies where they were easy prey to the night-biting malarial mosquitoes. Air Forces personnel taking planes from the United States to the United Kingdom via South America and West Africa were often billeted in unscreened or poorly screened quarters at Eknes Field and in the Dakar-Rufisque area of French West Africa where the malaria rates among the base personnel, in the autumn of 1943, sometimes exceeded 1,500 per 1,000. Many Air Forces officers who had spent a night or two in these areas, therefore, developed malaria in nonmalarious England and so were out of action when badly needed.

The epidemiology of malaria and the technical application of control measures are basically the same in military as in civilian communities. But there are some differences. The following features, for instance, tend to make malaria control easier under wartime military conditions than in civil life: Complete authority of the commanding officer, uniformity of living habits of the personnel, and ample antimalaria funds and supplies. But other features impose handicaps: for example, troop mobility and dispersion, necessarily based on tactics and not on sanitary conditions; a great deal of vital nocturnal activity; difficult logistics, especially in combat zones; enemy action, mines, and boobytraps; and combat tension when the chief concern is not malaria control but immediate life and death. Moreover, a military force operating where malaria is endemic generally finds the malaria potential greatly increased. In jungly areas, necessary clearing opens up breeding waters for anopheline vectors that prefer sunlight, and other operations often tend to multiply breeding places. In civilized areas, war often forces the people out of cities into the malarious countryside where they live in shelters exposed to infective mosquitoes. Local health services are disrupted or abandoned so that there is no civilian malaria control. Thus troops may be exposed to malaria incidence much greater than normal for the area. Trenches, foxholes, tank traps, gun emplacements, vehicle ruts, shell, bomb and mine craters, sabotaged irrigation projects, streams ponded by bridge rubble and improvised causeways, drainage blocked by hastily built airfields and highways, all may provide additional breeding places for malaria mosquitoes. An army must depend largely on its own efforts to prevent loss of manpower due to mosquito action.[6]

MALARIA LESSONS FROM WORLD WAR II

The following chapters make it clear that out of World War II came certain fundamental lessons regarding military malaria control. The principal general lesson was that it is impossible to control malaria effectively in military

[6] See footnote 5 (1), p. 4.

forces in highly malarious areas unless commanding officers from highest to lowest echelons are malaria conscious. Training and education of both medical and line officers in regard to malaria and its control are essential. Malaria control in the army is a military problem. A malaria policy must not only be formulated; it must be enforced. Malaria discipline is absolutely necessary to an army's success in fighting the *Plasmodium*-mosquito axis. This malaria discipline is a part of what Sir Neil Cantlie, Director General of British Army Medical Services, called "Health Discipline" and which he defined as "measures that concern the preservation of health and the prevention of disease which are enforced by disciplinary means."[7] Cantlie tells of one commander who, when he had grasped the importance of Brig. N. H. Fairley's proof that clinical malaria could be prevented by taking a tablet of Atabrine (quinacrine hydrochloride or mepacrine hydrochloride) a day, said: "You doctors think you can prevent malaria, but you can't. I can and I'm going to." This lay officer's declaration that he was going to prevent malaria signified a vital turning point that made victory possible. Again quoting Cantlie: "When for the first time in history a combatant officer was considered unfit to command a unit on the grounds that he had allowed his men to become ineffective through disease, a new day in military medicine dawned. The clouds of forgetfulness must not be allowed to overshadow the brightness of that day."

The second general lesson was that it is scarcely possible to control malaria successfully in any but lightly endemic areas, or in small units, unless there is a special military malaria control organization to survey, plan, execute, supervise, and maintain the numerous and technical measures that must be carried out continuously if malaria is to be defeated. Personnel charged with all manner of sanitary duties cannot give the time and care to malaria that is required for its control. Full and undivided attention by a specially trained malaria control organization is absolutely essential.

A third lesson was that malaria supplies and personnel require priority of movement commensurate with their importance. For example, in some areas of New Guinea, malaria supplies and personnel were more important to the success of the fighting than was much of the materiel being sent forward. Yet early in 1943, malaria supplies for use in the Southwest Pacific were mostly piled up on the piers of the west coast of the United States. The few supplies that went to Australia stayed there and were not moved on to New Guinea because malaria supplies were about tenth down the list of priority of movement. In wartime, everything moves from the rear toward the front on strict priorities set by the theater command. When the need became obvious in May 1943, the priorities for malaria supplies and personnel were raised to first place, and thereafter no serious shortages occurred. This action, together with the enforcement of malaria discipline and the provision of specialist malaria control and survey units, turned the scales, and malaria was thoroughly defeated. These were the fundamentals: (1) Malaria discipline, (2) special-

[7] Cantlie, N.: Health Discipline. U.S. Armed Forces Med. J. 1: 232-237, February 1950.

ized malaria control organization, and (3) high priorities for movement of malaria personnel and supplies. The military experience taught once again that the prevention of malaria is neither automatic nor simple but is compounded of law and persuasion, organization and training, supplies and technical application. Once the fundamental lessons were learned, the military malaria problem was solved.

ADVANCES IN MALARIOLOGY IN WORLD WAR II

Certain advances in malariology during World War II should be briefly mentioned. The greatest were in the development and use of (1) synthetic antimalarial drugs and (2) residual insecticides.

Antimalarial drugs.—As regards antimalarial drugs, World War II liberated us from quinine, taught us how to use Atabrine, and led us to such powerful new antimalarials as chloroquine and amodiaquin, primaquine, proquanil, and pyrimethamine. Quinine and its source, cinchona bark, had been the only effective medicament in malaria therapy and prophylaxis for over 300 years. Then, when the Germans were unable to obtain quinine during World War I, they began to experiment with synthetic substitutes, producing Plasmochin naphthoate (pamaquine naphthoate), in 1925; Atabrine, in 1930; Resochin or Aralen (chloroquine diphosphate), in 1943; and Sontochin or Sontoquine, a little later.[8] Resochin, strange to say, was discarded by them as apparently too toxic.

After the entry of Japan into World War II, the Allies were quickly cut off from Indonesia, the principal source of quinine, and so they began an extensive program of research on antimalarials both in the United Kingdom and in the United States. The secrets of Atabrine manufacture had been kept in Germany but were soon solved by Allied chemists, and the drug was put into large production in the United States. Atabrine immediately gained widespread recognition as an excellent therapeutic agent, but there was some confusion about its use as a prophylactic until the classic experiments of Brigadier N. Hamilton Fairley in Australia in 1943.[9] These proved beyond doubt that one tablet of Atabrine (100 mg.) a day would prevent overt attacks of malaria, curing those due to *Plasmodium falciparum* and postponing clinical manifestations of *P. vivax* infections until the drug was withheld. With relatively few exceptions, this suppressive Atabrine could be administered for many days without serious toxic effect. The evidence is clear that the taking of suppressive Atabrine, when strictly enforced by suitable malaria discipline, enabled our forces to fight in highly malarious surroundings without being hampered by clinical malaria.

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[8] (1) Covell, Gordon, Coatney, G. Robert, Field, John W., and Singh, Jaswant: Chemotherapy of Malaria. Monograph Series No. 27. Geneva: World Health Organization, 1955. (2) Most, Harry: Clinical Trials of Antimalarial Drugs. *In* Medical Department, United States Army. Internal Medicine in World War II. Volume II. Infectious Diseases. Washington: U.S. Government Printing Office, 1963.

[9] Fairley, N. H.: Researches on Paludrine (M. 4888) in Malaria. Tr. Roy. Soc. Trop. Med. & Hyg. 40(2): 105–151, October 1946.

After the Allied occupation of North Africa, the Allies learned that the French had found Sontoquine to have high antimalaria value. This led to the exploration of a large series of 4-aminoquinolines by investigators in the United States. They determined that Camoquin (amodiaquin) and Resochin or Aralen were excellent antimalarial drugs comparable to Atabrine. Neither drug became available to the Army in any quantity before the end of the war.

Other wartime studies were directed to the 8-aminoquinolines and led to the discovery of primaquine in 1945. In the overall U.S. wartime program up to 1946, more than 15,000 compounds were studied for antimalaria values.

British investigators also carried out extensive studies on malaria drugs, and these led to the synthesis of quite different but highly effective compounds, proguanil or Paludrine (chlorguanide hydrochloride) in 1944 and Daraprim or malocide (pyrimethamine) in 1952, reported by Covell and others.

DDT.—Dichlorodiphenyltrichloroethane (DDT) was first synthesized in 1874 by a Viennese pharmacist, Othmar Zeidler, who at the time was a chemistry student in Strasbourg interested in the then new phenomena of organic synthesis.[10] He did not investigate the properties of the new substance but simply published his synthesis. Then in 1939 in Switzerland, Paul Müller of the Geigy Company, searching for a toxicant that would kill clothes moths, resynthesized this compound and made his Nobel Prize-winning discovery that it was an insecticide of remarkable versatility. The Geigy Company began in 1940–41 to market the substance in two forms: (1) A 5-percent dust called Gesarol spray insecticide, at the time principally for use against potato beetles, and (2) a 3-percent dust called Neocid dust insecticide, for use as a lousicide.

Due in large measure to the U.S. Military Attaché at Berne, Maj. A. R. W. de Jonge, samples of these products were sent to the Geigy Company's New York branch and to London, in the autumn of 1942. Studies at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine demonstrated beyond question that this new insecticide had tremendous possibilities not only against lice but also against several other noxious insects, such as mosquitoes and houseflies.[11] With the help of the War Production Board, the new insecticide was put into large production as soon as possible. The now universally used name, DDT, was first applied by the British Ministry of Supply in 1943.[12] DDT was first added to U.S. Army supply lists in May 1943.[13]

Gahan and colleagues, in August 1943, appear to have made the first practical tests of DDT as a residual insecticide against adult vector mosquitoes.[14]

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[10] Russell, Paul F.: Man's Mastery of Malaria. New York: Oxford University Press, 1955.

[11] Knipling, E. F.: The Development and Use of DDT for the Control of Mosquitoes. J. Nat. Malaria Soc. 4: 77-92, June 1945.

[12] West, T. F., and Campbell, G. A.: DDT. The Industrial Chemist and Chemical Manufacturer 20: 461–465, September 1944.

[13] Bishopp, F. C.: Present Position of DDT in the Control of Insects of Medical Importance. Am. J. Pub. Health 36: 592–606, June 1946.

[14] Gahan, J. B., Travis, B. V., Morton, F. A., and Lindquist, A. W.: DDT as a Residual-Type Treatment to Control *Anopheles quadrimaculatus*: Practical Tests. J. Economic Entomology, 38(2): 231–235, April 1945.

They sprayed the interior surfaces of various types of houses and found the procedure to be quite effective against *Anopheles quadrimaculatus*. The first field test in which residual DDT was applied to the interior surfaces of all habitations and outbuildings of a community to test its effect on *Anopheles* vectors and malaria incidence was begun in Italy in the spring of 1944. This experiment was carried out in the town of Castel Volturno at the mouth of the Volturno River, north of Naples, by the Malaria Control Demonstration Unit of the Malaria Control Branch of the Public Health Sub-Commission, Allied Control Commission, Italy. Spraying began on 17 May 1944, and this experiment, together with a second one started later in the Tiber Delta area, lasted 2 years.[15] The Malaria Control Demonstration Unit, under the direction of Dr. F. L. Soper, consisted largely of members of the Rockefeller Foundation Health Commission who had brilliantly carried out their first assignment—that of assisting in typhus control in Naples.

These highly significant experiments, the first to prove the practical usefulness of residual DDT in malaria control, were possible only because of the support given to them by the ranking U.S. medical officer in the theater, Maj. Gen. Morrison C. Stayer, and his preventive medicine officer, Col. William S. Stone, MC, and by the commanding officer of the Public Health Sub-Commission, Brigadier George Parkinson.

As DDT supplies became more abundant, many other trials under military and civilian auspices were carried out in 1944 and 1945 in various parts of the world. They led directly to the concept of "nationwide malaria eradication" now being applied practically in so many countries. DDT no doubt would eventually have found its place in malaria control, but the war needs and experiments greatly accelerated its acceptance and use and led to the discovery and application of similar insecticides such as benzene hexachloride and dieldrin.

Allied malaria control units demonstrated the value of malaria control by modern methods all over the world with such striking success that civilian authorities were willing after the war to budget large funds for antimalaria programs. There can be no doubt that antimalaria activities of World War II constituted a prime factor in the development of the present move for worldwide malaria eradication.

Other advances.—Besides the major advances in preparation and use of synthetic antimalarials and insecticides just described, there were certain others as, for example, the improvement in repellents represented by dimethyl phthalate; the increased scope of airplane larvicidal dusting with paris green, due to wartime research which raised the prewar maximum load of 700 to 3,000 pounds, applied from the air with great efficiency; the development of pressure cylinders using liquid Freon–12 as a propellant for pyrethrum insecti-

[15] Soper, F. L., Knipe, F. W., Casini, G., Riehl, L. A., and Rubino, A.: Reduction of *Anopheles* Density Effected by the Pre-Season Spraying of Building Interiors with DDT in Kerosene, at Castel Volturno, Italy, in 1944–45 and in the Tiber Delta in 1945. Am. J. Trop. Med. 27: 177–200, March 1947.

cide expelled as an Aerosol mist; the broadening of taxonomic and biologic knowledge of the genus *Anopheles* around the world; and increased understanding of the *Plasmodium* and its growth in vivo, in vitro, and in tissue culture.[16]

The devising, manufacturing, and distributing of antimalaria supplies and equipment was notable in World War II from mid-1943 onward. Unusually effective cooperation from the beginning of the war was maintained among the Army, Navy, U.S. Public Health Service, National Research Council, Bureau of Entomology and Plant Quarantine of the U.S. Department of Agriculture, War Production Board, Institute of Inter-American Affairs, industrial firms, medical schools, research institutes, and foundations. Information was freely exchanged between the United States, United Kingdom, and Australia; moreover, the three Governments effectively supported vital laboratory and field experiments. Seldom, if ever, have research and practical application in preventive medicine come closer together.[17]

Man's net losses from World War II were so enormous that these lessons and advances can hardly be called dividends or be pointed to with pride. The progress in malariology, such as it was, constituted a sort of salvage, undoubtedly of considerable value.

But we can very definitely point with pride to the skill, courage, and devotion to duty of the personnel, officers and men, of the malaria organizations of the Army in World War II. Tribute is best expressed in the following message which Brig. Gen. (later Maj. Gen.) Guy B. Denit,[18] Chief Surgeon, Southwest Pacific Area, published at his headquarters in December 1944:

> The reduction of the malaria attack rate in this theater to a point at which it no longer constitutes a dangerous handicap to our military effort is an achievement of historical importance in preventive medicine. It has been the result of a joint effort which is to the great credit of all who have participated. In this accomplishment the malariologists and the malaria survey and malaria control units have played the major role. Despite hardships and often danger, their achievements have been notable. The Medical Department is proud of your initiative and perseverance, of your professional contribution, and of the striking success of your efforts.

The following 18th century quotation from Pringle (p. 2) seems appropriate in closing this introduction: "Yet, however, imperfect these sheets may be, I hope they may serve as a foundation for others to build upon; who, by making improvements on this subject, will concur with me, in attempting to draw from the calamities of war some benefit to mankind."

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[16] Russell, P. F.: Lessons in Malariology From World War II. Am. J. Trop. Med. 26: 5–13, January 1946.

[17] Symposium on a National Malaria Program for the Control of Malaria. *In* J. Nat. Malaria Soc. 3 (1): March 1944. Papers presented at the Joint Session of the National Malaria Society and the American Society of Tropical Medicine, meeting with the Southern Medical Association, at Cincinnati, Ohio, 16–18 Nov. 1943 by J. S. Simmons, O. R. McCoy, O. J. Brown, S. B. Freeborn, H. S. Cumming, G. C. Dunham, H. E. Meleney, F. C. Bishopp, G. A. Carden, Jr., W. A. Sawyer, and J. W. Mountin.

[18] Denit, G. B.: Message from the Chief Surgeon in the Far East. Bull. U.S. Army Med. Dept., No. 86, p. 53, March 1945.

CHAPTER II

War Department Provisions for Malaria Control

Oliver R. McCoy, M.D.

ORGANIZATION IN THE OFFICE OF THE SURGEON GENERAL

Although malaria and other tropical diseases had long been of concern to the Army in relation to posts in Panama, Puerto Rico, and the Philippines, the military importance of these diseases increased in the fall of 1940 with the acquisition and development of new bases in the Caribbean region. At this time, formulation of tropical disease control policies was included among the functions of the Preventive Medicine Subdivision, although no organizational unit for tropical disease control was established until the creation, in April 1941, of the Subdivision on Medical Intelligence and Tropical Medicine of the Preventive Medicine Division.[1] This new subdivision was to (1) collect and coordinate data concerning problems in tropical preventive medicine and sanitation, (2) coordinate the malaria control program of the Army in the United States and abroad, and (3) maintain files of reports on the incidence and prevention of the diseases indigenous to tropical possessions and bases.

The unit for tropical disease control continued in the same organizational status until 26 March 1942, when Preventive Medicine was reorganized as a service. At this time, the unit was transferred to the Epidemiology Division and remained there until 1 January 1944, when it separated to become an independent division.[2] This status was maintained until the end of the war.

Before 1 January 1944, the unit had no official internal organization. Upon becoming a division, the following organization and functions were authorized:[3]

> ***Tropical Disease Control Division*** * * * **Directs the activities of the Control Policies Branch, the Education Branch, the Field Survey Branch, and the Malaria Control Branch.**
>
> ***Control Policies Branch*** * * * **Establishes policies and procedures for the prevention and control of tropical diseases in the Army in this country and overseas. Maintains liaison with governmental and civilian agencies concerned with tropical disease control; analyzes data and reports dealing with the morbidity and mortality from tropical diseases in the Army; recommends investigations of special tropical disease situations when indicated.**

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[1] Office Order No. 87, Office of The Surgeon General, U.S. Army, 18 Apr. 1941.

[2] Office Order No. 8, Office of The Surgeon General, U.S. Army, 1 Jan. 1944.

[3] Manual of Organization and Standard Practices, Office of The Surgeon General, U.S. Army, 15 Mar. 1944.

Education Branch * * * Initiates informative circulars, posters, pamphlets, and other material; arranges programs of special training for selected personnel needed in tropical disease control.

Field Survey Branch * * * Maintains contact with field investigations and field conditions; participates in special field investigations dealing with tropical diseases.

Malaria Control Branch * * * Exercises general advisory supervision over activities related to malaria control in the Army; advises on investigations of new drugs, materials, and equipment applicable to the control of malaria, and makes recommendations as to their use.

In November 1944, after the Preventive Medicine Service moved to integrate the educational functions of the Service in a single Health Education Unit, the Tropical Disease Control Division was unofficially reorganized as follows:[4]

Tropical Disease Control Division * * * Deals with procedures and policies bearing on the prevention and control of tropical diseases and maintains liaison with governmental and civilian agencies concerned with the health of the Army in tropical theaters of operation.

Field Survey Branch * * * Studies and disseminates information and makes recommendations on reports from research laboratories and field experiences in new methods for the control of insect-borne and other tropical diseases.

Disease Analysis Branch * * * Analyzes and acts upon reports concerning the incidence of tropical diseases and initiates informative materials concerning tropical diseases for indoctrination and refresher training of troops.

Malaria Control Branch * * * Assists in the formulation of policy for malaria control, maintains liaison with other divisions of the SGO in matters relating to the training and operational use of malaria control personnel, and selects and arranges for special training of such personnel.

No personnel were specifically assigned to tropical disease control until 18 May 1942, when Lt. Col. (later Col.) Paul F. Russell, MC, reported for duty as chief of the Tropical Disease Control Section within the Epidemiology Branch. Personnel of the unit always remained a small group, never enlarging beyond four officers.

ORGANIZATION FOR MALARIA CONTROL

Control of malaria first became a problem when, in the fall of 1940, the mobilization program, involving the training of large numbers of troops in Southern States where malaria was endemic, was instituted. Planning of the organization, personnel, and finances necessary for malaria control at installations in the continental United States became a function of the Sanitary Engineering Division, Preventive Medicine Service, OTSG (Office of The Surgeon General). Early in the year, steps were taken to obtain the cooperation of the U.S. Public Health Service in carrying out measures of sanitation in

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[4] Annual Report, Tropical Disease Control Division, Preventive Medicine Service, Office of The Surgeon General, 1944.

extramilitary areas.[5] Cooperation of this agency, which was first utilized in maneuver areas, was soon extended to include extracantonment zones at Regular Army stations.[6] The malaria control program in the continental United States was thus a cooperative effort, mosquito control within military reservations being carried out by the Army and in extramilitary zones by the U.S. Public Health Service.

During 1941, the sum of $1,500,000 for the Army's mosquito control program was obtained through a special allocation of funds by the budget officer of the War Department.[7] The work was carried out by post surgeons under the general direction of the corps area surgeons, utilizing the advice and assistance of entomologists and sanitary engineers. In December 1941, the Corps of Engineers took over the responsibility for mosquito control work which was previously a function of the Quartermaster Corps. Post engineers were authorized to employ civilian laborers and supervisors to perform the control work. Beginning in July 1943, insect and rodent control sections were established in the Office of the Chief of Engineers and in the offices of service command engineers to promote and coordinate the various aspects of the mosquito control program. The Medical Department retained responsibility for surveying the malaria problem, recommending measures needed for control, and exercising technical supervision over the execution of these measures.[8]

As a result of the cooperative antimosquito program of the Army and the U.S. Public Health Service, the malaria rate among troops in the continental United States was maintained at satisfactorily low levels in 1941 and 1942 and dropped to almost negligible figures in the succeeding years. The rates per 1,000 per annum during the war period were as follows: For 1941, 1.7; 1942, 0.6; 1943, 0.2; 1944, 0.2; and 1945, 0.1.[9] The effectiveness of the program may be judged by comparison with the average annual rate during the 10 preceding peacetime years, 1931 to 1940 inclusive, which was approximately 2.3 (chart 1).

The situation was quite different, however, in oversea theaters, especially where conditions of combat prevailed. By the time the Tropical Disease Control Section was established in May 1942, malaria had become a disease of crucial military importance. A definite organization was needed to furnish the expert technical guidance required for effective control among troops operating in the field in highly endemic regions. Experience in other armies and in civilian malaria control programs had repeatedly demonstrated that, to obtain

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[5] Letter, The Secretary of War, to Administrator, Federal Security Agency, 30 Jan. 1940, and reply dated 12 Feb. 1940.

[6] Letter, The Adjutant General, War Department, to Commanding Generals, First, Second, Third, and Fourth Armies, and Commanding General of each Corps Area, 4 May 1940, subject: Extension of Present Utilization of the U.S. Public Health Service.

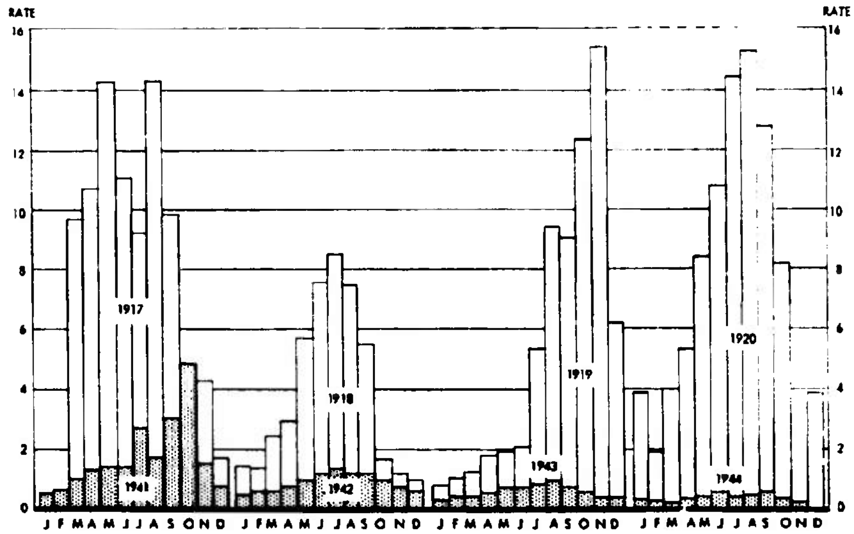
[7] Letter, Lt. Col. F. C. Tyng, Chief, Finance and Supply Division, to the Budget Officer of the War Department, 10 Feb. 1941, subject: Mosquito Control, and reply thereto, Maj. Gen. H. K. Loughry, Budget Officer for the War Department, 20 Mar. 1941.

[8] Army Regulations No. 40–205, 31 Dec. 1942; Army Regulations No. 40–210, 15 Sept. 1942.

[9] Statistical Health Reports, Medical Statistics Division, Surgeon General's Office.

CHART 1.—*Admission rates for malaria, U.S. Army, continental United States, World War I and World War II*[1]

[Rate expressed as number of admissions per annum per 1,000 average strength]



[1] Rates for 1944 are provisional, based on weekly statistical reports, and exclude cases resulting from oversea exposure.

successful results, technically trained personnel must be organized and designated to do the work. In September 1942, it was therefore recommended that a special malaria control organization be authorized within the Medical Department to function in the malarious areas in oversea theaters:[10]

> Experience has taught that an antimalaria organization in an army must be responsible not only for reconnaissance and plans but also for carrying out the actual control operations. It has proved impossible to obtain adequate protection when a malaria unit functions merely in a consulting or advisory capacity. The normal demands on the medical and sanitary personnel in nonmalarious areas continue to exist in very malarious areas—in fact, they are usually intensified. Therefore, the addition of specialist personnel for malaria control is advisable, logical and urgent. Without adequate control it is certain that malaria in many areas will immobilize large numbers of troops and will cause more casualties than the enemy.
>
> It is recommended that in those areas where malaria is a special problem, certain selected specialist personnel be added to the existing medical and sanitary establishment of the Army to deal primarily with malaria control * * *.

War Department General Staff, G–1 (Personnel), endorsed this request favorably on 9 October 1942 and recommended immediate action. The Assistant Chief of Staff, G–3 (Operations and Training), requested the com-

[10] Letter, The Surgeon General, to The Adjutant General, War Department, 21 Sept. 1942, subject: Malaria Control.

manding general of Services of Supply to determine the opinions of the several theater commanders on their requirements for special antimalaria personnel and authorized direct communication for the purpose.[11] Accordingly, The Surgeon General, on 24 October 1942, addressed letters to the Commander in Chief, Southwest Pacific Area, and to the commanding generals of U.S. Army Forces in the Middle East, Central Africa, China-Burma-India, South Pacific Area, the Caribbean Defense Command, and, in view of the landing in north Africa, the European Theater of Operations. These letters recommended that selected specialist personnel be added to existing medical and sanitary establishments to deal primarily with malaria control and asked that appropriate requisitions be submitted.

The malaria control organization was recommended to include:

1. A malariologist, and one or more assistant malariologists as needed: medical officers trained in large-scale malaria control methods.

2. Malaria survey unit.—An entomologist, a parasitologist, 11 technically trained enlisted personnel, and necessary laboratory and transportation equipment.

3. Malaria control unit.—A sanitary engineer, 11 enlisted men trained in field methods for malaria control, and equipment necessary for drainage, mosquito larvicidal work, and transportation.

4. Antimalaria labor gangs.—Laborers recruited locally as required to work under the supervision of a malaria control unit.

5. Antimalaria squads.—Military personnel assigned to conduct minor measures for mosquito control within their unit areas.

The basic functions of the malaria control organization were described to include:

1. Evaluation of the malaria problem by surveys to determine the amount and distribution of malaria and the species and habits of mosquito vectors in the area.

2. Institution and supervision of malaria control measures.

3. Training of troops in general control measures and methods of individual protection against malaria.

4. Assistance in the control of other insect-borne diseases when indicated.

The malaria survey and control units were new and untested organizations. War Department approval of them was contingent upon a favorable response from oversea theaters, which were just beginning to experience the impact of malaria casualties. The building up of the organization was slow because units could not be activated until requests for them had been received by the War Department. A major proportion of the activities of the Tropical Disease Control Division was devoted to promoting the development of the malaria control organization by encouraging use of the units overseas and through supervision of the selection and training of personnel in this country. It was

[11] Letter, Assistant Chief of Staff, G-3 (Operations Division), War Department General Staff, to Commanding General, Services of Supply, 14 Oct. 1942, subject: Malaria Control.

only after the organization had proved its worth in the field that malaria units were regularly included in the planning of future operations.

The first reply to the letters sent to the oversea theaters in October 1942 was received from the South Pacific Area on 26 November. Three malariologists, three assistant malariologists, three survey units, and three control units were requested. On 1 December 1942, a reply was received from the Southwest Pacific Area requesting 1 malariologist, 6 assistant malariologists, 3 survey units, and 12 control units. Transportation by air was authorized for certain of the officers and enlisted personnel. On the basis of these requests, the preliminary plans for tables of organization and equipment, which had been made in cooperation with the Laboratory and Sanitary Engineering Divisions, were completed in conjunction with the Plans and Operations Division, OTSG. In coordination with Operations Division, War Department General Staff, an administrative mechanism was adopted whereby the survey and control units were to be formally activated and each given a number.[12]

During December 1942 and January 1943, additional requests for malaria control personnel were received from Central Africa, China-Burma-India, the Middle East, North Africa, and the Caribbean Defense Command. Although certain of the malariologists and advance echelons of units were sent overseas by air early in 1943, the majority of the first units were not activated until 25 January 1943. Included in the first group of units which were activated at the Services of Supply Unit Training Center, New Orleans Port of Embarkation, were 6 survey and 15 control units. During January and February 1943, authorization was granted for the activation of an additional 10 survey and 12 control units. Officers for these units were obtained from a list of specially qualified personnel furnished by the Tropical Disease Control Section.

The programmed malaria control organization in the oversea theaters on 13 February 1943 is shown in table 1. The figures given are the numbers of malariologists and malaria survey and control units then projected for these theaters. Actually, only a portion of the malariologists and advance echelons of a few units were on duty or were en route to the theaters at that time.

Activation of Malaria Control and Survey Units

In March 1943, The Surgeon General sent a letter to the commanders of all theaters and service commands, describing the new malaria control organization and its functions. Authorization was granted for The Surgeon General's recommendation of 15 March that 10 survey and 15 control units be activated in anticipation of future requests. By 7 June, all these units, except one survey and one control unit, had been committed to oversea theaters. Meanwhile, on 30 May, the China-Burma-India theater had activated four control units within the theater. The status of the malaria control organization in the oversea theaters as of 15 July 1943 is shown in table 2.

[12] Memorandum, Tropical Disease Control Section, for Colonel Simmons, Chief, Preventive Medicine Division, Professional Services, 13 Feb. 1943, subject: Army Antimalaria Organization.

TABLE 1.—*Projected status of malaria control organization for the oversea theaters, 13 February 1943*

Theater	Malariologists	Assistant malariologists	Survey units	Control units
South Pacific	3	3	1	6
Southwest Pacific	1	6	3	12
China-Burma-India	1	3	3	3
North Africa	[1] 1	[1] 1	4	4
Central Africa	1		4	4
Middle East	1	1	1	[2] 1
Caribbean Defense Command	----	1		
European				
Total	8	15	16	30

[1] These officers were on duty in Central Africa. Transfer of these officers to North Africa had been requested, 5 February 1943.
[2] Units activated locally within the theater.

TABLE 2.—*Status of malaria control organization in the oversea theaters, 15 July 1943*

Theater	Malariologists		Survey units		Control units	
	Present or en route	Scheduled for shipment	Present or en route	Scheduled for shipment	Present or en route	Scheduled for shipment
South Pacific	8	12	4	5	6	8
Southwest Pacific	13	-------	3	3	12	-------
China-Burma-India	4	-------	3	1	7	3
North Africa	2	1	4	-------	4	-------
Central Africa	1	-------	[1] 1	1	[1] 1	1
Middle East	2	-------	-------	1	4	2
Caribbean Defense Command	1	-------	-------	-------	-------	-------
South Atlantic	-------	1	-------	-------	-------	-------
European	-------	-------	-------	-------	-------	[2] 1
Total	31	14	15	11	34	15

[1] Scheduled for transfer to North Africa upon arrival of replacement units.
[2] Later withdrawn from scheduled shipment to this theater.

Source: Semimonthly Report, Tropical Disease Control Section, Surgeon General's Office, 15 July 1943.

Requests for malaria units during the first half of 1943 had indicated that the medical malaria control organization was essential and was suited to perform a highly important function in the oversea theaters in malarious areas. As projected troop strengths in tropical areas increased, it became necessary to plan additional units to take care of anticipated requisitions. Accordingly, an estimate was made of requirements for units during the remainder of 1943, and, on 30 July, recommendation was made for the activation of 15 survey units and

25 control units. Authorization was granted for the activation of the 15 survey units and 23 of the control units. By the time these were activated, and personnel assigned and trained, all were committed to fulfill requests from oversea theaters.

In order in the future to avoid undue delay in shipment of units requested by oversea theaters, an estimate was made by the Tropical Disease Control Section in September 1943 of the number of units needed for the first 6 months of 1944. A requirement of 58 survey and 116 control units was projected, based upon past experience in the theaters and probability of future needs as troop strengths increased. Using this estimate, The Surgeon General, on 25 October 1943, recommended to the Commanding General, ASF (Army Service Forces), that 50 survey and 105 control units be activated during the remainder of 1943 and in early 1944.

In November 1943, the Tropical Disease Control Section was informed that the activations scheduled for that month were to be postponed a month and that the enlisted personnel for the units were to be assigned directly from induction centers without basic training. The addition of 4 months' time required to give basic training to the month necessary for unit training would thus result in prolonged delay in meeting the requirements of the oversea theaters during the first half of 1944. It was recommended that no further postponements in activating units be allowed and that consideration be given to the transfer of men who had already received basic training from established Medical Department organizations.

After a series of conferences with the Plans Division, OTSG, it was agreed that the policy of supplying men without basic training to the malaria units would result in failure to meet theater requirements on schedule. In view, however, of the personnel situation then current, no practical solution of the problem was evolved. Because highest priority for personnel was given to oversea replacements, great difficulty and delay were experienced in obtaining enlisted men for 16 survey and 36 control units activated in December 1943 at Camp Ellis, Ill. This situation was called to the attention of higher headquarters,[13] but only slow improvement resulted. The final complement of this group of units did not reach Camp Planche, La., for unit training until 20 March 1944. For a later group of 14 units (7 survey and 7 control) activated at Camp Grant, Ill., in February and March of that year, only 114 enlisted men out of a required complement of 154 had been assigned by 1 June 1944.

A summary of the status of malaria units in the oversea theaters as of 15 February 1944 is presented in table 3. A total of 35 survey and 65 control units, with a complement of 1,235 officers and enlisted men, were present in the oversea theaters. An additional 7 survey and 8 control units were en route, and 17 survey and 37 control units were activated and scheduled for shipment.

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[13] Memorandum, Brig. Gen. R. W. Bliss, Chief, Operations Service, OTSG, to Commanding General, ASF, attention: Mobilization Division, Troops Unit Branch, Col. Henry E. Harrison, Jr., 27 Jan. 1944, subject: Enlisted Personnel for Malaria Survey and Control Units.

Beginning in June 1944, a program for the preactivation training of malaria units was inaugurated.[14] Personnel for malaria units scheduled for activation were given basic military and technical training (totaling 16 to 17 weeks) as part of medical training battalions at Camp Grant before assignment to the units. The schedule for activation of units for the remainder of 1944 was fixed according to the Six Months Projection List revised monthly by Operations Division, War Department General Staff. Heretofore, shipment of malaria units had been authorized, for the most part, on the basis of individual requests for units from theater commanders. According to the 15th revision (May 1944) of the Six Months Projection List, 4 survey and 32 control units were planned for activation during the remainder of 1944. The authorized number of units fluctuated during subsequent revisions; actually, 38 control and 11 survey units were activated in this period. The status of the malaria control organization in the oversea theaters in malarious regions as of 30 September 1944 is shown in table 4.

Based upon experience in the use of malaria units in the malarious theaters, the War Department, in December 1944, addressed a letter to the commanders of the Pacific and Asiatic theaters recommending a standard for provision of units in future operations. In highly malarious territory, or in areas where other mosquitoborne diseases were a serious hazard, it was recommended that: (1) One survey and one control unit be attached to each division; (2) for other troops, one control unit be provided in an approximate ratio of one unit per 20,000 men; and (3) at least one control unit be provided for each

TABLE 3.—*Status of malaria units in oversea theaters, 15 February 1944*

Theater	Present		En route		Activated and scheduled		Total	
	Survey	Control	Survey	Control	Survey	Control	Survey	Control
South Pacific	9	11			11	6	20	20
Central Pacific	2	2					2	2
Southwest Pacific	12	21	5	3	6	26	23	53
China-Burma-India	4	10	2	5		2	6	17
North Africa	5	7				3	5	10
Middle East, including Central Africa and Persian Gulf Command	3	7					3	7
South Atlantic		1						1
Caribbean Defense Command								
European								
Total	35	65	7	8	17	37	59	110

[14] Letter, The Adjutant General, War Department, to Commanding Generals, Sixth and Eighth Service Commands, 29 May 1944, subject: Preactivation Training for Medical Units Beginning June 1944.

important post or station, at large installations in an approximate ratio of one unit per 7,500 men.

TABLE 4.—*Status of malaria control organization in oversea theaters, 30 September 1944*

Theater	Malariologists		Survey units		Control units	
	Present	Scheduled for shipment	Present	Scheduled for shipment	Present	Scheduled for shipment
Pacific Ocean Areas (Central and South)	16		13		13	--------
Southwest Pacific [1]	21		32	2	66	2
China-Burma-India	7		6		25	8
North Africa	9		6		17	--------
Middle East, including Central Africa, and Persian Gulf Command	3		3		9	--------
South Atlantic	1		1		1	--------
Caribbean Defense Command	1					--------
European						--------
Total	58		61	2	131	10

[1] Includes 10 malariologists, 9 survey units, and 13 control units which were transferred from the South Pacific to the Southwest Pacific when theater boundaries were redefined on 1 July 1944.

Using this basis, it was computed that by the fourth quarter of 1945, a total of 278 control units and 130 survey units would be required in the Pacific theaters (assuming the prior defeat of Germany).[15] Because the War Department Troop Basis then current authorized only 166 control and 77 survey units, it was recommended that in addition a minimum of 30 control and 15 survey units be activated from units then undergoing preactivation training. This recommendation was rejected by G-3, War Department General Staff, on the ground that a shortage of personnel existed for meeting current requirements.

The status of the malaria control organization overseas at the end of the war was essentially as shown in table 5. Eight additional control and three additional survey units were sent to the Pacific after 1 April 1945. At the end of the war in Europe, plans were made to redeploy malaria units from the Mediterranean theater to the Far East. The abrupt ending of the war with Japan permitted cancellation of these plans before more than a few of the control units had been directly redeployed.

Tables of Organization and Equipment

When the first malaria units were organized, tables of organization and equipment for both the survey and the control units were published as inclosures to the activation order. Various changes were made in the tables

[15] Memorandum, Brig. Gen. R. W. Bliss, Operations Service, OTSG, to Commanding General, ASF (attention: Mobilization Division, Troop Units Branch, Colonel Harrison), 20 Dec. 1944, subject: Projected Requirements for Malaria Control and Survey Units for Overseas Theaters for 1945.

of equipment (which included special lists of technical supplies and equipment authorized for issue to the units as Medical Department items) as the units accumulated experience in the field, but the tables of organization, except for certain adjustments in rank of personnel, remained unchanged throughout the war. First official publication of these tables was made on 23 April 1944.

TABLE 5.—*Status of malaria control organization in oversea theaters, 1 April 1945*

Theater	Malariologists	Control units	Survey units
Southwest Pacific [1]	21	70	34
Pacific Ocean Areas	15	15	18
India-Burma	4	34	4
China [2]	1	1	2
Mediterranean [3]	6	9	1
Africa-Middle East	1	7	3
Persian Gulf Command	1	2	----
South Atlantic	1	1	1
Caribbean Defense Command	1	1	----
European [4]	----	3	----
Total	54	143	63

[1] Includes 10 malariologists, 9 survey, and 13 control units which were transferred from the South Pacific to the Southwest Pacific when theater boundaries were redefined in July 1944.

[2] Units were allotted when the theater was separated from India-Burma.

[3] Five control and five survey units were deactivated and disbanded in the theater in December 1944.

[4] These units accompanied the Seventh U.S. Army in the invasion of southern France and subsequently came under the jurisdiction of the European theater.

In January 1944, tables of organization and equipment had been proposed for theater and battalion headquarters organizations for malaria control. Plans were made for a battalion headquarters organization to supervise the activities of a group of malaria survey and control units and to serve as an intermediate echelon between the units and theater headquarters. The plan was included in a proposed revision of TOE (tables of organization and equipment) 8-500, but it was not approved by G-3, War Department General Staff, which had previously disapproved a similar proposal from the North African theater. A compromise arrangement was then agreed upon, whereby the table of organization for a medical battalion headquarters was made applicable to malaria units, and this was published in January 1945. This action was too late to be of help in most of the theaters of operations, although such a malaria control organization was established in a battalion headquarters on Okinawa in May 1945.

Special Personnel and Units

A few medical malaria control organizations consisted of specially selected personnel. In February 1943, when plans were made to transfer malaria control personnel from Liberia to North Africa, the surgeon at Roberts Field, Liberia, requested that malaria units (one survey and one control) consisting of Negro personnel be sent as replacements. Since the command was predominantly Negro, it was believed that morale and malaria discipline would be improved by having Negro units. These units were activated on 15 April 1943, completed their training in August, and arrived in Liberia in September. Two other Negro units (one survey and one control) were activated on 21 January 1944 to serve with a Negro division in the South Pacific.

The China-Burma-India theater in August 1943 requested two units with Chinese-American personnel. The request was made because of difficulties in obtaining cooperation and malaria discipline in Chinese troops deployed in the highly malarious regions of northern Burma. Because it was difficult to locate qualified Chinese-American personnel, such units were not formed.

In July 1944, the War Department, without prior consultation with The Surgeon General, ordered activation of 30 malaria control units in the Antilles Department, the units to consist of Puerto Rican personnel. Because of the supervisory duties performed by malaria units and the uncertainty of obtaining properly qualified men, The Surgeon General recommended that this order be amended and that insular troops not be used in malaria units. Action on the order was later modified so that only two Puerto Rican control units remained activated. These units were trained at the Army School of Malariology in Panama, remained for some months on temporary duty there, and were en route to the India-Burma theater when the war ended.

Training of Malariologist Officers and Units

Tropical disease control was intimately connected with the development of programs and procedures for the training of malariologists and malaria units. The selection and training of officer personnel for the malaria control organization was a responsibility of the Tropical Disease Control Division in cooperation with the Laboratories and Sanitary Engineering Divisions, Preventive Medicine Service, and the Training Division, OTSG. Because few Medical Department officers had had practical experience in malariology, it was necessary to arrange training programs for most of the personnel who were to be assigned as malariologists or as officers for the malaria units. Medical Corps officers who had successfully completed the 8-week course in tropical medicine at the Army Medical School, Army Medical Center, were usually selected for such training.

Entomologists and parasitologists for malaria survey units were obtained at first mainly from the teaching and research staffs of educational institutions and from such governmental agencies as the U.S. Department of Agriculture and the U.S. Public Health Service. Later, commissions were granted to graduate students in these specialties who had been inducted into the Army as enlisted men. Sanitary engineers to command malaria control units were obtained at first principally from State and city health departments. In the later stages of the war, students from the Army Specialized Training Program who had studied engineering were commissioned in the Sanitary Corps and assigned to malaria control units after special training.

The first field training courses in malaria control were arranged in the summer of 1942 through cooperation of the Tennessee Valley Authority. The 2-week courses were conducted at Wilson Dam, Ala. Instruction consisted principally of field trips in order to enable students to observe and participate in the various procedures employed for malaria surveys and mosquito control. Six courses were held during August, September, and October 1942 and were attended by a total of 67 Medical and Sanitary Corps officers.[16]

As the location at Wilson Dam was not favorable for malaria control training during the winter season, arrangements were made with the Rockefeller Foundation and the Florida State Board of Health to conduct similar field courses in Florida. The length of the course was increased to 3 weeks, and instruction in mosquito dissection and further experience in the identification of malarial parasites were added. Fourteen courses were given between November 1942 and December 1943, and a total of 140 Medical Corps and Sanitary Corps officers were trained.[17] The Navy also took advantage of this facility: 32 Navy officers attended the classes.

To supplement the Florida field course in malaria control, arrangements were made in December 1942 with the Corps of Engineers whereby medical officers who had taken this course could be sent to Costa Rica for several months of duty with the field headquarters of the Pan American Highway project in order to gain practical experience in the control of tropical diseases. The first group of 4 officers arrived in Costa Rica in March 1943, and by September a total of 10 Medical Corps officers had received from 2 to 3 months of field experience in Central America.[18] When the Pan American Highway project began to close in the fall of 1943, no additional officers were sent to this location for training.

At about this time, the Army planned to establish a school of malariology at Fort Clayton, C.Z. This school was intended to provide more satisfactory applicatory training in malaria control than was possible in the Florida field training course and on the Pan American Highway project. Exigencies of the military situation and of transportation had prevented the previous establishment of such a school in Panama. Authorization for the Army School of Malariology in the Canal Zone was granted in September 1943.[19] In conjunction with the Sanitary Engineering Division and the Training Division, a program

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[16] Annual Report, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 1942.

[17] Annual Report, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 1943.

[18] Annual Report, Tropical Disease Control Section, Epidemiology Branch, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 1943.

[19] War Department General Staff Disposition Form, Maj. Gen. Thomas T. Handy, Assistant Chief of Staff, G–3, to Commanding General, ASF, 29 Sept. 1943, subject: Army School of Malariology (Canal Zone), and first indorsement thereto, dated 29 Sept. 1943.

was developed for a 4-week course, and a qualified staff of seven instructors was selected. Several men with experience in malaria control in the oversea theaters were brought back for this assignment. The course was designed to emphasize field work under tropical conditions, and opportunity was afforded the students to make surveys in highly malarious native communities (figs. 1, 2, and 3).

Between 7 February 1944 and 1 September 1945, 14 classes were held, and 107 Medical Corps and 153 Sanitary Corps officers successfully completed the course. In addition, 24 officers from Allied countries attended classes at the School, and training was given to 2 officers of the U.S. Public Health Service and to 9 civilians (mainly employees of the Panama Canal Department).

Throughout the war, the unit training of malaria survey and control units was carried out at the Unit Training Center, Camp Planche. In cooperation with the Training Division, a 4-week training program was arranged and published officially in May 1943.[20] The climate and terrain at Camp Planche were suitable for the training of units throughout the year, although conditions were most favorable during the spring, summer, and fall. Since most units after completing the 4-week training program had to wait some weeks for oversea movement orders, opportunity was afforded for practice field bivouacs and other additional training exercises (figs. 4 and 5).

When the Army School of Malariology was established, it was planned to send units to Panama for training; however, difficulties in transportation and the necessity for meeting oversea commitments of units prevented this plan from being carried through. Only two control units, with Puerto Rican personnel, were trained at the Army School of Malariology in July 1944.

Antimalaria Details

Although Army regulations clearly defined the responsibility of commanders of all organizations to institute and enforce the measures necessary to control malaria within their units and unit areas,[21] no definite means were prescribed to carry out this responsibility. In the summer of 1943, when the full impact of malaria on military operations in the Pacific area became apparent, steps were taken to designate antimalaria details in each unit of company size. In War Department Circular No. 223, published on 21 September 1943, these units were defined and their duties described as follows:

> *Antimalaria details.*—In order to assist unit commanders in the control of malaria there will be formed in each company, battery, or similar unit, an antimalaria detail to consist of a minimum of two enlisted men, including one noncommissioned officer. In nonmedical units this detail will be made up of nonmedical personnel. This detail will be specially selected by the commander and will be given immediate training in use and minor maintenance of repairs of screening and bed nets; hand-killing and spray-killing adult

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[20] War Department Mobilization Training Program No. 8–21, 4 May 1943.

[21] See footnote 8, p. 13.

FIGURE 1.—Army School of Malariology, Fort Clayton, C.Z.

FIGURE 2.—Parasitology classroom, Army School of Malariology, Fort Clayton, C.Z.

mosquitoes; larvicidal oiling of puddles and minor collections of water; minor ditching; minor water tidiness around a company encampment; and individual measures of malaria control in rear areas and in combat. These antimalaria details will carry out ordinary antimalaria housekeeping measures, such as those listed above, in and immediately around the company encampment.

This circular reiterated responsibilities of commanders for malaria control and also contained provision for a special 1-hour period of training in malaria control which is discussed later under "Educational Activities."

The unit antimalaria details, when properly trained and employed, performed an important function in the overall malaria control program in endemic areas.

FIGURE 3.—Class in field exercises in anopheline breeding area, Chagres River, Army School of Malariology, Fort Clayton, C.Z. A. Dipping for larvae. B. Spraying larvicide over test plot.

FIGURE 4.—Malaria control unit receiving instruction in drainage procedures, Unit Training Center, Camp Plauche, La.

Growth and Achievements of the Malaria Control Organization

The success of the special medical malaria control organization in the oversea combat theaters was attested by the rapid growth of the organization as the war progressed and by its accomplishments in bringing malaria and other insect-borne diseases under control. The situation in regard to malaria improved vastly during the last 2 years of the war in spite of the fact that operations continued in highly malarious territory and involved increasing numbers of troops. Malaria rates dropped dramatically after their peak in 1943. Casualties due to the disease were reduced to a point where they were not a significant influence on military operations. The decisive factor in bringing about this reduction was the activities of the special medical malaria control

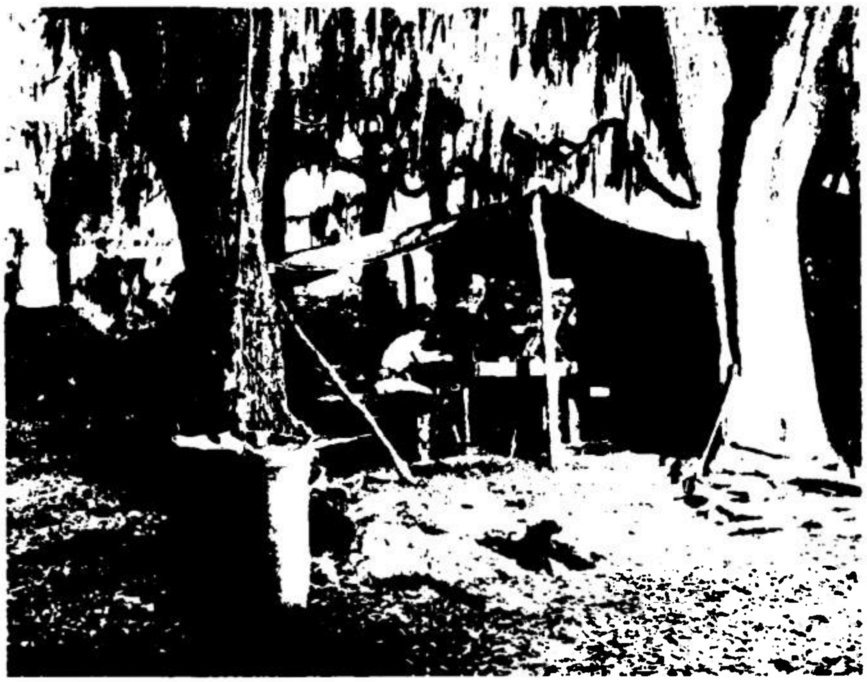


FIGURE 5.—Field laboratory established by malaria survey unit during training exercises, Unit Training Center, Camp Plauche, La.

organization;[22] in most theaters the drop in malaria rates paralleled closely the building up of that organization (chart 2).

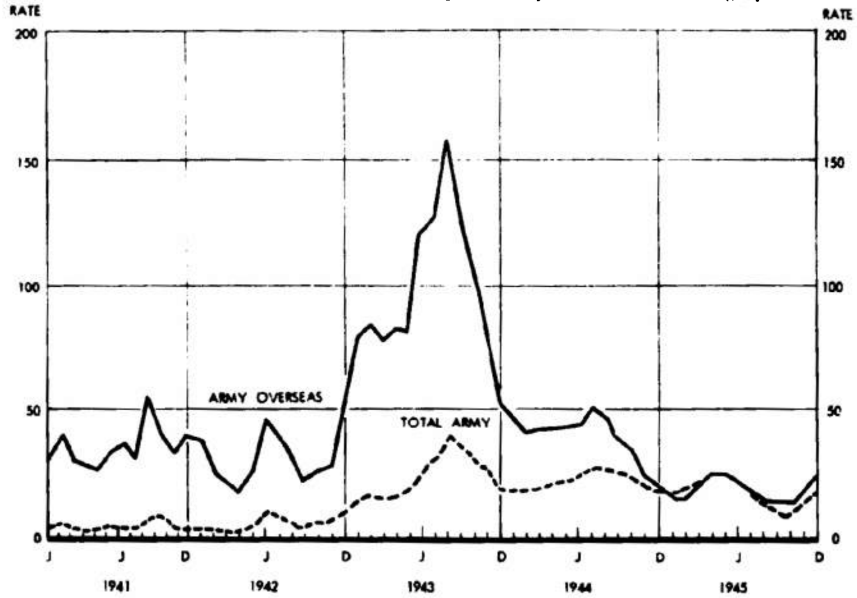
By the end of the war, a total of 159 control units and 68 survey units had served overseas. Of this number, 133 control and 66 survey units were activated and trained in the United States; 26 control and 2 survey units were activated in the oversea theaters with personnel locally available. More than 60 malariologists had been assigned in oversea theaters. The total personnel specifically designated for malaria control overseas was thus approximately 350 officers and 2,500 enlisted men. In addition, many thousands of troops and native laborers were employed under their direction.

The organization played the major role in the training of troops in malaria control and supervised the work of unit antimalaria details. The mission of the organization included prevention of other insect-borne diseases as well as malaria; in particular, dengue, scrub typhus, typhus, and filariasis. Because of their special training, malaria units were also used to assist in the control

[22] Dealt, G. B.: Message from the Chief Surgeon in the Far East. Bull. U.S. Army M. Dept. No. 80: 53, March 1945.

CHART 2.—*Admission rates for malaria, U.S. Army, by year, 1941–45*

[Rate expressed as number of admissions per annum per 1,000 average strength]



of certain other diseases, such as schistosomiasis and those spread by rodents.

Since malaria control and survey units were new and untested organizations, proper planning for their inclusion in projected troop requirements overseas was not attained until the later stages of the war. During 1943 and the first half of 1944, units were activated only after specific request for them had been made by oversea commanders. Since considerable time was needed to locate the technically trained personnel and to conduct unit training, long delays often occurred between theater requests and their fulfillment. Usually, from 6 to 8 months elapsed between the receipt of a request and the arrival of units at their oversea destination. For example, request was made for a large number of units in the Southwest Pacific on 23 August 1943. Activation was recommended on 25 October and accomplished on 10 December. Because of the personnel shortage, 3 months elapsed before the units were brought to full strength. In March 1944, they were finally transferred to Camp Plauche for unit training, and in the following June, 10 months after the request was made, they were scheduled for shipment.[23]

At no time was it possible to build up a reserve of malaria units in anticipation of requests. As a result, additional demands for units brought about by changes in the military situation sometimes could not be met. For example,

[23] Memorandum, Capt. Nils W. Bolduan, MC, Chief, Malaria Control Branch, Tropical Disease Control Division, Preventive Medicine Service, for Brig. Gen. Simmons (through: Col. Karl R. Lundeberg, 8 June 1944), subject: Status of Malaria Units as of 30 May 1944.

in January 1944, a request for seven control units to set up a malaria control program for the Twelfth Air Force in the Mediterranean theater could not be filled promptly, and later the units had to be activated within the theater with personnel locally available.

Experience during the war demonstrated that an organization specially trained and equipped for malaria control and specifically assigned to this duty was essential for effective control of this disease in the oversea theaters.

DRUGS FOR SUPPRESSIVE TREATMENT OF MALARIA

Throughout the war, the Preventive Medicine Service recommended policy in regard to the suppressive drug treatment of malaria and encouraged and guided the search for new and better agents for this purpose. Directives emphasized that suppressive treatment did not prevent infection and was an emergency measure to enable troops to operate in highly malarious territory despite infection which would otherwise incapacitate them.[24]

The dosage for suppressive treatment recommended in June 1941 was Atabrine 0.2 gm. twice a week at intervals of 3 or 4 days, or quinine 0.3 gm. (5 gr.) daily. In 1942, when conservation of quinine became imperative, it was directed that quinine be used for suppressive treatment only when Atabrine was not available. The dosage of quinine recommended for this purpose was increased to 0.64 gm. (10 gr.) daily.

Previous experience with Atabrine for the suppression of malaria in military forces was not very extensive. At the beginning of the war, little was known about absorption, blood concentration, or excretion of Atabrine, nor was it known whether prolonged use would lead either to transient toxicity or to permanent injury. The drug had heretofore been completely synthesized only in Germany. After American industry took over the manufacture of Atabrine, question was raised as to whether the American product was equal to the German, because of the frequency with which gastrointestinal disturbances were noted when new supplies of the drug were administered for suppressive treatment. This problem was referred to the National Research Council. After thorough study by a committee of the Division of Chemistry and Chemical Technology of the Council, it was concluded that there was no significant difference between Atabrine of domestic and German manufacture and that whatever toxicity was manifested by commercial preparations of Atabrine was due to the inherent properties of the drug.[25]

Conference on Atabrine

A conference was called in November 1942 by the National Research Council to organize a thorough investigation of the pharmacology of Atabrine and

[24] (1) Circular Letter No. 56, Office of The Surgeon General, U.S. Army, 9 June 1941. (2) Circular Letter No. 135, Office of The Surgeon General, U.S. Army, 21 Oct. 1942.

[25] Report, Committee on the Toxicity of Commercial Atabrine, Division of Chemistry and Chemical Technology, National Research Council, 3 Oct. 1942.

to obtain more precise knowledge of the relation of dosage schedules to efficient therapeutic use of the drug.[26] Results of these studies were reported during the ensuing months at meetings of the Subcommittee on Coordination of Malarial Studies which was organized under the Division of Medical Sciences acting for the Committee on Medical Research of the National Research Council on 20 January 1943.[27] Investigation of the relationship of different schedules of suppressive doses of Atabrine to plasma concentration of the drug led to recommendation of a change in the routine method of administration. This action was taken in July 1943 at a joint meeting of the Subcommittee on Coordination of Malarial Studies and the Subcommittee on Tropical Diseases of the National Research Council.[28] Based on these recommendations, the following schedules for Atabrine suppressive treatment were adopted by the Army in August 1943:

1. Recommended method.—0.1 gm. of Atabrine once daily, 6 days a week (total 0.6 gm. per week).

2. Alternative method satisfactory in certain areas. 0.05 gm. of Atabrine, once daily 6 days a week, and 0.1 gm. on the seventh day (total 0.4 gm. a week).

More extensive and precise information concerning the relation of plasma concentration of Atabrine to weekly dosage was obtained through a cooperative study conducted by the Commission on Tropical Diseases, the Board for the Investigation and Control of Influenza and Other Epidemic Diseases in the Army, the Office of The Surgeon General, and the Armored Medical Research Laboratory, Fort Knox, Ky., in the fall of 1943.[29] Upon the basis of these studies and reports from the field which were then becoming available in increasing numbers, in July 1944, the recommended dose of Atabrine for suppressive treatment was raised to 0.1 gm. once daily (total 0.7 gm. per week).[30] No further change in the recommended dosage was made during the remainder of the war.

Conservation and Production of Atabrine and Quinine

Conservation of quinine and production of Atabrine were problems of considerable concern to the Tropical Disease Control Division. When early in 1942 the Japanese captured the Netherlands East Indies, the world's principal source of cinchona alkaloids, it became imperative to conserve the stocks of quinine which had been accumulated in this country. In February 1942, The Surgeon General addressed a memorandum to the Army-Navy Munitions Board advising that use of quinine in the United States be limited to treatment

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[26] Minutes, Atabrine Conference, Committee on Medical Research, National Research Council, 2 Nov. 1942.

[27] Minutes, First Meeting, Subcommittee on Coordination of Malarial Studies, Committee on Medical Research, National Research Council, 20 Jan. 1943. *In* Bulletin of Malaria Research, pp. 50–55.

[28] Minutes, Joint Meeting of Subcommittees on Tropical Diseases and the Coordination of Malarial Studies, Committee on Medical Research, National Research Council, 20 July 1943. *In* Bulletin of Malaria Research, pp. 106–112.

[29] Report, Armored Medical Research Laboratory, Fort Knox, Ky., 23 Dec. 1943, subject: Final Report on Investigation of the Effects of Activity and Environment on Atabrine Therapy.

[30] War Department Technical Bulletin (TB MED) 65, 3 July 1944.

of malaria. On 2 March 1942, the Army-Navy Munitions Board forwarded this to the War Production Board and added a further recommendation that cultivation of cinchona be undertaken in South America. This action led to issuance by the War Production Board of Conservation Order M-131 in April 1942, which established control over the supply and distribution of quinine in the United States and permitted sale of the drug only for use as an antimalarial agent.

The Surgeon General supported a project for the establishment of cinchona plantations in tropical America sponsored by Col. Arthur F. Fischer, MI, who had brought cinchona seeds to this country from the Philippines after the fall of Bataan.[31] With these seeds, it was planned to establish a permanent source of high quality cinchona bark in the Western Hemisphere. The initial phases of this project were carried through under the auspices of the Board of Economic Warfare (later a division of the Foreign Economic Administration) with support from the War Department, and cultivation was started in several Central and South American locations. Because of the natural slow growth of the trees, this project did not influence quinine supplies during the war period.

Estimates, prepared in the spring of 1942 by Preventive Medicine Service of requirements for antimalarial drugs, were based on the assumption that quinine would be needed to supply at least 50 percent of antimalarial medication. At that time, uncertainty prevailed as to possible toxic effects from long-continued use of Atabrine. By the fall of 1942, further positive steps by the Army were needed to conserve stocks of quinine. At the meeting of a board appointed by The Surgeon General to consider this question, it was stated that at the current rate of consumption quinine stocks would probably be exhausted by the end of 1943.[32] The board decided upon a policy whereby Atabrine would be utilized as extensively as possible in the suppressive and clinical treatment of malaria. Upon recommendation of the board, letters were sent to commanders in the field to advise them of this policy and of the necessity to conserve quinine. The board also recommended that Atabrine production in this country be expanded and urged the purchase of certain supplies of quinine known to be in South America.[33] Circular Letter No. 179 was issued on 21 December 1942 by The Surgeon General to stress further the necessity of conservation of quinine by utilization of Atabrine to the fullest possible extent.

As the fighting fronts were extended in tropical regions during 1942 and 1943, more and more men were placed on regular suppressive medication for malaria, and the demand for Atabrine increased enormously. Domestic pro-

[31] Letter, The Surgeon General, U.S. Army, to the Secretary of War (through the Commanding General, Services of Supply), 22 Sept. 1942, subject: Quinine Plantations.

[32] Memorandum, Lt. Col. K. R. Lundeberg, Chief, Epidemiology Branch, Preventive Medicine Division, Professional Services, Office of The Surgeon General, to The Surgeon General, U.S. Army, 16 Oct. 1942, subject: Proceedings of a Board of Officers Appointed to Consider the Present Status of Antimalarial Drugs.

[33] Letter, The Surgeon General, U.S. Army, to Commanding General, Services of Supply, 17 Oct. 1942, subject: Bolivian Quinine.

duction of the drug already had been increased severalfold during 1941 and early 1942. Foreseeing future increased requirements for Atabrine, The Surgeon General, in October 1942, recommended further expansion of production. Despite this effort, the supply of Atabrine was critical during the first quarter of 1943, and allocations were necessary to meet the needs of the U.S. military forces and lend-lease requirements. The War Production Board expedited the construction of new facilities for the production of Atabrine, and, after the first 6 months of 1943, supplies of the drug were adequate.

Throughout the war, the Tropical Disease Control organization of the Office of The Surgeon General, U.S. Army, assisted in preparing estimates of requirements for antimalarial drugs. Based upon probable exposure to malaria, calculations were made of the amounts of drugs required per 10,000 men per year in different geographic areas. Because of uncertainty about the possible toxicity of Atabrine, calculation of quinine requirements was at first made on the assumption that 25 percent of men receiving suppressive medication might require quinine; in December 1943, this figure was dropped to 15 percent; and, in May 1944, to 3 percent.[34]

Since actual issue of quinine fell far below the estimated requirements, by May 1944 Army stockpiles had accumulated so that they could be expected to last until early 1947. The War Production Board was apprised of this fact.[35] After V-E Day, it was recommended that the War Production Board release amounts of quinine sufficient for domestic civilian medicinal use. This modification of Conservation Order M-131 was put into effect 18 August 1945.

Ample supplies of quinine were available for military needs throughout the war. Because of the superiority of Atabrine, consumption of quinine was far less than was anticipated early in the war period. As a result of experience, Atabrine became the preferred drug for the suppression of malaria.

Cooperation With the National Research Council

The Tropical Disease Control unit served as liaison between The Surgeon General and those agencies involved in the development and trial of new drugs for suppression and treatment of malaria. The wartime program for the development of new antimalarial drugs had its inception in the Subcommittee on Tropical Diseases which was organized in May 1940 by the Division of

[34] (1) Memorandum, Lt. Col. Paul F. Russell, MC, Tropical Disease Control Section, Epidemiology Branch, Preventive Medicine Division, Professional Services, OTSG, for Lt. Col. H. E. Coler, Chief, Requirements Branch, Distribution and Requirements Division, Supply Service, OTSG, 3 July 1943, subject: Estimated Atabrine, Quinine, and Plasmochin Requirements of the Army. (2) Memorandum, Maj. O. R. McCoy, MC, Tropical Disease Control Section, Epidemiology Branch, Preventive Medicine Division, Professional Services, OTSG, for Chief, Requirements Branch, attention: Lt. Col. Martin A. Compton, 17 Dec. 1943, subject: Estimated Atabrine, Quinine, and Plasmochin Requirements of the Army. (3) Memorandum, Maj. O. R. McCoy, MC, Director, Tropical Disease Control Division, Preventive Medicine Service, OTSG, for Chief, Supply Service, 6 May 1944, subject: Requirements of Quinine for Suppressive Treatments of Malaria.

[35] Memorandum, Brig. Gen. Albert J. Browning, GSC, Director, Purchases Division, ASF, for The Surgeon General, 17 May 1944, subject: Quinine Procurement, and 1st Indorsement thereto, dated 20 May 1944.

Medical Sciences of the National Research Council upon recommendation by The Surgeon General. From its first meeting in June 1940 until the summer of 1941, the Subcommittee dealt with various recommendations covering the prevention, chemoprophylaxis, and chemotherapy of malaria, and promotion of research in this field.[56] In the summer of 1941, this Subcommittee instituted a series of conferences on malaria research, the first of which was held on 8 July.[57] In September 1941, research projects were initiated which were recommended by the Subcommittee on Tropical Diseases and were financed through the Committee on Medical Research of the OSRD (Office of Scientific Research and Development).[58]

Early in 1943, the Conference on Malaria Research was replaced by a Subcommittee on Coordination of Malarial Studies, organized under the Division of Medical Sciences acting for the Committee on Medical Research of the National Research Council. This Subcommittee coordinated the research projects on the synthesis and biochemistry of antimalarial drugs, carried out under the auspices of the Division of Chemistry, and the studies on the pharmacology and clinical testing of antimalarials sponsored by the Division of Medicine. Throughout the history of these conferences and committees, representatives of the Preventive Medicine Service attended the meetings and acted in a liaison capacity to the research program on problems encountered by the Army. In November 1943, the Subcommittee on the Coordination of Malarial Studies was superseded by a Board for the Coordination of Malarial Studies which included officers from the military services.[59] The director of the Tropical Disease Control Division served on this Board which functioned through the remainder of the war.

When, in the spring of 1943, the clinical testing of new antimalarial drugs was expanded under enlarged OSRD contracts, 3 Medical Corps officers under a special allotment to the Preventive Medicine Service were assigned to assist in the drug research program, and, in the winter of 1944, this group was enlarged by The Surgeon General to 15 officers. The group actively participated in the clinical studies made during the remainder of the war.

Clinical Testing of New Antimalarial Drugs

The first new drug recommended to the Armed Forces for trial was sulfamerazine. Field tests of sulfamerazine as a causal or true prophylactic were proposed by the Subcommittee on Coordination of Malarial Studies at its meeting on 20 January 1943. The recommendation was based upon the prophy-

[56] Report, Owsei Temkin, M.D., and Elizabeth M. Ramsey, M.D., Antimalarial Drugs. Summary of Classified Material File, Office of Medical Information, Division of Medical Sciences, National Research Council, August 1944, p. 1.

[57] Minutes, Conference on Chemotherapy of Malaria, 8 July 1941.

[58] Minutes, Subcommittee on Tropical Diseases, Division of Medical Sciences, National Research Council, 4 Sept. 1941.

[59] Minutes, Board for the Coordination of Malarial Studies, Division of Medical Sciences, National Research Council, 10 Nov. 1943. *In* Bulletin of Malaria Research, pp. 162–166.

lactic action of sulfadiazine in bird malaria and in *falciparum* malaria in human beings and upon the demonstration of sulfamerazine's superiority over sulfadiazine from the standpoint of physiologic disposition and toxic hazard.[40]

In accordance with this advice from the National Research Council, permission was obtained from the War Department to conduct field tests of sulfamerazine in oversea theaters where men were exposed to malaria, in order to determine whether this drug could act as a causal prophylactic in human malaria; that is, actually prevent infection. Direct correspondence from The Surgeon General to the oversea commands was authorized, and, early in March, letters were sent to the commanding generals in the Southwest Pacific, South Pacific, China-Burma-India, and the Caribbean Defense Command to ask that tests be arranged. A suggested protocol was enclosed, and 4,800 tablets (0.5 gm.) of sulfamerazine were shipped to the surgeons concerned. The protocol suggested that approximately 200 uninfected men proceeding to a highly malarious area be used for the tests. One-half of the group was to be given one 0.5 gm. tablet of sulfamerazine daily; the other half, the usual suppressive treatment with Atabrine. The drugs were to be given 2 days before exposure to malaria and were to be continued for 10 days thereafter. The period of exposure was to be at least 30 days, and the period of observation at least 30 days after the last dose of the drug.

Trials which conformed in general to the aforementioned protocol were carried out during the spring of 1943 in New Guinea, the Solomon Islands, India, and Panama. Final reports of these studies were summarized for the National Research Council.[41]

Sulfamerazine, in doses of 0.5 gm. daily, was not a causal prophylactic against malaria. Although this dosage showed a fairly high degree of suppressive action against *vivax* and *falciparum* infections, its effectiveness was not equal to that of Atabrine in doses totaling 0.4 or 0.6 gm. per week. Significant toxic effects from sulfamerazine were noted only in India where the men were living under harassing conditions; however, in no instance did the drug have to be stopped because of toxic reactions.

The report of the New Guinea trial was of particular interest because this study included a control group of 51 men who did not receive any antimalarial drug and because it was impossible to continue the followup observations for a period of 98 days.[42] Although 3 percent of the group receiving sulfamerazine and 22 percent of the control subjects acquired *Plasmodium falciparum* infections, no cases of malaria caused by *P. falciparum* occurred among the 107 men who received Atabrine (0.6 gm. per week). None of the 33 cases of *vivax*

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[40] See footnote 36, p. 34.

[41] Malaria Report No. 94, Office of The Surgeon General, U.S. Army, to Division of Medical Sciences acting for Committee on Medical Research, Office of Scientific Research and Development, National Research Council, 4 Mar. 1944.

[42] Report, Col. Maurice C. Pincoffs, MC, Chief Consultant in Medicine, United States Army, Services of Supply, Southwest Pacific Area, to The Surgeon General, ASF (through: Chief Surgeon, United States Army, Services of Supply, Southwest Pacific Area), 6 Jan. 1944, subject: Summary of Field Test of Sulfamerazine.

malaria which ultimately developed in the latter group appeared while Atabrine was being administered. These observations were highly significant because they afforded well-controlled evidence obtained under field conditions that Atabrine in a total dosage of 0.6 gm. per week was completely effective in suppressing *Plasmodium vivax* infections and in preventing the subsequent development of *P. falciparum* infections, a fact borne out by subsequent experience.

No additional drugs for suppressive treatment of malaria were recommended for field trial until chloroquine diphosphate (SN 7618), hereafter referred to as chloroquine, was investigated late in 1944. The first recommendation that this drug was suitable for field tests was made at a meeting of the Board for the Coordination of Malarial Studies in September 1944.[43] It was agreed that a protocol would be prepared to include suggested field trials of the drug as a suppressive agent. This protocol was subsequently given restricted publication.[44] At that time, however, reports of toxic reactions began to be received, and consequently, it was recommended at the next meeting of the Board that current studies with chloroquine in Army and Navy installations be discontinued until the uniformity and homogeneity of the various batches be established.[45] Later, it was found that no chemical differences existed between the different lots and that toxic effects could be minimized by employing smaller doses.

Early in 1945, arrangements were made at the Army Medical School for a study of plasma levels of chloroquine in groups of volunteers who were given suppressive doses of 0.3 gm. or 0.5 gm. once a week. This investigation showed that although there were wide individual variations, plasma levels presumably effective for suppression were generally maintained by a single dose (0.3 gm.) of the drug taken once a week. Equilibrium in the level was apparently reached after the third week of administration.[46] Similar studies productive of essentially the same results were carried out at Moore General Hospital on a group of patients who had relapsing tertian malaria. No relapses occurred during 8 weeks of suppression with 0.3 gm. of chloroquine once a week, and toxic effects from this dosage were extremely mild.[47]

The Board for the Coordination of Malarial Studies reviewed the status of the researches on chloroquine in March 1945 and again recommended that the suppressive action of the drug be investigated in military forces in hy-

[43] Minutes, Board for the Coordination of Malarial Studies, National Research Council, 21 Sept. 1944. *In* Bulletin of Malaria Research, pp. 472–513.

[44] Malaria Report No. 239, Board for the Coordination of Malarial Studies, 20 Sept. 1944.

[45] Minutes, Board for the Coordination of Malarial Studies, National Research Council, 6 Nov. 1944.

[46] Malaria Report No. 417, Capt. John M. Mason, SnC, Division of Chemistry and Physics, Army Medical School, Army Medical Center, to Board for the Coordination of Malaria Studies, May 1945.

[47] (1) Malaria Report No. 407, Medical Division, Office of The Surgeon General, U.S. Army, to Board for the Coordination of Malarial Studies, 1 May 1945. (2) Malaria Report No. 440, Moore General Hospital (through the Tropical Disease Treatment Branch, OTSG) to Board for the Coordination of Malarial Studies, 1 June 1945.

perendemic areas. A protocol of a suggested plan of study was written.[48] In April 1945, The Surgeon General sent letters to the surgeons in four oversea theaters to suggest that trials of chloroquine for suppressive treatment be undertaken. The chief advantages of this drug over Atabrine at that time were as follows:

1. A single weekly dose of 0.3 gm. was apparently sufficient to maintain a suppressive plasma level of the drug.

2. This dosage did not cause gastrointestinal irritation or other significant toxic effects.

3. The drug did not discolor the skin. Experiments in civilian hospitals had already demonstrated that chloroquine was not a causal prophylactic against malaria or a curative drug for malaria caused by *P. vivax*.

Redeployment after V–E Day and later demobilization after V–J Day interfered with conducting suitable trials overseas. Tests with chloroquine for suppression of malaria were, however, carried out in India and in the Philippines during the summer and fall of 1945.[49] These studies showed that a single dose of 0.3 gm. of the drug per week was effective in suppressing relapses in the field of malaria caused by *P. vivax*. Only a few significant untoward effects, mainly gastrointestinal disturbances, were noted in approximately 700 men who took the drug for a period of from 3 to 4 months.

SUPPLIES AND EQUIPMENT FOR INSECT CONTROL

Repellents

A research program to develop improved methods of insect control was instituted by the Subcommittee on Tropical Diseases. At the first meeting of this Subcommittee, it was suggested that chemical repellents against mosquitoes be studied and the cooperation of civilian industry be sought.[50] In the fall of 1941, after funds became available through establishment of OSRD, a contract was approved with the Bureau of Entomology and Plant Quarantine of the U.S. Department of Agriculture for investigation of new insect repellents.[51] This contract later was extended to include investigation of other

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[48] (1) Minutes, Board for the Coordination of Malarial Studies, 16 Mar. 1945. *In* Bulletin of Malaria Research, vol. 2, pp. 831–837. (2) Letter, Robert F. Loeb, M.D., Chairman, Board for the Coordination of Malarial Studies, to Maj. Gen. Norman T. Kirk, Surgeon General, U.S. Army, 20 Mar. 1945. (3) Malaria Report No. 353, James A. Shannon, M.D., Chairman, Panel on Clinical Testing, to Board for the Coordination of Malarial Studies, 16 Mar. 1945.

[49] (1) Malaria Report No. 536, 20th General Hospital, India-Burma theater, submitted by Tropical Disease Control Branch, OTSG, to Board for the Coordination of Malarial Studies, 7 Nov. 1945. (2) Malaria Report No. 637, Tropical Disease Control Branch, OTSG, to Board for the Coordination of Malarial Studies, 11 Feb. 1946.

[50] (1) Minutes, Committee on Tropical Diseases, National Research Council, 19 June 1940. (2) Minutes, Subcommittee on Tropical Diseases, Division of Medical Sciences, National Research Council, 30 July 1940.

[51] Minutes, Subcommittee on Tropical Diseases, Committee on Medical Research, National Research Council, 13 Oct. 1941.

phases of insect control.[52] Contracts with other governmental agencies and civilian laboratories were made as the scope of the program increased after the beginning of the war. Studies of the toxicity of new compounds by the U.S. Food and Drug Administration were included as an essential phase of the research program. In June 1942, the U.S. Department of Agriculture was asked by the War Department to undertake investigation of new mosquito larvicides in addition to studies which already were being conducted on insecticides for lice and insect repellents.

The first field studies on repellents were conducted in the fall of 1941 at the Gorgas Memorial Laboratory in Panama. Later, as it became apparent that field studies in the tropics were necessary to supplement laboratory investigations in this country, four Sanitary Corps entomologists were assigned to the Gorgas Memorial Laboratory to conduct such studies on the new repellents and insecticides. They began work in the spring of 1943 and during the course of the war made a number of notable contributions to the research program.[53]

To coordinate and evaluate the investigations, conferences were called from time to time under the auspices of the National Research Council at which recommendations were made to the armed services. At the first of these conferences, held in August 1942, it was recommended that Indalone (butopyronoxyl) be adopted immediately by the Armed Forces as a repellent against flying insects and that Rutgers 612 (2-ethyl-1, 3-hexanediol) be substituted as soon as it could be produced in sufficient quantity.[54] At a subsequent meeting in November 1942, dimethyl phthalate was also recommended for use as a standard repellent.[55] Dimethyl phthalate and Rutgers 612 gave protection against bites of mosquitoes for several hours and were far more effective than insect repellents heretofore available. At first, these repellents were issued separately for individual use. Later, after a recommendation of the National Research Council in September 1943, a mixture of the three repellents, referred to as "6-2-2," (6 parts of dimethyl phthalate, 2 parts of 612, and 2 parts of Indalone) was adopted.[56]

These repellents were developed primarily for use against mosquitoes. Investigations in the field soon disclosed that they were also of value in protection against other insect vectors of disease. Studies in Egypt by the Neurotropic Virus Disease Commission of the Army Epidemiological Board showed that dimethyl phthalate was effective against *Phlebotomus papatasii*.

[52] Minutes, Subcommittee on Tropical Diseases, Committee on Medical Research, National Research Council, 9 May 1942.

[53] Hertig, Marshall: Chronological History 1943 to 1945, Unit of Sanitary Corps Officers, Gorgas Memorial Laboratory, Panama, 1 Nov. 1945. [Official record.]

[54] Minutes, First Conference on Insect Repellents, Committee on Medical Research, National Research Council, 18 Aug. 1942.

[55] Minutes, Conference on Insect Repellents, Committee on Medical Research, National Research Council, 12 Nov. 1942.

[56] Minutes, Fifth Conference, Insect Repellents and Insecticides, Office of Scientific Research and Development, National Research Council, 28 Sept. 1943.

the vector of sandfly fever, for a period of from 5 to 7 hours.[57] Tests in Peru by investigators of the Gorgas Memorial Laboratory demonstrated the effectiveness of both dimethyl phthalate and Rutgers 612 against local species of *Phlebotomus* which were vectors of verruga peruana (bartonellosis).[58]

As part of the investigation of mosquito repellents at the Orlando Laboratory of the Bureau of Entomology and Plant Quarantine, tests were also made on larval mites (chiggers). It was found that Indalone, Rutgers 612, and dimethyl phthalate were all effective in protection against larval mites, especially when applied around the openings in clothing.[59] These substances were thus of value as a preventive measure against scrub typhus which is transmitted by certain species of larval mites in the Orient. Australian workers reported that dimethyl phthalate acted as a lethal agent against larval mites rather than as a repellent. Members of the United States of America Typhus Commission working in New Guinea developed a field method for the impregnation of clothing with dimethyl phthalate, utilizing a soapy water emulsion.[60] This was found more practicable than previously used methods of applying repellents to clothing and was widely employed as a preventive measure to protect troops from scrub typhus in the western Pacific.[61] Bulk supply of dimethyl phthalate in gallon containers for application to clothing was recommended in the fall of 1943 for certain of the oversea theaters. In December 1944, it was recommended that an emulsifier be incorporated with the dimethyl phthalate to facilitate the preparation of emulsions in the field.

As investigations of repellents continued, a number of substances were discovered which were superior to dimethyl phthalate for impregnation of clothing to protect against larval mites. Benzyl benzoate was selected because of its rapid action against mites and its persistence in clothing after laundering. In March 1945, recommendation was made to the Office of the Quartermaster General that benzyl benzoate, together with an emulsifier, be substituted for dimethyl phthalate in the bulk issue of insect repellent. Because of difficulties in procurement, however, supplies of benzyl benzoate did not reach the field in time to be of use before the end of the war.

Insecticides

Coincident with plans for the deployment of increasing numbers of troops in tropical regions, need was foreseen for greatly increased amounts of insecti-

[57] Report, Maj. Albert B. Sabin, MC, "U.S. Army Virus Commission," U.S. Army Forces in the Middle East, to Commission on Neurotropic Virus Diseases of the Board for the Investigation and Control of Influenza and Other Epidemic Diseases of the Army, Office of The Surgeon General, U.S. Army, May 1943, subject: Preliminary Observations on the Effectiveness of Certain Repellents Against *Phlebotomus papatasii*.

[58] Office of Scientific Research and Development Monthly Progress Report No. 4, 15 Feb. 1944, subject: Studies on Repellents, Sprays and Other Control Measures Against *Phlebotomus* Carried Out in the Rimac Valley, Peru, December 1943 to January 1944.

[59] A Summary of Investigations on the Development of Insect Repellents and Lousicides, OSRD Projects M–723, M–920, and M–631, 4 Mar. 1943.

[60] Letter, Lt. Col. Joseph F. Sadusk, Jr., MC, United States of America Typhus Commission, to Dr. W. E. Dove, Bureau of Entomology, Department of Agriculture, 7 July 1944, inclosure thereto.

[61] War Department Technical Bulletin (TB MED) 121, December 1944.

cides to control insect pests and disease vectors. Pyrethrum was the active ingredient of most of the insecticides employed for spray killing and also of some of the preparations used as mosquito larvicides, and was widely used in this country as an agricultural insecticide. After the beginning of the war, Kenya, British East Africa, became almost the sole source of pyrethrum. Increased military demand, crop failure in Kenya, and shipping difficulties resulted in a critical shortage in the spring of 1942. At a conference held in the U.S. Department of Agriculture on 22 May 1942, it was agreed that priorities should be established to control stocks of pyrethrum and that cultivation of the plant should be developed in the United States. By action of the War Production Board, supplies of pyrethrum in the United States were "frozen" on 11 June, and thereafter allocations were made primarily upon the basis of military needs.

In the spring of 1943, a joint United States-United Kingdom committee was established under the International Aid Division, ASF, to consider technical aspects of the use and conservation of pyrethrum and to determine policies to govern allocations of pyrethrum flowers by the Combined Raw Materials Board.[32] It was agreed that the amount of pyrethrum allocated for military use should be in proportion to the number of troops exposed to the risk of insect-borne disease, and, so far as practical, American and British standards of issue of pyrethrum preparations should be identical for similar conditions. Although stocks of pyrethrum remained critical during 1943 and allocations continued through 1944, supplies were always sufficient to meet essential military needs.

Aerosol Dispensers

Economy and efficiency in the use of pyrethrum by the Army was accomplished by the adoption of the Aerosol insecticide dispenser as the principal means for spray killing adult mosquitoes. In 1941, scientists of the U.S. Department of Agriculture discovered the principle of using a propellent gas to disperse an insecticidal mixture into a fine mist, or Aerosol. With the advice and assistance of officers of the Preventive Medicine Service, manufacturers, during the summer of 1942, developed a suitable small container utilizing Freon-12 as the propellent. One pound of the pyrethrum mixture contained in this cylinder was sufficient to treat 150,000 cubic feet of space and was more than equivalent to 1 gallon of pyrethrum oil spray in insecticidal efficiency. Because of their small size, Aerosol insecticide dispensers, popularly known as mosquito bombs, effected a saving of approximately 85 percent in shipping space and could conveniently be carried into forward areas (fig. 6). They were also highly valuable for disinsectization of aircraft. Specifications and requirements were submitted in October 1942, and production began in November. By 1 March 1943, approximately 600,000 dispensers had been manufactured.

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[32] Minutes, Joint United States-United Kingdom Committee on Pyrethrum, 15 and 18 May 1943.

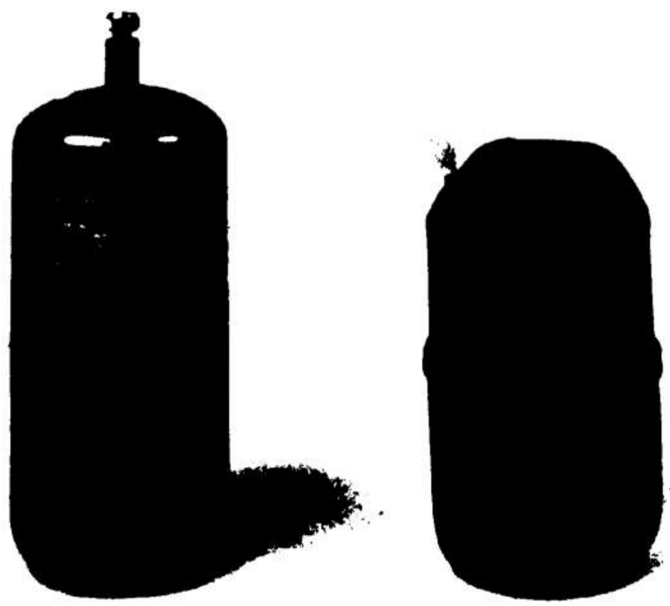

FIGURE 6.—Aerosol insecticide dispensers. Both types contain the same insecticide. Net weight of contents, approximately 1 pound.

As Aerosol insecticide dispensers proved their worth in the field, recommended allowances for use in malarious areas in oversea theaters were increased by 50 percent in March 1943. By summer, difficulty was experienced in obtaining sufficient Freon-12 to permit manufacture of the number of dispensers needed to meet oversea requirements. Strong support was given by The Surgeon General to increased allocation of Freon-12 for insecticide use.[63] As a result, War Production Board Order M–28 was immediately amended further to conserve Freon-12 by prohibiting its use for comfort cooling installations, and steps were taken to increase its production. A proposal to mix methyl chloride with the Freon-12 used in insecticide dispensers was rejected because of the toxicity of the compound and because the gain from the use of methyl chloride would not compensate for the loss of production due to required alteration of manufacturing facilities.[64] Supplies of Freon-12 for Aerosol dispensers remained critical until new plant facilities for its manufacture were completed in the summer of 1944.

[63] Letter, Maj. Gen. Norman T. Kirk, The Surgeon General, U.S. Army, to the Commanding General ASF, 10 July 1943, subject: Freon-12 for Insecticide Use.
[64] See footnote 56, p. 38.

DDT

The principal advance in insect control during the war was the discovery and application of the various insecticidal actions of DDT against the vectors of disease. In February 1943, the Orlando Laboratory of the U.S. Department of Agriculture first reported the remarkable effectiveness of DDT as an anopheline larvicide. Further field studies during the summer of 1943, including a series of carefully controlled experiments, confirmed the value of DDT oil solutions and dust preparations as mosquito larvicides. Production during 1943 was limited, and all the DDT was used for louse powder because other noncritical materials were available as effective larvicides. Small amounts, however, (approximately 50 pounds) were shipped to each of five oversea theaters in September in order that the usefulness of DDT as a mosquito larvicide might be tested under the varying conditions prevailing in the field.

In the meantime, studies of the toxicity of DDT were being conducted to determine the safety of the different preparations of DDT for various insecticidal uses. By September 1943, these investigations had progressed to the point where the National Research Council Conference on Insecticides and Repellents recommended use of the following preparations:

1. Commercially pure DDT for use (a) in a 5-percent solution in kerosene as residual-type spray to control mosquitoes, flies, and bedbugs, and (b) in concentration of not more than 10 percent in petroleum oil solutions as an anopheline larvicide.

2. DDT in powder form for use (a) in dilution not exceeding 10 percent with inert diluents for application as anopheline larvicide dusts, and (b) in water suspension with a suitable wetting agent as residual-type spray to control mosquitoes and flies.

3. DDT in concentrated (20 percent) solution for dilution with water and use in emulsion form as a residual-type spray and as a mosquito larvicide (figs. 7 and 8).

The first estimate of requirements for DDT for use as a mosquito larvicide was submitted in December 1943; however, except for small amounts employed for experimental purposes, DDT was not available for mosquito control until the spring of 1944. Directions for its use as a mosquito larvicide were published in March 1944.[65] Fifty thousand pounds were allocated from production in April, and recommendation was made for this amount to be distributed among the various theaters in malarious areas. Automatic shipment of this supply was ordered. Regular allowances of DDT for mosquito control were first authorized in April 1944, but because expanding production did not keep pace with the increase in authorized allowances, allocation of supplies to the theaters was necessary through the remainder of 1944.[66]

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[65] War Department Technical Bulletin (TB MED) 14, 3 Mar. 1944.

[66] (1) War Department Circular No. 151, 17 Apr. 1944. (2) Memorandum, Col. Edward V. Macatee, OMC, [Chief, General Supplies Branch, Storage and Distribution Division], for Office of The Surgeon General, Preventive Medicine Section, attention: Major McCoy, 23 June 1944, subject: Larvicide, DDT, Powder, Dissolving.

FIGURE 7.—Mixing DDT in the field.

Even before allowances of DDT mosquito control items were published, it became apparent that larger amounts of this agent would be required, especially for area control of mosquitoes by airplane application. In March 1944, estimated requirements for DDT were approximately quadrupled, and, in May 1944, this amount was doubled as a basis for calculation of Army procurement in 1945.

Airplane Spraying

First studies of airplane application of DDT to kill mosquitoes were conducted during the fall of 1943 at the Orlando Laboratory. In January 1944, a conference was held in the Office of The Surgeon General at which liaison was established between the various agencies concerned with the development of methods for aerial dispersion of insecticides. Cooperation of the Army Air Forces was obtained to facilitate development of equipment and for further trials of DDT airplane spraying at Orlando. A project was established under the Army Air Forces Board in April 1944 to determine the practicability of employing standard aircraft and equipment for this purpose.

In order to confirm in a tropical jungle location the promising results obtained in Florida, arrangements were made for representatives of the U.S. Department of Agriculture to conduct a field trial against anopheline mosquitoes in Panama (fig. 9). The spraying of DDT oil solution over jungle forest at

FIGURE 8.—Preparation of DDT oil solution for use as a mosquito larvicide.

the rate of 0.4 pound of DDT per acre reduced the number of adult anophelines by more than 90 percent and killed practically all anopheline larvae.[67]

Upon the basis of favorable results obtained in Florida and in Panama, a summary of information then available concerning airplane spraying of DDT was sent in April 1944 to the surgeons of theaters in malarious areas, and further trial of this method of insect control was encouraged. Also, the possibility of DDT airplane spraying for mosquito control in combat areas was emphasized. During the summer, airplane spraying projects were carried out in all the theaters where mosquitoborne diseases were important, in many instances, with equipment improvised in the field. This method of control was

[67] Interim Report No. 0-76: Studies on the Application of DDT from the Air and on the Ground for Control of Mosquitoes in Panama, Arthur W. Lindquist, U.S. Department of Agriculture, Agricultural Research Administration, Bureau of Entomology and Plant Quarantine, Orlando, Fla., and Capt. W. C. McDuffie, SnC, Army of the United States, to Committee on Medical Research of the Office of Scientific Research and Development, 29 Apr. 1944, subject: Insect Repellents, Contract No. M-723.

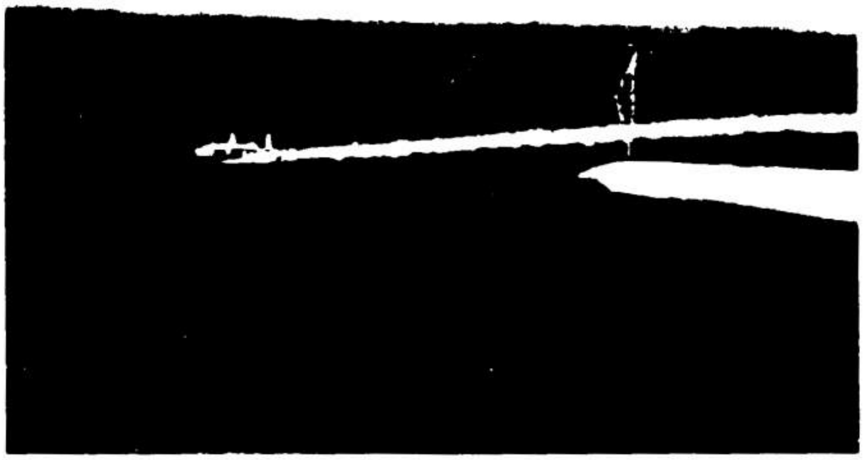

FIGURE 9.—B 25 airplane spraying DDT oil solution over jungle area in Panama.

especially valuable in newly occupied territory before ground control measures could be established. In order that aerial spraying might be performed most efficiently, it was proposed that special squadrons be authorized for this purpose. In May 1945, certain of the oversea theaters were questioned concerning the extent to which such units could be utilized. The war ended, however, before special Air Forces units were organized and trained in this country.

Further experimentation in the development and trial of apparatus for dissemination of DDT from aircraft was conducted throughout the war, both in this country and overseas. Much of this work was carried out by the Army Air Forces Board in close cooperation with Division 10 of the National Defense Research Committee, OSRD, and other Government agencies. Important information was acquired concerning the principles and practical applications involved in the dissemination of insecticides from aircraft.[60]

Because DDT not only kills disease vectors but also may destroy fish and wildlife and certain species of insects beneficial to agriculture, consideration was given to precautions to be observed in large-scale use of DDT in this country. A conference was held between representatives of the Army and the U.S. Public Health Service in March 1945, and it was agreed that certain safeguards should be adopted to prevent indiscriminate application from air-

[60] Andrus, E. C., Keefer, C. S., Bronk, D. W., Lockwood, J. S., Carden, G. A., Jr., Wearn, J. T., and Winternitz, M. C. (editors): Advances in Military Medicine. Boston: Little, Brown & Company, 1948, vol. II, pp. 643–644.

craft in the United States.[69] War Department Circular No. 207, published on 10 July 1945, prescribed that projects for airplane spraying of DDT at military installations in the continental United States must first be approved by the Army Committee for Insect and Rodent Control. Nine such projects were approved in 1945.[70]

Army Committee for Insect and Rodent Control

When problems in the supply and use of DDT assumed increasing importance early in 1944, the Commanding General, ASF, at the suggestion of the director of OSRD requested The Surgeon General to form a committee to coordinate the activities of various agencies concerned with this new insecticide and to make recommendations regarding production, allocation of current supplies, and new applications for use in the field. This committee, known as The Surgeon General's DDT Committee, consisted of representatives of the Navy, U.S. Public Health Service, U.S. Department of Agriculture, and OSRD, as well as various branches of the War Department. The committee served as a valuable channel for the interchange of information and the correlation of various phases of research, production, distribution, and field uses of DDT.[71]

By the fall of 1944, the scope of research aspects and civilian applications of DDT had become so extensive that the OSRD created an Insect Control Committee to correlate the diverse and expanding research projects involved in this program and to act as an information bureau for the collection and dissemination of information on DDT. The Surgeon General's DDT Committee became the Army Committee for Insect and Rodent Control which continued to deal with the military aspects of DDT and also considered other measures for the control of insects and rodents.[72] Close liaison was maintained between the two committees. Reports from Army sources were submitted to the OSRD Committee for abstracting and distribution to the various U.S. and Allied agencies interested in DDT.

The Subcommittee on Field Uses of the Army Committee for Insect and Rodent Control dealt with matters of immediate concern to the Army's tropical disease control program. The field testing of new repellents, the dissemination of DDT from aircraft, and the development of Aerosol methods of dispersal were the most important subjects of consideration. Although experiments were conducted with smoke generators and explosive charges as means of dissemi-

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[69] (1) Letter, Brig. Gen. James S. Simmons, U.S. Army Chief, Preventive Medicine Service, OTSG, to Dr. Thomas Parran, The Surgeon General, U.S. Public Health Service, 12 Apr. 1945, inclosure thereto, subject: Use of DDT for Mosquito Control in the United States—A Joint Statement of Policy by the U.S. Army and the U.S. Public Health Service. (2) Letter, C. L. Williams, Assistant Surgeon General, U.S. Public Health Service, to The Surgeon General, U.S. Army, 20 Apr. 1945.

[70] Minutes, Ninth Meeting, Army Committee for Insect and Rodent Control, 28 Aug. 1945. Appendix II: Report of Subcommittee on Field Uses, 28 Aug. 1945.

[71] Minutes, The Surgeon General's DDT Committee, 16 June 1944.

[72] War Department Memorandum No. 40-44, 8 Nov. 1944.

nating DDT, these methods had not been adopted for field use by the end of the war.

Dissemination of Information to Field Workers

The circulation of information concerning new developments in insect control to workers in the field was an important phase of the tropical disease control program. Minutes of meetings of The Surgeon General's DDT Committee and later of the Army Committee for Insect and Rodent Control and the "Abstract Bulletin" of the Insect Control Committee, OSRD, were sent directly to key persons in this country and overseas. As new insecticides were adopted, directions for their use were published in War Department technical medical bulletins.[73] Arrangements were made, through cooperation of the U.S. Department of Agriculture, for selected Medical Department officers to observe demonstrations of the field uses of DDT insecticides and the new repellents at the Orlando Laboratory of the Bureau of Entomology and Plant Quarantine. These 4-day demonstrations were held at intervals of approximately 6 weeks, beginning in November 1943 and continuing through July 1945. They were extremely valuable for the instruction of preventive medicine officers, especially those assigned to oversea service.

Distribution of Supplies and Equipment

Because supplies of insecticides and other items for control of insects were often limited, it was necessary to distribute what was available among the various theaters in accordance with the estimated needs. Accordingly, the Preventive Medicine Service usually recommended allowances of insecticides and pest control equipment in terms of so much per thousand men per month in specified geographic areas. These allowances served as a basis both for the Army supply program and for the requisitions from oversea theaters. The first published table of allowances was issued in March 1943 and was revised as supplies increased. Since some items were supplied by the Quartermaster Corps and others by the Corps of Engineers, it proved convenient to publish subsequent tables of allowances in the form of War Department circulars.[74]

Issuance of insect control supplies was a constant problem, not only because of frequent materiel shortages in this country and the necessity for allocations but also because of inadequate distribution in the oversea theaters. When the Aerosol insecticide dispenser and the new repellents were adopted, establishment of adequate supplies overseas was particularly difficult. Automatic supply of these items was therefore ordered in March 1943. Because troops often arrived in malarious localities without provision for adequate insect control supplies and equipment, it was ordered that a 30-day supply of essen-

[73] (1) See footnote 65, p. 42. (2) War Department Technical Bulletin (TB MED) 110, 25 Oct. 1944. (3) War Department Technical Bulletin (TB MED) 194, 17 Aug. 1945.

[74] (1) War Department Circular No. 239, 1 Oct. 1943. (2) See footnote 68 (1), p. 42. (3) War Department Circular No. 163, 4 June 1945.

tial antimalarial drugs, insecticides, and repellents accompany troops embarking in this country and that they be so stored aboard ship as to be immediately available upon landing.[75] Provision also was made that troops carry a mosquito bar and a bottle of insect repellent as part of their individual equipment.[76]

EDUCATIONAL ACTIVITIES

Instruction for Medical Officers

Development of special courses and programs of instruction formed part of Tropical Disease Control activities at intervals throughout the war. As the Medical Department began to expand in the prewar period, physicians who were being recruited from civil life had little or no practical experience with tropical diseases. Teaching of tropical medicine in U.S. medical schools was generally either inadequate or altogether lacking. To meet this deficiency, a special 8-week Course in Military and Tropical Medicine was organized at the Army Medical School for medical officers coming into the service. The instruction emphasized the preventive and control aspects of tropical infections as well as the methods for their diagnosis and treatment. The first course began in August 1941. During the war, 28 courses were held, attended by 1,797 Medical Department officers who completed the course and by 48 others who received part of the instruction. As approximately 55,000 doctors were mobilized into the Army, this program of courses met only a small fraction of the need for special instruction in tropical medicine.[77]

As a longer range program, steps were taken through the Subcommittee on Tropical Diseases of the National Research Council, in the summer of 1942, to improve undergraduate teaching of tropical medicine in medical schools which were then largely given over to the training of future medical officers for the Army and Navy.[78] Grants from the John and Mary R. Markle Foundation, totaling $170,000, in the years 1942, 1943, and 1944 enabled medical schools to send one or two staff members to the 8-week course in tropical medicine at the Army Medical School and to Central America for a month of practical field experience in the tropics. Of the 77 medical schools in the United States, 63 took advantage of these opportunities.[79] With the support of the foundation grants, specially qualified lecturers and parasitologic specimens and other teaching materials also were furnished to medical schools.

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[75] (1) Letter, Brig. Gen. L. S. Ostrander, USA, Adjutant General, U.S. Army Forces in the Far East, to The Adjutant General, War Department, 1 Oct. 1943, subject: Malaria Control. (2) Letter, Maj. Gen. J. A. Ulio, Adjutant General, War Department, to the Commanding Generals, Ports of Embarkation; the Commanding Officers, Ports and Subports of Embarkation; the Quartermaster General; The Surgeon General, and Chief of Transportation, 30 Dec. 1943, subject: Antimalaria Supplies for Troops Moving Overseas.

[76] Preparation for Overseas Movement (Short Title: POM), 2d edition, 1 Aug. 1943.

[77] Data were obtained from the Resources Analysis Division, Office of The Surgeon General.

[78] Minutes, Eleventh Meeting, Subcommittee on Tropical Diseases, Committee on Medical Research, National Research Council, 8 July 1942.

[79] Annual Report, The John and Mary R. Markle Foundation, 1944.

When the war in Europe ended and the redeployment of large forces to the Pacific was scheduled, arrangements were made for refresher training in tropical medicine for medical officers during redeployment. A 2-week program of instruction, known as the Course in Diseases of the Pacific Area, was established at Carlisle Barracks, Pa., and a group of 12 specially qualified officers was selected to give refresher instruction on the prevention, control, diagnosis, and treatment of these diseases. The course was intended for Medical Corps officers assigned as unit surgeons, as medical inspectors, or as chiefs of hospital medical services. The first course began on 20 August 1945, but, because the war ended, only four courses were given. A total of 66 officers attended.

The issuance of informational bulletins and other educational materials was an important activity, because Medical Department officers, in general, lacked knowledge and experience relating to tropical diseases. The first digest of essential information concerning tropical infections was distributed in June 1941 as a circular letter for medical officers.[80] It was republished in an expanded form early in 1943.[81] The prevention and control of malaria was discussed at more length in a separate publication.[82] Later, as more information was accumulated from the Army's field experience, individual bulletins were issued dealing with specific diseases which had proved to be of military importance. As a rule, these described diagnosis and treatment, as well as prevention and control, and were prepared in collaboration with other interested divisions of the Preventive Medicine Service and the Medical Consultants Division, OTSG. Because of the outstanding military importance of malaria, War Department technical medical bulletins were prepared from time to time in order to summarize latest field experiences with the disease and give information concerning the development of new control measures. These bulletins were 8 of 24 War Department technical medical bulletins on tropical diseases which were prepared primarily or in part by the Tropical Disease Control Division during the war.

Eleven articles relating to the control of tropical diseases were printed in medical and scientific journals. The most significant of these publications were a key to the anopheline mosquitoes of the world and a mosquito atlas which summarized important information concerning the vectors of malaria and other mosquitoborne disease.[83] These were issued in the spring of 1943 and were highly valuable to entomologists and other members of the worldwide malaria control organization.

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[80] See footnote 24 (1), p. 30.

[81] Circular Letter No. 33, Office of The Surgeon General, U.S. Army, 2 Feb. 1943.

[82] Circular Letter No. 22, Office of The Surgeon General, U.S. Army, 16 Jan. 1943.

[83] (1) Russell, Paul F., Rozeboom, Lloyd E., and Stone, Alan: Keys to the Anopheline Mosquitoes of the World, with Notes on Their Identification, Distribution, Biology, and Relation to Malaria. Philadelphia: The American Entomological Society, The Academy of Natural Sciences, 1943. (2) Ross, Edward S., and Roberts, H. Radclyffe: Mosquito Atlas. Philadelphia: The American Entomological Society, The Academy of Natural Sciences, pt. 1, 1943.

The Division of Medical Sciences of the National Research Council developed a series of compact and practical textbooks designed particularly for use by Army and Navy medical forces. Two of the volumes had special value in malaria control and were prepared by staff members of the Army Medical School.[84]

Troop Training in Malaria Control

During the summer of 1943, efforts were made to strengthen the training and indoctrination of troops in malaria control measures. In September 1943, War Department Circular No. 223 was published which prescribed a special 4-hour course in malaria control and discipline for everyone in the Army. For future officers and inductees, it was ordered that this instruction be included during their training in the continental United States. For personnel already in the Army, both in the United States and overseas, the instruction was to be completed at the earliest date possible. Details of the instruction, including an outline of the material to be presented during the 4-hour course, were published in War Department Training Circular No. 108, 21 September 1943. These provisions for special training in malaria control were kept in effect by a subsequent War Department circular published in April 1945, at which time a revision of the training circular including new developments in preventive measures was also issued.[85]

Training Aids

Throughout the war, the Tropical Disease Control unit promoted and gave consultative technical assistance in the preparation of various training aids for the instruction of troops in the prevention and control of malaria and other tropical diseases.

Informative material to serve as a basis for lectures on malaria control was published in circular letters from the OTSG and in War Department training circulars.[86] Portfolios, measuring 30 by 40 inches, of mounted illustrations with suggested texts for the lecturer printed on the reverse side were designed to assist instructors in presenting lectures on prevention of tropical diseases in such a manner that they could be understood readily by troops.[87]

A number of motion picture films were produced under the auspices of the Army Pictorial Service or were adapted from those produced by other agencies to supplement basic instruction. The first of these on malaria control (TF 8–953, Malaria—Cause and Control), issued early in 1943, showed the life

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[84] (1) Mackie, Thomas T., Hunter, George W., and Worth, C. Brooke: A Manual of Tropical Medicine. Philadelphia: W. B. Saunders Co., 1945. (2) Russell, Paul F., West, Luther S., and Manwell, Reginald D.: Practical Malariology. Philadelphia: W. B. Saunders Co., 1946.

[85] (1) War Department Circular No. 117, 14 Apr. 1945. (2) War Department Training Circular No. 16, 14 Apr. 1945.

[86] (1) Circular Letter No. 44, Office of The Surgeon General, U.S. Army, 15 Feb. 1943. (2) War Department Training Circular No. 108, 21 Sept. 1943.

[87] (1) War Department Graphic Training Aid 8–4: Malaria (Graphic Portfolio), 1944. (2) War Department Graphic Training Aid 8–17: Personal Health (Graphic Portfolio), 1945.

cycle of the malaria parasite and emphasized environmental control measures. In 1944, another film (TF 1-3343, Malaria Discipline), produced primarily under the auspices of the Army Air Forces, stressed individual protective measures and malaria discipline. Later, films were issued which portrayed experiences in the field and served as a background for refresher training; for example:

Miscellaneous Film 1016, Silent Battle, a portrayal of Australian Army experience with malaria.

Film Bulletin 195, DDT—Weapon against Disease, an account of the development and early Army uses of DDT insecticides.

Film Bulletin 200, Malaria Control on Corsica, a picture of field application of recommended control measures.

Miscellaneous Film 1230, Schistosomiasis, a brief portrayal of the geographic distribution, epidemiology, clinical aspects, and control of schistosomiasis, most of which was photographed on Leyte where this disease was a military problem during the early stages of the campaign to reoccupy the Philippines.

Educational Propaganda

In order to supplement instruction given during formal training periods, advantage was taken of every opportunity to issue reminders or educational propaganda concerning tropical disease preventive measures, especially those which the individual had to apply himself. Various media were employed for this purpose, including posters, pamphlets, cartoon moving picture films, recordings for broadcasts, signs, and printed warnings on match covers and ration containers. Because of the prime military importance of malaria, most of these reminders were designed to promote malaria discipline and the use of individual protective measures against mosquitoes.

In the summer of 1943, a booklet entitled "This is Ann," prepared by Maj. Munro Leaf and the cartoonist Theodor S. Giesel (Dr. Seuss), was published and distributed to troops proceeding to tropical theaters. The booklet presented in humorous style the essential facts about malaria and the protective measures which the soldier himself should apply (fig. 10). It was well received and widely publicized and distributed. Several million copies were printed before the end of the war. Material from the booklet also was printed on the back of oversea news maps which were given wide distribution throughout the Army.

During the summer of 1943, the cooperation of the Special Services Division (later Morale Services Division), ASF, was secured to promote an educational propaganda program in malaria prevention among troops in the field. Through this cooperative effort, 15 posters, 3 cartoon motion picture films, and a recording were produced which utilized the facilities and specially qualified talent of the Special Services Division. The posters emphasized personal

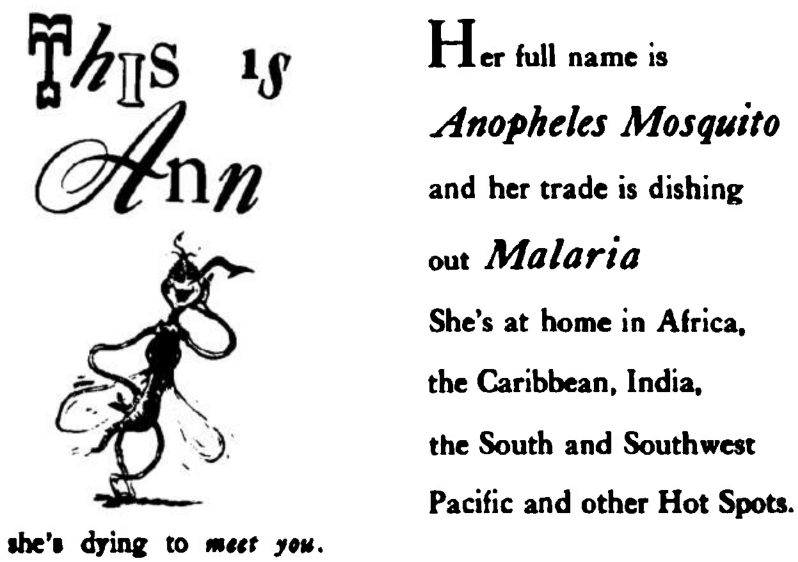

FIGURE 10.—Cover and opening page of booklet explaining the facts about malaria and individual measures of prevention.

protective measures against malaria (figs. 11 and 12). Twenty-five thousand copies of each were printed and distributed to the oversea theaters in malarious areas early in 1944.

Cartoon motion pictures were produced as part of the Snafu Series which was regularly included in the *Army-Navy Screen Magazine.* These cartoons, each with a running time of about 4 minutes, depicted in humorous fashion the difficulties experienced by Private Snafu when he neglected antimalaria precautions. They were entitled and released as follows:

"Private Snafu vs. Malaria Mike," released in *Army-Navy Screen Magazine* No. 23, March 1944, and later issued as Miscellaneous Film No. 1035.

"Target Snafu," released in *Army-Navy Screen Magazine* No. 38, October 1944.

"It's Murder, She Says," released in *Army-Navy Screen Magazine* No. 52, May 1945.

One hundred copies of a recording entitled "Know Your Enemy—Malaria" were produced and distributed in the spring of 1944. About 20 minutes in length, this recording was suitable for broadcasting over local radio networks and loudspeaker systems and was intended for use in orientation programs and for refresher instruction. It stressed the hazards of malaria in the tropical theaters and the individual means of malaria prevention.

Experience had shown that short cartoon trailers attached at the beginning of feature motion pictures shown in the oversea theaters were effective

Figure 11.—Antimalaria poster.

FIGURE 12.—Antimalaria poster.

reminders in promoting malaria discipline. Arrangements were made with the Army Pictorial Service for the production of 50 appropriate cartoon trailers, each of which stressed an aspect of personal measures for prevention of malaria.

Other reminders were issued in the form of stickers for vehicle windshields displaying antimalaria slogans such as "Prevent Malaria—Shorten the War," and an admonition to "Stay on Authorized Roads—Malaria Mosquitoes Breed in Road Ruts—Do Your Part to Stop It." Reminders to observe malaria precautions also were printed on ration box containers and on matchbook covers sold by Army Post Exchanges.

In connection with plans for redeployment in the Pacific, a series of posters on tropical diseases was prepared in conjunction with the Health Education Unit. Release was postponed because of the sudden end of the war with Japan. However, three posters dealing with schistosomiasis and four relating to scrub typhus were issued in December 1945. Other posters on plague, filariasis, and malaria were still in the process of publication at that time. The importance of health education as a program separate from didactic training in disease prevention was not appreciated early enough nor its value widely recognized. Experience indicated that the propaganda phase of preventive medicine warranted more thorough and systematic exploitation.

From time to time, members of the staff of the Tropical Disease Control unit were called upon to lecture at meetings of various medical and public health societies. In these lectures, opportunity was afforded to present accounts of the tropical disease problems faced by the Army and the steps taken by The Surgeon General to meet them. Attendance and discussion at such meetings served as a valuable liaison between the Office of The Surgeon General and the medical and public health professions in the country at large. In addition to these lectures, members of the staff lectured on numerous occasions at Army training centers including the Army Medical School; the Medical Field Service School, Carlisle Barracks; the Unit Training Center, Camp Planche; and the Schools of Military Government at Charlottsville, Va., and New Haven, Conn.

PRECAUTIONS AGAINST THE INTRODUCTION OF TROPICAL DISEASES INTO THE UNITED STATES

General Policies

As the zones of military operations were extended and large numbers of men were deployed in tropical regions, it became apparent that the possible introduction of exotic diseases into this country by returning service personnel would be a serious problem. At the request of the armed services, this matter was considered at a meeting of the Subcommittee on Tropical Diseases in

January 1943, and a report of its recommendations was circulated to representatives of the armed services in March 1943.[88] As then visualized, the risks especially to be guarded against were:

1. Introduction of diseases not then existent in the United States.

2. Introduction of new strains or types of disease organisms which might be more dangerous than those already in the country.

3. Admission of large numbers of persons infected with diseases then existent in the United States, with the result of wider distribution and increased incidence.

4. Introduction of the vectors of certain diseases which were presumably then absent because of the lack of those vectors.

The recommendations contained in this report were discussed at conferences of representatives of the Army, Navy, and U.S. Public Health Service held in the OTSG on 13 and 27 April. At the latter conference, agreement was reached regarding general recommendations on the introduction of tropical diseases into the United States and also specific recommendations on certain diseases which presented the greatest military problem; namely, malaria, filariasis, and schistosomiasis.[89] In substance, it was decided that: (1) control of the mosquito vectors in known endemic areas in the United States was the most practical solution to the problem of preventing postwar malaria epidemics; (2) the presence of microfilariae in the blood without symptoms should not warrant restriction of the location or movement of infected persons in this country; and (3) studies should be undertaken to determine whether local species of snails could act as vectors of schistosomiasis and to develop more satisfactory drugs for treatment.

The recommendations made at this conference were adopted by the Subcommittee on Tropical Diseases in July 1943 and served as the basis for Army policy. Questions on measures to prevent the introduction of disease vectors into the United States were handled by the Interdepartmental Quarantine Commission of the Army, Navy, and the U.S. Public Health Service. Subsequent conferences of representatives of the Army, Navy, and the U.S. Public Health Service to discuss problems in connection with the introduction of exotic diseases were held on 13 March 1944 and on 8 June 1945. Although a number of additional recommendations were made, chiefly to encourage better diagnosis and reporting of tropical diseases by civilian agencies, no important changes affecting the policies of the armed services were adopted.

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[88] (1) Minutes, Thirteenth Meeting, Subcommittee on Tropical Diseases, Committee on Medical Research, National Research Council, 12 Jan. 1943. (2) Minutes, Fourteenth Meeting, Subcommittee on Tropical Diseases, Committee on Medical Research, National Research Council, 20 July 1943, and Appendix A thereto, dated 28 Apr. 1943, subject: Conference on Precautions Against the Introduction of Tropical Diseases Into the United States by Returning Military Personnel.

[89] See footnote 88 (2).

Program for Returning Soldiers and Prisoners of War

As more and more men returned from tropical areas, many of whom were infected with malaria, further steps were taken to minimize the hazard of possible spread of the disease in this country. In June 1943, Circular Letter No. 111, Office of The Surgeon General, U.S. Army, was published on the management of malaria cases; it emphasized antimosquito precautions and prescribed thick-blood film examination of all patients who had had recent duty in an oversea area where malaria was endemic. Adequate control of anopheline mosquitoes was maintained at military installations, including hospitals, throughout the country. In accordance with the agreement between the Secretary of War and the Federal Security Administrator, the U.S. Public Health Service carried out mosquito control, when needed, in extramilitary zones adjacent to reservations. This program was originally instituted to protect troops from acquiring malaria from civilians, but it also served equally well to help prevent spread of malaria from soldiers to civilians.

In the spring of 1943, large numbers of prisoners of war from the North African campaign, many of whom were infected with malaria, were brought to this country. The same antimosquito measures were employed at prisoner-of-war camps as at regular military installations to prevent possible spread of malaria among the prisoners and to surrounding civilian communities.[90] In the 1944 season, the problem of malaria control was made more difficult because prisoners were widely dispersed in branch camps to work on farms and other scattered labor projects. In camps which were to be occupied for comparatively short periods, emphasis was placed on screening, on the use of bed nets, and on the employment of insecticidal sprays, rather than on drainage and larvicidal programs.[91]

Cooperation With the U.S. Public Health Service and State Health Offices

As the prospect of demobilization approached, support was given to extend the program of Malaria Control in War Areas, U.S. Public Health Service, to include selected locations in Southern States where the risk of transmission was considered greatest.[92] Evidence of the effectiveness of this coordinated mosquito control program was afforded by the extremely low malaria rate which prevailed among troops permanently stationed in this country after 1941 and also because, so far as was known, only an insignificant number of secondary cases of malaria were traced to oversea veterans.

During the summer of 1944, the number of malaria relapses occurring among veterans caused concern on the part of civilian public health authorities.

[90] Army Service Forces Memorandum No. S40-10-43, 19 June 1943. [Malaria Among Prisoners of War.]

[91] Army Service Forces Circular No. 206, 5 July 1944.

[92] Letter, Maj. Gen. Norman T. Kirk, The Surgeon General, U.S. Army, to Dr. Thomas Parran, The Surgeon General, U.S. Public Health Service, 11 Oct. 1944.

This was manifested in a series of letters to The Surgeon General from State health officials asking that the Army furnish the names and addresses of all persons discharged from the service who had had malaria. The question was brought before a meeting of the Subcommittee on Tropical Diseases in September.[93] After discussion by representatives of the services and the Association of State and Territorial Health Officers, a resolution was adopted to the effect that no essential public health purpose would be accomplished by reporting to civil health authorities the names and addresses of persons who had had malaria or had been exposed to it during the course of their military experience. The consensus was that malaria control in the United States should be based upon antimosquito measures in endemic and potentially endemic areas rather than upon control of individual cases.

Special Medical Processing for Returning Troops

In order to lessen the risk of possible introduction of tropical infections, a supplement to the usual quarantine procedures was adopted, which required special medical processing of troops returning from foreign duty.[94] During this medical processing, special effort was to be made to identify and hospitalize or treat individuals who, while on furlough, were likely to suffer from a recrudescence of a chronic infection, especially malaria or other tropical disease. Thick-blood film examinations were prescribed routinely for those who had discontinued taking suppressive antimalarial drugs within the previous 30 days. All persons who had had malaria overseas or had served in a hyperendemic area and had had suppressive treatment were to be warned that they might suffer a relapse or an initial clinical attack while on furlough. They were instructed to seek prompt medical attention and to have a blood examination in case of a febrile illness. This warning and instruction was also printed in War Department Pamphlet No. 21–16, 1944, which was distributed to soldiers about to go on furlough after oversea service. With the prospect of extensive redeployment and demobilization, the procedures relating to the medical processing of troops returned from foreign duty were later revised and emphasized in TB MED 180, published in July 1945.

Another measure which helped to prevent spread of malaria in civilian communities was the policy on discontinuance of malaria suppressive treatment in returnees which was established in November 1944.[95] In order that personnel who were still taking suppressive medication upon arrival in the United States might be protected from malarial attacks during travel and furlough and also to insure that medication was given for at least 4 weeks after last exposure in an oversea malarious area, it was ordered that suppressive treatment should be

[93] Minutes, Seventeenth Meeting, Subcommittee on Tropical Diseases, Committee on Medical Research, National Research Council, 28 Sept. 1944.
[94] War Department Technical Bulletin (TB MED) 2, 3 Jan. 1944.
[95] War Department Circular No. 449, 25 Nov. 1944.

CHAPTER III

Experience in the United States

Justin M. Andrews, Sc. D.,

and

Jean S. Grant

MILITARY MOBILIZATION IN POTENTIALLY MALARIOUS AREAS OF THE UNITED STATES

The prescribed missions of troops stationed in the continental United States of America are (1) to protect the area and (2) to be trained for military duty at home and abroad. Malaria had been an impediment to military training in the Southern United States during World War I.[1] It continued to be endemic in certain parts of this area as late as 1940. To prevent the disease from becoming an incapacitating risk to the fulfillment of these two objectives and to preclude the hazard of exporting military personnel with latent infections to become disease casualties abroad, large-scale antimalaria operations were undertaken from 1941 to 1946 on and near U.S. Army areas in the potentially malarious sections of the continental United States, mainly the southeast quadrant of the country. This region, where the climate allowed year-round outdoor operations, was selected by both the ground and air forces for the establishment of numerous military installations, mostly for training purposes. In 1942, there were 499 such facilities in the 17 States where it was believed that malaria might infect troops and thereby seriously hamper training programs. The ever-widening spread of war created an urgent demand for greater numbers of trained fighting men. In 1943, 90 additional military posts were opened, raising the total number in these States to 589. This figure remained virtually the same in 1944 (583) but by 1945, as a result of the cessation of hostilities, decreased to 520.[2]

There is a direct correlation between these figures and the numbers of troops involved. In 1942, approximately 2 million men, many of them from nonmalarious areas of the country and therefore highly susceptible to infection,

[1] The Medical Department of the United States Army in the World War. Communicable and Other Diseases. Washington: U.S. Government Printing Office, 1928, vol. IX, pp. 515–519.

[2] Table of the number of Army and Air Forces Installations in 17 States for 1942–45 Inclusive, August 1945. The 17 States were Alabama, Arkansas, California, Florida, Georgia, Kentucky, Louisiana, Mississippi, Missouri, New Mexico, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.

were assigned to these posts and training centers. In 1943, the number was 3.6 million.[3] This figure does not show merely the assignment of additional troops but probably indicates almost a complete replacement of men who had finished training and were then in combat zones. By 1944, the peak period of training had passed, and the number of military personnel in the malarious regions had declined to 2.8 million and by 1945 showed a further reduction to 1.9 million.[4]

MALARIA INCIDENCE IN THE UNITED STATES BEFORE WORLD WAR II

The last rise of malaria prevalence in this country to epidemic proportions occurred in the midthirties (chart 3) probably as a direct effect of the depression. Living standards deteriorated in most rural areas where malaria is traditionally focused. As a result, those antimalaria defenses normally supported by householders (screening, drugs, insecticides) were relaxed. This outbreak constituted essential evidence on which was based the theory of cyclical increases in the incidence of paludism in the United States.[5] The fact that brief periods of high endemicity accompanied by scattered epidemics occurred historically in the United States at intervals of from 5 to 7 years had been noted; from this it was predicted that malaria prevalence would again reach a peak sometime near 1941 or 1942, though it was not expected that this increase would be as important as its predecessors. In the first place, no further depression was anticipated which would paralyze resistance to such an outbreak. Secondly, the direction of overall malaria incidence, including epidemic years, had been steadily downward ever since the last quarter of the 19th century, and malariologists were not aware of any unusual circumstances which might reverse this trend.

Malaria, which at one time had been highly prevalent over a large portion of this country, had been concentrated since 1912 in the southeastern quadrant. The total area involved receded and expanded with the rises and falls in incidence of the disease until 1932 when it reached its minimal extent (maps 1, 2, 3, and 4 (redrawn from Williams, L. L., Jr.: The Anti-Malaria Program in North America. *In* A Symposium on Human Malaria. Washington: American Association for the Advancement of Science, 1941, p. 365)). From that time until 1940, it remained at varying intensities in the same portions of the

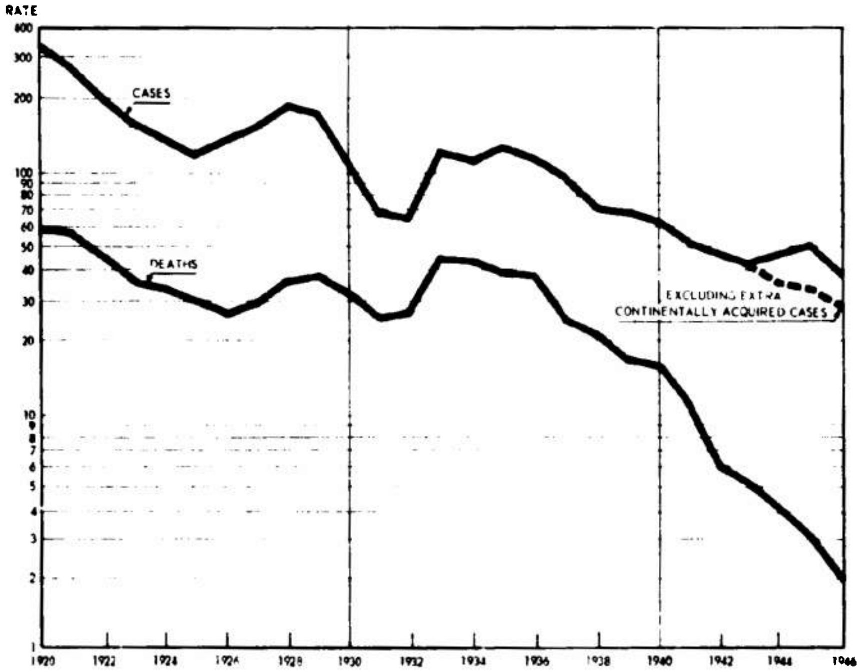
[3] Strength of CONUS Army Installations and Activities, 1942–43. Prepared for War Department General Staff by Machine Records Branch, Office of the Adjutant General, under direction of Statistical Branch.

[4] Strength of the Army, 1944–45. Prepared for War Department General Staff by Machine Records Branch, Office of the Adjutant General, under direction of Statistical Branch.

[5] (1) Williams, L. L., Jr.: The Anti-Malaria Program in North America. *In* A Symposium on Human Malaria. Washington: American Association for the Advancement of Science. 1941, pp. 365–370. (2) Faust, E. C.: Clinical and Public Health Aspects of Malaria in the United States From a Historical Perspective. Am. J. Trop. Med. 25: 185–201, May 1945.

CHART 3.—*Morbidity and mortality rates for malaria in all States[1] reporting cases[2] and deaths,[2] 1920 to 1946, inclusive.*

[Rate expressed as number of cases and number of deaths per 1,000,000 population per annum]



[1] Includes all States and the District of Columbia which reported cases or deaths during the respective years.

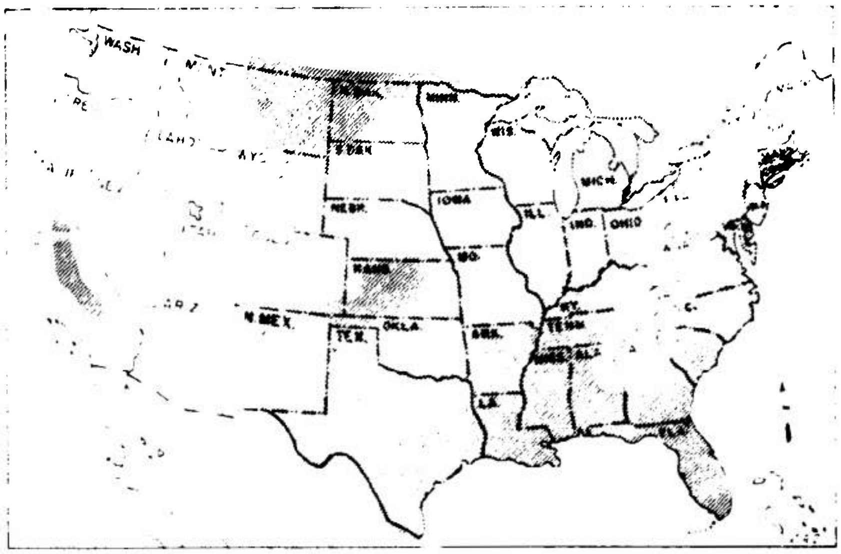
[2] Data on cases from "The Notifiable Diseases," and data on deaths from "Vital Statistics of the United States," National Office of Vital Statistics, U.S. Public Health Service.

Source: Communicable Disease Center, U.S. Public Health Service, Atlanta, Ga.

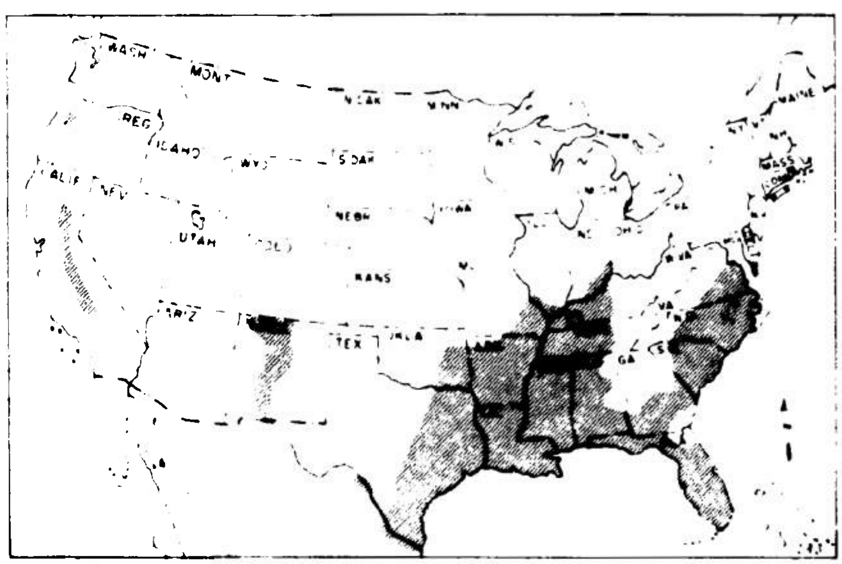
same States. It was in these regions that many military and defense establishments were located when the United States put its World War II defense program into effect.

Because for the most part it is possible to maintain regular training operations in these areas throughout the year, the seasonal distribution of malaria was important only as it related to malaria control planning. In Georgia, for instance, a typical malarious State before World War II, the greatest number of cases was reported from July through November while deaths occurred chiefly from August through December.[6] This parallelism in trend and lag in

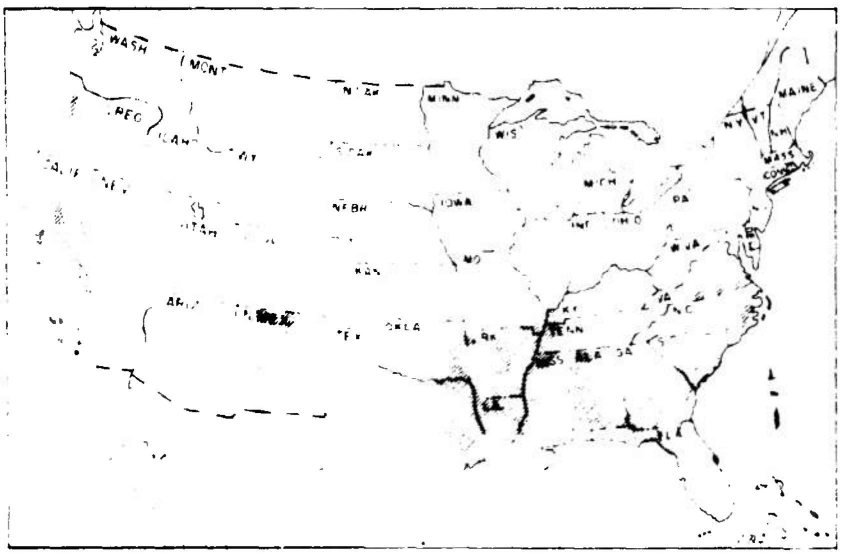
[6] Andrews, Justin M.: General Considerations in Planning Malaria Control. *In* A Symposium on Human Malaria. Washington: American Association for the Advancement of Science, 1941, pp. 285–294.



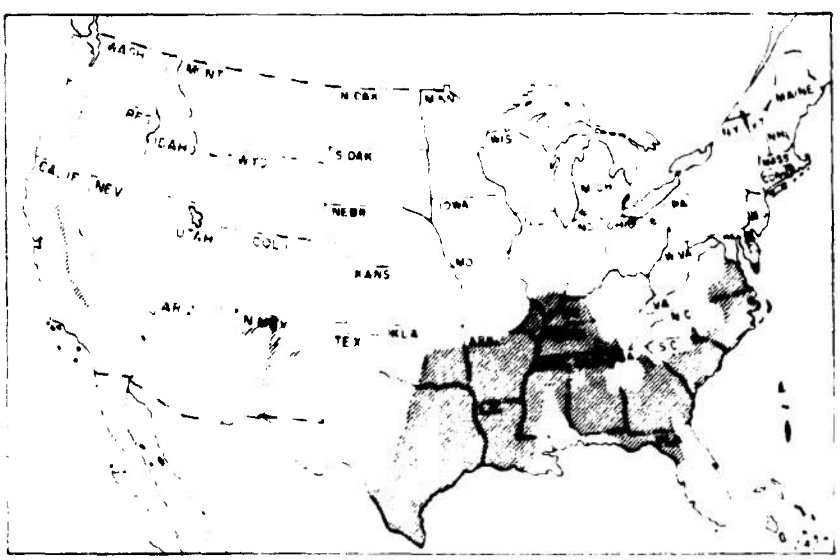
MAP 1. Areas of the continental United States believed to be malarious in 1882.



MAP 2.—Areas of the continental United States believed to be malarious in 1912.



MAP 3.—Areas of the continental United States believed to be malarious in 1932.



MAP 4.—Areas of the continental United States believed to be malarious in 1934 35.

the rise and decline in the numbers of deaths as compared to cases was typical of reported malaria in the southern United States. While the mortality and morbidity reporting of this disease have been notoriously inaccurate, especially before 1940, those responsible for the prevention and control of malaria have had to rely on them, together with the findings of special field surveys and diagnostic laboratories, as guides for operations. Thus, during the war years extracantonmental and intracantonmental malaria control activities were based on this type of information.

The endemic areas of the United States have a climate compatible with the occurrence of both *falciparum* and *vivax* malaria, though at higher temperatures the former flourishes somewhat more exuberantly than does *vivax* infection. While quartan malaria has been encountered occasionally in this country, it has never contributed significantly to morbidity and mortality.

The ratio between the number of cases and the number of deaths resulting from paludism is determined by the type of parasite involved. *Vivax* malaria is extremely debilitating to its victim and makes him liable to secondary infections which may prove fatal, but it is not generally a primary cause of death.[7] On the other hand, untreated *falciparum* malaria tends to fulminate rapidly and frequently kills its host directly. Thus, generally speaking, wherever there is a high proportion of *falciparum* infection, death rates from malaria will be high; conversely, when this proportion is low, malaria death rates are low. This factor appears to have manifested some influence on cyclic epidemic malaria in this country. During the last of these outbreaks, there was a greater proportional increase in the prevalence of *falciparum* malaria than of *vivax* malaria. Judging by the sharp rises in mortality during previous epidemics, the same dominating role of *falciparum* parasitism may have been in operation.

Another factor which modified the occurrence of malaria in this nation was racial differences in susceptibility. Our white natives are readily infectible with all types of malaria parasites. On the other hand, the Negro is relatively refractory to *vivax* malaria but can be a great reservoir of *falciparum* infection in the South. Furthermore, the easier access of anophelines to the poorly constructed and maintained homes of many of the Negroes increased the numbers of their new infections, and the general unavailability of adequate treatment prolonged their parasitemias. Thus, the location of military camps in the Southeast, where the adjacent Negro population frequently outnumbered the white, could have resulted in an enhanced exposure of training troops to the more deadly type of malaria, unless active measures had been taken to forestall it.

Both *vivax* and *falciparum* infections are more prevalent during the warm seasons of the year than in the winter. In areas where they coexist, the pattern of *Plasmodium falciparum* incidence is the simpler of the two. It makes

[7] Faust, E. C.: Malaria Incidence in North America. *In* Malariology, edited by Mark F. Boyd. Philadelphia: W. B. Saunders Co., 1949, vol. I, pp. 749–763.

its appearance in the spring and increases very slowly. When warm weather arrives, the rate accelerates and a sudden peak is attained in the late summer or fall. In comparison, the *Plasmodium vivax* cycle is more complex in that it usually shows two separate increases during a season. The greater of these increases may coincide with or slightly precede that of *P. falciparum*. The lesser one manifests itself as a rule in the late winter or early spring months. These vernal attacks are either relapses of infections contracted and exhibited during the previous summer and fall, or represent primary onsets occurring after overwinter incubation.[8] This latter characteristic has been found to be typical of Temperate Zone strains of *vivax* malaria.[9]

During World War I, mosquito control operations were carried on within military reservations by the Army, and around camps, recreation areas, and war industrial plants in malarious regions by the U.S. Public Health Service to protect military trainees and civilian war industry workers. Some $3,250,000 were spent by military authorities on drainage and oiling during 1918 and 1919.[10] No records are available to show just how much of the $2 million appropriated by Congress to the U.S. Public Health Service for extracantonmental sanitation was used for malaria control—nor of the additional funds, labor, and materials, contributed by the American Red Cross, railroads, State and county health departments and, in some instances, by cities—but the total must have been considerable.[11]

In spite of these expenditures, 10,510 admissions for malaria were reported among Zone of Interior troops from April 1917 through December 1919, involving a loss of 130,673 training days.[12] This experience emphasized the necessity for devising more economical methods of malaria prevention. Therefore, studies on rural malaria control technology were continued after World War I, and cheaper temporary measures such as screening and larviciding were demonstrated and promoted in the years following. Parasitologic and entomologic studies were resumed by the U.S. Public Health Service and State health departments. In 1931, the Bureau of Entomology in the U.S. Department of Agriculture established the Orlando Laboratory in Florida for the study of insects affecting man; this led to productive research in the entomology of malaria. Improvements in malaria reductive techniques included the dem-

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[8] Boyd, M. F.: Epidemiology of Malaria: Factors Related to the Intermediate Host. *In* Malariology, edited by Mark F. Boyd. Philadelphia: W. B. Saunders Co., 1949, vol. 1, pp. 551–607.

[9] (1) de Buck, A.: Some Results of Six Years' Mosquito Infection Work. Am. J. Hyg. 24: 1–18, July 1936. (2) Coatney, G. R., Cooper, W. C., Ruhe, D. S., Young, M. D., and Burgess, R. W.: Studies in Human Malaria. XVIII. The Life Pattern of Sporozoite-Induced St. Elizabeth Strain *Vivax* Malaria. Am. J. Hyg. 51: 200–215, March 1950. (3) Alving, A. S., Arnold, J., and Robinson, D. H.: Status of Primaquine. 1. Mass Therapy of Subclinical *Vivax* Malaria with Primaquine. J.A.M.A. 149: 1558–1562, 23 Aug. 1952.

[10] The Medical Department of the United States Army in the World War. Sanitation. Washington: Government Printing Office, 1926, vol. VI, p. 332.

[11] Annual Report, Surgeon General of the Public Health Service of the United States. Washington: Government Printing Office, 1919.

[12] The Medical Department of the United States Army in the World War. Statistics. Washington: Government Printing Office, 1925, vol. XV, pt. 2, pp. 87 and 215.

onstration of paris green as an anopheline larvicide.[13] The extensive use of this substance brought about more effective and cheaper methods of application, including power dusting from trucks, boats, and airplanes. In 1923, the Rockefeller Foundation opened a malaria research station in south Georgia from which came many basic contributions and where the majority of the outstanding malariologists of this generation were trained.[14]

Another postwar development destined to become of great significance was the utilization of a traditional component of insect-killing dusts, pyrethrum, in kerosene as a spray.[15] This was introduced in 1919 but did not become popular as a household insecticide until about 10 years later.

Quinine had long been taken prophylactically by the residents of highly endemic areas to reduce the symptoms of malaria,[16] but it could not be depended upon to effect radical cures. While it may have interfered to some degree with malaria transmission, it is doubtful that it ever did so to any major extent. Atabrine was introduced in the early thirties and was promptly tested in south Georgia with considerable success;[17] indeed, its intensive use may have modified the distribution of *falciparum* malaria in the South.

Since its creation in 1933 for the development of the Tennessee River system, the Tennessee Valley Authority has been interested in malaria control. The studies and operations of the Health and Safety Department of the Tennessee Valley Authority have resulted not only in significant reductions in the malaria and anopheline problems in this region but have provided the basis for improved water management principles and procedures which can be applied wherever water is impounded in potentially malarious areas.[18]

During the depression years and up to World War II, Federal relief organizations (the Federal Civil Works Administration and Federal Emergency Relief Administration established in 1933 and the Works Progress Administration in 1935) supplied manpower for malaria control purposes. A tremendous amount of drainage was accomplished through these projects. It has been estimated that the combined relief programs involved a daily average of 211,000 men for 6.5 years working on malaria control drainage in an average of 250 counties.[19] In the 16 southeastern States, 33,655 miles of ditches were dug eliminating 544,414 acres of anopheline breeding area.

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[13] Barber, M. A., and Hayne, T. B.: Arsenic as a Larvicide for Anopheline Larvae. Pub. Health Rep. 36: 3027–3034, 9 Dec. 1921.

[14] Russell, Paul F., West, Luther S., and Manwell, Reginald D.: Practical Malariology. Philadelphia: W. B. Saunders Co., 1946.

[15] Gnadinger, C. B.: Pyrethrum Flowers. Minneapolis: McLaughlin Gormley King Co., 1933.

[16] Andrews, J. M.: What's Happening to Malaria in the U.S.A.? Am. J. Pub. Health 38: 931–942. July 1948.

[17] Seckinger, D. L.: Atabrine and Plasmochin in the Treatment and Control of Malaria. Am. J. Trop. Med. 15: 631–649, November 1935.

[18] Federal Security Agency, U.S. Public Health Service, and Tennessee Valley Authority, Health and Safety Department. Malaria Control on Impounded Water. Washington: U.S. Government Printing Office, 1947.

[19] See footnote 5 (1), p. 62.

The Social Security Act passed in 1935 and its extension in 1939 provided for malaria survey and control personnel to be added to State health departments and for an increase in the number of local health departments through which antimalaria activities could be promoted and administered.[20] This stimulated the interest of States and counties in malaria control which, with operational assistance from the Works Progress Administration (renamed Work Projects Administration on 1 July 1939), advanced environmental malaria control until late 1941. It was from these malaria survey and control teams in States that the Armed Forces were to draw so heavily for their own units.

CIVILIAN RESERVOIR OF INFECTION

The civilian population which constituted the reservoir in the southeastern United States from which military personnel were liable to infection was made up of underprivileged inhabitants—white and Negro—of rural areas. For the most part they were tenant farmers, sharecroppers, or hired farm laborers. Many were undernourished and chronically ailing from secondary anemias due to their limited diet but frequently compounded by malaria and, in sandy coastal areas, by heavy hookworm infestation. Medical care was scantily available and beyond the financial reach of many of these families, so these defects were rarely corrected.

The principal forms of recreation of these people were sitting out in front of their homes in the hot summer evenings, fishing at night, and an occasional sociable which brought groups of all ages together after dark at country churches or schoolhouses. All these pastimes permitted free exposure to mosquitoes. Nor were these people much better protected when they were within their own homes, for these structures were rude, ramshackle hovels, unscreened and with gaping holes in floors, sidewalls, and roofs, providing easy access by nocturnally active, blood-hungry anophelines. Thus, malaria was continuously maintained in this population at levels which were notably lower than those which had prevailed during previous generations but which in many localities were still considerable. This was evidenced by high indices of blood parasitism and splenomegaly among school children.[21]

The construction and operation of military training camps offered lucrative opportunities of which many of these people hastened to take advantage. In numerous instances, they relocated their families near military installations, thus bringing malaria parasite carriers into proximal relationship to military trainees. Added to this was the special risk of troops during maneuvers, night

[20] (1) Public Law 271, 74th Cong., 1st sess. (2) Public Law 379, 76th Cong., 1st sess.

[21] (1) Watson, R. B., and Rice, M. E.: Some Epidemiological Characteristics of Malaria in North Alabama as Determined by Data Collected Over the Twenty-Year Period 1923–1942. Am. J. Hyg. 40: 199–208, September 1944. (2) Final Summary of 1937 Fall Malariometry. *In* Georgia Malaria Bulletin 1: 47–51, October 1938. (3) 1938 Malariometry. *In* Georgia Malaria Bulletin 2: 59–60, November–December 1938. (4) Hill, A. W.: Summary of 1939 Malariometry. *In* Georgia Malaria Bulletin 3: 56–59, June 1940.

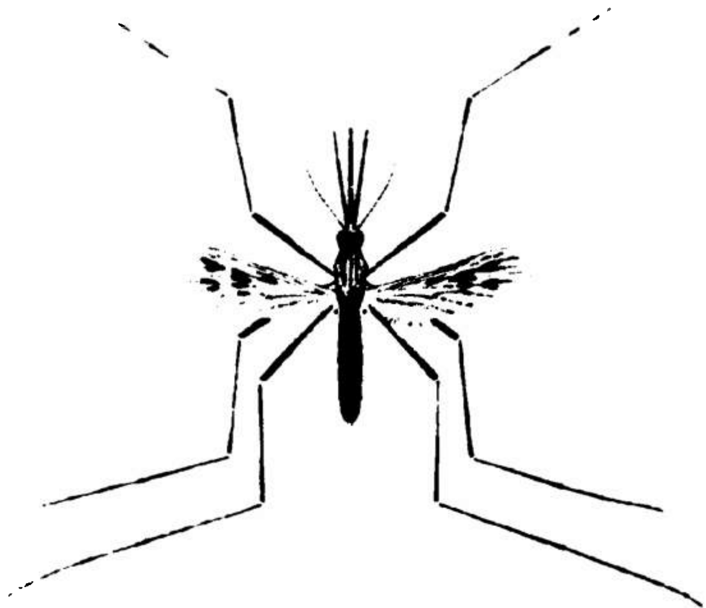

FIGURE 13.—*Anopheles quadrimaculatus*, the vector of malaria in the eastern and southern regions of the continental United States.

exercises, guard duty at night, and other details and activities entailing exposure to anophelines after dark. It is truly remarkable that more cases of malaria did not develop among the military population. It seems reasonable to suppose that malaria would have been much more prevalent among the trainees had not effective measures been taken to minimize this hazard.

MOSQUITO VECTORS

On the basis of experimental infectibility, observed infection in nature, human-blood feeding habits, and epidemiological correlation with the occurrence of human malaria, two species of mosquitoes have been shown to be the principal and possibly the only transmitters of malaria in the United States. These are *Anopheles quadrimaculatus* Say (fig. 13) found in the eastern and southern regions of this country and *Anopheles freeborni* Aitken (fig. 14) found west of the Rocky Mountains (map 5). A third species, *Anopheles albimanus* Wiedemann, an important transmitter of malaria in the Caribbean area, has been found in the lower Rio Grande Valley of Texas and rarely in southern Florida. However, since none of this species has been found natu-

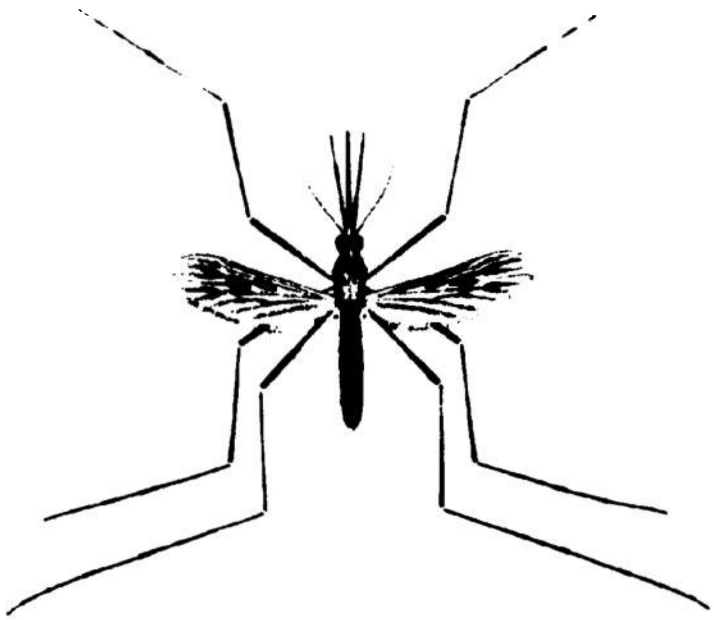

FIGURE 14.—*Anopheles freeborni*, the vector of malaria west of the Rocky Mountains in the continental United States.

rally infected and since *A. quadrimaculatus* occurs in large numbers in the same areas, *A. albimanus* is not considered a malaria vector of any consequence in the United States.[22]

There are certain characteristics of these two important species of anophelines which are of significance in planning malaria control programs. *A. quadrimaculatus* and *A. freeborni* are primarily fresh water breeders and are found more often in the clean, still, slightly alkaline waters of permanent or semipermanent pools or ponds where surface-intersecting vegetation or inanimate flotage is abundant. In the larval microhabitat, *A. quadrimaculatus* is associated predominantly with mixed sunshine and shade or "broken shade" and *A. freeborni* with open sunlit water surfaces. Both species can tolerate considerable variation in and departure from optimal light values when the other ecologic factors favor oviposition and larval development. Thus, throughout the southeastern United States, *A. quadrimaculatus* thrives in large and small artificial impoundments, marginal river swamps, wet lime sinks, and flooded ricefields.

[22] Andrews, Justin M.: Malaria Control in the Nearctic Region. *In* Malariology, edited by Mark F. Boyd. Philadelphia: W. B. Saunders Co., 1949, vol. II, pp. 1385–1399.

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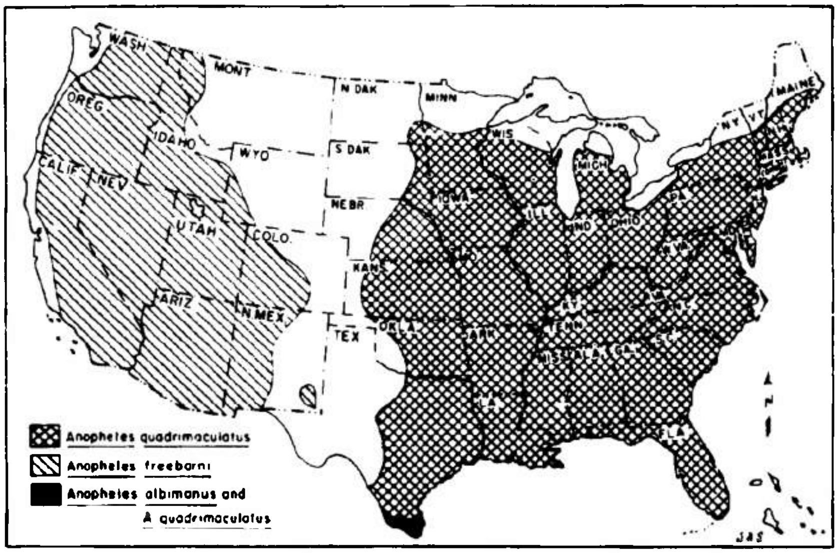

MAP 5.—Geographic distribution of three species of anophelines associated with malaria transmission in the continental United States.

In the western United States, *A. freeborni* is often associated with irrigation, being found in the seepage or overflow water from such systems or in their neglected grass-grown ditches. Like *A. quadrimaculatus*, this species flourishes in ricefields and borrow pits but, unlike its eastern counterpart, shows a propensity for temporary breeding places such as water-holding animal hoofprints and vehicle ruts. It can adapt itself successfully to brackish water (salinity equal to 15 percent sea water), where its distribution carries it to coastal zones, and also to highly mineralized desert pools. The larvae of both species, in common with those of all other mosquitoes, are eagerly sought by the top minnow, *Gambusia affinis*. Under optimal conditions, the aquatic stages require at least 10 days for their development.

The adults of these two species also have similar habits. Precipitin tests of the stomach contents of females of both species indicate a high proportion of bovine blood, with equine, porcine, and human appearing in decreasing amounts. Even though these mosquitoes are the nearctic anophelines most fond of human blood, these tests reveal that they prefer cattle hosts.

During the transmission season, both *A. quadrimaculatus* and *A. freeborni* enter homes without hesitation and rest in the darkest corners and nooks in the day and emerge at night to feed; even larger numbers of them choose stables and other animal shelters.[23] *A. quadrimaculatus* also gather in tree holes, in caves, and under bridges and culverts.

Although both species overwinter in the adult stage, their habits in this period vary somewhat. The fertilized *A. quadrimaculatus* females retire in the fall to dark sheltered spots, such as unoccupied buildings, basements, root cellars, tree holes, and similar locations, usually in close proximity to breeding places, where they remain relatively inactive. On the other hand, during the fall and winter months, *A. freeborni* females convert their blood meals to fat body rather than to eggs. After mating, they migrate for long distances, sometimes as far as 10 to 12 miles from breeding areas, and seek shelter in outbuildings, houses, cellars, caves, and under bridges, without regard to the presence of man or other animals. Throughout the winter months, they manifest considerable activity, moving about and changing from one resting place to another. During this period of semihibernation, these mosquitoes are prone to bite man in warm buildings or even to attack him in the open on warm evenings. In February, the females emerge, bite viciously in full daylight, and continue their fall migration. This spring emergence and distribution flight is said to cover distances, as great as the fall migration, but in a shorter period. At this time their eggs develop, egg laying occurs in both favorable and unfavorable breeding places, and within 2 or 3 weeks all the adult females disappear and only the larval stages are found. Within approximately a month, the first brood of adults for the new season appears.

The effective flight ranges of both species are usually considered to be about one mile, but it is known that longer flights occur occasionally.

DEVELOPMENT OF MILITARY MALARIA CONTROL PLAN AND POLICY

The outbreak of hostilities in Europe in 1939 set the U.S. defense program into motion. The President declared a limited national emergency, and the Congress passed the Selective Training and Service Act in 1940. By the end of 1940, the training of troops had begun, and industrial plants were being enlarged or constructed to produce the necessary materiel to supply not only our own needs but also those of our future allies. Many munitions plants, airplane factories, and shipyards were erected in the South where both space and manpower were readily available. Army posts and training centers were established also in this region where climatic conditions favored the year-round operations necessary to our all-out defense preparation effort. As a result of these activities, large numbers of individuals—both military and civilian—were introduced from other parts of the United States into these areas where malaria was historically endemic. These new opportunities for employment cut heavily into the numbers of men on Work Projects Administration (formerly Works

[23] Freeborn, Stanley B.: Anophelines of the Nearctic Region. *In* Malariology, edited by Mark F. Boyd. Philadelphia: W. B. Saunders Co., 1949, vol. I, pp. 379-398.

Progress Administration) rosters. Thus, malaria control drainage projects previously manned by this organization tapered off rapidly.

On military property, Army authorities operated malaria control activities, but they were not authorized to extend these to adjacent civilian establishments and domains certain to be used by trainees, nor to undertake them on and about the areas where defense industries essential to the future war effort were located. Experienced State malaria control and survey teams were being drawn upon heavily for staffing the Army malaria control organization, so that State health departments were unable to assume this responsibility.

Fortunately, arrangements had already been effected through an interchange of communications early in 1940 between the Secretary of War and the Federal Security Administrator whereby the U.S. Public Health Service, operating under the authority of existing laws and using its own resources, was to cooperate with the Army "in safeguarding the health of military personnel by suitable measures of extramilitary area sanitation in connection with the present concentration of troops in the South."[24] This had been developed initially to help check the increases in venereal diseases acquired by soldiers from civilians. For this purpose, during or shortly after November 1940, liaison personnel had been detailed by the U.S. Public Health Service to each Corps Area Headquarters to effect operational contact between military and civilian health authorities during maneuvers. This provision was quickly extended to include extracantonmental zones.[25] The existing authority was broad enough to carry on extramilitary malaria control activities under the same auspices, and so it was proposed originally to operate malaria mosquito control projects around camps through these liaison officers, the State health departments, the Work Projects Administration, and the district offices of the U.S. Public Health Service.

Experience during 1941, however, proved the infeasibility of this procedure, and, in early 1942, the Army requested information concerning future plans of the U.S. Public Health Service regarding extramilitary mosquito control activities.[26] Shortly thereafter, the U.S. Public Health Service activated a special organization[27] known ultimately as the Office of Malaria Control in War Areas, generally referred to as the "MCWA," to direct and coordinate the efforts of Federal, State, and local health agencies near military establishments and to help integrate on an area basis the malaria mosquito control activities of military and civilian workers.

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[24] Letter, The Secretary of War, to Paul V. McNutt, Administrator, Federal Security Agency, 30 Jan. 1940, and reply thereto, 12 Feb. 1940.

[25] Letter, The Adjutant General, War Department, to the Commanding General, Fourth Corps Area, Atlanta, Ga., 4 May 1940, subject: Extension of Present Utilization of the U.S. Public Health Service.

[26] Letter, Henry L. Stimson, Secretary of War, to Paul V. McNutt, Administrator, Federal Security Agency, 6 Feb. 1942, and reply thereto, 12 Feb. 1942.

[27] Extra Military Zone Circular Letter No. 7, Surgeon General, U.S. Public Health Service, Federal Security Agency, to District Directors, U.S. Public Health Liaison Officers, and State Health Officers concerned, 10 Feb. 1942, subject: The Policy and General Procedure to Govern the Operation of the Malaria Mosquito Control Program.

Thus, two related but separately administered programs of insect control were carried on in the United States to protect the health of military personnel and war industry employees in World War II. The first program was directed, executed, and financed by the Army on Army property. It was aimed at reducing the number of all pestiferous insects—whether or not they transmitted malaria or any other disease—as the Army has always recognized the important role of all insect pests in decreasing the morale, comfort, and efficiency of troops.[28] It is not possible therefore to identify from existing records the volume of work done nor money spent by the Army for malaria mosquito control alone.

The second program was directed and coordinated by the U.S. Public Health Service and executed by this organization with the collaboration of State and local health departments. It was supported by funds appropriated for "Emergency Health and Sanitation Activities"[29] and was designed solely to prevent malaria transmission on civilian property used by military personnel and civilian war industry workers.

MALARIA CONTROL ACTIVITIES WITHIN MILITARY AREAS

The story of intramilitary malaria control activities within the Zone of Interior is related in other chapters of this history.[30] It is the purpose of this section to supplement that information where possible, to indicate the magnitude of the total accomplishments, and to estimate the probable impact of these events on the prevalence, control, and prevention of paludism in this country during peacetime and in future wars. In this connection, it is important to recall that it was during World War II that advances were made in antivector malaria control technology which were probably of greater consequence than any other preventive information developed since Ross solved the mystery of malaria transmission just before the turn of the century. These improvements changed the emphasis in type of antimalaria activity within and beyond military reservations from 1940 to 1946, and this, in turn, resulted in a shift in the professional direction of antianopheline and other insect control operations on military establishments during and after World War II. The new procedures, first practiced by the Army, led to an enlargement of the

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[28] Army Regulations No. 40–205, 31 Dec. 1942.

[29] (1) Public Law 9, 77th Cong., 1st sess. (2) Public Law 146, 77th Cong., 1st sess. (3) Public Law 150, 77th Cong., 1st sess. (4) Public Law 463, 77th Cong., 2d sess. (5) Public Law 647, 77th Cong., 2d sess. (6) Public Law 132, 78th Cong., 1st sess. (7) Public Law 135, 78th Cong., 1st sess. (8) Public Law 373, 78th Cong., 2d sess. (9) Public Law 529, 78th Cong., 2d sess. (10) Public Law 124, 79th Cong., 1st sess.

[30] (1) Hardenbergh, William A.: Control of Insects. *In* Medical Department, United States Army. Preventive Medicine in World War II. Volume II. Environmental Hygiene. Washington: U.S. Government Printing Office, 1955. (2) McCoy, O. R.: War Department Provisions for Malaria Control. Chapter II of this volume, p. 11. (3) Hardenbergh, William A.: The Research Background of Insect and Rodent Control. *In* Medical Department, United States Army. Preventive Medicine in World War II. Volume II. Environmental Hygiene. Washington: U.S. Government Printing Office, 1955.

civilian objectives of malaria control from incomplete reduction of morbidity in limited areas to total eradication of the disease from large ones.

Hardenbergh [31] reported that the organizational responsibility in the Army for the control of insects, including anopheline mosquitoes, was not clearly defined in 1940 and that it underwent substantial evolution during the early years of defense preparation and actual engagement in World War II. To recapitulate briefly, the probability of malaria incapacitating training troops in southern camps was recognized in 1940 within the Preventive Medicine Subdivision, Professional Service Division, Office of The Surgeon General, U.S. Army. Immediate responsibility for planning, organizing, staffing, and financing malaria mosquito control was assumed by the Sanitary Engineering Division of that Service as it was evident that the Quartermaster Corps, traditionally liable for such activities, would be unprepared to cope with an anopheline reduction program of such unprecedented magnitude by the time operations should be commenced in 1941 in order to protect troops quartered that summer in southern camps. Thus, for the balance of fiscal year 1941, the malaria mosquito control operations in the continental United States were financed by the Medical Department and executed under the immediate direction of the Medical Department personnel (map 6). On 1 July 1941, the nominal work responsibility was resumed, and the program was financed by the Quartermaster Corps, though the activities were actually directed for the rest of the mosquito season by the Medical Department.

On 1 December 1941, responsibility for the entire Army construction, maintenance, and repair—including insect and rodent control—was transferred by law [32] from the Quartermaster Corps to the Corps of Engineers. The continental mosquito control program was taken over by the Corps of Engineers on 16 December 1941 and was operated by them thereafter in accordance with their provisions [33] and the recommendations of the Medical Department, and under such Medical Department technical guidance as was necessary.[34] Until 1 July 1943, these activities which included budgeting funds, authorizing post engineers to employ supervisors, foremen, and laborers for the execution of control measures, and supplying specialized equipment and materials for use by the Corps of Engineers were nominally supervised and coordinated in the Repairs and Utilities Division of the Office of the Chief of Engineers.[35] The Sanitary Engineering Division of the Preventive Medicine Service, Surgeon General's Office, continued, however, to provide much professional guidance and direction Service Command engineers consolidated estimates of mosquito control costs submitted from camps and posts and exercised general

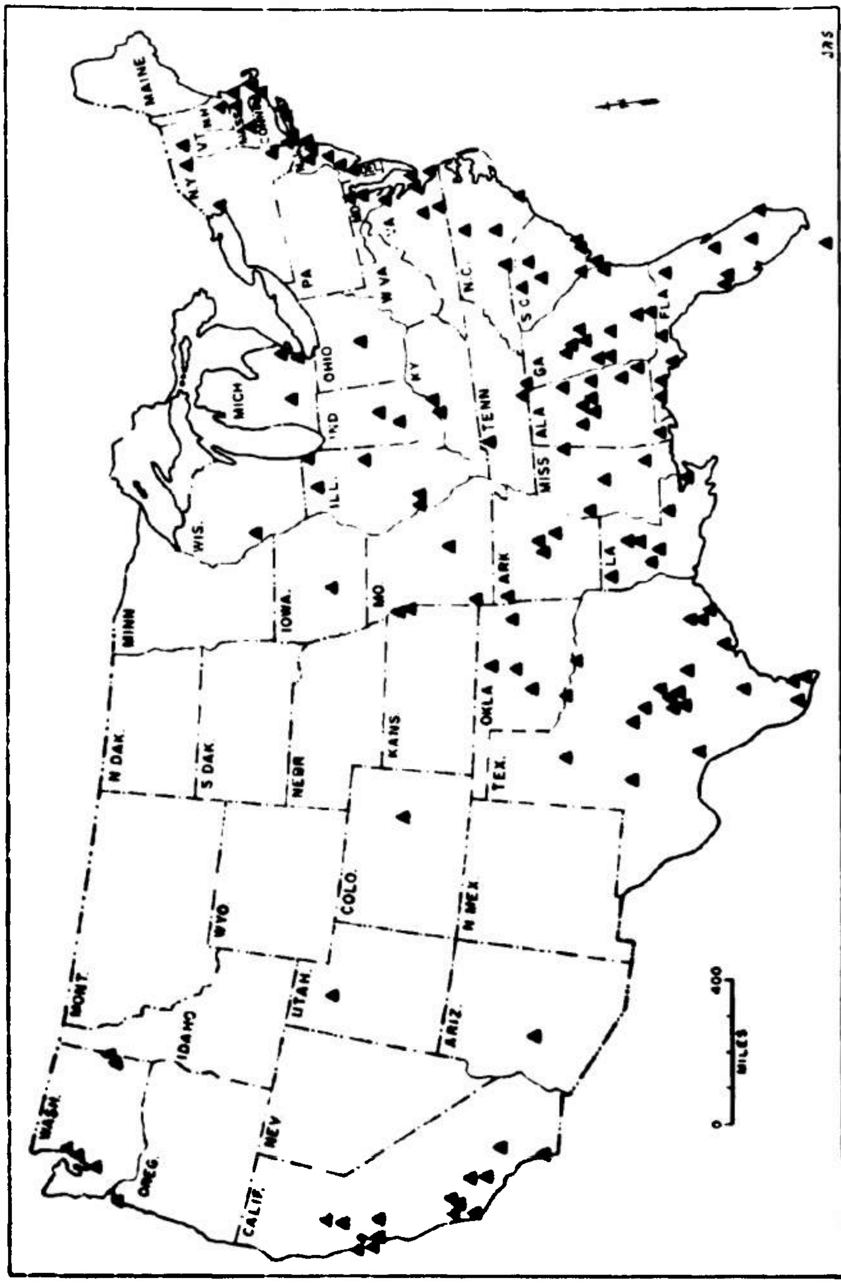
[31] See footnote 30 (1), p. 75.

[32] Public Law 326, 77th Cong., 1st sess.

[33] Army Regulations No. 100-80, 9 June 1942, and changes thereto.

[34] (1) See footnote 28, p. 75. (2) Army Regulations No. 40-210, 15 Sept. 1942, and changes thereto.

[35] Memorandum, Col. Robert J. Carpenter, MC, Executive Officer, Office of the Surgeon General, U.S. Army, for Chief of Engineers, ASF, 13 Mar. 1946, subject: Source Material for Malaria Control History, and reply thereto, April 1946, subject: Malaria Control History—World War II—Corps of Engineers.



MAP 6.—Location of Army installations in the continental United States, where mosquito control was carried out in 1941.

U.S. Army photograph

FIGURE 15.—Area of Army installation (A) before and (B) after mosquito control drainage.

coordination of the work. This included drainage, filling, ditch lining and stabilization, clearing, cleaning, and larviciding with oil, paris green, and other chemicals (fig. 15). Post engineers directed these operations and made estimates of future costs with the assistance of Sanitary Corps engineers and entomologists assigned to most of the military installations in the south.

With all the insect control sanitation accomplished during the early years of the war effort, it might be assumed that the continental malaria hazard on military areas would have diminished to a negligible level. However, the rotation home of troops from malarious areas overseas and the importation of prisoners of war and labor battalions from endemic areas abroad resulted in the frequent, almost continuous, introduction on or near Army installations in the Zone of Interior of clinically obvious cases of malaria and undoubtedly many more asymptomatic carriers of malaria parasites. It was proved experimentally by U.S. Public Health Service scientists that the native anopheline vectors in this country were infectible with and could transmit extracontinental strains of malaria organisms.[36] Thus, it was necessary until the end of the war to maintain constant vigilance to discover previously unknown sources of anophelism and to evaluate repeatedly the results of antimosquito efforts (map 7). This required ecologic knowledge of these insects, beyond that possessed by most engineers, and a more thorough and extended familiarity with the terrain of camps than could be developed by Sanitary Corps entomologists if detailed to these camps for brief periods.

By July 1, 1943, the program had become so large and technically exacting that an Insect and Rodent Control Section was organized in the Repairs and Utilities Division, Office of the Chief of Engineers, and placed under the direction of an experienced entomologist. Lt. (later Lt. Col.) W. Doyle Reed, SnC, was detailed to duty with the Corps of Engineers to fill this position, and Capt. (later Maj.) George D. Jones, SnC, was assigned as his assistant. The establishment of Insect and Rodent Control Sections in the offices of Service Command engineers was also authorized together with the appointment of technically trained professional entomologists. This had the advantage of providing competence not only against vector and pestiferous insects but also against property-destroying species of arthropods with which the engineers were now obliged to deal. The duties of the Service Command entomologists, as far as mosquito control was concerned, were to promote and coordinate these activities at post level,[37] to assist post engineers in planning and executing these operations, to prepare field instructions concerning them, to review insect control budget estimates made by post engineers for installation commanders, and to maintain liaison between the Corps of Engineers and the Medical Department, the Quartermaster Corps, and the U.S. Public Health Service with reference to mosquito control plans and activities. Post engineers were authorized to hire civilian labor who executed all mosquito control activities on posts, except where Medical Department units were stationed for mosquito control training purposes. This was all done in compliance with Medical Department recommendations and requirements.

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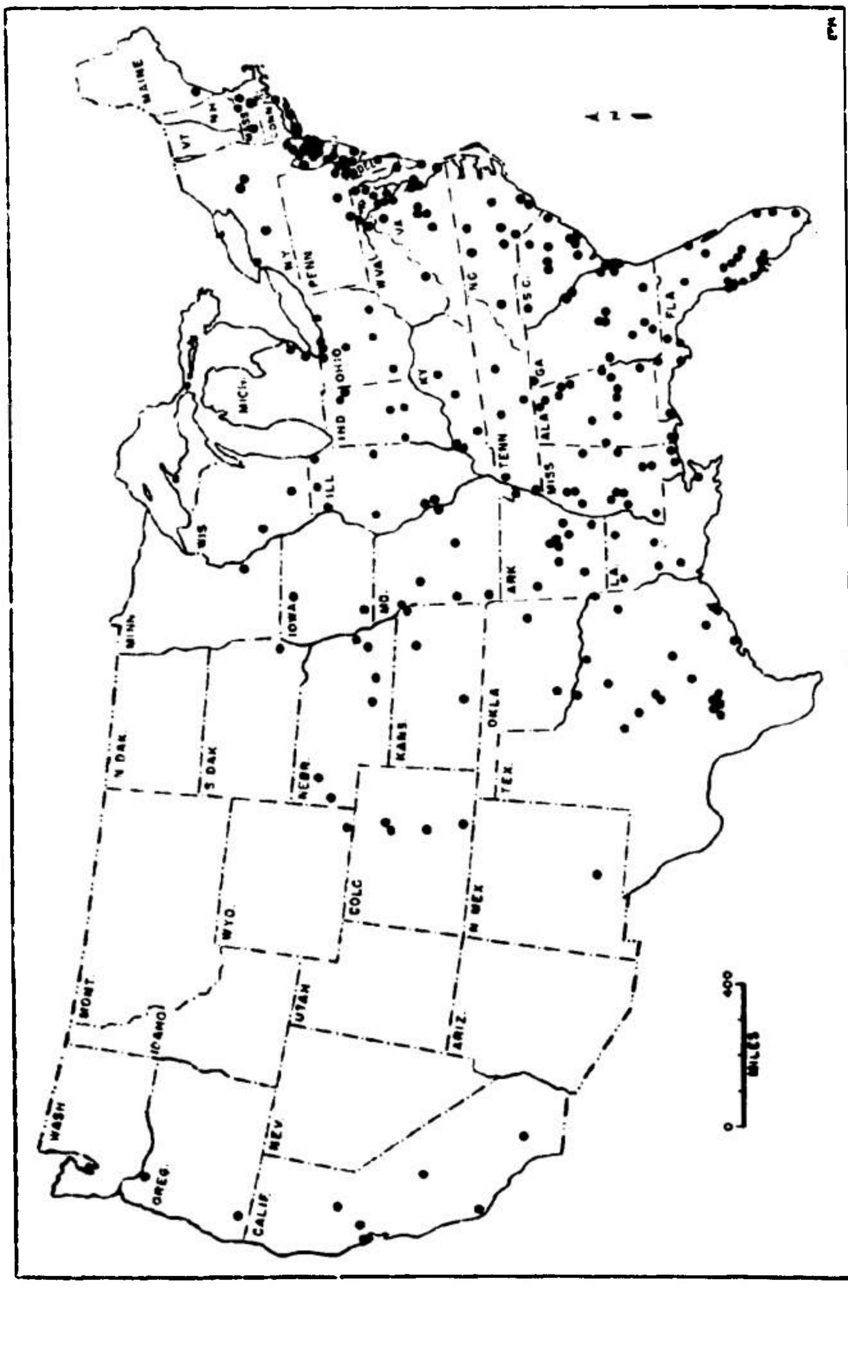
[36] Young, M. D., Eyles, D. E., and Burgess, R. W.: Studies on Imported Malarias; Evaluation of Foreign Malarias Introduced Into the United States by Returning Troops. J. Nat. Malaria Soc. 7: 171–185, September 1948.

[37] Anopheline control was never separated from culicine control within military establishments.



Map 7.—Location of Army installations in the continental United States, where mosquito control work was carried out in 1945.

FIGURE 16.—Knapsack-type sprayer developed by the Corps of Engineers for applying insecticides for mosquito control.

Developmental work was conducted in cooperation with the Engineer Board, Fort Belvoir, Va., for the improvement of equipment used in the dispersal of insecticides. A new 3-gallon knapsack sprayer was developed to replace the old 5-gallon type (fig. 16). Improvements were also made in mechanical high-pressure sprayers (fig. 17) and in the rotary, hand-operated dusters supplied by the Corps of Engineers for mosquito control.

FIGURE 17.—Portable power sprayer, gasoline engine driven, skid mounted, for application of insecticides for mosquito control.

Table 6 summarizes the intramilitary mosquito control work accomplishments and costs for the 5 fiscal years for which data are available. During this period, approximately 70 percent of the funds budgeted for insect and rodent control were spent for mosquito reduction. These expenditures, amounting to $11,584,525, were made at military posts, camps, and stations, totaling in area some 12,758,138 acres. Of these, approximately 1,164,855 acres were improved and maintained grounds where about 55 percent of the total outlay was made for permanent mosquito control measures. The remaining area (11,593,283 acres), consisting largely of rough terrain, received temporary treatment, such as larviciding and residual spraying.

In addition to setting forth the substantial dimensions of the total enterprise, table 6 shows that the antimosquito efforts changed materially in character and emphasis from 1 July 1943, with a decided shift away from heavy physical and costly operations aimed at destroying mosquito breeding areas by dewatering them. Much of the decrease in drainage, filling, and related activities was undoubtedly due to the fact that less remained to be done after 1 July 1943 because of previous accomplishments. It is believed, however, that this sharp reduction also reflects more careful and conservative technical discrimination, based upon entomologic considerations, in selecting for ditching

TABLE 6. *Summary of continental mosquito control operations on military property, fiscal years 1941–45*

Year	New ditching or channeling	Clearing or brushing	Channel or ditch cleaning	Fill	Ditch lining	Water surface eliminated
	Linear feet	*Acres*	*Linear feet*	*Cubic yards*	*Linear feet*	*Acres*
1941	1, 008, 530	1, 773	1, 245	130, 987	10, 554	.....
1942	3, 414, 144	66, 598	12, 297, 940	1, 912, 649	419, 926	15, 340
1943	3, 353, 454	97, 579	14, 525, 922	3, 018, 973	586, 736	17, 532
1944	684, 108	20, 172	8, 876, 952	691, 848	269, 950	6, 575
1945	188, 161	17, 379	4, 648, 972	666, 059	113, 082	4, 383
Total	8, 948, 397	203, 591	40, 351, 031	6, 420, 516	1, 400, 308	43, 830

Year	Diesel oil larvicide	Paris green larvicide	Other larvicides	5 percent DDT in oil	Expenditures
	Gallons	*Pounds*	*Gallons*	*Gallons*	
1941	100, 553	1, 920	4, 849	.....	[1] $1, 058, 000
1942	1, 704, 645	45, 904	241, 161	.....	3, 000, 000
1943	1, 591, 002	33, 384	129, 193	.....	3, 591, 205
1944	1, 236, 430	2, 403	36, 441	45, 102	2, 159, 717
1945	1, 150, 073	1, 771	23, 841	80, 155	1, 775, 603
Total	5, 782, 703	85, 382	435, 485	125, 257	11, 584, 525

[1] The "expenditures" for 1941 is quoted from Hardenbergh (Medical Department, United States Army. Preventive Medicine in World War II. Volume II. Environmental Hygiene. Washington: U.S. Government Printing Office, 1955, p. 180). It is probable that about 70 percent of this figure represented funds obligated in fiscal year 1941 for materials and purchases delivered after 30 June 1941.

Source: (1) April, May, and June Mosquito Reports for 4th and 8th Corps Areas for fiscal year 1941. Other Corps Area reports were not available, but it is believed that they would not have increased the totals shown by more than 25 percent. (2) Monthly Mosquito Control Activities Reports for fiscal years 1942–45, extracted and consolidated by Lt. Col. W. Doyle Reed, SnC. *In* Memorandum: Col. Robert J. Carpenter, MC, Executive Officer, Office of The Surgeon General, U.S. Army, for Chief of Engineers, ASF, 13 Mar. 1946, subject: Source Material for Malaria Control History, and reply thereto, April 1946, subject: Malaria Control History—World War II—Corps of Engineers.

or filling only those watered areas which were actually producing mosquitoes and the elimination of projects which could not properly be financed by mosquito control funds. A Surgeon General's Office directive to this effect had been issued in 1943.

Another factor of importance in the shift of emphasis from fiscal year 1943 to fiscal year 1944 was the advent of DDT. The effectiveness of this new and potent weapon against mosquitoes and numerous other vector and pestiferous arthropods was verified in the Orlando Laboratory of the U.S. Department of Agriculture. This remarkable compound became available in quantity for military use in the spring of 1944 and was effective either as a larvicide or as a residual insecticide. It could be dispersed by manually operated sprayers, mechanized spraying, or fogging equipment, or from airplanes (fig. 18). However DDT was applied, its distribution to secure maximum effectiveness

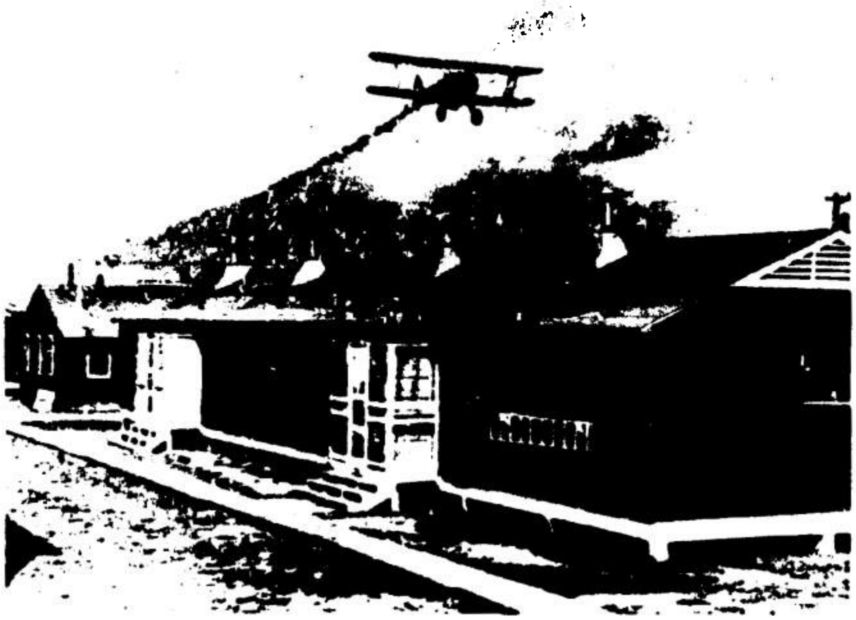


FIGURE 18.—Stearman biplane applying DDT to control anophelines over Stuttgart, Ark., Army Air Base.

without damaging consequences to wildlife required a fairly comprehensive biological understanding, thus justifying further the entomologic direction of the insect control activities within the continental United States. Within a brief period, residual DDT (fig. 19) decreased the necessity for and took the place of many other mosquito control measures. The demonstration of its unprecedented antianopheline effectiveness upon miliary premises during the last 2 years of the war led to its employment in 1945 in the Extended Malaria Control Program which was later phased into the National Malaria Eradication Program carried on cooperatively by the U.S. Public Health Service and various State health departments.[26]

Table 6 also indicates that diesel oil remained the preferred larvicide, presumably because of its destructive effect against both culicine and anopheline larvae and pupae, as well as its easy visibility on water which facilitates checking its recent application. Its use decreased slightly from year to year but not in proportion to the amount of water surface eliminated. Thus, it is evident

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[26] Andrews, J. M.: Nation-Wide Malaria Eradication Projects in the Americas. I. The Eradication Program in the U.S.A. J. Nat. Malaria Soc. 10: 99–121, June 1951.

FIGURE 19.—Hand-spraying residual DDT in Army barracks.

that a considerable extent of breeding area remained which could not be drained or filled practicably. Paris green and other larvicides (except diesel oil and DDT) were virtually discarded after the entomologists were placed in charge of insect control activities.

That these activities, supplemented by the U.S. Public Health Service Malaria Control in War Areas program, were successful from the standpoint of preventing malaria is shown in the following tabulation by (1) the low levels of admission rates for malaria among military personnel quartered in the United States, and (2) comparison with similar admission rates during World War I:

Year:	Rate [1]
1917	[2] 7.5
1918	[3] 3.9
1919	[3] 3.3
1941	[4] 1.7
1942	[4] .6
1943	[4] .2
1944	[4] .2
1945	[4] .1

[1] The rates shown in the tabulation are not limited to hospital cases only. They may include cases treated in quarters on an excused-from-duty basis and perhaps some cases treated on an outpatient basis.

[2] Rates are for enlisted men only.

[3] For 1917–19, the rates are for white enlisted men stationed in continental United States (including Alaska) and show the number of new cases of malaria reported as the primary cause of admission per 1,000 average strength. The rates for all Army personnel in continental United States were 3.9 (same as the rate for white enlisted men) in 1918 and 3.3 in 1919 per 1,000 average strength. For 1917, a similar rate is not available; however, for all enlisted men, the rate was 7.5 (same as the rate for white enlisted men).

[4] For 1941–45, the rates are for all Army personnel in continental United States and show the malaria attack rates (consists of new admissions, readmissions, and cases reporting malaria as secondary to other admission diagnoses) per 1,000 average strength.

Source: The rates for 1917–19 were derived from the annual reports of The Surgeon General. The rates for 1941 were derived from the periodic summaries of the Statistical Health Reports (provisional), 1941–45.

MALARIA CONTROL ACTIVITIES AROUND MILITARY AREAS [39]

Because malaria was the greatest menace to military training in the southeastern section of the country, the Surgeon General of the U.S. Public Health Service assigned his chief malariologist, Medical Director Col. Louis L. Williams, Jr., to the liaison detail with the Fourth Corps Area Headquarters, Atlanta, Ga., on 13 November 1940. Dr. Williams served in this capacity for over a year assisting State health departments, Corps Area personnel, and The Surgeon General's Office, U.S. Army,[40] in planning and executing malaria control projects on and near military bases. He was relieved 9 February 1942 and ordered "to remain in Atlanta, Georgia, to establish headquarters in connection with malaria control." After serious deliberation as to whether this mission might best be fulfilled through existing U.S. Public Health Service District Offices or by a special, nationwide organization, the decision was made

[39] Except as otherwise indicated, all data in the remaining portion of the chapter are derived from the following three sources: (1) Malaria Control in War Areas, 1942–46. *In* Summary of Activities, 1943–46. Office of Malaria Control in War Areas, Atlanta, U.S. Public Health Service. (2) Field Bulletins, Malaria Control in War Areas, October 1944–September 1945. (3) Organization Report in Lieu of Monthly Report, Malaria Control in War Areas, March–June 1942, pp. 1–2.

[40] Report, Lt. Col. W. A. Hardenbergh, SnC, to Chief, Preventive Medicine Subdivision, Professional Service Division, Office of The Surgeon General, undated, subject: Report of Trip with Dr. L. L. Williams to State and Local Health Departments and Camps in Fourth and Eighth Corps Areas.

for the latter, and Dr. Williams proceeded with the difficult task of assembling and organizing a malaria control staff.

The proposed plans, policies, and procedures of this organization were announced in two of the Extra Military Zone Circular Letters, a special series of communications issued by The Surgeon General for the guidance and coordination of U.S. Public Health Service Liaison Officers and District Directors, State health officers, the Work Projects Administration, and other concerned in the reduction of extramilitary health hazards. The first of the letters pertaining to the Atlanta malaria control headquarters was relased on 10 February 1942.[41] This refers to the organization as the "National Defense Malaria Control Activities," though current letterheads show that "Malaria Control in Defense Areas" was the name actually in use. On 20 April 1942, this name was changed officially "in conformity with the trends of the times" to "Malaria Control in War Areas,"[42] and the Circular Letter of 27 April 1942,[43] which superseded its predecessor, confirms the designation by which the organization was subsequently known.

This document stated that extramilitary malaria control activities would be confined to malarious areas; that pest mosquito control would not be undertaken as stipulated by the Bureau of the Budget; and that appropriated funds would be available to employ labor directly, to purchase equipment and supplies, to provide technical supervision of drainage projects operated by the Work Projects Administration, and to construct essential drainage facilities where the resources of the Work Projects Administration were insufficient. Operations were to be restricted to areas (1) contiguous to military establishments or essential war industries, (2) where large numbers of military personnel congregated, and (3) within or near housing developments for war workers. It specified the States, Territories, and Possessions in which these activities would be authorized. It indicated that the Office of Malaria Control in War Areas would function as an individual unit separate from the other Emergency Health and Sanitation Activities of the U.S. Public Health Service and that its authority would be exercised and its responsibility discharged in collaboration with the U.S. Public Health Service District Offices. Every effort was to be made to secure and utilize funds and other resources through State and local agencies. Lastly, it defined the respective roles, relative to malaria control, of its Headquarters Office, the District Offices, and the cooperating State health departments. The important principles embodied in these definitions were:

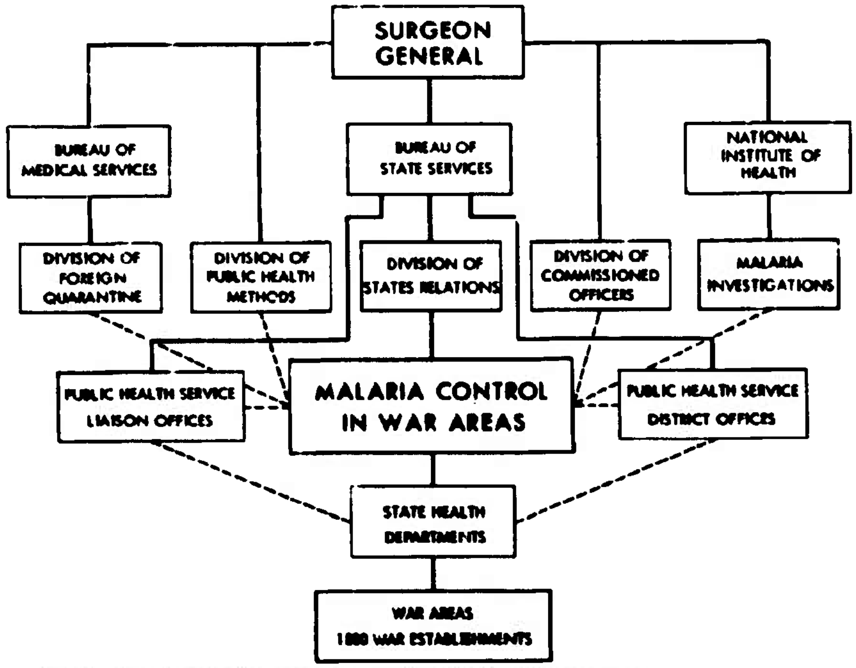
1. State health departments would perform the necessary surveys, plan, and operate the malaria control projects, supervising U.S. Public Health Service personnel assigned to them for those purposes.

[41] See footnote 27, p. 74.

[42] Manual Letter No. 14, Manual of Operations, Malaria Control in War Areas, U.S. Public Health Service, 20 Apr. 1942, subject: Change of Name to Malaria Control in War Areas.

[43] Extra Military Zone Circular Letter No. 3, Surgeon General, U.S. Public Health Service, Federal Security Agency, to District Directors, Public Health Service Liaison Officers, and State Health Officers concerned, 27 Apr. 1942, subject: Review of Policy and General Organization of Malaria Control in War Areas.

CHART 4.—*Malaria Control in War Areas, lines of authority and interrelations*



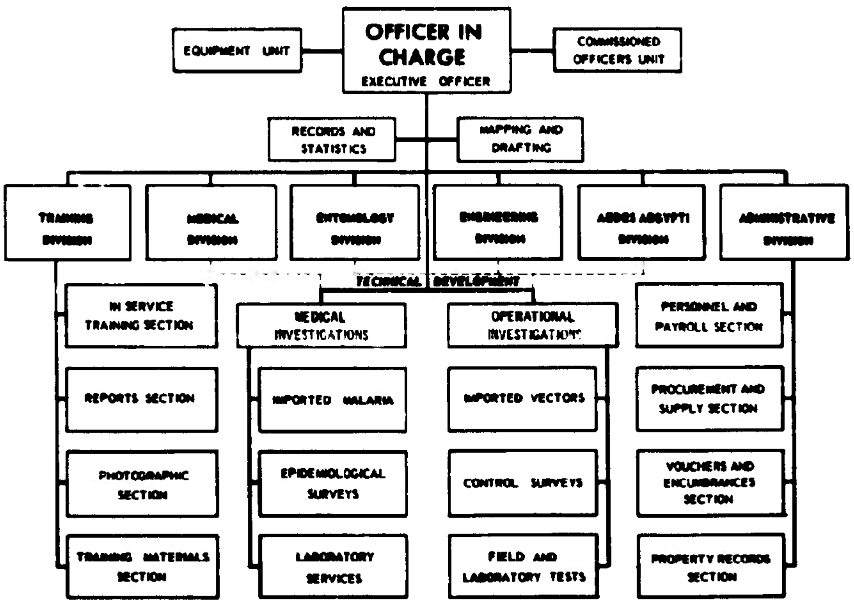
Source: Malaria Control in War Areas Field Bulletin, September 1944.

2. The Office of Malaria Control in War Areas would formulate policies governing the operation of the program; execute administrative control of and assume responsibility for fiscal personnel, and supply considerations; and exercise general technical supervision and coordination of projects and project operation.

3. District Offices would accept responsibility for Federal-States relations, assist in program planning and policy formulation, and collaborate in exercising general supervision over project operations.

Chart 4 shows that the Malaria Control in War Areas derived its authority from the Surgeon General, U.S. Public Health Service, through the Division of States Relations which in November 1943 became a division in the newly created Bureau of State Services. The military urgency of its mission and the broad geographic scope of its operations made this organization unique in the history of the U.S. Public Health Service. It was wisely recognized by officials at both Bureau and Division levels that to succeed in its objectives, the program must be allowed an unprecedented degree of autonomy and freedom. They encouraged rapid expansion and assisted in relaxing the usual strictures of government procedure in personnel and procurement actions. By the end of

CHART 5.—*Headquarters organization of the Office of Malaria Control in War Areas*



Source: Malaria Control in War Areas, 1943–44, p. 6. *In* Summary of Activities, 1942–46. Office of Malaria Control in War Areas, Atlanta, U.S. Public Health Service.

June 1942, Dr. Williams had obligated approximately $1,400,000 and had put 2,600 men to work in 93 areas within 15 States, the District of Columbia, and Puerto Rico.

Collaborative relations with other Bureaus and elements of the U.S. Public Health Service are also indicated in chart 4. On this basis, Malaria Control in War Areas entomologists were detailed to international airports where they assisted U.S. Public Health Service Foreign Quarantine authorities in excluding insect vectors of malaria and other diseases. Investigations were carried on with the National Institute of Health to determine whether or not native anophelines could transmit foreign strains of malaria parasites imported with infected military personnel. The Office of Malaria Control in War Areas depended largely on the U.S. Public Health Service Liaison Officers for coordinating its efforts with those of military health authorities, and upon the District Offices for initiating its program relations with States, for handling special problem situations, and for operating the activities in marginal States where the work volume did not justify a special Malaria Control in War Areas unit at State level.

The organizational plan of the Office of Malaria Control in War Areas varied somewhat from time to time, but chart 5 is representative of its structure.

With the exception of the *Aedes aegypti* Division (discussed later under "Related Activities"), it was laid out primarily on a professional category basis, though its activities were invariably characterized by a high degree of team work in planning and execution. The staff was composed for the most part of commissioned personnel from other elements of the U.S. Public Health Service, or recruited from other Federal or State agencies, and from universities. From the beginning, engineering and entomologic competences predominated, which was consistent with the nature of the operational objectives. Medical and parasitologic skills were recruited primarily for malariometric purposes in the field and in the laboratory, respectively. Training and health education specialists were acquired to carry on inservice training and a program of lay health education concerning malaria and its prevention. A relatively unique but indispensable adjunct of the organization was the Equipment Unit which was located in the Henry Carter Memorial Laboratory at Savannah, Ga., where its professional and technical personnel developed new and improved equipment, materials, and procedures for use in malaria control.

Before the war, several of the Southern States had developed basic organizations for malaria survey and control. These usually included a physician, an entomologist, and an engineer, a team which could locate and confirm malaria cases, appraise the local transmission potential, and initiate desirable control measures. This concept was accepted and actively promoted by the Malaria Control in War Areas in developing its field organization. In certain States, supervisory personnel had to be provided to replace or strengthen the staff of the State director of malaria control. The most frequent and pressing needs were for entomologists to train inspectors and to assist in organizing and checking field and laboratory activities, and for engineers to plan and supervise operations. Administrative and clerical personnel were also assigned where necessary. All of these individuals were directly responsible to the State director of malaria control in the State to which they were detailed. In some instances, this individual was the State health officer; in others, the director of preventable diseases, the State sanitary engineer, or a full-time malariologist without other duties.

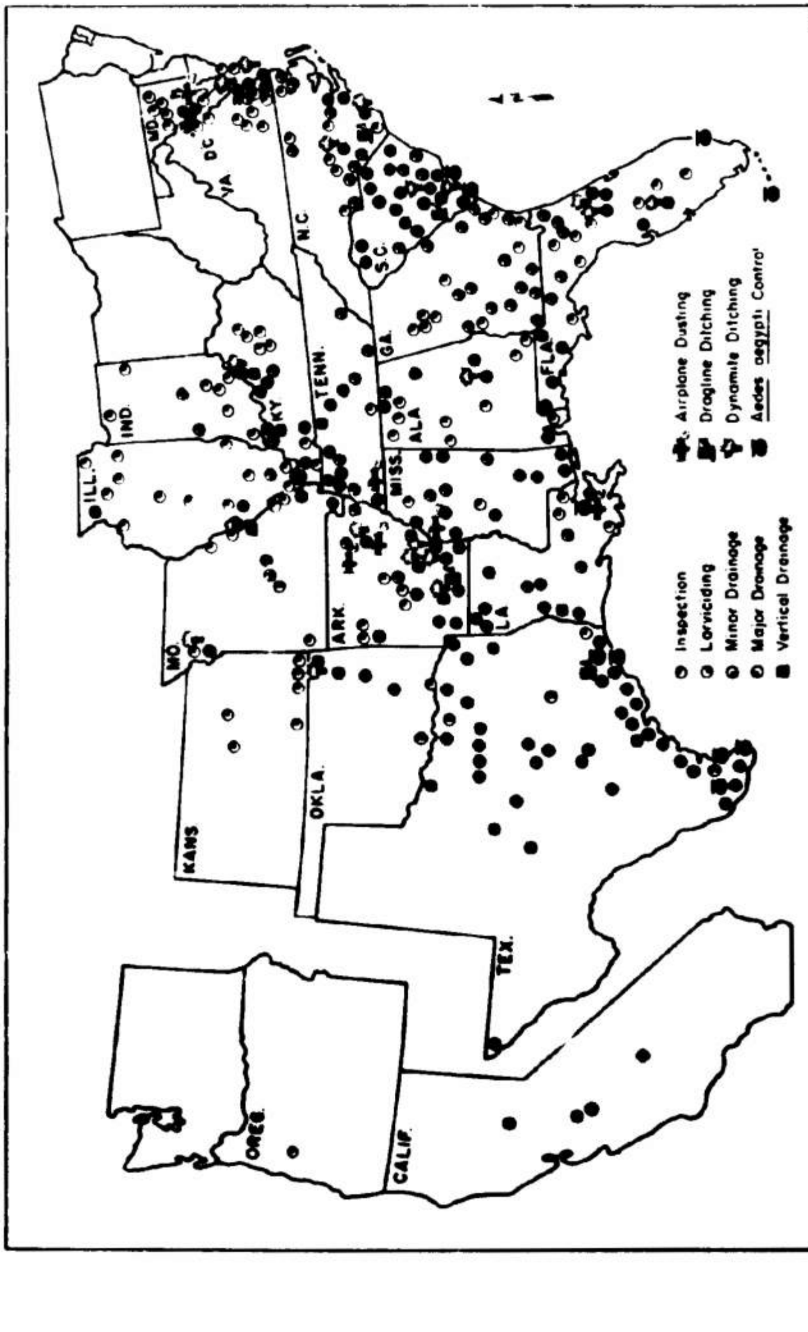
Recruiting and training on such short notice the large force of professional specialists, technical, administrative, and clerical assistants, and both skilled and unskilled labor needed to carry on the Malaria Control in War Areas activities would have been extremely difficult in normal times. In the face of mounting draft quotas and the high pay offered by war industries, it seemed impossible. It is the more remarkable that this technical operation which required some 3,300 employees before the end of 1942 and a maximum of 4,556 in August 1945 was accomplished with relatively few requests for deferment.

Actual operations were carried out almost entirely by the States, each State directing its own program through existing administrative channels and on the basis of its own legal authorization. Assistance from Malaria Control in

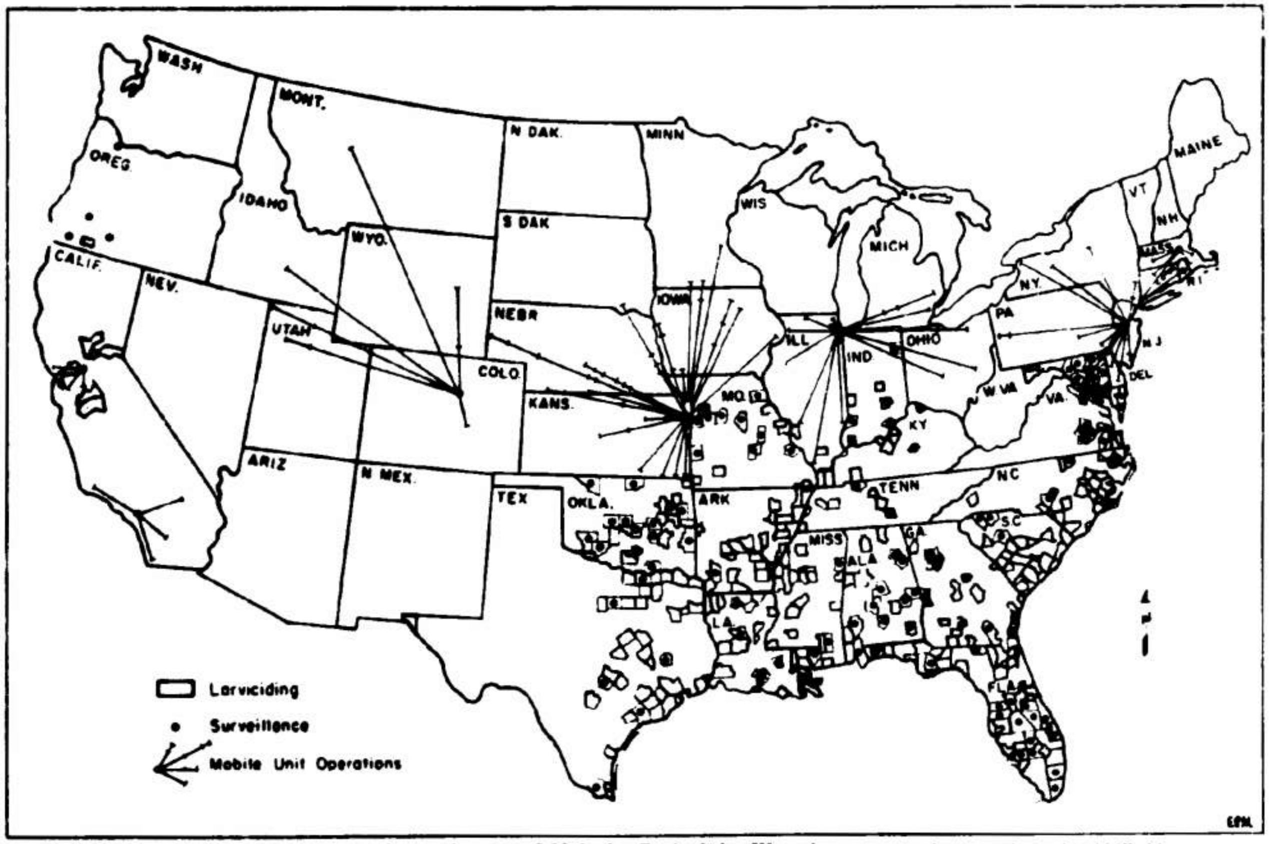
War Areas, in addition to trained personnel, consisted of specialized equipment, materials under wartime priority, technical development and consultation, advice on administrative and fiscal matters, training and training aids, and laboratory services. In the States where malaria had been endemic in the past, there were in 1942 some 900 so-called war establishments to be protected: by January 1945, the total had risen to approximately 2,000. These included military posts, camps, stations, bases, hospitals, depots, airfields, Navy yards, other military port areas, staging areas, prisoner-of-war camps, maneuver areas, access highways, extramilitary recreational centers, shipyards, airplane factories, ordnance works, other essential war industries, and housing developments for war workers. These war establishments were grouped, according to location and the nature and extent of the problem, into some 250 war areas, and an area supervisor, usually an engineer, was placed in charge of the malaria control activities to be carried on around each group of war establishments. He worked closely with the sanitation officers on adjacent military installations and with the local health officers. Thus, the war area was the geographic unit of operations (maps 8 and 9).

Efforts were made by the medical epidemiologists to get current, reliable appraisals of malaria prevalence near these war establishments using conventional methods of malariometry, but none of these was satisfactory because of the short time available, the paucity of trained medical investigators, and the general low prevalence of the disease. Ultimately, it was decided that the safest procedure was to base and evaluate malaria control activities on evidence of vectoral anophelism, on the thesis that the presence of malaria transmitters is a potential hazard even though malaria cases or parasitism may not be demonstrable in the area. When the density of malaria-carrying species of mosquitoes was considered significantly high, a control zone, 1 mile in width (the usual flight range of native vectors), was established around the military installation. All breeding places were located and spotted on the area map. Adult mosquito-catching stations were selected in representative locations so that the results of mosquito control operations could be assessed entomologically.

The area supervisor then visited and studied the control zone around the war establishment, usually with the entomologist. He observed the type and extent of the anopheline breeding places and decided what type of antilarval procedure—larviciding, minor drainage, or major drainage—would be most effective, feasible, and economical and whether or not it could be constructed or operated in conjunction with the intramilitary mosquito control activities. On the basis of these observations, he made cost estimates, planned a work program for the entire war area or areas under his supervision, requisitioned the necessary vehicles, equipment, and supplies, hired and trained inspectors, foremen, and laborers, and proceeded with the antimosquito operations. The activities and accomplishments of his crews were reported to the State office, Malaria Control in War Areas, at prescribed periods. Certain of the entomologic findings were sent directly to the Atlanta headquarters where current



MAP 8.—Geographic distribution and types of projects being carried on by Malaria Control in War Areas, 1 July 1943.



MAP 9.—Geographic distribution and types of Malaria Control in War Areas control operations in 1945–46.

information with which to answer official inquiries was maintained about the status of each project.

In States where the anopheline hazard was not sufficiently extensive or continuous to warrant maintaining state organizations for Malaria Control in War Areas, malaria mosquito control service was rendered as needed by mobile units. These were developed to provide surveillance around isolated war establishments such as Army general hospitals or prisoner-of-war camps in States of marginal endemicity and to take action if vector densities indicated the need for control. Each unit consisted of a passenger vehicle and a heavy truck containing the supplies, material, and equipment necessary to conduct surveys and inspections and to execute larvicidal or minor drainage operations. An entomologist or engineer was in charge of each unit and was responsible to the Office of the U.S. Public Health Service District in which the unit operated. The officer in charge hired his assistants and laborers locally. Arrangements for the assignment of units to areas within States were made between the District Office personnel and the health officers of the States involved. Each unit operated under the jurisdiction of the health officer of the State to which it was temporarily assigned. In 1944, two mobile units were assigned to each of two U.S. Public Health Service Districts and one each to four other Districts. Others were held at the Atlanta headquarters for emergency use.

The task of procuring supplies and equipment to implement these far-flung operations was a mammoth and continuing one. In arduousness, it was surpassed only by the problem of finding competent and industrious personnel. Wartime priorities and the scarcity of certain items added to its complexity. The acquisition of automotive equipment was an early necessity which never ceased to be a critical one. The Appropriation Acts prohibited the purchase of new or used passenger-carrying vehicles without special authorization, and during the war years such permission was virtually impossible to obtain. Thus, the most efficient utilization of equipment on hand was imperative. Fortunately, at that time, there was no regulation against the interdepartmental transfer of vehicles on a reimbursable basis, and, at the start of the program, 79 cars and trucks were so obtained from the Army. Other vitally needed prewar equipment was transferred from the Work Projects Administration and the National Youth Administration. More was acquired through the ingenuity and resourcefulness of those charged with this responsibility. By the end of the war, the inventory of the Malaria Control in War Areas carried a total of 1,046 separate kinds of items ranging from $12,000 draglines to rattraps. According to its official property records, vehicular units included at that time 3 airplanes, about 250 passenger cars, and roughly 2,000 trucks.

With such a highly dispersed operation carried on under duplicative authority and virtually autonomous state direction, the problem of coordination and integration and the maintenance of high standards of work performance was a most complex and challenging one. It was solved to a remarkably high degree by means of personal visits of headquarters staff to field operations sites, of annual conferences in Atlanta of District and State operational personnel who gathered to discuss and share their experiences, and of several types of official communications issued by the Atlanta office.

The first of these was a Manual of Operations which consisted of a looseleaf series of mimeographed Manual Letters issued at irregular intervals, starting 30 March 1942. The primary purpose of these letters was to interpret Extra Military Zone Circular Letter No. 8,[44] and to guide the operation and administration of the program. It was intended that the Manual would discuss items of a relatively permanent nature; information and instructions of a more temporary category were transmitted as Field Memoranda. A copy of the Manual was issued to each supervising employee for his guidance, and the letters in it were frequently revised. Thus, it served as a medium for maintaining current contact between the Atlanta office and the field, providing the latter with statements of policy, operating and administrative instructions, directives, and information concerning procedural improvements based upon group experience, research, and other activities. As of 1 July 1943, the Manual Letters were revised and reissued in separate numerical sequences for each of the following Sections: Introduction, Administration, Engineering, Entomology, Training, and Medical.

On 27 August 1943, the first of 69 numbered Field Memoranda made its appearance.[45] These were used to convey announcements, directives, program notes, and instructions pertaining to administration or operations but were of a more transient significance than the contents of the Manual Letters.

Activities data were consolidated in State headquarters and in Atlanta to form tabular summaries by States of (1) areas in operation, (2) war establishments protected, (3) accounts of larvicidal activities in terms of amounts of larvicides used and of areas treated, (4) minor and major drainage accomplishments, (5) areas of water surfaces eliminated, (6) man-hours required, and (7) personnel and payroll by category. To the statistical information were added brief but profusely illustrated narrative interpretation, comments about the various programs and organizational units, job and materials specifications, news items, and technical features such as insect identification keys, field and laboratory tests, and special survey reports. These were reproduced and distributed to all concerned starting in July 1942 and continuing through March 1944. The first of these was entitled "Organization Report in Lieu of Monthly Report of Malaria Control in War Areas." Succeeding issues were called "Monthly Reports, Office of Malaria Control in War Areas." Essentially the same material was distributed for the remainder of the calendar year as the "Field Bulletin, In-Service Training and Information, Malaria Control in War Areas," and, beginning in January 1945, it was captioned the

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[44] See footnote 43, p. 87.

[45] Field Memoranda, Malaria Control in War Areas, 1943–48.

"Malaria Control in War Areas Field Bulletin." Through July, it was sent out each month, but by the end of 1945 it had become first a bimonthly and then a quarterly release. This was continued to the end of the fiscal year 1946 when the Office of Malaria Control in War Areas was terminated. At the close of each fiscal year from 1942 through 1946, annual consolidations of these reports were developed with many illustrations, tables, analyses, conclusions, and special accounts of state and district malaria mosquito control activities. These volumes were also given wide distribution.

All of this material was prepared skillfully with an awareness of its educational and integrative possibilities. In an unobtrusive fashion, it kept the staff and employees of Malaria Control in War Areas, at all organizational levels and in all States and districts, well informed regarding the dimensions of their total effort. Thus, it had much to do with catalyzing the development of the notable esprit de corps which prevailed throughout the organization. Lastly, it provided for future reference a detailed record of procedure and accomplishment, even under the stringencies of wartime conditions, in steadily reducing an age-old menace to health and prosperity by exerting the combined efforts of military, Federal, State, and local health agencies.

A summary of activities based on information from these sources is shown in table 7. This includes the costs, by fiscal years, of antimosquito activities from 1942 through mid-1946, 1 year in addition to the period covered in the otherwise comparable analysis of similar operations on military establishments within the country (table 6). This is because it was considered necessary for the Malaria Control in War Areas to continue its wartime antianopheline program around military areas after V–J Day, since service personnel continued to return to separation centers for demobilization. Among them were many who, as in 1945, still suffered from recurrent attacks of malaria (chart 3). These individuals were treated in Army general hospitals, if their attacks occurred before separation; if they came afterward, they sought relief mainly in Veterans' Administration facilities, and also from private physicians or by self-medication. Consequently, it was believed prudent to keep the malaria vector density reduced around the Federal establishments, in which malaria cases were concentrated, and in endemic or formerly endemic rural areas of the country where it was known that malaria relapses were occurring in veterans.

Table 7 emphasizes the fact that larvicidal measures were basic in the early years of the extramilitary War Areas program, as the desirability of permanent destruction of anopheline breeding places had to give way to the expediency of using more immediately beneficial measures. The first such project operated under the Malaria Control in War Areas was begun on 17 March 1942 in Florida.

Oil was the most common larvicide used except in such places as Puerto Rico where the cost of transportation made it prohibitive. While not as economical as paris green which kills only the larval stages of *Anopheles*, oil

TABLE 7.—*Summary of continental (and Puerto Rico) mosquito control operations near areas of military importance, fiscal years 1942–46*

Year	Larviciding			Drainage					DDT spraying		Expenditures [4]
	Diesel oil	Paris green	Acres treated	Clearing	Ditching	Cleaning	Filling	Acres drained	DDT	Houses sprayed	
	Gallons	*Pounds*	*Number*	*Acres*	*Linear feet*	*Linear feet*	*Cubic yards*	*Number*	*Pounds*	*Number*	
1942	281, 880	11, 432	[1] 18, 000	1, 148	[2] 5, 121, 697	----------	239	(3)	-------	----------	$1, 400, 000
1943	1, 876, 607	152, 267	198, 208	12, 940	6, 715, 761	22, 805, 651	60, 009	8, 161	-------	----------	6, 147, 000
1944	1, 527, 008	155, 735	268, 504	8, 035	6, 915, 316	42, 769, 486	79, 230	6, 878	-------	----------	6, 571, 117
1945	1, 003, 168	132, 283	214, 666	3, 942	740, 663	9, 547, 875	76, 954	637	103, 957	264, 482	8, 494, 968
1946	1, 003, 518	132, 274	129, 897	3, 938	742, 438	9, 547, 855	76, 954	1, 024	694, 365	1, 025, 381	9, 047, 616
Total	5, 692, 181	583, 991	829, 275	30, 003	19, 335, 875	84, 670, 867	293, 386	16, 700	798, 322	1, 289, 863	31, 660, 701

[1] Estimated by adding the ponded area to twice the linear footage of treated ditches, assuming an average width of 2 feet.

[2] Includes cleaning.

[3] Data not provided.

[4] In addition to expenditures for antianopheline activities in this country and Puerto Rico includes relatively minor outlays made for *Aedes aegypti* control in the United States and the Territory of Hawaii.

Source: (1) Malaria Control in War Areas Field Bulletin, August-September 1945. (2) Malaria Control in War Areas, 1942-46. *In* Summary of Activities, 1943-46. Office of Malaria Control in War Areas, Atlanta, U.S. Public Health Service. (3) Monthly Reports, Office of Malaria Control in War Areas, July 1942-March 1944.

was preferred by personnel operating local programs because its application served the dual purpose of destroying all the aquatic stages of pest mosquitoes as well as anophelines. This made the program more popular with the residents of the area and usually secured their cooperation. In some zones, it was used exclusively and accounted for the bulk of the financial and labor expenditures. During early 1942 and the fiscal year of 1943, more than 2.1 millions of gallons were applied on nearly 115,000 acres of breeding area using 3,577 hand sprayers, 13 power sprayers, and 19 oil-water units. In this and other field activities, power equipment was advocated wherever feasible both to expand control operations without increasing manpower requirements and because it generally cost less. Thus, in 1944, power equipment was increased to include 50 high-pressure sprayers mounted in trucks or boats. This power application was particularly effective in areas of dense vegetation or heavy flotage. About 80,705 acre treatments of oil were made at an average cost per acre treatment of \$9.55 by hand and \$2.26 by power method. The rate of application in 1944 varied with different types of breeding places from 12 to 50 gallons per acre, averaging 18.9.

As the result of experience and skills acquired during the earlier years, oil larviciding was done in the fiscal year of 1945 in 174 war areas in 27 States at an average cost of \$5.90 per acre treatment for the spraying of some 81,940 acres. The following year saw the general use of "DDT oil-mist," a procedure for using DDT as a mosquito larvicide. This was developed at the Henry Carter Memorial Laboratory in Savannah and was field tested in 1945. It consisted of spraying 5 percent DDT in No. 2 fuel oil through an atomizing nozzle, such as is used in fuel oil burners, at a pressure of 30 to 50 pounds per square inch. A spreading agent was added to assist coverage. Three gallons of this mixture could be spread on 3 acres of ponded area in 3 hours at a cost of approximately one-eighth that of applying oil by hand, or one-half the cost of hand dusting with paris green.

In spite of the general preference for oil, paris green maintained its special usefulness as a larvicide throughout the war. It was cheaper than oil and was especially useful in treating watered areas overgrown with aquatic plants, as the dust mixture did not cling to the overgrowth as did oil. Furthermore, paris green mixtures had a much wider potential radius of application than did oil sprays under identical meteorologic conditions so that less accessibility to breeding places was required. In relatively small areas which could be approached by men on foot, the usual method of spreading paris green was by means of rotary hand dusters. Under favorable atmospheric circumstances, the mixture would be airborne for distances up to 150 feet. In larger areas, power dusting from trucks and boats was more practical and economical.

Early in August 1942, because of prolific *A. quadrimaculatus* breeding within flight range of important military establishments near Washington, D.C., it became necessary to larvicide approximately 3,500 waterchestnut infested acres along the Potomac River and its tributaries. The growth was so

FIGURE 20.—Airplane application of larvicide over a waterchestnut infested area of the Potomac River.

dense as to preclude dusting from boats, and it was decided to try airplane application for this project (fig. 20). This was shown to be both effective and economical. Thus, the use of airplane dispersal for larviciding was introduced into the Malaria Control in War Areas program. Preparations were made immediately to use it more extensively during the 1943 season, and, by June 1943, four airplane dusting projects were in operation at New Orleans, La., Newport and Walnut Ridge, Ark., and Greenville, Miss.

During the second year of Malaria Control in War Areas operations (1943–44), airplanes were used on contract on nine projects in the States of Virginia, Mississippi, Arkansas, Louisiana, Tennessee, and in Puerto Rico. About 350,000 pounds of 25 percent paris green mixture were applied in 64,780 acre applications. The effectiveness of airplane dusting varied widely, being lowest in irregular, wooded swamps and at its best on areas covered with low aquatic vegetation as in the Potomac River waterchestnut project. During the fiscal year of 1944, 187,799 acre treatments of paris green were made, 45 percent by hand, 21 percent by power duster, and 34 percent by airplane. Respective costs per application were $2.98, $0.65, and $1.06 per acre. Dust mixtures varied from 4 to 10 percent by weight for hand and power dusting and from 15 to 25 percent for airplane application. Rates of application were from one-half pound of paris green per acre in relatively clear areas, to 2 pounds per acre in densely vegetated areas or in highflying airplane operations over swamps. The average application rate was 1.3 pounds per acre.

There was a substantial decrease in hand larviciding—oil and paris green—in the 1944–45 season. Experience during the two previous years had resulted in a greater selectivity of methods to save time and materials. In addition, the need for labor conservation became more acute in most areas as the war progressed. Of the 214,666 acres treated with paris green and oil during the fiscal year ending 30 June 1945, approximately one-third of the applications were made with power equipment, including airplanes.

Until the days of DDT and the other residual insecticides, drainage was generally considered the most satisfactory means of achieving permanent malaria control. However, in an emergency program such as the Malaria Control in War Areas, geared to wartime speed and urgency and carried on for the most part around temporary war establishments, drainage had to be secondary to the more rapid methods of malaria control. The general rules of the Malaria Control in War Areas with respect to drainage priority were (1) to consider minor drainage operations normal adjuncts of the larviciding activities and (2) to undertake major drainage construction where effective control by larviciding could not be achieved without drainage or where the cost of effective larviciding was greater than that of drainage.

From 17 March to 30 June 1942, the Malaria Control in War Areas attempted very little major drainage construction as this was being carried on by the Work Projects Administration within the framework of its Malaria Control Drainage Program. A letter from the President to the Federal Works Administrator, dated 4 December 1942, authorized the liquidation of the Work Projects Administration.[40] Certain of the projects survived through April 1943, and some Work Projects Administration labor was still available to the end of fiscal year 1943. The few drainage projects not on military property begun by that organization and still incomplete at its demise were taken over by the Malaria Control in War Areas if these could be approved within existing policy.

In the fiscal year of 1943, 68 major drainage projects were operated in 13 States and Puerto Rico; 966,281 feet (183 miles) of new ditches were constructed, 75.9 percent by hand, 19.5 percent with dynamite, and 4.6 percent with machines. A total of 1,257,104 man-hours of labor were expended on the various aspects of drainage works. During the winter of 1943–44, a maximum of 63 major drainage projects were in operation in 46 areas of 13 States and Puerto Rico. Since a majority of the malaria mosquitoes in the continental United States do not fly more than one mile, drainage was usually concentrated within

[40] U.S. Government Manual, 1945. Second edition. p. 622.

a 1-mile radius of war areas. Where excessive breeding did not occur between the ½- and 1-mile radius, control of this area by larviciding was generally sufficient. In a few instances, it was necessary to install drainage works past the 1-mile radius in order to obtain satisfactory outlets.

Although nearly all the drainage work originally proposed for the older military establishments had been completed by the middle of the fiscal year 1944, many new areas were being added, mostly prisoner-of-war camps and military hospitals. Major drainage was seldom justifiable around prisoner-of-war branch camps because of their temporary nature. However, larvicidal work was supplemented by drainage at some of the more nearly permanent base camps. In most instances, plain earth ditches were dug, without lining, sodding, erosion control, or appurtenant structures. The average cost for this type of excavation with hand labor was $1.46 per cubic yard. A total of 1,059 miles of this type of hand ditching was completed by 30 June 1944, involving over 600,000 cubic yards of excavation.

Drainage activities on the Malaria Control in War Areas program continued on a gradually decreasing scale during 1945. This included machine and dynamite excavations, filling, installation of permanent ditch lining, ditch stabilization, cross-drain, and outlet construction. At the close of the fiscal year, little major drainage remained to be done because in most established areas it had been completed, military bases were being inactivated, and most States were no longer expanding antimalaria activities.

Extramilitary permanent ditch lining was limited in the United States to a few situations where materials were furnished by property owners or local governments. The use of lining was more extensive in Puerto Rico where malaria mosquito production was more difficult to control and where the malaria hazard was greater, but even there, ditch lining by Malaria Control in War Areas was confined to the vicinity of permanent military establishments.

Special types of drainage structures were used where they offered the best solution to the control problem. At Jackson Barracks, La., a levee and a manually operated floodgate were constructed. At Macon, Ga., and in Puerto Rico, pumps were used for drainage. An inverted siphon was installed at Macon. Hydraulic dredging was utilized effectively at Leesburg, Fla., and at Macon and vertical drainage at Jefferson Barracks, Mo.

In addition to these larviciding and drainage operations, which comprised the principal malaria control activities of the Malaria Control in War Areas, filling was used to a limited degree. This was done by bulldozer, by diversion of streams, by sanitary landfill, and by dragline.

To determine the extent of mosquito breeding and the amount eliminated by drainage, a census of 190,646 acres of watered area was conducted during the winter of 1944 throughout the control zone. Fifty-two percent of these wet acres were classified as permanent problems, 28 percent as semipermanent, and 20 percent as temporary. In addition to the above, 55,000,000 linear feet of water-holding ditches, canals, and other watercourses less than 10 feet in width were reported. More than one-third of each class of watered area (42,177 acres plus 25,000,000 linear feet of ditches) was found to be breeding malaria mosquitoes, probably representing the significant acreage from the standpoint of Malaria Control in War Areas. It was further reported that 15,000 acres and 680,000 linear feet of watered area were eliminated by drainage during the course of Malaria Control in War Areas operations.

The need for a shift in emphasis of Malaria Control in War Areas activities became apparent in 1943 with the arrival in this country of malaria cases from overseas. These included hospitalized, sick, or wounded servicemen, prisoners of war sent to the United States, and furloughed or discharged veterans returning to their homes in all of the 48 States. It was suspected—and later proved [47]—that malaria transmission could take place from these carriers in areas where domestic mosquito vectors existed. This led to the conviction that a major public health problem would ensue—one which would increase with demobilization.[48]

Thus, in 1944 it was proposed to extend the Malaria Control in War Areas program to protect all previously endemic civilian areas in addition to those adjacent to strategic installations. By this time, the antimalaria effectiveness and low cost of residual insecticiding with DDT had been amply demonstrated by its military use in the tropics. The proposal, therefore, called for residual spray treatment with DDT in rural areas as a major operation and for some larviciding and drainage around urban locations. Work was to begin on 1 January 1945 in the most malarious counties in the southeast.

This proposed Extended Malaria Control Program of the Malaria Control in War Areas was endorsed by the Association of State and Territorial Health Officers in October 1944, with the recommendation that the Surgeon General of the U.S. Public Health Service present the program to the Congress; military authorities approved the proposal. The initial appropriation for the Extended Program was included in the First Supplemental Appropriation Act, October 1944, and was approved December 1944.[49]

The administrative pattern of the Extended Program was similar to that of other Malaria Control in War Areas activities, but the underlying philosophies governing the two were quite different. The regular Malaria Control in War Areas program was designed to protect military and war industrial personnel from civilian malaria. The Extended Program, on the other hand, was primarily intended to protect general civilian populations from returning military carriers of the disease. Therefore, increased emphasis was placed upon participation by State and local health agencies.

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[47] See footnote 36, p. 79.

[48] (1) Freeborn, S. B.: Problems Created By Returning Malaria Carriers. Pub. Health Rep. 59: 357–363, 17 Mar. 1944. (2) Simmons, J. S.: American Mobilization for the Conquest of Malaria in the United States; Introduction to a Symposium on Our National Program for the Control of Malaria. J. Nat. Malaria Soc. 3: 7–10, March 1944.

[49] See footnote 29 (9), p. 75.

The county was the usual unit of operation in the Extended Program and most projects were countywide, excluding communities of 2,500 or more. Those in which residual spray treatment was to be carried out were selected on the basis of (1) average annual reported malaria death rates of 10 or more per 100,000 during the prewar years 1938–42, inclusive, and (2) supplemental information from the malariologists of the various State health departments as to the distribution of the disease in their own States. From these data, 68 counties in 9 States were approved in 1945 for participation in the residual spray program.

Consideration was given to the possible requirements of five other States in the traditionally malarious belt where malaria had been transmitted with sporadic frequency. It was believed at first that the needs of these States might be met by the use of mobile units, but further analysis indicated that better and more permanent results would be achieved by establishing local projects under trained personnel in these areas.

During the 1945 season, 644,000 spray applications were made in 400,000 homes. In the fiscal year of 1946, the number of counties included in the Extended Program increased to 274, involving 1,025,381 homes.

Larvicidal and minor drainage projects were undertaken in the Extended Program around urban areas wherever the annual cost of larviciding was lower than, or did not greatly exceed, the cost of residual spraying. Reconnaissance surveys or experience in previous project operations were used to determine these comparative costs. For each population group, either antilarval or antiadult measures were used, not both. In general, larviciding and minor drainage were the methods used for urban populations. A few major drainage projects were proposed under the Extended Program and submitted for approval as prescribed for regular Malaria Control in War Areas activities. Residual spray project proposals were prepared by the State health departments for each operational area where such work was contemplated. These were then reviewed by the Headquarters office before work was inaugurated.

Only a fraction of the total number of homes was sprayed before the end of the fiscal year of 1945. Spraying began in most States during March, and all but one State had started by the middle of April. Because of the delay in supplying equipment and materials to meet the essential requirements in all States, only 264,482 houses had been sprayed by the end of the fiscal year.

During the last half of 1945, 413,500 houses in 123 counties were sprayed with DDT. This program was expanded in 1946 to operate in 274 counties in 13 States, accomplishing 611,861 house spray applications. With the experience gained from one year's operation and the increased development of equipment and materials, the average man-hours required for residual spraying were reduced from 1.15 man-hours per house application at the beginning of the 1945 spraying season to 0.96 man-hour at the end of the year. The rate of DDT application varied from State to State, but the program average was 0.68 pound per house, or approximately 135 mg. per square foot for the aver-

FIGURE 21.—Application of DDT residual spray in the interior of a rural home.

age size home (fig. 21). In 1945, two seasonal applications of DDT were made at the rate of 100 mg. per square foot. However, evaluation data indicated that a single seasonal application of 200 mg. per square foot would be equally effective from the standpoint of long-lasting residual spraying and at the same time would be more economical. Consequently, from 1946 this rate was used in nearly all the States.

A major problem involved in the Extended Malaria Control Program operations was to obtain proper equipment in time and in sufficient quantity to meet project requirements. Procurement, specifications, testing, and modifications of equipment were joint responsibilities of the Engineering Division, the Equipment Unit, and the Carter Laboratory at Savannah. Numerous types of sprayers, spray nozzles, gaskets, hose, solvents, emulsifiers, and other items incidental to DDT residual spraying were tested. Procurement of xylene-resistant gasket and hose material was the most serious difficulty. Of the variety of gasket materials tested, only two were found satisfactory for field use. Three kinds of synthetic rubber hose proved useable. After testing and selecting suitable materials, further delay was experienced in furnishing such large supplies of specialized equipment, because of the failure of various manufacturers to meet delivery schedules. Most of the difficulties were finally overcome so that field crews eventually received all essential equipment.

Residual spraying with DDT was an entirely new method of malaria control for civilian purposes. Field testing had been limited to projects in Arkansas, Tennessee, Georgia, and Puerto Rico. With only a handful of trained men and the most critical transportation situation in the history of our country, an extensive decentralized training program was set up, starting with a basic course at the Henry Carter Memorial Laboratory at Savannah. This was designed for District and State supervisory personnel and was conducted as a series of discussions and field demonstrations. As a result of this course, the nucleus of trained men was increased from a dozen to over 75, and each Extended Program State had at least two men with firsthand knowledge of the subject. Decentralized training within States was then inaugurated. Each State arranged for a training course for area supervisors and for others charged with immediate responsibility for doing the work. Two mobile training units were equipped with literature, training aids, and equipment and were made available to the States. An officer with firsthand experience in DDT residual spraying was available to all States that requested assistance in conducting their inservice training programs.

Results of the DDT training program can be measured only in terms of smooth working operations. The fact that 1,200 men were put in the field within 2 months and carried on the program without any evidence of occupational hazards, major public complaints, or operational failure testifies to the effectiveness of the job.

Because of the low malaria rates prevailing at the time and the errors of available methods of measurement during the low ebb of the disease, the effectiveness of the residual spray program was determined entomologically; that is, on the basis of its ability to maintain houses free of *A. quadrimaculatus*. Random inspections of a number of premises on each control project were made at monthly intervals after the start of spraying to determine if any live anophelines were present. From 1946, the number found in unsprayed houses adjacent to the treated areas was also determined. The results of these surveys for 1945 and 1946 are summarized in table 8. It is evident from these figures that effective control of malaria mosquitoes was achieved in counties operating under the Extended Malaria Control Program. The role of this program in maintaining the downward trend of malaria incidence in this country may never be known, but in combination with the Malaria Control in War Areas program it must have contributed significantly to the negligible level of malariousness in the continental United States during and after World War II.

During the immediate postwar years, continental malaria rates declined still further and it was, therefore, proposed to capitalize on the existing situation by making a serious effort at eliminating malaria from the United States as an endemic disease. Thus, the National Malaria Eradication Pro-

TABLE 8.—*Summary of entomological surveys on the extended (residual spray) program, 1945–46*

Months after spraying	Houses sprayed[1] Number	Houses sprayed[1] Percent free of *A. quadrimaculatus* in p.m.
1945		
0 to 1	3,916	98.9
1 to 2	4,558	98.3
2 to 3	3,557	95.7
3 to 4	1,375	94.7
4 to 5	723	94.2
Total	14,129	97.2
1946		
0 to 1	6,018	99.2
1 to 2	6,739	99.0
2 to 3	5,321	99.1
3 to 4	2,974	98.7
4 to 5	899	98.2
Total	21,951	99.0
Grand total	36,080	98.3

[1] In 1946, in a total of 1,630 unsprayed houses adjacent to the treated areas, 87.3 percent were free of *A. quadrimaculatus* in p.m.

Source: Bradley, G. H., and Lyman, F. E.: Discussion of Five Years' Use of DDT Residuals Against *Anopheles quadrimaculatus*. J. Nat. Malaria Soc. 9: 113–128, June 1950.

gram was begun on 1 July 1947. This was an augmentation of the previous Extended Malaria Control efforts.[50] As a result of these measures and possibly other circumstances, cases of truly indigenous malaria became difficult or impossible to find in subsequent years.[51] These facts are noted here because it is believed important to record and emphasize this essential relationship; namely, that what started as a relatively modest extramilitary malaria control program in 1942 culminated in 1947 in the first national malaria eradication campaign of substantial dimensions. This directly related descendant of the combined War Areas Malaria Control Programs stimulated other malaria eradication activities in various parts of the world and, therefore, was of international significance.

[50] See footnote 38, p. 84.

[51] Andrews, J. M., Grant, J. S., and Fritz, R. F.: Effects of Suspended Residual Spraying and of Imported Malaria on Malaria Control in the USA. Bull. World Health Organ. 11: 839–848, 1954.

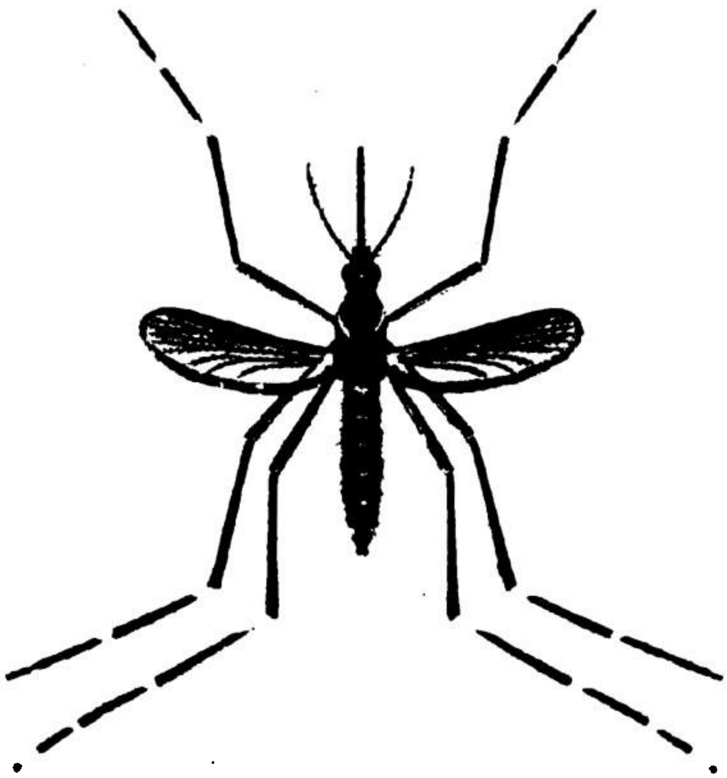

FIGURE 22.—*Aedes aegypti*, the vector of yellow fever and dengue along the coastal areas of the continental United States from Virginia to Texas.

Related Activities

In addition to malaria, there were other insect-borne diseases which could occur within the continental United States and its territories and would become threats to the military effort if they reached epidemic proportions. Of these, yellow fever was considered the most dangerous. The last epidemic of this disease occurred in New Orleans in 1905,[52] but the vector, *Aedes aegypti* (fig. 23) was present along the coastal areas from Virginia to Texas. Furthermore, epidemics of dengue, an incapacitating disease also transmitted by this mosquito, had flared up periodically in South Carolina, Georgia, Florida, Alabama, Louisiana, Mississippi, and Texas.[53]

[52] Smith, Hugh H.: Controlling Yellow Fever. *In* Yellow Fever, edited by George K. Strode. 1st edition. New York: McGraw-Hill Book Co., 1951, p. 558.

[53] Information was obtained from the National Office of Vital Statistics, U.S. Public Health Service, U.S. Department of Health, Education, and Welfare, Washington, D.C.

In the years before World War II, a number of large South American cities had eradicated *A. aegypti*.[54] Millions of dollars had been spent on these projects. To protect this investment, Bolivia had proposed at the Eleventh Pan American Sanitary Conference in Rio de Janeiro in 1942 an *A. aegypti* eradication project to include all the Americas. With the outbreak of war came a tremendous increase in air travel and the very real danger of introducing yellow fever and dengue into military training areas in this country. There was also the possibility that South American health authorities might quarantine airplanes arriving from *A. aegypti*-infested cities in the United States which could have seriously impeded the U.S. defense effort. As a result of these two potentialities, the anti-*A. aegypti* program was instituted. This was a lesser activity of the Malaria Control in War Areas and was restricted accordingly in funds and manpower; thus, great emphasis was placed on education of the public to supplement control operations aimed at eliminating major breeding foci. Projects of varying dimensions were carried on in Norfolk and Portsmouth, Va.; Charleston, S.C.; Savannah, Ga.; Jacksonville, Key West, Miami, and Tampa, Fla.; Mobile, Ala.; and Brownsville, Corpus Christi, Galveston, Hidalgo County, Houston, Laredo, and San Antonio, Tex. During the 4 war years, some 4,700,517 premises were inspected.

The first of these projects was started at Key West on 1 June 1942 with the special objective of eradicating the vector species; in this respect, it differed from all other antiaedine programs undertaken by Malaria Control in War Areas. Each room in every dwelling and business establishment was visited each week. All mother foci of *A. aegypti* breeding were systematically located and were visited and treated each week. Searches were continued for casual breeding containers such as tin cans, rubber tires, and outdoor cooking utensils. When breeding was discovered indoors, the entire premises were sprayed with pyrethrum Aerosol. The original breeding index of 13.2 was reduced to less than one percent with relative ease, but, as it was necessary in 1944 to redistribute funds and manpower to give protection to more critical war areas, complete eradication was not achieved.

In most other projects, the numbers of premises where *A. aegypti* breeding occurred were held at or below 5 percent, a level which at that time was considered to be the threshold of sanitary importance. Mobile *A. aegypti*-control units operated in Savannah, Ga., and New Orleans, La. These served a double purpose; while they maintained control activities in these cities, they also were immediately available for dispatch should dengue or yellow fever be reported anywhere in the United States. To provide further controls in case of such eventualities, an epidemic plan was developed, and stockpiles of yellow fever vaccine and of mosquito control materials and equipment were held in readiness at headquarters in Atlanta.

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[54] Soper, F. L., and Wilson, D. B.: Species Eradication: A Practical Goal of Species Reduction in the Control of Mosquitoborne Disease. J. Nat. Malaria Soc. 1: 5–24, 1942.

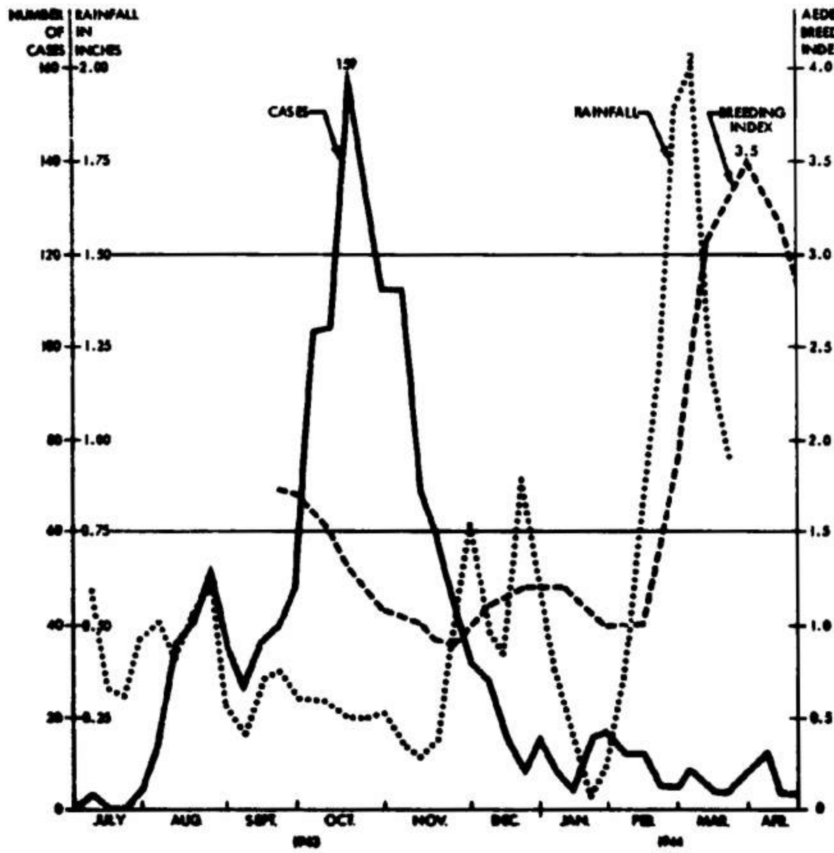
Fortunately, it was not necessary to use the epidemic plan in the continental United States, but a call did come from a location remote from the mobile units and stockpiles of equipment and supplies. Dengue was reported in Honolulu, T.H., on 24 July 1943, for the first time in 30 years.[55] This occasioned some alarm in Army circles both because of its sudden and unexplained appearance—which was finally traced to an infected Army Air Force pilot who, during his own incubation period, had flown a plane from the Fiji Islands where a dengue outbreak was in progress—and because a general epidemic in this area was to be avoided at all costs during 1943 as the Islands were to be the staging area for critical campaigns destined to turn the tide of battle during the fall of 1943 and the spring of 1944. Dengue built up rapidly until it was necessary on 8 August 1943 to declare Waikiki, one of the world's greatest centers for servicemen, "off limits" to military personnel.

When the first two cases were reported, the Territorial Board of Health took immediate action against the spread of the disease. Nine sanitary inspectors, supplemented by 24 new employees and 5 soldiers (supplied because of the military importance of the disease), made routine exterior inspections of premises, eliminating mosquito breeding where possible and suggesting corrective measures to householders. An educational campaign was also carried on by press and radio, and printed instructions were distributed requesting residents to spray their homes with insecticide and to eliminate all water-holding containers.

In spite of these precautions, the number of dengue cases increased, especially in the Waikiki area. During the latter part of August 1943, at the suggestion of the Surgeon, Central Pacific Area, U.S. Army, all houses in this section were sprayed with undiluted commercial insecticide using high-pressure chemical warfare decontamination sprayers. A request was made by the Territorial Board of Health for assistance from the U.S. Public Health Service, and, on or about 1 September 1943, a sanitary engineer, Wesley E. Gilbertson, and an entomologist, Dr. Robert L. Usinger, from Malaria Control in War Areas, both experienced in *A. aegypti*-control activities, were sent to Honolulu. By that time, 148 cases had been reported. These cases were scattered throughout the city, thus precluding all hope of confining the epidemic to the Waikiki district and making citywide coverage essential. Thirteen civilian employees together with a medical officer made available by the Army to do epidemiologic work and 55 enlisted men were added to the existing mosquito-control organization. Operations began on 15 September 1943. By the end of the fiscal year, 150 men were employed on *aegypti* control in Honolulu by the Army. The city was divided into districts and zones of such size that one man could inspect the inside and outside of each of the premises in the zone within 10 days.

[55] Gilbertson, W. E.: Sanitary Aspects of the Control of the 1943–1944 Epidemic of Dengue Fever in Honolulu. Am. J. Pub. Health 35: 261–270, March 1945.

CHART 6.—*Trend of dengue cases compared with rainfall and the* Aedes *breeding index during the dengue epidemic in Honolulu, T.H., 1943–44*



Aedes control in the Hawaiian Islands involved two species, *aegypti* and *albopictus*, both of which were involved in the transmission of dengue.[56] The inspection-correction-education method was used to reduce the breeding indices of these species in and around dwellings, while simultaneous high-pressure spraying with emulsified pyrethrum-kerosene mixtures was used to fog entire areas of high dengue prevalence. This treatment of the epidemic foci was followed by a sharp reduction in numbers of new cases. The outbreak reached its peak in October 1943 (chart 6), but the end of June 1944 the attack rate had

[56] (1) Usinger, R. L.: Entomological Phases of the Recent Dengue Epidemic in Honolulu. Pub. Health Rep. 59: 423–430, 31 Mar. 1944. (2) See footnote 55, p. 109.

subsided to less than one case per week. No cases were reported during the last 2 months of 1944 and the first 4 months of 1945. The total number of civilian cases was 1,506; of military personnel, 56.

The Malaria Control in War Areas organization also undertook, on a reimbursable basis, the control of certain obnoxious insects for the Armed Forces when this could be done advantageously. In several instances, pest mosquito reduction projects were thus extended into civilian areas near military establishments to provide greater freedom from the continual annoyance of bloodsucking insects, with consequent improvement in the physical effectiveness of military inductees during their training experience. Similarly, the control of stable flies, *Stomoxys calcitrans*, on the north Florida beaches to protect Army Air Force personnel from the depredations of these vicious biters was undertaken jointly with the Bureau of Entomology and Plant Quarantine of the U.S. Department of Agriculture.

Evaluation of Malaria Control in War Areas Activities

As shown in chart 3, the rates of reported civilian malaria morbidity and mortality continued to decline during the war years with no indication of an upswing due to cyclical manifestations. Probably many factors were involved in producing this result, but it seems evident that among the major ones were the competent leadership and conscientious workmanship of the Malaria Control in War Areas and the State health departments concerned.

The best measure of effectiveness for intramilitary and extramilitary malaria control efforts is displayed in table 4 which contrasts the continental Army malaria admission rates during the 5-year periods beginning in 1917 and 1941, representative of World War I and World War II experience with this disease. Table 9 shows real progress in malaria control accomplishment in the 24-year interval between the two World Wars.

CONCLUSIONS AND RECOMMENDATIONS

The conclusions reached from this account of malaria control activity within and near military areas in the continental United States is that a capable job was done both by the military personnel concerned with the former, and by the civilian organization developed for the latter. The joint objective of these two operations was to protect military trainees from malaria. Malaria morbidity was held to progressively and virtually unprecedented lower levels in this group during each succeeding year of World War II. In addition, the achievements of the combined War Areas Malaria Control Programs contributed directly to the attempts to eradicate malaria in this country and abroad. This experience proves the feasibility of cooperative and productive accomplishment by military and civilian health authorities.

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Therefore, it is recommended that, if the need should ever arise again, the Armed Forces and the U.S. Public Health Service, acting in behalf of the State health departments, should collaborate on essentially the same basis as they did in World War II.

TABLE 9.—*Admissions and attack rates of malaria acquired by U.S. Army personnel in continental United States,[1] by month and year, 1917–21 and 1941–45*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	Admission [2] rate for all enlisted men					Attack [3] rate for all personnel				
	1917	1918	1919	1920	1921	1941	1942	1943	1944	1945
January	(4)	1.3	0.6	3.7	2.5	0.4	0.2	0	0.1	0.1
February	(4)	1.3	.8	1.7	3.9	.5	.3	.1	.1	.2
March	(4)	2.4	1.0	3.7	4.1	.8	.3	.2	.1	.1
April	(4)	2.9	1.8	4.9	6.7	.9	.4	.2	.1	.2
May	10.6	5.7	2.0	8.0	9.0	1.2	.6	.3	.2	.1
June	14.3	7.4	2.1	10.5	9.6	1.6	.9	.4	.2	.1
July	10.7	8.4	5.3	14.0	11.8	1.4	1.1	.4	.2	.1
August	9.1	7.3	9.4	14.8	17.0	1.7	1.0	.4	.2	.1
September	14.2	5.4	9.0	12.3	12.0	3.2	1.0	.3	.2	.1
October	9.9	1.6	12.4	7.8	7.4	4.9	.7	.2	.2	.1
November	4.2	1.0	15.6	3.8	3.1	1.4	.4	.1	.2	.1
December	1.7	.7	6.2	3.7	.6	.5	.3	.1	.1	.1

[1] The rates shown for 1917–21 and 1941–42 were not reported as having been acquired in the United States but as reporting to a medical treatment facility in the United States. It is assumed that most of these cases were acquired in the United States. The rates for 1943 were estimated based on summary report data. For 1944 and 1945, the Statistical Health Report furnished data on cases of malaria acquired in the United States.

[2] Refers to cases in which malaria (new) was the primary cause of admission to a medical treatment facility. During part of this period, however, secondary cases of malaria may have been included in the admission rate.

[3] Consists of malaria shown as the cause of admission (whether new or recurrent) as well as malaria which was secondary to some other admission diagnosis.

[4] Data not available.

Source: (1) The Medical Department of the United States in the World War, Vol. XV, Statistics, Part 2, II 17–19. (2) Annual reports of The Surgeon General, U.S. Army, 1921 and 1922. (3) Periodic summaries of Statistical Health Report (provisional), 1941–45.

CHAPTER IV

The South Atlantic and Caribbean Areas

Luther S. West, Ph. D.

Part I. General Considerations

The total geographic area covered by this report extends approximately from 30° north latitude to 40° south latitude and from 30° west longitude to 95° west longitude. It comprises both the Caribbean Command and the South Atlantic Command at their greatest expansion during the war years, 1941–45. The Caribbean Defense Command consisted of the Panama Canal and Antilles Departments, represented in prewar years by permanent installations in the Canal Zone and the island of Puerto Rico.

War Department Pamphlet No. 8–2, dated 2 April 1943, indicates that malaria was most prevalent in tropical regions of Central America and in the great river basins of South America, especially those in Brazil, the Guianas, Venezuela, Colombia, and Northwestern Argentina. It is believed to occur in all Caribbean islands except Barbados and the Netherlands Antilles. In some areas, up to 80 percent of the native population may show infection.

The southern range of malaria in the New World terminates at 32° south latitude, in Cordoba, Argentina.[1] The only recorded exception was a brief epidemic in 1935–37 near Mendoza, at 33° south latitude. No cases have been reported in Brazil south of the 30th parallel, and in Chile the disease does not occur south of the Pica stream in the Province of Tarapacá, at 20°30′ south.

The malaria problem in these areas has long been very real. The prevalence of the disease in the native population of various Central American, South American, and West Indian countries has played its part in sapping the energy of these peoples and in preventing the attainment of economic standards which natural resources and commercial opportunities would otherwise have made possible. Conversely, a low economic level, whether due to malaria, hookworm, other diseases, or merely to overpopulation, as in certain of the Antilles, provides little money for expenditure on public health. Thus, most of the governments concerned, though realizing the need for malaria control, were not able to command the funds necessary to utilize approved control procedures.

The example set for the Central American Republics by the United States, in connection with the sanitation of the Canal Zone, had both a desirable and

[1] Hackett, Lewis W.: Distribution of Malaria. *In* Malariology, edited by Mark F. Boyd. Philadelphia: W. B. Saunders Co., 1949, vol. I, pp. 722–735.

an undesirable effect. The practical elimination of mosquito breeding by the use of oiling and drainage techniques showed what could be done, and stimulated imitation. The enormous expense involved, however, made it abundantly clear that the Republics could not hope to raise, by any system of taxation, sufficient money to parallel the U.S. achievement. Educational effects were nevertheless apparent in the greater use of screens or bed nets, avoidance of unnecessary exposure during the biting hours of vector species, and in other ways. These practices were more closely followed in villages and towns than in open country, as evidenced by a higher spleen rate, for example, among children who were transported to village schools, than among those who lived close by.

In contrast, however, is the fact that native populations, in all tropical regions, tend to develop a degree of tolerance to malarial infection, so that adults though perhaps exhibiting a parasitemia may be relatively free from morbid symptoms. Except for exacerbations brought on by fatigue, malnutrition, chilling, or illness of some other type, they may carry on effectively for long periods of time and be neither a burden to themselves nor to others. Both natural selection and immune reaction are involved. Natural selection operates largely through infant mortality, the survivors being, it may be assumed, somewhat better fitted by nature to cope with the parasite. This selected group then stands to profit by whatever immunity can be developed through repeated exposure to infection. It should be pointed out that frequent reinfection is necessary to accomplish this. Such an immunity is termed premunition. If the individual remains free of parasites for any considerable period of time, his immunity is lost. Untreated natives have, of course, but little opportunity to become parasite free.

The introduction of a new, nonimmune population into a malarious area is always a hazardous procedure. As long as the newcomers arrive in relatively small groups, make plans for their own medical protection, and tend to engage in more privileged occupations (executive, clerical, professional), no great challenge of existing practices is likely to occur. If, on the other hand, there should be an influx of some numbers destined to engage in common labor and to live under perhaps less than desirable sanitary conditions, an epidemic among the new arrivals is almost certain to take place. The arrival of troops from a nonmalarious region parallels this example in its first aspect because the duties of military personnel necessarily take them into situations where risk of infection may be very great. The second problem, involving living conditions and especially housing, need not exist if there be sufficient advance knowledge of control procedures, the means to apply them, and effective instruction of the troops. Actual combat conditions may destroy all this, at least temporarily, but since this discussion is concerned with an area in which no fighting took place, it is unnecessary to go further into this aspect of the subject.

INCIDENCE

Central and South America

During the year 1941, malaria caused the death of 1,178 persons in the United States.[2] This represented a malaria death rate of 0.9 per 100,000 inhabitants. It will be evident from table 10 that malaria, at the outbreak of the war, was a much more serious matter in most of the other American Republics.

The statistics in table 10 make clear the extent, as well as the importance, of the malaria problem in selected geographic areas in Central and South America.

TABLE 10.—*Malaria as a reported cause of death in Central and South American Republics and neighboring States, with selected examples*

[Rate expressed as number of deaths per annum per 100,000 population]

Country (or city)	Year	Deaths	
		Number	Rate
Bolivia	1940	178	(1)
Rio de Janeiro (Brazil)	1941	227	12.5
São Paulo (Brazil)	1941	42	2.1
Colombia	1940	4,817	52.8
Costa Rica	1940	916	139.6
Cuba	1938	1,035	25.2
Chile	1941	30	(1)
Ecuador	1940	4,847	(1)
Guayaquil (Ecuador)	1941	580	390.0
El Salvador	1941	2,937	163.2
San Salvador (El Salvador)	1941	122	115.1
Guatemala	1938	10,609	256.0
Mexico	1941	26	(1)
Nicaragua	1941	2,584	188.0
Panama City (R.P.)	1941	15	(1)
Paraguay	1941	216	54.0
Lima (Peru)	1939	84	28.0
Dominican Republic	1941	2,518	142.4
Venezuela	1940	1,261	34.0
Caracas (Venezuela)	1940	16	7.5
British Guiana	1941	288	82.3
Jamaica	1938	535	44.7
Puerto Rico	1940	1,814	97.0
Dutch Guiana	1937	48	(1)
Trinidad (B.W.I.)	1941	480	96.8

[1] Data were not provided.

Source: Informe Biodemográfico y Epidemiológico de las Américas. Washington: Oficina Sanitaria Panamericana, Publication No. 193, February 1942.

[2] Informe Biodemográfico y Epidemiológico de las Américas. Washington: Oficina Sanitaria Panamericana, Publication No. 193, February 1942.

U.S. Army, 1942–45

During the war years, the personnel of the U.S. Army suffered more or less seriously from malaria (tables 11 through 15). From a global standpoint, the year 1943 was certainly the most alarming. In Latin America, however, where troop concentrations were well underway at the outbreak of the war, 1942 became the year of disastrous experience, followed by rather consistent improvement for the remainder of the war period.

The figures given in the tables are adapted from material supplied by the Medical Statistics Division, Office of The Surgeon General, U.S. Army.

TABLE 11.—*Number of cases [1] and attack rates of malaria in the U.S. Army, worldwide and Latin America, by type of* Plasmodium *and year, 1942–45*

[Preliminary data based on sample tabulations of individual medical records]

[Rate expressed as number of cases per annum per 1,000 average strength]

Type of *Plasmodium* and year of admission	Worldwide		Latin America	
	Number	Rate	Number	Rate
Malaria, all forms:				
1942	23,267	7.18	11,042	108.34
1943	174,867	25.45	4,874	40.34
1944	168,155	21.58	1,245	14.51
1945	126,010	16.95	730	10.19
Total	492,299	19.43	17,891	47.05
Vivax malaria:				
1942	11,435	3.53	7,672	75.27
1943	92,221	13.42	3,430	28.39
1944	129,810	16.66	990	11.54
1945	107,810	14.51	565	7.88
Total	341,276	13.47	12,657	33.29
Falciparum malaria:				
1942	4,481	1.38	2,803	27.50
1943	28,209	4.12	1,173	9.71
1944	12,925	1.66	200	2.33
1945	5,575	.75	159	2.09
Total	51,190	2.02	4,336	11.38
Malariae malaria:				
1942	122	0.04	59	0.56
1943	685	.10	33	.27
1944	800	.10	5	.06
1945	270	.04	5	.07
Total	1,877	0.07	102	0.27

See footnote at end of table.

TABLE 11.—*Number of cases* [1] *and attack rates of malaria in the U.S. Army, worldwide and Latin America, by type of* Plasmodium *and year, 1942–45*—Continued

Type of *Plasmodium* and year of admission	Worldwide		Latin America	
	Number	Rate	Number	Rate
Mixed malarial infections:				
1942	216	0.07	127	1.25
1943	1,193	.17	29	.24
1944	1,150	.15	5	.06
1945	885	.12		0
Total	3,444	0.14	161	0.42
Other and unspecified forms of malaria:				
1942	7,013	2.16	381	3.74
1943	52,469	7.64	209	1.73
1944	23,470	3.01	45	.52
1945	11,470	1.54	10	.14
Total	94,422	3.73	645	1.70

[1] Consists of new admissions and readmissions for malaria as well as secondary cases in which admission was for other causes, but in which malaria existed concurrently or developed subsequently.

TABLE 12.—*Incidence of malaria in the U.S. Army, by area and year, 1940–41*

[Preliminary data based on sample tabulations of individual medical records]

[Rate expressed as number of admissions per annum per 1,000 average strength]

Year	Total Army		U.S. troops in Panama [1]		U.S. troops in Puerto Rico [1]		Native Puerto Rican troops	
	Number	Rate	Number	Rate	Number	Rate	Number	Rate
1940	2,370	7.04	1,178	54.74	191	73.21	260	147.30
1941	6,364	4.74	1,534	51.01	494	77.48	1,191	90.30

[1] For white enlisted men only.

TABLE 13.—*Deaths due to malaria in U.S. Army, by area and year, 1940–41*

[Preliminary data based on sample tabulations of individual medical records]

[Rate expressed as number of deaths per annum per 100,000 average strength]

Year	Total Army		U.S. troops in Panama [1]		U.S. troops in Puerto Rico [1]		Native Puerto Rican troops	
	Number	Rate	Number	Rate	Number	Rate	Number	Rate
1940	4	1.19	3	13.94		0		0
1941	17	1.27	5	16.63	1	15.66	1	8.35

[1] For white enlisted men only.

TABLE 14.—*Deaths due to malaria in the U.S. Army, worldwide and Latin America, by type of* Plasmodium *and year, 1942–45*

[Preliminary data based on tabulations of individual medical records]

[Rate expressed as number of deaths per year per 100,000 average strength]

Type of *Plasmodium* and year of death	Worldwide		Latin America[1]	
	Number	Rate	Number	Rate
Malaria, all forms:				
1942	25	0.77	12	11.77
1943	113	1.64	5	4.14
1944	89	1.14	1	1.17
1945	75	1.01	-------	0
Total	302	1.19	18	4.73
***Vivax* malaria:**				
1942	5	0.15	3	2.94
1943	25	.36	2	1.66
1944	19	.24	-------	0
1945	19	.26	-------	0
Total	68	0.27	5	1.32
***Falciparum* malaria:**				
1942	11	0.34	7	6.87
1943	47	.69	2	1.66
1944	32	.41	1	1.17
1945	35	.46	-------	0
Total	125	0.49	10	2.62
Mixed malarial infections:				
1942	-------	0	-------	0
1943	1	.01	-------	0
1944	3	.04	-------	0
1945	2	.03	-------	0
Total	6	0.02	-------	0
Other and unspecified forms of malaria:[2]				
1942	9	0.28	2	1.96
1943	40	.58	1	.82
1944	35	.45	-------	0
1945	19	.26	-------	0
Total	103	0.41	3	0.79

[1] Area of admission.

[2] There were no deaths due to malariae malaria.

TABLE 15.—*Admissions and deaths from fever of undetermined origin*[1] *in the total U.S. Army and in the Latin American area, by year, 1942–45*

[Admission rate expressed as number per annum per 1,000 average strength]

[Death rate expressed as number per annum per 100,000 average strength]

Year	Total Army		Latin America	
	Number	Rate	Number	Rate
	Admissions			
1942	7,711	2.38	4,385	43.02
1943	40,163	5.85	2,340	19.37
1944	52,586	6.75	951	11.08
1945	42,270	5.69	1,000	13.95
Total	142,730	5.63	8,676	22.82
	Deaths			
1942	3	0.09		0
1943	5	.07		0
1944	13	.17		0
1945	5	.07		0
Total	26	0.10		0

[1] Probably malaria in many cases.

ANTIMALARIA ORGANIZATION

The malaria control machinery of the various Republics and European possessions, included in this extensive area, differed greatly in magnitude and efficiency at the outset of the war. Wherever the local government organization was well developed, and more or less experienced, as in Brazil, close cooperation was sought by U.S. authorities, and cooperative administration of control activities in the vicinity of military installations was the rule. This was particularly true near the several bases used for air transport purposes along the Atlantic coast. In other areas, the full responsibility had to be assumed by military authorities. More detailed information will be given in connection with the history of particular installations.

By 1945, there were 70 malaria survey units and 153 malaria control units working in oversea theaters throughout the world.[3] In addition, nonmedical antimalaria details, consisting of one noncommissioned officer and one or more additional enlisted men, were assigned to serve individual companies, batteries,

[3] Simmons, James Stevens: Control of Malaria in the United States Army. *In* Malariology, edited by Mark F. Boyd. Philadelphia: W. B. Saunders Co., 1949, vol. II, pp. 1455–1468.

or similar units in malarious areas. These carried out minor control measures and watched for breaches in malaria discipline.

The malaria survey units consisted of 11 enlisted men, directed by 2 officers of the Sanitary Corps, one an entomologist and one a parasitologist. Control units consisted of 1 sanitary engineer and 11 enlisted men. Such units were trained and equipped to carry out and supervise large-scale malaria control programs. Survey units and control units frequently assisted one another in adjacent areas.

CONTROL ACTIVITIES

As in other theaters of operations, malaria control activities in the Caribbean and South Atlantic Commands were divisible into three general types:

1. Permanent improvement of the environment, by drainage, filling, installation of floodgates, and other engineering procedures. These activities were, of course, expensive and were only followed where longtime use of the area by military, industrial, or commercial interests, with attendant concentration of population, seemed assured.

2. Temporary control measures of various kinds, calculated to protect large numbers of individuals, were employed but were effective for only limited periods of time. If the installation continued to function longer than originally expected, such procedures had to be repeated at required intervals. The use of larvicides in breeding places, the screening of barracks, and later, residual spraying of quarters, inside and out, are examples. The eventual employment of DDT, from the air, to render large areas temporarily free from vector species falls here also. It was justified only in connection with the movement of large bodies of troops in combat areas, or in the carrying out of large-scale maneuvers.

3. Measures usually classed under the head of malaria discipline. The wearing of protective clothing, remaining in protected buildings during the hours of greatest anopheline activity, and the consistent application of repellents are examples. Proper use of jungle hammocks may be included. These practices were valuable in combat zones, while on maneuvers, and in temporary bivouac areas. For these, the individual soldier was held responsible.

Malaria discipline included the application of repellents. Granett,[4] at the time a research fellow at Rutgers University, New Brunswick, N.J., summarized the attributes of a suitable repellent for use by the Armed Forces:

> The repellent must be effective; i.e., it must be able to prevent biting by many pests for long periods of time even under adverse conditions. It must not be injurious to the user or any articles of clothing or objects he may touch. It must possess certain miscellaneous properties such as an acceptable odor, availability, and stability, under storage or field use.

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[4] Granett, P.: The Significance of the Development of Mosquito Repellents for the Protection of Military and Civilian Populations. Proc. N.J. Mosq. Extermin. Ass. 30: 203–210, 1943.

The most satisfactory list of insecticides and repellents as developed for the Armed Forces is found in U.S. Department of Agriculture Miscellaneous Publication No. 606 released in August 1946. Rutgers 612 (2-ethyl-1, 3-hexanediol), Indalone (butopyronoxyl), and dimethyl phthalate, alone and in combination, excelled as repellents.

A memorandum from Headquarters, South Atlantic Ferrying Wing,[5] lists precautions to be taken by the various commands wherever conditions were such as to require them:

1. Effective screening and mosquitoproofing of all buildings occupied by troops.
2. Use of mosquito bars or netting for sleeping.
3. Prohibition of loitering or sitting in unscreened buildings or outdoors when not required by military duties, between dusk and dawn. Wearing of protective clothing by personnel on outdoor duty during these hours.
4. Systematic spraying of barracks, kitchens, messhalls, storerooms, and recreation buildings where indicated.
5. Keeping of doors tightly closed. Prompt reporting and repair of holes in screening. Enforcement by periodic inspection of buildings.
6. Elimination of local breeding places of mosquitoes. Spraying with larvicide recommended where practical.
7. Spraying of aircraft as directed by regulations.
8. Use of chemical prophylaxis in areas indicated.

The protection of personnel from malaria and the disinsectization of aircraft were considered command functions.

MILITARY DEVELOPMENT

Mission

The missions of troops in the Caribbean and South Atlantic were various but not especially complex. They were both offensive and defensive, the latter being more important during the early years of the war. American territory had been attacked at Pearl Harbor, and it was considered highly probable that the enemy might attempt to gain control of the Panama Canal, or at least to cripple its operation. The United States was also interested, jointly with the British Government, in maintaining full, functional use of the West Indies. The greatest menace in the West Indies consisted of German submarine activity against Allied shipping.

In September 1940, the United States acquired bases on Bermuda, Exuma (Bahama Islands), Jamaica (at Kingston), Antigua (Leeward Islands), Saint Lucia (Windward Islands), Trinidad (Great Britain), and Georgetown (British Guiana).

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[5] Medical History World War II, U.S. Army Forces, South Atlantic. Appendages thereto. [Official record.]

As the Allies gathered strength for the African offensive, the importance of these airbases in both the Antilles and northern South America became much greater and necessitated more and larger installations, with emphasis on transport function rather than aerial defense.

Transport of lend-lease equipment had, of course, been a function of many of these bases from the beginning.

Meantime, both Puerto Rico and the Canal Zone were being developed as training centers for troops intended for employment in jungle warfare. An important training area was developed and maintained in southern Trinidad (by the 33d Infantry). It was necessary that this training be both realistic and thorough, if survival and success in Asia, South Pacific, and the Philippines were to be achieved. An important phase of such training consisted of instruction concerning the nature and transmission of malaria, as well as practice and discipline in the use of those preventive and suppressive practices which are under the control of the individual soldier. In patrol activity and in actual combat, these are the chief measures available.

The mission of troops in the Caribbean and South Atlantic may thus be summarized:

1. Defense of the Panama Canal and adjacent areas.

2. Defense of the West Indies, particularly with a view to suppressing German submarine activity.

3. Provision of a chain of bases along which both troops and supplies might be transported to the African theater.

4. Provision of a training area in which conditions of jungle warfare might be duplicated or at least paralleled.

5. The disciplining of troops in regard to prevention of tropical and parasitic diseases (including malaria) with which they were sure to be confronted, both in African and in oriental service.

This last objective was not recognized, at first, as being particularly important, and was not defined in early directives. Experience in the Pacific theater soon forced attention to these problems, however, and the inclusion of malaria discipline became a routine matter in preparing troops for foreign duty. The acceptance of responsibility on the part of officers of various levels of command was a necessary step in making the program effective.

Air Force Installations

Reference has already been made to bases acquired by the United States in 1940 by arrangement with Great Britain. In July 1941, the Brazilian Government passed legislation permitting the United States to develop a number of airbases in that country. These were at Amapá, Belém, São Luís, Fortaleza, Natal, Recife, Maceió, and Bahia.[4] Construction was carried out by the Pan American Airways System, Inc., through its subsidiary, the Air Port Develop-

[4] Medical History World War II, U.S. Army Forces, South Atlantic. [Official record.]

ment Project. To conduct operational activities, the Army Air Forces created the Army Air Corps Ferrying Command, which later became the global Air Transport Command. Expansion of transport activities and the necessity of better provision for the defense of Northeastern Brazil brought about the establishment of the South Atlantic Wing, Air Transport Command, in June 1942. Headquarters were established at British Guiana on 9 July, where a U.S. Army base already existed.

The various airbases established in the area controlled by the Caribbean Defense Command will be listed in separate discussions of the Panama Canal and Antilles Departments.

AREA CHARACTERISTICS

Physiography

The area covered by this discussion includes all islands and coastal regions surrounding the Caribbean Sea, together with such further malarious portions of South America as were occupied or used by U.S. troops. It lies approximately between 35° and 90° west longitude and extends from a little north of the Tropic of Cancer to 35° south latitude (map 10). From the standpoint of mosquito bionomics and malaria transmission, a considerable variety of ecologic situations exist, altitude as well as prevailing winds being factors in some instances. Since it is difficult to generalize for an area characterized by the division of its landmass into so many widely separated units, specific physiographic information will be reserved for presentation in connection with the discussion of mosquito vectors, some of which breed in peculiar and restricted situations, not always typical of surrounding territory.

Climate

As with physiographic characteristics, the area under consideration is too large to permit very concise statements as to climate. From a general standpoint, one is concerned here with the climate of the Torrid Zone, from the Tropic of Cancer to the Tropic of Capricorn. Seasonal differences are measured largely in terms of rainfall, rather than temperature. The striking climatic differences sometimes encountered as one travels from east to west, or vice versa, are practically all explicable in terms of altitude, as, for example, when one proceeds from the Pacific coast of South America, crosses the Andes, and descends into the valley of the Amazon. Apart from altitude, air movements can be a factor, evidenced, for example, by the reduction in precipitation along the coast of South America, as one proceeds westward from French Guiana to Curaçao and Aruba, N.W.I. This is due to loss of moisture by easterly trade winds. Climate tends to favor the occurrence and transmission of malaria when the following conditions are met:

MAP 10.—Caribbean area and South Atlantic theater.

1. A continuous supply of suitable water for the breeding of the vector. Species in which the eggs can survive temporary "mudbank" conditions are obviously more adaptable in this respect. On the other hand, no anopheline does well when there is an excess of precipitation, as when the terrain is covered with a flowing sheet of water.

2. Maintenance of water temperatures above the point where immature stages of the vector will be killed or rendered incapable of recovery.

3. Maintenance of air temperature above the point where adult anophelines are rendered permanently incapable of mating, feeding, or egg laying.

4. Frequent and prolonged association of warm temperatures with high relative humidity, which, by favoring the uninterrupted breeding of the vector, insures its presence in great numbers in the vicinity of both parasitized and nonparasitized human hosts. The same factors tend to favor the use of little or no clothing on the part of native populations, a practice that exposes them to unrestrained attack by enormous numbers of mosquitoes.

5. Freedom from strong, persistent winds during the normal biting hours of the vector, as mosquitoes do not readily take to wing when winds are severe. It should be remarked, however, that gentle winds are no barrier to vector activity and may even be a positive factor in malaria dispersal. Schiavi,[7] for example, conducted a survey in 1944 in the town of Iguape, situated on the coast in the southern portion of the State of São Paulo, Brazil. *Anopheles albitarsis domesticus*, captured in houses where cases of malaria had occurred, yielded both oocysts on the stomach and sporozoites in the salivary glands. Local opportunities for breeding were so limited, however, that the mosquitoes were considered to have flown to the mainland from the low, marshy island of Ilha Camprida when a sea breeze was blowing. Specimens were observed in flight, over the channel.

Although certain species of anophelines are adapted to breeding at higher altitudes than others, even the hardiest eventually reaches a level at which frequency of low temperatures prevents the survival of the species.

From the foregoing remarks, it is evident, therefore, that the coastal regions are, in general, more hazardous from a malaria standpoint than the interior areas, and that within these interior areas, the great river valleys may be expected to be more malarious than the mountain slopes. The peculiar habits of certain vector species are responsible for occasional exceptions.

Special relations of climate to the incidence of malaria in limited areas will be treated in another section of this chapter.

Native Population

The population of the Latin American countries is composed of a mixture of races, proportions differing according to locality. American Indian blood is more persistent in Mexico and South America than in certain of the Central American countries, though isolated tribes survive there practically untouched by outside influence. The use of the Portuguese language in Brazil and of Spanish (with various modifications) in the great majority of political units testifies to the dominant character of the European influence. One should not

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[7] Schiavi, A.: Nota sôbre mosquitos vetores em Iguape. Arq. hig. e saúde púb. 10: 67–73, September 1945.

forget, of course, the French, Dutch, and British interests in the Guianas.

British, French, and Spanish bloodlines exist in the West Indies, where, however, as in Panama, the tremendous biological vigor of the African element, introduced in the period of the slave trade, tends to obscure the characteristics of all races with which it interbreeds. East Indian stocks introduced labor and augmented by later arrivals are making themselves felt. Many merchants in Panama, for example, are East Indians. Chinese and other oriental groups are evident in many cities and towns. Superimposed on all this is the constant coming and going of nationals, from almost all the leading countries of the world, who visit the American Republics in the interest of commerce and industrial development and who frequently become residents for varying lengths of time.

Racial makeup of particular countries or areas will be noted, where significant, in other sections of this chapter.

Mosquito Vectors [8]

The anopheline mosquitoes considered to be important carriers of human malaria in the regions under consideration number eight. These are:

1. *Anopheles albimanus* Wiedemann, 1921.
2. *Anopheles albitarsis* Lynch Arribálzaga, 1878.
3. *Anopheles aquasalis* Curry, 1932 (referred to as *Anopheles tarsimaculatus* by certain authors).
4. *Anopheles bellator* Dyar and Knab, 1906.
5. *Anopheles darlingi* Root, 1926.
6. *Anopheles gambiae* Giles, 1902 (exterminated in New World).
7. *Anopheles pseudopunctipennis* Theobald, 1901.
8. *Anopheles punctimacula* Dyar and Knab, 1906.

In addition to the species just listed, Mexico and Central America, including the Caribbean, support at least 34 anopheline species usually not considered vectors, while South America boasts a total of 52 probably nonvector species and varieties,[9] not counting 3 species of *Chagasia* and omitting some 13 or more forms of questionable validity. Among potential vectors is *Anopheles neroces-*

[8] (1) Komp, W. H. W.: The Anopheline Mosquitoes of the Caribbean Region. Nat. Inst. Health Bull. No. 179, 1942. (2) Kumm, Henry W.: The Geographical Distribution of the Malaria Carrying Mosquitoes: A Collection of Recorded Material in the Literature, and in Personal Communications to the Author. Baltimore: The Johns Hopkins University Press, 1929. (The American Journal of Hygiene Monographic Series No. 10.) (3) Kumm, H. W., and Zúñiga, H.: The Mosquitoes of El Salvador. Am. J. Trop. Med. 22: 399–415, July 1942. (4) Russell, Paul F., West, Luther S., and Manwell, Reginald D.: Practical Malariology. Philadelphia: W. B. Saunders Co., 1946. (5) Mackie, Thomas T., Hunter, George W., and Worth, C. Brooke: A Manual of Tropical Medicine. Philadelphia: W. B. Saunders Co., 1945. (6) Malariology, edited by Mark F. Boyd. Vols. I and II. Philadelphia: W. B. Saunders Co., 1949.

[9] (1) Dyar, Harrison G.: The Mosquitoes of the Americas. Publication No. 387, Carnegie Institute. Washington, D.C., 1928. (2) Gast-Galvis, A.: Biologia y distribución geográfica de los anofelinos en Colombia, Rev. Fac. Med. Univ. Nac. 12: 53–103, August 1943. (3) Lane, J.: Catálogo dos Mosquitos Neotrópicos do Instituto de Higiene de S. Paulo. Editado pelo Clube Zoológico do Brasil. S. Paulo Brasil, Boletim Biologico. Série Monográfica, 1939.

FIGURE 23.—*Anopheles albimanus* breeding along the edges of a quiescent stream.

tensis Galvão, which Coutinho[19] found infected in Brazil but which has not been shown to transmit malaria to man.

Habits and distribution of vectors

Anopheles albimanus.—This mosquito ranges from Texas through Mexico and the West Indies into Venezuela, Colombia, and Ecuador. The larvae are found in a variety of situations, including fresh or brackish lagoons, swamps, marshes, lakes, ponds, pools, puddles, pits, hoofprints, and artificial containers (fig. 23). Exposed, sunlit waters are favored, though some shade is tolerated. This adaptability is the chief reason for its great importance as a vector

[19] Coutinho, J. O.: O "*Anopheles (N.) oswaldoi metcalfi*" Galvão e Lane, 1937 e o "*Anopheles (N.) albitarsis*" Arribalzaga, 1878 como transmissores de malaria no Distrito Federal. Brasil-med. 56: 53–56, 24–31 Jan. 1942.

both in Central America and in the Caribbean. The adults are nocturnal biters, and prefer man, but will also feed on animals. They will enter houses but in most cases leave after feeding. The adults are very secretive in daylight hours, and even experienced collectors have difficulty in locating them.

Plant associations have an important bearing both on the suitability of the environment for *A. albimanus* breeding and on preferred methods of control when the vector is present. Studies carried out by Pratt in Puerto Rico have thrown considerable light on this problem.[11] Thus drainage and dusting are most successful in coastal swamps where *Phragmites* and *Typha augustifolia* are dominant species. Only the sunlit margins are utilized by *A. albimanus*. For pool containing tall grasses, drainage is preferable, as larviciding becomes difficult. Sugarcane fields produce few mosquitoes just after the cane is cut, but sinking of the trash in the irrigation ditches soon results in a sunlit surface where *A. albimanus* is at home. Reflooding intensifies this condition. *Anopheles grabhami* tends to replace *A. albimanus* when the canes reach a meter in height, and *A. vestitipennis* usually takes over when canes are full grown.

Azolla, *Pistia*, and other plants which form floating mats tend to inhibit mosquito breeding. On the other hand, low-floating plant growth, such as is formed by *Chara*, *Utricularia*, and *Ceratophyllum*, protect the larvae from their natural enemies, and so favor their development. In Puerto Rico *Ceratophyllum demusum* is a very common associate of *A. albimanus*.

Anopheles albitarsis.—The typical *A. albitarsis* from Buenos Aires is not domestic, nor does it prefer human blood.[12] On the island of Marajó, however, in the State of Pará, Brazil, the females invade dwellings in large numbers during the evening, even when cattle are conveniently available. This variety has come to be known as *A. albitarsis domesticus*, a form erroneously referred to by certain authors as *Anopheles albitarsis* var. *brasiliensis* Chagas and by others as *Anopheles argyritarsis* Robineau-Desvoidy. *Anopheles albitarsis* var. *limai* Galvão and Lane is possibly identical with the typical form.

Anopheles albitarsis, which is a vector in Brazil, is found from Guatemala into northeastern Argentina and Uruguay. It also occurs in Trinidad. It breeds chiefly in ponds, ricefields, marshes, lagoons, and the overflows of rivers. Matted vegetation and the availability of a certain amount of shade favor its development. The adults show a preference for human blood in certain areas but not in others, indicating the existence of geographic races.

Anopheles aquasalis.—The geographic distribution of *A. aquasalis* in the neotropical region is discussed by Lucena [13] under the name of *A. tarsimaculatus*

[11] Pratt, H. D.: Relation of Plants to Malaria Control in Puerto Rico. Pub. Health Rep., Suppl. No. 200, December 1947.

[12] Galvão, A. L. A., and Damasceno, R. G.: Observações sobre anofelinos do complexo albitarsis. An. Fac. de med. Univ. São Paulo 20: 73–87, 1944.

[13] Lucena, D. T.: Esboço ecológico do *Anopheles* (*N.*) *tarsimaculatus* Goeldi, 1905, no nordeste Brasileiro. Folha med. 27: 140, 1946.

Goeldi. Because extensive areas of salt land stretch inward from the coast, the species occurs much further inland than was formerly supposed. Larvae have been collected 70 miles inland from the State of Paraíba and 160 miles inland in Pernambuco. In these localities, they breed in ditches, pools, or overflows from rivers in which the water is brackish due to the heavy chloride content of the soil. Coastal breeding goes on in waters ranging from 0.117 to 33.345 gm. chloride per liter. This variation is due to tides. Inland, the variation is less extreme, ranging from 5.733 to 29.835 gm. per liter. The concentration at any one spot is usually greater in summer than in winter because of evaporation.

The adults enter houses in large numbers, being in greatest concentration between 10 p.m. and 10 a.m. They have a strong preference for human blood and will attack man in buildings during the day and in the open air. In those localities where it shares a range with *A. albitarsis*, *A. aquasalis* is most numerous in January and February, *A. albitarsis*, in October.

Anopheles aquasalis occurs in Nicaragua, Panama, the Lesser Antilles, Trinidad, and on south into Brazil. It is a widespread vector. Favorite breeding situations are brackish lagoons and marshes and the irrigation water in open fields. Strictly fresh water is avoided, hence the species is usually limited to coastal situations. It breeds in either sun or shade. Adults may fly as far as 3 miles.

***Anopheles bellator*.**—This is one of the most unusual of the vector species. It ranges from Trinidad and parts of Venezuela into Brazil. Eggs are laid and larvae develop in the water found in certain species of bromeliads (wild pineapples), which grow epiphytically in the branches of the immortelle trees (figs. 24 and 25). The adults attack man with avidity, both day and night.

In survey work, the larvae are collected by breaking the plant loose from the tree, on which it is growing, and by dumping the water into a pan. Larvae which adhere to the leaves are washed off by means of a pipette. Spraying the trees with copper sulfate under high pressure has been used to kill the bromeliads.

Bromeliads of the genus *Gravisia* are more typical of the dry, canopy stratum, while species of the genus *Gusmania* occur chiefly in the lower shade.[14] The latter type has only a small reservoir for holding water (about 80 cc.). *Anopheles homunculus*, a doubtful vector, shows a strong preference for these forms, while *A. bellator* favors *Gravisia*, the capacity of which may exceed 600 cc. Such forms are referred to as "tank" bromeliads.

***Anopheles darlingi*.**—This species is recorded from British and Spanish Honduras, Guatemala, Venezuela, coastal British Guiana, Brazil, and northern portions of Argentina. As a vector, it is especially important south of the Equator. The larvae, which prefer shade, may usually be found among debris and surface vegetation in fresh marshes, lagoons, and overflows. Water-hyacinth (*Eichornia*) and waterlettuce (*Pistia*) frequently shelter the larvae

[14] Preliminary Report, C. S. Pittendrigh, 1944, subject: Malaria-Bromeliads and Bromeliad Anophelines, Trinidad, B W.I.

FIGURE 24.—Bromeliad attached to tree, a typical breeding place for *Anopheles bellator* Dyar and Knab. (Courtesy of the Rockefeller Foundation.)

of *A. darlingi*. This is a domestic species. The adults invade houses and show a preference for human blood.

Anopheles darlingi is the chief vector in the district of Campos, State of Rio de Janeiro, Brazil.[15] Surveys have shown 6.8 percent of captured females to contain oocysts, as opposed to 2 percent for *A. albitarsis*. Sporozoites were found in *A. darlingi* only, to the extent of 4 percent.

Anopheles gambiae.—This species, now believed extinct in South America, is an African species which was accidentally introduced into the New World and became responsible for a great deal of malaria in Brazil between 1930 and 1940.[16] Systematic eradication measures accomplished its elimination. It is an adaptable species, breeding in either sun or slight shade, and seems equally

[15] Coutinho, J. O., and Ricciardi, I.: Contribuição para o estudos dos vetores de malaria no Brasil. *Anopheles (Nyssorhynchus) Darlingi* Root, em Campos, no Estado do Rio. Mem. Inst. Oswaldo Cruz 42: 263–290, February 1945.

[16] Soper, Fred L., and Wilson, D. Bruce: *Anopheles gambiae in Brazil, 1930 to 1940*. New York: The Rockefeller Foundation, 1943.

FIGURE 25.—Horizontal section through a bromeliad to show water-holding area among leaf bases.

at home in puddles, pools, shallow ponds, burrow pits, hoofprints, ditches, and overflows. Rain barrels, cisterns, and other peridomestic containers are sometimes used. The adults prefer human blood and are usually abundant in huts and houses.

Anopheles gambiae was first discovered in Brazil in March 1930.[37] The parasite rate in these mosquitos was 63 percent, including a sporozoite rate of 30 percent. An intense malaria epidemic soon struck suburban Natal. Dry seasons caused a recession in breeding activities for a few years, but normal

[37] (1) Shannon, R. C.: Brief History of *Anopheles gambiae* in Brazil. Caribbean Med. J. 4: 123–128, 1942. Abstr. Trop. Dis. Bull. 40: 822, July 1943. (2) Shannon, R. C., and Cesar De Andrade, G.: Dry Season Observations on the African Mosquito, *Anopheles gambiae*, in Brazil in 1938. Am. J. Trop. Med. 20: 641–668, September 1940.

rainfall in 1936 reversed this trend, and in 1938 and 1939, a total of 14,000 deaths from malaria were reported, chiefly from the Açu, Mossoró, and Jaguaribe Valleys. The Brazilian authorities at this point requested aid of the Rockefeller Foundation. By cooperative effort of the Foundation and the Yellow Fever Control Service of Brazil, complete eradication was effected in 19 months, from January 1939. The last living specimen was found in September 1940. The entire cost of this achievement was in the vicinity of approximately $2 million.

An extended and fully documented acount of the joint activities of the U.S. Army and the Brazilian Government in relation to the problem of *A. gambiae*[18] shows that much anxiety existed and that procedures were not always what they should have been; however, that *A. gambiae* did not again establish its residence in the New World is distinctly to the credit of all concerned. A brief summary of the manner in which the problem was handled follows:

Anopheles gambiae had been eradicated in Brazil, in 1940. In 1942, the air traffic across the Atlantic became greatly augmented, thereby vastly increasing the danger of a second colonization in the New World. Increasing numbers of specimens began, in fact, to be found on newly arrived planes. There was some question as to accuracy of identification in all cases, and proof of living specimens seems never to have been certain, but the possibility of a second establishment nevertheless loomed ominously. In an attempt to prevent this, a program was instituted by which all aircraft arriving from Africa were sprayed at once with a mixture of pyrethrum, carbon tetrachloride, and kerosene.[19]

The added complications of military travel soon led to a cooperative program administered jointly by the U.S. Army and Brazilian authorities. In this program, the use of Aerosol bombs became routine (except at the first opening of the doors). It was demonstrated that the spraying of the airplanes in flight had no supplementary value, as most of the insecticide escaped through the tail. In 1943, the U.S. authorities adopted the policy of carrying out sanitation procedures before departure from African airfields. The justification for such routine is made abundantly clear by the insect counts at Brazilian airports between October 1941 and December 1945. Belém, Fortaleza, Natal, and Recife were the bases concerned. A total of 352 specimens of *A. gambiae* were collected at those points. These were carried by 126 of the 9,229 landplanes and by 16 of the 831 flying boats which landed during the 4-year period.

In January 1943, it had been made mandatory for all incoming pilots to keep cabin windows closed, and canopies down, until their planes were

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[18] See footnote 6, p. 122.

[19] Carneiro de Mendonça, F., and Cerqueira, N. L.: Insects and Other Arthropods Captured by the Brazilian Sanitary Service on Landplanes or Seaplanes Arriving in Brazil between January 1942 and December 1945. Bol. Ofic. san. panam. 26: 22-30, January 1947.

sprayed.[20] Some violations were inevitable, however, especially in the case of pilots who were in ignorance of the regulation, or who, not realizing its importance, attempted to improve visibility for taxiing by manipulating windows. Investigation by a special commission toward the end of 1943 resulted in the conclusion that spraying alone, at takeoff or arrival, did not give sufficient protection to South American ports. The commission therefore recommended that measures should be taken to render the West African airfields wholly free from *A. gambiae*.

The War Department, accordingly, assigned a malariologist, together with appropriate mosquito control personnel, to the Middle East theater for the purpose of coordinating mosquito control activities in Sénégal, Liberia, Nigeria, and the Gold Coast. Sixteen officers and ninety enlisted men made up the group. Before this group arrived, the Pan American Airways-Africa, Ltd., and the U.S. Army authorities in West Africa had based their program on the assumption that the flight range of *A. gambiae* is rarely in excess of 1 mile. Investigations by the new group showed, however, that the essential factor in dispersal was not the flight range of the mosquito but the influence of prevailing winds. In some instances, it became necessary to deepen the control zone to more than 5 miles to counteract this.

The degree of success achieved at the several airfields was not uniform, due to the great difference in terrain. In Liberia, for example, the location of the airfield in a jungle clearing, close to native settlements, forced reliance chiefly on malaria discipline. In Sénégal, improvement was effected by removal of activities to a more healthy site where control procedures could be more effective. At Accra, an extensive system of drainage ditches was devised, and although far from being completed, this system had so reduced the breeding of *A. gambiae*, by July 1944, that Brazilian officials expressed complete satisfaction with the results. All things considered, the program was and is highly effective as insurance against a possible second invasion of the Americas by one of the world's worst vectors.

***Anopheles pseudopunctipennis*.**—This mosquito has a wide geographic range. It occurs from the south-central United States to Chile and Argentina and is recorded from Grenada, B.W.I. The larvae prefer sunlit waters and may be found in clear seepages, puddles, pits, pools, streams, and springs. An abundance of algae favors their existence. This species is a vector in Mexico, Argentina, Peru, and possibly elsewhere. Adults enter houses and feed on man only in certain areas.

Anopheles pseudopunctipennis has been shown by Hackett[21] to behave rather differently in various portions of its range. Since it breeds in the beds of hill streams when their volume is diminishing, it is well adapted to moun-

[20] Farrell, E.: The *Anopheles gambiae* Problem in Brazil and West Africa, 1941–44. Bull. U.S. Army M. Dept. 8: 110–124, February 1948.

[21] Hackett, L. W.: The Malaria of the Andean Region of South America. Rev. Inst. salub. y enferm. trop. 6: 239–252, December 1945.

tainous regions with a long, dry season. During flood periods, it survives in secondary breeding spots, at lower levels. The species reaches its greatest altitude in the Cinti Valley, Bolivia, where it has been recorded from 8,500 feet. In most Andean countries, the incidence of malaria appears directly correlated with the rise and fall of *A. pseudopunctipennis*, but in Colombia malaria transmission is slight at higher altitudes, even when *A. pseudopunctipennis* is common. The same is true for Central America. This suggests geographic races, which Vargas [22] has attempted to distinguish. Variety *typicus* is believed to have been described originally from Grenada, B.W.I., rather than from Granada, Nicaragua, as indicated by certain authors. It occurs in the United States, Mexico, Costa Rica, Panama, and Venezuela, probably also in Argentina and Chile. It is a significant vector of malaria above 2,275 feet but only when present in large numbers. Variety *franciscanus* McCracken, which is found in the southern United States, is perhaps the correct name for the nonvector form of Central America and Colombia, mentioned previously. Variety *boydi* Vargas occurs in California, *willardi* Vargas in Mexico.

A new variety of *A. pseudopunctipennis*, *Anopheles pseudopunctipennis patersoni*, has recently been described from Tucuman, in Argentina. The distinction is based on characteristics on the ova.[23]

Anopheles punctimacula.—The species is found from Mexico through Central America, into Brazil and Peru, and also on Trinidad. Breeding occurs only in well-shaded pools, swamps, and sluggish streams. The adults, which are abundant in undrained jungle, are strong fliers and invade houses in order to feed on man. So far as is known, vectorship of malaria is limited chiefly to Panama.

Zoogeographic subdivisions

Lane [24] makes use of zoogeographic subdivisions in discussing the distribution of neotropical anophelines. The Cariba center involves Venezuela and the Guianas. The Incasic center includes the Andean region from Panama to approximately 20° south latitude. The Central Plateau area lies in interior Brazil and is the source of streams which flow in many directions. The Sêca areas are somewhat isolated in the mountainous portion of Eastern Brazil. The Tupí center extends along the southeastern coast of Brazil from Bahia nearly to the 30th parallel. The Chilean center is confined to the northern two-thirds of Chile. The Patagonian centers are in the area west of Buenos Aires. Anopheline mosquitoes tend to migrate southward from the Cariba,

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[22] Vargas, L.: Consideraciones sobre el Complejo del *Anopheles pseudopunctipennis*. Rev. Inst. salub. y enferm. trop. 6: 265–270, December 1945.

[23] Alvarado, C. A., and Heredia, R. L.: Observaciones sobre una nueva variedad del *Anopheles (A.) pseudopunctipennis* Theobald 1901, encontrada en la provincia de Tucuman. An. Inst. med. regl. 2: 72–78, November 1947. Abstr. Trop. Dis. Bull. 45: 290, April 1948.

[24] Lane, John: Anophelines of the Neotropical Region. *In* Malariology, edited by Mark F. Boyd. Philadelphia: W. B. Saunders Co., 1949, vol. I, pp. 399–418.

eastward from the Incasic, northwesterly from the Tupí, and centrifugally from the Plateau and Patagonian centers. The Sêca and Chilean are negative areas; that is, they receive species from elsewhere but do not disperse them.

Using these terms, the distribution of the vectors here concerned is described in table 16.

TABLE 16.—*Distribution of major mosquito vectors by zoogeographic subdivisions in the neotropical region*

Species	Type of locality	Range
A. albimanus	Not definite	Central American and Incasic centers and West Indies.
A. albitarsis	do.	All centers except Chilean and Sêca.
A. aquasalis	do.	All centers except Chilean and Sêca. Occurs in Windward Group, Lesser Antilles.
A. bellator	Trinidad, B.W.I.	Cariba and Tubí centers.
A. darlingi	Rio de Janeiro, Brazil	Widespread in neotropics.
A. gambiae	Africa	Eradicated from northeast Brazil in 1940.
A. pseudopunctipennis	Grenada, B.W.I.	Mountainous parts of Central America, Cariba, Incasic and Chilean centers. (Also in North America.)
A. punctimacula	Colon, Panama	Widespread, but absent from Plateau, Chile, and Patagonic centers.

Secondary vectors

Besides the principal vectors, just discussed, the neotropical region includes a number of additional species which are believed to convey malaria at times, especially when abundant.

Gabaldon [25] recognizes as secondary or minor vectors, *Anopheles crucians*, *A. grabhami*, *A. vestitipennis*, *Anopheles evansi*, *Anopheles nuñez-tovari Gabaldon*, *Anopheles triannulatus*, and *Anopheles cruzi*. All these have at one time or another been found infected in nature, but it is believed that, if these species were to be eliminated, the total amount of malaria in most localities would remain the same. To these vectors, one might add *A. homunculus*,[26] a bromeliad breeder, somewhat similar in habits to *A. bellator*.

[25] Gabaldon, Arnoldo: Malaria Incidence in the West Indies and South America. *In* Malariology, edited by Mark F. Boyd. Philadelphia: W. B. Saunders Co., 1949, vol. 1, pp. 764–787.

[26] Downs, Wilbur G., and Pittendrigh, Colin S.: Malaria Transmitted by Bromeliad-Breeding Anophelines. *In* Malariology, edited by Mark F. Boyd. Philadelphia: W. B. Saunders Co., 1949, vol. 1, pp. 736–748.

Anopheles pessoai Galvão and Lane is considered a secondary vector in Brazil, along with *A. albitarsis*.[27] *Anopheles neivai*[28] is also a possible minor vector.

Effect of Military Occupation on Malaria Potentialities

Increase of mosquito production due to alteration of the terrain by combat was, of course, no factor in these areas. Similar problems arose, however, in connection with the building of roads, landing fields, and port facilities, where excavations and other manmade impoundments due to engineering activities remained to be filled by subsequent rains and thus became potential mosquito-breeding situations. In some cases, incidence of malaria among troops was traced definitely to such conditions, and their correction brought about marked improvement in malaria rates.

Deliberate improvement of terrain either by the military alone or in cooperation with native governments was carried out in the vicinity of practically every installation of any size. In most places, a substantial reduction of mosquito vectors resulted. Exceptions occurred where an attempt was made to apply general measures without knowledge of the biology of specific vectors. For example, no amount of attention to salt marshes could possibly affect the breeding of *A. bellator* in epiphytic bromeliads.

In general, it may be said that the longer U.S. troops remained at Caribbean and South Atlantic bases, the lower did the incidence of malaria vectors in the vicinity of such points become. This was especially true after malaria survey and malaria control detachments began to function. It is significant that the bulk of such accomplishment took place before the general availability of DDT.

Two possibilities existed regarding the enhancement of the gametocyte reservoir. Assuming no essential change in the concentration of native population, one has merely the problem which results through infection of troops and civilian newcomers from the endemic reservoir. To the extent that new arrivals become active cases and eventually carry gametocytes in their blood, these cases add to the local reservoir and increase the possibility of epidemic manifestations. Under routine military procedure, however, such cases were quickly diagnosed, hospitalized, given drug therapy, and though not necessarily cleared of all infection, rarely carried the gametocyte form of the parasite after return to active duty. Suppressive Atabrine therapy particularly tended to eliminate gametocyte forms of *Plasmodium vivax* and *Plasmodium malariae*.

The second aspect of the problem, and the more important, relates to the concentation of native labor for the carrying out of engineering projects. Such labor is often recruited from scattered areas, including some relatively remote

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[27] Deane, L. M., Causey, O. R., and Deane, M. P.: Studies on Brazilian Anophelines from the Northeast and Amazon Regions. Baltimore: The Johns Hopkins University Press, February 1946. (The *American Journal of Hygiene* Monograph Series No. 18.)

[28] Rey, H.: Revista de nuestros conocimientos sobre vectores de malaria en Colombia. Tijeretazos sobre Malaria 11: 30–32, March and June 1947. Abstr. Trop. Dis. Bull. 45: 1053, December 1948.

points. In tropical regions, a certain percentage of these persons is almost certain to be malarious, and a lesser percentage actively infective. If a vector is present, these gametocyte carriers act as a seedbed for infecting the entire labor camp, and a sharp rise in the malaria rate may be expected. The results are serious and manifold: (1) The efficiency of the labor camp is greatly reduced by reason of the hospitalized cases; (2) the hospital and dispensary services of the base or installation may be strained by the double load of military and civilian cases; (3) laborers who are not too ill to work may nevertheless be gametocyte carriers and thus contribute to the further spread of infection; and (4) many mosquitoes then have access to gametocyte carriers which would normally have bitten either normal or noninfective persons. The number of infective anophelines in the vicinity of military personnel thus becomes tremendously increased.

All this can take place even when first energies are devoted to terrain improvement with a view to malaria control; that is, while ditching, filling, and the installation of tide gates are in progress. Much trouble can be forestalled, however, if less expensive control procedures are practiced in the beginning. These include administration of prophylactic chemotherapy to all exposed persons, larviciding of obvious mosquito-producing areas, screening and spraying of barracks, and use of repellents in the field. These are the same procedures which constitute the total and permanent program of installations too small in size to warrant large-scale engineering procedures of an expensive nature.

While these precautionary measures are in operation, mosquito and parasite surveys should be continuous in order to evaluate their efficacy and to form the basis of recommendations for expansion, modification, or abandonment of specific practices. In tropical America, as in other theaters, personnel qualified to conduct such surveys were not available in organized groups (malaria survey detachments) until long after most installations had been fully developed. Military engineers, in cooperation with civilian health authorities, did commendable work, however, in keeping the incidence of malaria among troops and civilian laborers at a desirable low point.

Part II. Experience in South Atlantic Command [29]

Because the areas in the South Atlantic involve different latitudes, altitudes, and especially different vectors, these subjects will be discussed under separate commands and subdivisions.

EXTENT OF COMMAND

The South Atlantic Command was activated on 24 November 1942. It included Brazil, Paraguay, and Uruguay, and extended from Amapá, Brazil,

[29] See footnote 6, p. 122. This document, covering medical activities in the South Atlantic, has been used widely as a source for this section.

to Montevideo, Uruguay; that is, from 20° north latitude to 35° south latitude. The most westerly point was Asuncion, Paraguay, the most easterly Ascension Island, Great Britain, 1,437 miles east of Natal. There were no U.S. Army facilities south of Rio de Janeiro.

Nine stations were established. These were located at Amapá, Belém, São Luís, Fortaleza, Natal, Recife, Bahia, Fernando de Noronha (Brazilian Penal Settlement), and Ascension. Belém and Natal (together with Ascension), were the principal bases in connection with the ferrying route. There were no tropical disease problems at Ascension Island, but at all other stations, serious hazards existed, malaria among them.

PREVALENCE OF MALARIA ON BRAZILIAN COAST

In 1940, malaria had ranked third as a cause of death in Pernambuco, where it caused 4.5 percent of all deaths. U.S. Army surveys of native populations disclosed indices of parasitemia, ranging from 0.26 to 8.4 percent. *Vivax* infections outnumbered *falciparum* infections five to one. Civilian efforts at control were somewhat hindered by lack of funds. Also, division of responsibility between the Brazilian National Malaria Service, the Servico Nacional de Febre Amarela (Yellow Fever), and various local health agencies sometimes made concerted action difficult.

Malaria was endemic in the vicinity of all U.S. Army installations in Brazil but was particularly prevalent around the airbases at Belém, Natal, and Recife. The average annual rainfall along the coastal area is given as 60 to 70 inches, the average temperature as 87° F.

Because of the great importance of keeping men and materiel moving to North Africa, the small service force in the South Atlantic had to be maintained in a high state of health and efficiency, and rigid malaria control measures at all bases became a necessity.

A malaria control training program was instituted early in the history of the South Atlantic Command. Because of the possibility of transfers, malaria discipline was taught at well-sanitated bases as well as elsewhere. Flight surgeons were required to brief transient crews on malaria and its control. Antimalaria posters were distributed, and a circular letter was used to instruct transient personnel. Film strips were used for instruction, and the malaria training film, TF 8-953, issued in 1943, was shown at movie theaters. Some of these theaters, it should be mentioned, were of the open-air type, but no cases of malaria were ever traced to them. Strategic spraying of movie areas at Recife by the 202d MSD (Malaria Survey Detachment) was doubtless a desirable precaution. It is to the credit of all concerned that no significant disability among the troops from malaria ever existed and that serious cases of malaria within the Command were very few. All evacuations of patients, between June 1943 and 12 October 1945, included only nine cases of tertian malaria—four in 1943, four in 1944, and one in 1945.

Protection, by suppressive medication only, gave reasonably satisfactory results under some conditions.[30] For the duration of the war, Brazilian troops were stationed in various towns and villages along the coast in the State of São Paulo, where malaria is always endemic. Both mepacrine (Atabrine) and metoquine (quinacrine hydrochloride) were used. Heavy dosage for 5 days was followed by continued weekly administration. During the 3-year period concerned, only 37 of 4,112 officers and men contracted malaria, a figure equivalent to 0.9 percent. A much higher malaria rate prevailed in nearby cantonments where drug prophylaxis was not in force.

Since many *A. tarsimaculatus* (*A. aquasalis*) and *A. albitarsis* were collected in the barracks and 11,142 cases of malaria were recorded from the civilian population with which the soldiers were associated, the general good health of these particular troops may be said to have depended upon the suppressive medication program.

SUMMARY OF ADMINISTRATIVE HISTORY (MEDICAL)

Earliest medical reports from this theater of operations were informal communications from two officers of the Army Air Corps Ferrying Command, Capt. Fred A. Heimstra, MC, who was stationed at Natal, in April 1942, and Lt. Francis M. Dougherty, MC, who assumed duties at Belém in May 1942. Malaria was pointed out as a major medical problem.

With the activation of the new command on 24 November 1942, Wing Headquarters were established at Natal. Brazil had entered the war as an ally on 22 August 1942. Lt. Col. (later Col.) George E. Leone, MC, became surgeon, with Capt. (later Maj.) Millard E. Smith, SnC, as sanitary engineer and malaria control officer. On 2 December 1942, Maj. Harold F. Funsch, MC, assumed the duties of Wing Surgeon. Colonel Leone continued to plan the development of the theater medical service. Brazilian Armed Forces were available for home defense, so that the main function of the U.S. Army forces in that country thenceforth was to provide logistic support to the activities of the Air Transport Command.

Recife (Pernambuco) was selected as the site for concentration of medical activities. For malaria control in the environs of Recife, the services of the Division of Health and Sanitation of the Office of the Coordinator of Inter-American Affairs in Rio de Janeiro were requested and obtained. This group had already accomplished good results around the U.S. Army Air Force installations at Belém.

Recife also became the site of general headquarters for the USAFSA (U.S. Army Forces, South Atlantic). Brig. Gen. (later Maj. Gen.) Robert L. Walsh, previously in command of the South Atlantic Wing, took over the additional duties of commander of the USAFSA. To avoid confusion of

[30] Coda, D.: Expériences sur la chimioprophylaxie du paludisme au Brésil. Bull. Soc. path. exot. 42: 168-172, 1949. Abstr. Trop. Dis. Bull. 47: 297, March 1950.

responsibility in medical matters, General Walsh utilized the theater surgeon, Colonel Leone, in the added capacity of surgeon for the Air Transport Command. Colonel Leone became qualified for this dual function by attendance at the course in aviation medicine at Randolph Field, Tex.

This arrangement continued in effect until May 1945. Redeployment of U.S. Army forces had by then greatly increased aviation medical problems, and the Air Transport Command, in executing the "Green" and "White" projects,[31] once again began to operate its medical service without reference to theater headquarters. On 25 July 1945, Lt. Col. Joseph Nagle, MC, was designated as Division Surgeon, South Atlantic Transport Division, Air Transport Command. The theater surgeon temporarily retained responsibility for theater medical problems not strictly related to aviation. After the defeat of Japan in August 1945, steps were taken which resulted in the transference of all medical responsibilities to the Air Transport Command by the date of closeout for the South Atlantic theater. This took place on 31 October 1945.

The table of organization for Headquarters, Medical Section, USAFSA, was approved by War Department letter, dated 21 September 1943 (chart 7). As of 31 December 1943, the staff included Capt. (later Maj.) Gus R. Herzik, Jr., SnC, Sanitary Engineer and Assistant Medical Inspector; Capt. Millard E. Smith, SnC (duty status from South Atlantic Wing, Air Transport Command), in charge of malaria control work; Capt. Jacob M. Benson, MC, Theater Malariologist, in charge of disinsectization of aircraft and liaison officer with the Brazilian Port Health Service; and Capt. Sylvanis N. Landis, MC, in charge of the theater laboratory. Of this group, only Captain Herzik remained to be listed as of 31 December 1944. Captain Landis was replaced during the year by Capt. (later Maj.) Benjamin M. Kagan, MC, who served as liaison officer as well as theater laboratory officer and epidemiologist. Major Herzik was replaced by Maj. John E. Vogt, SnC, on 27 March 1945.

ORGANIZATION

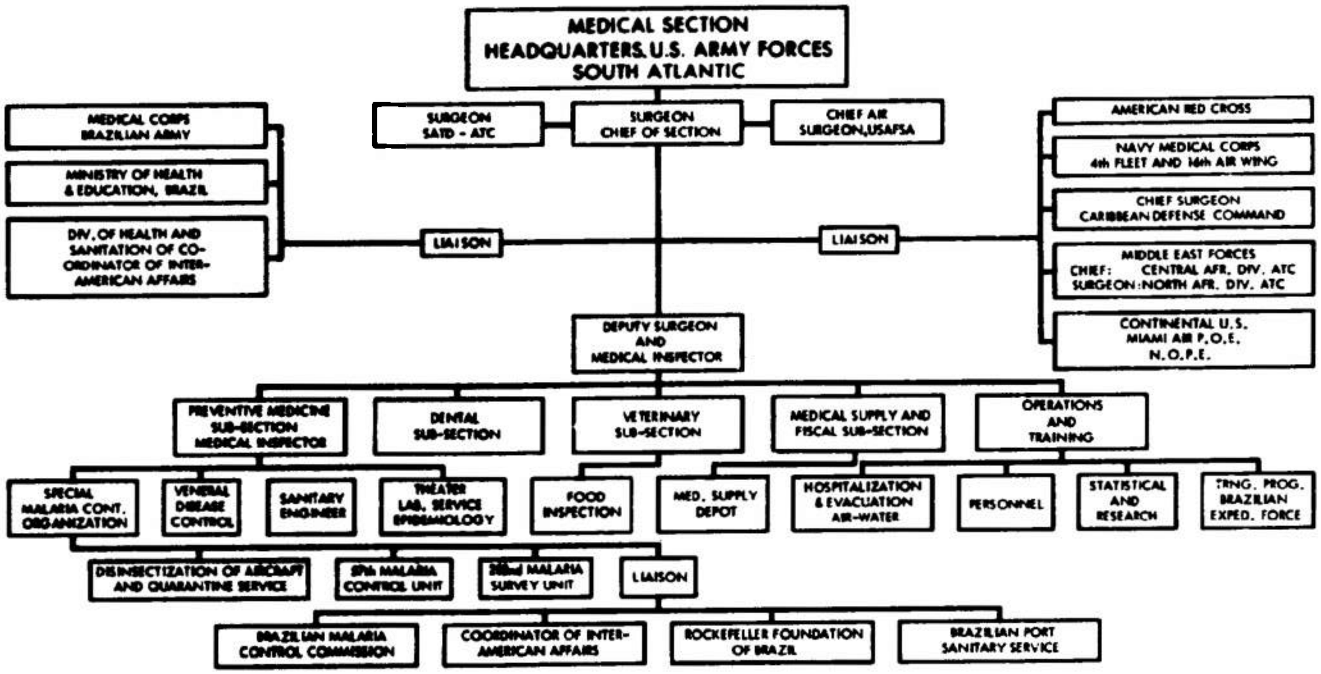
Malariologists

The special malaria control organization of the Medical Department of the Army was established in 1942.[32] A chief malariologist was appointed for each theater of operations in which malaria was a problem. Capt. (later Lt. Col.) Everett W. Ryan, MC, served as theater medical inspector for the South Atlantic, until the appointment of Capt. Jacob M. Benson, MC, in 1943. These malariologists both planned and supervised the control program for

[31] The "Green Plan" provided for the redeployment of troops from Europe to the United States by air. Provision was made to transport approximately 50,000 troops per month, of which half would travel the South Atlantic Route. The "White Plan" pertained to the return of aircraft.

[32] Malaria Control Overseas (News and Comment). Bull. U.S. Army M. Dept. 4: 501–503, November 1945.

CHART 7.—*Table of organization, Headquarters, Medical Section, U.S. Army Forces, South Atlantic*



their respective areas and served as liaison officers between field units and higher headquarters. Effective function in the field dates from February 1943. The total personnel specifically designated for malaria control overseas, by the end of the war, included approximately 345 officers and 2,350 enlisted men.

Sanitary Corps Activities

Sanitary Corps officers were used as sanitary engineers, malaria control officers, assistant medical inspectors, laboratory officers, and administrative assistants. All these functions, especially the first four, related more or less intimately to the malaria problem. The services performed by 2d Lt. (later Capt.) Irving E. Linderman, SnC, Commanding Officer, 57th MCD (Malaria Control Detachment), may be cited as an example. This officer, with his detachment, reported to Headquarters, USAFSA, at Recife on 3 December 1943. Because the greatest problem in malaria control existed in the Belém area, he and his unit were assigned to that station. The unit engaged in malaria control activity at Belém, Amapá, and São Luís. Inasmuch as Captain Linderman was trained as a sanitary engineer, it was decided to utilize him as a consultant in this field whenever his duties in malaria control work might permit. In this connection, Captain Linderman was appointed assistant base medical inspector at Belém, 17 February 1945.

A request had been submitted to the War Department on 17 November 1943 for the services of a malaria survey unit. On 15 April 1944, 2d Lt. (later Capt.) Herbert T. Dalmat, SnC, and 2d Lt. (later 1st Lt.) Aran S. Johnson, SnC, reported to headquarters. Since the principal anxiety in the matter of malaria control related to the possible reintroduction of *A. gambiae* into Brazil, Lieutenant Dalmat was assigned to Natal, as aircraft disinsectization officer, to assist the Brazilian authorities in the treatment of airplanes arriving from Africa. Lieutenant Johnson, an entomologist, was retained at Recife, until the arrival of the 202d Malaria Survey (later designated the 202d Malaria Survey Detachment) on 3 July 1944. He was then sent to Belém and was attached to the 57th Malaria Control Unit which was doing survey as well as control work and could well utilize his services.

The activities at Natal were very important from the standpoint of Brazilian-U.S. relations. It became necessary to make the officer in charge directly responsible to the Commanding General, USAFSA.

History of Malaria Survey and Control Units

202d Malaria Survey Detachment.—The 202d MSD was activated at Camp Ellis, Ill., on 10 December 1943, in accordance with General Orders 85, Headquarters, Camp Ellis. Enlisted personnel were drawn from various casual detachments at the camp, except for three laboratory technicians who were assigned from Fort Sam Houston, Tex. Capt. Rupert L. Wenzel, SnC, and 2d Lt. (later Capt.) Leon Jacobs, SnC, joined the organization on

13 and 17 January 1944, respectively. Captain Wenzel left the unit on 24 October 1944, and Captain Jacobs assumed command.

The unit received some preliminary training in Camp Ellis and then proceeded to Camp Planche, La., where it received specialized malaria training from 1 March to 20 April 1944, and arrived in Recife on 3 July 1944.

After 10 days of quarantine, the detachment's enlisted personnel were attached to the 200th Station Hospital for rations and quarters, while the officers were quartered with Headquarters, USAFSA, officers.

The 202d MSD, like the 57th MCD, was assigned a theater function, and came under Headquarters, USAFSA, for the major part of its administration, only minor details being subordinated to the base command. In addition to the theater function of malaria survey work, it was charged with malaria control responsibility in the Recife military area, mainly routine larviciding, ditching, and ditch maintenance. However, when opportunity permitted, it performed some permanent filling operations. It managed its own survey work entirely. The laboratory staff did mosquito identifications and blood surveys. In its theater survey function, it performed malaria surveys at Amapá and Fortaleza and assisted in survey work at Natal and Belém. It performed experimental work on DDT as a mosquito larvicide and on an A-24 airplane fitted for spraying DDT. Personnel of the unit also performed fly survey and control work on Ascension Island. The unit was inactivated on 21 September 1945.

57th Malaria Control Detachment.—The 57th MCD was officially activated in the spring of 1943 at Camp Planche, which was then the New Orleans staging area. Personnel to make up the organization were assigned from various medical replacement centers and pools. The unit embarked at the New Orleans Port of Embarkation early in 1944 and arrived at Belém on 8 February 1944. Personnel were attached to the 193d Station Hospital for rations and quarters.

The Detachment was charged with malaria control at the bases of Belém, Amapá, and São Luiz. Usually two men were sufficient to handle routine control operations at Amapá, and the rest remained working at Belém. It was only necessary to send a man to São Luiz occasionally, because of good control effected there by the Brazilian National Malaria Service. At first the unit confined itself to control work, obtaining its survey information from the SESP (Serviço Especial de Sáude Pública). Later, in September 1944, with the aid of Lieutenant Johnson, who remained on temporary duty with the detachment from September to December 1944, a larva survey team was set up. The unit borrowed a microscope and did its own mosquito identification, although it still received daily reports from SESP. Enlisted men of the 202d MSD were placed on detached service with the 57th MCD in September and October 1944, one at Belém and one at Amapá, to aid in survey work.

The chief activity of the 57th MCD was carrying out temporary and semipermanent control measures. Larviciding, wherever larvae were found, was performed regularly, and stream training, construction of new ditches, and the maintenance of old ones were also carried on. This work occupied the efforts of 40 to 60 Brazilian workers who were employed by the post engineer and supervised by the 57th MCD.

ACTIVITIES AT VARIOUS BASES

Housing

Inspection in July 1942 disclosed that no provision had been made for mosquitoproofing of buildings to be occupied by troops. Especially to be criticized were the loosely laid tiles which formed the roofs of the one-story mortar, tile, and brick structures being erected by Brazilian contractors. The very satisfactory screened wooden buildings, on concrete supports, used in British Guiana, could not be duplicated in Brazil, because of lack of lumber and other technical difficulties. Repeated protests and considerable correspondence resulted in commitment of mosquitoproofing either by cementing the tile or by copper screening the ceilings. There was a shortage of material, however, and troops arrived before the quarters were completed. It was therefore necessary to house some of them in tents.

Transient personnel for whom transportation could not be immediately provided were housed in tents at Natal, and a "Tent City" was established at Recife to give temporary shelter to transients, to overflow personnel, to prisoners of war, and to survivors of disasters at sea. Most of these persons remained only a short period, but 140 permanently assigned individuals lived there for considerable time.

Tent City was within a malaria zone, and the tents were not in any way mosquitoproof. Infected natives lived within flight range of the area, and suitable vector species were present. Repellents and mosquito nets constituted the only protection, and it is remarkable that only nine cases of malaria were determined as originating there. Since requested construction of mosquitoproof barracks did not materialize, these troops were moved into existing barracks regardless of the crowding which resulted. It would appear that malaria discipline among the permanently stationed personnel of the South Atlantic Command was usually satisfactory. Educational efforts to this end on the part of the theater surgeon were not lacking. Number five of the seven "health precautions," set forth by a War Department poster distributed throughout the command in November 1943, read as follows: "Use mosquito bed net every night. Use protective clothing and mosquito repellents if on out-door night duty."

General Health Measures

Data on the number of malaria cases among U.S. Army troops in Brazil in 1942 are inaccurate. Some figures will be presented in the sections on the individual bases. Malaria attacks among command personnel in the South

Atlantic theater during the year 1943 totaled 133 cases, with 20 of these recurrences. During 1944, there were 75 cases of which 22 were recurrences. From January through August 1945, there were 39 cases of which 17 were recurrences. These figures include all cases originating in permanent personnel regardless of whether the disease was contracted outside the theater. The breakdown of these cases per month is presented in table 17.

Since particular problems existed at the various bases, further data appear on each one, individually, as follows:

TABLE 17.—*Total cases of malaria in U.S. Army Forces, South Atlantic, by months, January 1943–August 1945*

[Rate expressed as number of new cases per annum per 1,000 average strength]

Month	1943			1944			1945		
	New	Recurrent	Rate (new cases)	New	Recurrent	Rate (new cases)	New	Recurrent	Rate (new cases)
January	3	0	9.3	2	0	3	0	1	0
February	7	0	20.7	2	0	3	1	2	2.3
March	33	0	99.3	0	1	0	2	0	3.7
April	20	0	46.4	5	0	9	1	1	2.2
May	10	0	17.7	12	2	22	7	4	15.8
June	12	3	26.8	20	1	30	5	3	6.7
July	6	2	9.8	5	3	10	2	1	2.5
August	6	3	11.8	2	3	4	4	5	4.1
September	4	4	5.6	1	2	2			
October	5	0	8.6	0	4	0			
November	4	7	6.6	1	2	2			
December	3	1	4.8	3	4	6			

Belém.—Val de Cans Field was situated 6 miles outside of the city of Belém on the south side of the Rio do Pará (Guajará Bay). The airbase bordered this river and the Val de Cans River.

Close to the Rio do Pará in the low areas, there is much marsh and swamp, while the higher ground is covered by dense tropical rain forest. The proximity of the base to the flood plane, together with intense humidity and a climate which is never dry and which has a prolonged season of heavy rains, all aided in producing optimum mosquito-breeding conditions. Rainfall averages 112 inches per annum, of which 75 percent falls during the first 6 months of the year. Brackish waters of the Pará River infiltrating in areas close to the shore produce conditions suitable for the breeding of *A. aquasalis*, while seepage and storm waters collecting in unshaded depressions produce foci of the mosquito second only to *A. gambiae* as a malaria vector, *A. darlingi*.

A report by Colonel Leone revealed poor malaria conditions at Belém in July 1942. Though malaria registers were not kept, the local medical officer reported at least 30 cases of malaria within the preceding 2 months, among a base population of 6 officers and 105 enlisted men. There was no way of ascertaining how many of the 25 to 50 transients per day who were passing through the field acquired malaria during that time. One-half mile northeast of the closest U.S. Army barracks, there was located a Brazilian Army post where no precautions against malaria were taken, with the consequence that the malaria rate (new cases only) among the Brazilian troops for the period April through July 1942 was 506 per 1,000 per annum, and for April only, always a month of high incidence, 910 per 1,000 per annum. At the U.S. Army installation, meager control measures were being effected by the base personnel. These consisted of oiling stagnant waters on the base with crude oil, and some minor drainage. Control was limited because of lack of adequate supervision and equipment. All personnel were required to sleep under mosquito netting, and head nets, gloves, and mosquito boots were worn by guards at night. Malaria prophylaxis, consisting of quinine sulfate—7½ grains daily—or of Atabrine—6 grains (4 tablets) weekly—was required.

Even during the dry season (from August to November) of 1942, cases of malaria occurred among the small troop complement stationed at Belém. Three cases of malaria occurred in August, and the malaria incidence was still high with 12 cases in October. Action was initiated by the Office of the Surgeon, USAFSA, to mosquitoproof all buildings at the base at Belém and to insure the proper construction of any additional barracks. Arrangements were also made with Serviço Especial de Sáude Pública to carry on a treatment program of all known cases of malaria among the neighboring natives. Further recommendations included extension of the drainage system. In the absence of screening, cloth was to be used for mosquitoproofing buildings; however, not much of this work was accomplished. Fortunately, not much jungle was cleared. In those places where this work was accomplished, at the ends of the runways—not for malaria control but as a necessary measure in the construction of the airfield—innumerable pools of water were exposed to direct sunlight, providing an ideal environment for the breeding of *A. darlingi*, the worst vector of malaria in the area.

Factors peculiar to the military situation contributed to a high rate of malaria in Belém. It was necessary for airplanes remaining overnight to be guarded by military personnel of the command. These men were exposed to malaria-infected mosquitoes, which abounded in the grassy areas of the field where the planes were parked. Head nets, mosquito boots, and repellent were not always available for these guards; so undoubtedly many cases of malaria could be attributed to night activity.

The SESP, a joint health project of the Brazilian Government and the Coordinator of Inter-American Affairs organized during 1942 at Belém, set up a program of permanent and temporary malaria control measures. The permanent measures consisted of a vast drainage system and the installation of tide gates at the mouth of small streams emptying into the Rio do Pará. Larvicidal measures were directed principally against *A. darlingi*, the most important vector in Belém and secondarily against *A. aquasalis*. The vastness of the permanent control program caused slow progress, but the effects of the larviciding became evident much sooner. In a report to the chief surgeon, 2 December 1942, Capt. Millard E. Smith described the larvicidal work of SESP as excellent. Paris green (copper acetoarsenite) larvicide (50–50 paris green and kerosene, diluted with water at the site of application and dispersed by knapsack sprayers) was used twice a week on the breeding areas. It was anticipated, however, that larviciding without drainage would be inadequate at the height of the rainy season.

By May 1943, an improvement had been effected in the malaria situation. Most of the living quarters were completely screened and mosquitoproofed. Others were being repaired. The malaria rate was kept relatively low, in comparison with 1942, because of the larviciding activities of SESP and the improved living conditions. The observance of individual malaria discipline was lax, however, and cases were being acquired needlessly.

The malaria incidence in Belém during 1943 was ameliorated, too, by the establishment of a sanitary detail supervised by the sanitary inspector and composed of 2 enlisted men and 40 natives employed by the Air Port Development Project. This detail accomplished such antimalaria measures as drainage and filling of stagnant pools in borrow pits, cleaning streams of debris and vegetation, and clearing underbrush around the field.

No figures are available for the number of malaria cases contracted at Belém during the months of February through April 1943. However, it is estimated on the basis of vague statements in the monthly sanitary reports that 1 to 3 cases occurred per month, of which some may have been recurrences. (In January, only one recurrent case was reported.) The incidence of the disease rose slightly during the months of May and June 1943, when 5 and 6 cases were reported respectively, giving rates per annum of 76 and 103. This was a considerable improvement over 1942. During the rest of the year, only five more cases of malaria appeared in the command at Belém—two in July, two in September, and one in December.

At the beginning of December 1943, Lieutenant Linderman arrived in the theater. The 57th MCD had been requisitioned for service at Belém, and air transportation had been requested for its commanding officer so that it would be possible for him to orient himself with the situation before the arrival of his unit. The enlisted men of the detachment arrived on 8 February 1944, but the organizational equipment, due to transportation difficulties, was not delivered until 29 April 1944. Until arrival of the supplies, the unit did its best with borrowed equipment and took over the malaria control procedures on the base.

In November and December 1943, reports were received that Eighth Air Force combat crews ferried through the South Atlantic had incurred many cases of malignant tertian malaria. The striking power of the Eighth Air Force had been materially reduced as a result of malaria, with 17 percent of a group of combat personnel becoming ill with the disease upon arrival at their oversea destination. The complaint from Headquarters, Eighth Air Force, referred to the first week of November as the time when this incidence of malaria was encountered. The rates in the South Atlantic Command had fallen off sharply in the second half of 1943. Moreover, the predominant infection among permanent troops was always caused by *P. vivax*. (In the entire history of the command, only five *falciparum* infections were incurred.)

Consequently, it was not considered likely that the aircrews had become infected in Brazil. The record spoke for itself, and except for the more rigid enforcement of malaria discipline at Belém, no major changes in the malaria control program had to be effected. Directives on the control of malaria had been published for the entire command, and the importance of malaria was reiterated in additional letters. Col. Paul C. Gilliland, MC, Air Transport Command Surgeon, made a special inspection of Belém and Natal in regard to malaria. Suppressive treatment for malaria was directed by Colonel Gilliland for transient combat crews using the South Atlantic route.

After the arrival of the 57th MCD, Belém showed considerable improvement over 1943, with only 17 cases throughout the year 1944. Some of these cases were contracted at remote outposts, such as Clevelandia, where it was impracticable to carry on control. Most of the 17 cases occurred during the period from April through June 1944, with 4 cases in April, 8 in May, and 3 in June. Of these cases, one in April, two in May, and two in June were recurrences.

The 57th MCD inherited the original Air Port Development Project Sanitation Squad and augmented it to include from 50 to 60 native laborers, who were employed regularly under the supervision of enlisted personnel of the organization. These employees were divided into various crews for larviciding, barracks spraying, ditching and maintenance, and survey work. The activities formerly performed by SESP came under the control of the 57th MCD. However, since the control detachment was not equipped for survey work, SESP continued to make surveys and perform identifications. Liaison between SESP and the 57th MCD was maintained closely during the entire year, and it was therefore possible to perform effective spot oiling for the elimination of foci of *A. darlingi*.

The native larva survey team mentioned previously was established with the help of a sanitary technician on detached service with the 57th MCD from the 202d MSD in Recife. In accordance with theater policy on the use of malaria control personnel, the 202d MSD had detailed men to Belém and Amapá to aid in survey work. Also, from August 1944 to January 1945, Captain Linderman had the assistance of Lieutenant Johnson, who aided in the administration of the unit and in the establishment of survey procedures.

From July 1944 until August 1945, only five cases of malaria were charged against Belém. Of these, two in June 1945 were in recently assigned personnel who arrived at the base within the incubation time of the disease. This record is enviable, considering the high incidence of malaria during the early history of the base. During the rainy season of 1945, DDT was used very successfully for the first time in Belém as a larvicide, and this may account for the excellent malaria control during this particularly difficult portion of the year. (Previous to April 1945, sufficient DDT was available for residual spraying, which had been accomplished routinely in the Army dwellings.)

Natal.—Parnamirim Field, the most important airbase of the U.S. Army in Brazil, was located about 8 miles from the city of Natal, which is at 5°50′ south latitude and 38°5′ west longitude. The airfield, at an elevation of 133 feet above sea level, was surrounded by hilly, generally well drained terrain, although there were a number of small fresh water lakes. Except for a small lake adjacent to the area of the field, no bodies of water exist in a radius of 2½ miles of the area. The surrounding country is dry, with sandy soil, rapid drainage and a covering of low brush, "catinga." In the south, there are two streams, the Rio Cajupiranga and the Riacho Cajupiranginha, joining in an area which was about 2½ miles directly below the base. Further east, the combined stream unites with the Rio Pitimbu to form the Rio Pirangi which empties into the sea southeast of area in which the field was located. The Rio Pitimbu has its origin west of this area, makes a circuit around it to the north, and then descends south to its confluence with the Rio Cajupiranga, over 2 miles from the area of Parnamirim Field.

The borders of these streams are cut by irrigation ditches which are required for cultivation along the river valleys. Sometimes these are abandoned and become covered with grass which protects numerous foci of *Anopheles* mosquitoes. In addition, there are low banks, cutoffs and meanders along the paths of these waters which are well vegetated and serve for mosquito breeding.

The climate is good with an average daytime temperature of 86° F., and an annual rainfall of approximately 55 inches, most of which falls during the months of April to July. There is a constant wind blowing from the south or southeast.

Because of the favorable topography of the area and the distance of the base from mosquito-breeding foci, malaria was not considered as a serious health problem at Parnamirim Field. Most of the control activities were in the hands of the Brazilian National Malaria Service. The activities of the Brazilians included stream training, brush clearing, minor drainage and ditch maintenance, and some larvicidal work using paris green. Their service, because of lack of funds, was not adequate, as evidenced by an epidemic of malaria which broke out in June 1943 in villages along the Pirangi Valley. The favorable situation of Parnamirim Field is evidenced by the fact that only a few cases of malaria occurred among base personnel during the period of the epidemic in the nearby valley.

During the entire history of the airbase at Natal, most of the cases of malaria could be traced to off-base activities. A radio range situated about 5 miles from the base was the site of many infections that were incurred, and emphasis frequently had to be placed on the use of individual protective measures. Soldiers required to attend the warning lights, situated between the base and the Rio Cajupiranga, also became infected. The city of Natal itself was not free of malaria, and soldiers visiting the city at night or wandering around the native habitations near the base despite "off-limits" orders were exposed to bites of *Anopheles*. Occasional cases of malaria among permanent personnel were incurred, although, on the base proper, mosquitoes were seen rarely.

In April 1944, a malaria control officer, Lieutenant Dalmat, was assigned to Parnamirim Field. This officer had the double duty of aiding the Brazilian Government in the disinsectization of aircraft arriving from Africa and of supervising whatever malaria control activities were required at the field. To supplement the work of the Brazilian National Malaria Service in the Parnamirim area, this officer set up a system of survey and control work on and around the base. Routine checks were made of all water deposits on the base and within a radius of 4 miles around it. Barracks and other buildings were searched every day for adult mosquitoes, and inspections were made of screening defects. A mosquito light trap was kept in operation near the Army outdoor theater as a further check on adult mosquitoes. Control measures consisted of weekly oiling all water deposits on the base and 1 mile around with a mixture of waste oil and kerosene. When areas outside of a 1-mile radius were found to harbor mosquito larvae, the Brazilian National Malaria Service was notified.

From 1 May 1944 to 31 December 1944, only five *A. albitarsis* adults were found on the base. All of these were dissected, and none was found to harbor sporozoites of the malaria plasmodia. These adults were found in unscreened buildings of the base laundry and in buildings on the Navy side of the base. The mosquito light trap situated near the outdoor movie theater was operated continually for 14 days, and only one culicine was found.

Despite these results of vigilant survey work, which indicated a fairly safe situation on the base, malaria cases appeared among permanent personnel during May, June, and July. In May, one case of malaria was incurred by a soldier who gave no history of having been outside the geographic limits of the base for over 3 weeks before the onset of the disease. Moreover, five cases of malaria developed among U.S. Navy personnel of whom one man stated he had not left the field for considerable time.

In June 1944, seven cases of malaria were hospitalized at the 194th Station Hospital. Of these cases, however, only one was a "new" infection in permanent personnel. The others were either relapses or transients. In July, two more cases were reported in permanent base personnel. The occurrence of these cases of malaria, although few, still led to a reiteration of the need for malaria discipline. Except for one more new case of malaria which developed in August in a soldier who visited off-base areas in his work, no malaria cases directly attributable to Parnamirim Field were encountered during the rest of the year. During the entire year of 1944, there were only 19 cases of malaria treated in the 194th Station Hospital, including permanent and transient personnel and recurrences.

The use of DDT as a residual spray, both for the control of malaria and for the elimination of bedbugs, was instituted in Parnamirim Field in September 1944. Thereafter, barracks were sprayed regularly every 3 or 4 weeks or slightly less frequently. Its effect against bedbugs was easily judged, in that a previously ever-present pest was entirely eliminated. Its effect against mosquitoes could not be judged because of the small number of these insects found on the base. It was incorporated into the control program as an adjunct to the other antimalaria measures in force.

During the year 1945, malaria was somewhat more of a concern at Parnamirim Field than in previous years. One of the most important factors influencing this was a rainy season that exceeded in intensity and duration the precipitation that had been experienced in the 12 years preceding. Another factor was the crowding of the base under the Green Project and the appearance of malaria among men assigned to the base as "Green Support" after having served in Africa and Italy. Some of these men either had suffered previous malaria attacks or had been taking suppressive Atabrine therapy. A number of these individuals had to be hospitalized for malaria during the year. Moreover, the malaria rates for the city of Natal as well as for the small villages near the airbase were higher this year than for many years in the past. The personnel of Parnamirim Field were allowed to visit the city, and some of them worked in outlying areas.

Routine survey work was maintained in order to provide protection of troops against malaria. In addition, after an upsurge of malaria occurred on the base in May, a special survey team from the 202d MSD in Recife was sent to Natal to aid in the survey work. Despite vigilant searches, no *Anopheles* mosquitoes were found on the base. However, control measures were carried on as follows:

To control malaria on Parnamirim Field and for 2½ miles around it, the malaria survey and control teams were increased in size from two to four men, and an additional vehicle was furnished for their use. Spraying of DDT as a residual spray was instituted in native houses within a 2-mile radius of the base. For this purpose, a gasoline-driven compressor improvised by the 202d MSD was used with a paint spray gun. All barracks on the base were routinely sprayed with DDT as usual. Larviciding activities were also performed, with all water deposits within a radius of 2½ miles of the base receiving a weekly treatment of 2.5 percent DDT in oil. Screening was installed in Army buildings situated off the base, such as the radio range and the market center.

During the month of August 1945, DDT treatment of larval breeding areas beyond the 2½-mile control zone was accomplished thoroughly by means of airplane spraying. An A-24 airplane equipped with a venturi spray apparatus and an 80-gallon tank was used, and enlisted men of the 202d MSD in Recife were detailed to Natal to aid in performing the work and in evaluating the results.

The malaria record at Parnamirim Field showed 16 new cases among permanent military personnel during 1945. Of these 16 cases, 8 were recently assigned from Italy and Africa where they had been receiving suppressive Atabrine therapy; the other 8 cases possibly contracted the disease on the base area. Of these latter individuals, most had left the base and had spent some time in town, but the actual place where the disease was incurred could not be definitely established. Because no anopheline larvae or adults could be found on or within 2½ miles of the base, it was difficult to understand how 8 cases could possibly be contracted there. It was surmised that mosquitoes flew in (with the air of prevailing winds) from the Rio Cajupiranga in the south. Surveys of this area uncovered very few larvae or adults; yet to cause eight cases (six of the men becoming ill at approximately the same time), large numbers of *A. albitarsis* would have to be present. In endemic regions near Parnamirim Field, less than 1 percent of the *A. albitarsis* were ever found infected. It is believed that most of these cases were contracted away from Parnamirim Field, where the number of mosquitoes was great enough to allow easy malaria transmission.

Recife.—Ibura Field, Brazil, established about 6 miles south of the city of Recife on an area of level ground about 33 feet above sea level, was surrounded by the populous villages of Ibura, Imbiribeira, Boa Viagem, Prazeres, and Piedade. The terrain around the field consisted of a low narrow coastal plain, bounded on the west by a range of low hills. Much of the terrain near the shore was dune country, with irregular rises of sand above a soft soil consisting largely of decayed vegetation. The hills to the west had poor natural drainage and an impervious subsoil resulting in the formation of many springs. Because of the dune formations and because a large amount of the land was only slightly higher than sea level, drainage was poor and the water table was high. The streams, which form at the western hills, are sluggish and meandering and enter into salt marshes near the outskirts of the city of Recife, or into a vast swamp about 2 miles south of the area of the field. A long tidal drainage ditch, running parallel to the beach and about 100 yards inland, joined the salt marshes to the north and south. The rainfall per year varies between 60 and 100 inches, the greater portion (93 percent) of which occurs during the months of April to September with as much as 32 percent falling during the month of May or June.

The saline waters along the shore provided excellent breeding conditions for *A. aquasalis*, the most important malaria vector in the area. The fresh springs and deposits of rainwater in the valleys to the west provided foci for *A. albitarsis*, of secondary importance in malaria transmission. The natural water deposits were supplemented by many manmade collections of water. The natives cultivated the soil by forming little hillocks at the base of which seepage and rainwater collected and was impounded. When these were abandoned, the high grass obscured numerous small pools which were the producers of many mosquitoes. The natives, in searching for crabs, also excavated small holes at the borders of the tidal marsh; these holes became filled with water and remained unaffected by the fluctuation of the tides, furnishing ideal situations for larvae of *A. aquasalis*. Among the other anophelines found in the vicinity were *Anopheles argyritarsis*, *Anopheles peryassui*, *A. triannulatus*, *A. pessoai*, and *A. noroestensis*, none of which is incriminated as a malaria vector.

In October 1942, a sanitary survey of the Recife base was made by SESP at the request of Colonel Leone. Dr. Oswaldo Silva, malariologist, and Mr. C. Heard Field, sanitary engineer, arrived in Recife on 11 October 1942 and spent several days in a survey of the malaria situation. As a result of their work, SESP contemplated performing drainage and filling operations and stream training around Ibura Field and the use of larvicides on breeding areas. The U.S. Army was to furnish a preliminary topographical survey and construct lined ditches to connect with the drainage system to be installed by the civil agency. It was recommended that all living quarters be mosquitoproofed and be sprayed regularly and, also, that mosquito netting be used and that chemical prophylaxis be instituted for night guards.

The Serviço Especial de Sáude Pública was organized especially for work in the Amazon and Rio Doce Valleys. In a question of jurisdiction, the Brazilian National Malaria Service was assigned control responsibility around U.S. Army bases in other localities. The Brazilian National Malaria Service was very helpful in furnishing data to the U.S. Army authorities throughout the war and also performed malaria control activities in conjunction with the U.S. Army. Around Recife, close liaison was always maintained with Dr. Durval T. Lucena, laboratory chief of the region.

From the Brazilian National Malaria Service, the following data on malaria among the natives around Ibura Field in 1942 were obtained: The village of Boa Viagem showed 11.2 percent of 3,026 persons with malaria; Prazeres 41.2 percent of 1,835 persons; Piedade 32.4 percent of 377 persons; Imbiribeira 32.2 percent of 986 persons. Adjacent villages of Venda Grande and Candeias showed 27.9 percent of 340 persons and 17.6 percent of 319 persons as malaria carriers. Obviously, the malaria control problem around Ibura Field required considerable attention. The incidence of malaria among Brazilian troops stationed on the base was 30 percent during the months of July and August 1942, and 10 percent of a small detachment of U.S. Marines had malaria during the same period.

At the request of the Commanding General, South Atlantic Wing, Air Transport Command, the sum of $15,000 was made available for malaria control at Recife. Colonel Leone had requested a sanitary engineer officer in early July 1942. This officer, Lt. Millard E. Smith, arrived on 14 November 1942 and took over the duties of theater malaria control and sanitary engineering around the Recife area.

A barracks-spraying detail, organized in late 1942, functioned under the supervision of the base surgeon, performing routine spraying of all living quarters every 48 hours. No larviciding, however, was done either by the Brazilian National Malaria Service or the Army until February 1943. At that time, the Brazilian National Malaria Service used paris green to a small extent because their supplies were always limited. Most emphasis was placed on drainage of the area. The Brazilian National Malaria Service had constructed a series of ditches in the tidal areas and was working on excavation of a drainage system in a fresh water swamp west of the base. The Air Port Development Project had eliminated some mosquito foci on the base by filling or drainage but, on the other hand, had created additional breeding places by the excavation of topsoil in swampy ground, leaving large borrow pits.

The manner in which the engineering projects were planned apparently took no cognizance of the malaria control problems involved in the area. Difficulties such as those encountered at Belém in regard to mosquitoproofing of buildings were met, and the situation had to be remedied by the grouting-in of the loose tile roofing. The most important difficulty encountered was the lack of action on drainage required for malaria control. A swamp on the southeasterly side of Ibura Field was the subject of much correspondence and was still not drained or filled a year after the first recommendation. Even in 1945, swampy areas between the runways on Ibura Field required larviciding regularly.

It soon became apparent that the facilities of the Brazilian National Malaria Service were not sufficient to provide adequate protection against malaria for U.S. Army personnel stationed at Ibura Field. Between 27 February and 23 March 1943, 21 cases of malaria appeared among Army personnel on the field. In the several months previous to this outbreak, only six cases had been reported. The unseasonal increase was probably due to the rains which fall during the early part of the year and are called *chuvas de caju* by the Brazilians. It was necessary to discontinue the showing of outdoor movies and to reinstruct personnel in malaria discipline, which had become lax during the dry season. Consequent to this outbreak, a larviciding squad of Brazilian employees was established for the control of mosquito breeding around the area, and another crew of natives was organized to do ditching and maintenance work. These two crews, in addition to the barracks spraying detail, came under the supervision of the base surgeon and of the malaria control officer, USAFSA, who acted in an advisory capacity. Routine oiling was performed of all waters within a 1-mile radius of the base. The larviciding and ditching crews were placed under the direct charge of three enlisted men of the base complement, and the spraying crew was supervised by men of the office of the base surgeon.

As a result of the efforts of these antimalaria details, no further serious malaria outbreaks occurred during the year. The rainy season passed with three cases in April, one in May, one in July, and two in September. November and December showed an increase, with five cases and one case, respectively, indicating that some malaria transmission occurred, even during the height of the dry season.

In April 1943, a survey was made of mosquito-breeding areas in the vicinity of Ibura Field by the Wing sanitary officer, Capt. Millard E. Smith, Dr. Mario Pinotti, Director of the Brazilian National Malaria Service, and Maj. Benjamin Ganse, SnC, of the Office of the Coordinator of Inter-American Affairs. The object of this survey was to determine the feasibility and practicability of permanent malaria control measures around the base. It was Captain Smith's opinion that permanent ditch lining would not be feasible because the type of soil would render even lined ditches unstable and subject to shift in grade and alignment and because of the scarcity of materials and high cost. He believed that tide gates would serve no useful purpose, and that larviciding would be the cheapest method of control even over a 5- to 10-year period. However, he considered that help should be given the Brazilian National Malaria Service in the construction and maintenance of the system of unlined malaria control ditches around the field.

The antimalaria squads continued functioning in the same manner, under the supervision of the base surgeon, Ibura Field, and later of the medical inspector under the Commanding Officer, 200th Station Hospital, throughout 1943 and part of 1944. With the expansion of Ibura Field into its two subposts and the establishment of the hospital area, in the spring of 1943, it was necessary to include a larger amount of terrain in the control program. The squads were gradually expanded to include approximately 40 Brazilian laborers, exclusive of the barracks spraying crew.

In April 1944, two malaria survey officers arrived, Lieutenant Dalmat and Lieutenant Johnson. These officers performed some malaria survey work around Ibura Field and its two subposts. They found anopheline breeding in areas to the north of Ibura Field and to the south of the hospital and recommended control in these areas. Lieutenant Dalmat was transferred, on 22 April 1944, to Natal to take charge of the disinsectization of airplanes and of malaria control there. Lieutenant Johnson was left in charge of malaria control in the Recife area.

In May and June 1944, a small outbreak of malaria occurred among troops quartered in tents in an area between the USAFSA headquarters and the 200th Station Hospital. Fifteen cases occurred among a command of 140 men during these 2 months. The tents were unscreened, and malaria discipline was apparently poor. The need for reemphasizing malaria discipline and control measures during the rainy season was pointed out by the malaria control officer, USAFSA, in various letters in May 1944. It was also recommended that the tents in the area concerned be screened or that permanent type barracks be provided for the personnel involved. The men were moved to permanent type barracks elsewhere in the area during the latter part of June 1944.

However, one more case of malaria from this group of men was admitted to the hospital in early July.

One additional case of malaria among 87 transient officers and men was traced to the Tent City area where these troops were quartered between 3 July and 28 July 1944. In addition, one other new malaria case was contracted in late July elsewhere in the Recife area (admitted to hospital 6 August 1944). These were the last new cases of malaria to originate in the command up until September 1945.

Among the troops billeted at Tent City, during the month of July 1944, was the 202d MSD. The unit was relieved from quarantine on 14 July 1944 and after setting up headquarters and laboratory at the 200th Station Hospital assumed the duties of malaria control in the Recife military area, on 1 August 1944.

One of the first preoccupations of the detachment was the source of the malaria outbreak in the Tent City area. It was clear that the same source could menace the hospital and USAFSA establishments, only one-quarter of a mile away on either side. A physical survey of the area was made, and the terrain was rezoned to follow ridge lines and easily identifiable boundaries. Adult collecting stations consisting of groups of native houses, numbered by the unit for identification, were established throughout the area. An adult collecting crew was established to investigate these stations routinely. A larva survey team of Brazilians supervised by sanitary technicians of the detachment performed routine survey work around the area, and the oiling crew was regularly employed, as in the past, to cover all zones. The rest of the laborers were used in ditch maintenance and construction, and, in addition, attempts were made to perform some permanent control work.

The tidal drainage ditch, in the area between the hospital and USAFSA headquarters, was incriminated many times as the source of *A. aquasalis* mosquitoes. The malaria control officer, USAFSA, had earlier, in December 1943, negated a proposal by the U.S. Engineer Department to fill in areas adjacent to this canal, considering that cutting through the spoil bank would be all that would be necessary. The 202d MSD, however, found these areas too low to be drained by laterals, as the soil along the margins of the ditch was very boggy and the water level lower than in the canal itself. They hauled a total of 90,000 cubic feet of earth to fill and grade the sides of the canal and produced a permanent improvement.

The 202d MSD took advantage of the dry months to prepare for the intensive malaria control program which would be required during the rainy season in 1945. In contrast to the earlier malaria control work by the U.S. Army in the area, advantage was taken of time and equipment to do small amounts of permanent control work, although large projects were not feasible. When idle engineering equipment was available, it was borrowed by the detachment from the post engineer and used for filling low areas and eliminating small swamps.

The 202d MSD performed blood survey work in addition to its mosquito surveys, in an effort to evaluate the malaria reservoir in the native population. When DDT became available in sufficient quantity, the houses of infected natives were sprayed with DDT residual spray. Later, this method of control was extended to all native habitations. DDT was also employed routinely as a larvicide, with the inception of the rainy season. It was possible, by the use of this insecticide, to economize on the use of oil by means of a spot-oiling technique in the less dangerous zones.

In addition to malaria control around the Recife military area and survey work elsewhere in the theater, the 202d MSD performed studies on the larvicidal effect of DDT in collaboration with the Brazilian National Malaria Service. It also performed fly control work on Ascension Island and fitted an A-24 airplane for the spraying of DDT. The airplane was used at Natal, and later at Belém in an attempt to eliminate *A. darlingi* from the environs of the airbase and the city. The 202d MSD thus was engaged in considerable experimental work in addition to its routine duties. No new cases of malaria were contracted in the Recife military area after the assumption of malaria control by the detachment.

Amapá.—Amapá Air Base was situated on a stretch of level grassy terrain about 6 miles from the village of Amapá and about 60 miles inland at 2°8′ north latitude and 50°49′ west longitude. The altitude was 32 feet above sea level. The country surrounding the base was an undulating series of knolls, producing a rolling type of landscape. Beneath a 3-foot clay soil there was a hard bedrock, which inhibited absorption of storm water and caused the formation of swampy areas in the depressions between the knolls. During the dry season, the nearest surface water was about 1 mile away from the base, but during the rainy season there were many swamps close by. Rainfall during the rainy season of 1942 (January to July) measured 92.78 inches, while 6.15 inches fell during the rest of the year.

The airport was developed first by the Air Port Development Project during 1942. During the dry season, about 25 Americans and 500 local Brazilian employees were engaged in construction work. During the intense rainy season, only a skeleton force of about 6 Americans and 100 Brazilians was maintained, since construction work could not be prosecuted effectively because of the heavy rains.

Soon after the onset of the 1942 dry season, malaria appeared and reached epidemic proportions. Over 300 natives had to be returned to their homes because of malaria, and 7 of the 25 Americans were stricken. Because of the lack of oral quinine or Atabrine, treatment was effected by intramuscular injection of quinine, or quinine plus methylene blue intravenously.

A medical officer of the Air Transport Command at Belém was sent to Amapá to render whatever assistance possible. This officer aided in the evacuation of many laborers who were too ill to work. He brought supplies of quinine and Atabrine, ordered prophylactic treatment of all Americans, also investigated the mosquito population, and performed blood examinations.

The vector of malaria was identified as *A. darlingi*. Blood smears indicated a predominance of *Plasmodium falciparum*. The small number of Americans who became ill is probably attributable to the use of screened barracks and bed nets.

Two medical officers of the Trinidad Sector and Base Command were sent to Amapá from the U.S. Engineer Department Hospital, Trinidad District, to help out in the epidemic. At the time of their arrival, 28 November 1942, the epidemic was already subsiding. They provided additional quinine and Atabrine for treatment, placed all local civilian employees on chemical prophylaxis, 5 grains quinine daily, and recommended that prophylaxis could be omitted after the period of heavy mosquito breeding, depending on the findings of the station medical officer.

No further reports on malaria control at Amapá are available until the first monthly sanitary report from the base was submitted on 1 September 1943. Apparently no control measures against a reoccurrence of malaria had been undertaken by the Air Port Development Project, and the only control measure in effect was the spraying of barracks and tents by six workers of the Serviço Especial de Sáude Pública. All the native workers were removed from the confines of the post to a distance of about 1 mile, and their shacks were burned and their wells filled. The medical officer recommended some drainage measures on the post to reduce the number of mosquito-breeding foci. A request was also made for a malaria control officer.

Some larvicidal oiling was undertaken by a sanitary squad under the supervision of the base surgeon. The medical officer noted that the number of mosquitoes present on the base was far less than at Amapá village or the barge landing on the Rio Amapá Grande, about 55 miles from the post. Personnel employed at the docks on the river, or on barges unloading ships lying off the island of Maracá were required frequently to work at night, because the shipping was dependent on tides. These personnel were given malaria control lectures, and individual protective measures were enforced among them.

In late July and early August 1943, a visit was made to Amapá by the theater malariologist, USAFSA. Because of the small size of the base, extensive permanent control measures were not indicated. However, some drainage of swamps on the base was recommended. Emphasis was to be placed on larviciding and on the rigid enforcement of malaria discipline.

Larvicidal measures against mosquitoes were prosecuted vigorously by the sanitary squad. Native laborers were employed for hand oiling, using waste engine oil and kerosene, and an improvised power sprayer and drip oilers were used wherever possible. In addition, the routine spraying of barracks was performed once nightly by the crew of SESP workers. One case of malaria occurred in December 1943, in an enlisted man who worked at night at the docks. This was the only case of malaria acquired among U.S. Army personnel at Amapá Air Base after it was taken over by the Air Transport Command. A few cases occurred among Navy and civilian personnel.

The barracks spraying detail of SESP became unsatisfactory due to lack of control by the Army. At the end of March 1944, the medical officer at the base was informed that SESP would discontinue this work. The barracks spraying and the larviciding operations were taken over by two enlisted technicians of the 57th MCD, in June 1944. The commanding officer of this unit had visited Amapá in January 1944 and had made some recommendations regarding control there, and, in the interim between the cessation of work by SESP and the arrival of the enlisted technicians, the barracks spraying was accomplished by other base personnel.

In August 1944, one enlisted man of the 202d MSD was sent to Amapá to aid in survey work around the base. The work of this man was intended to supplement the control activities of the men of the 57th MCD, providing knowledge of the extent and location of the breeding places of *Anopheles* and of the effectiveness of control measures. The need for such work had been brought out in an earlier report.

Captain Linderman modified the larviciding program at Amapá by using only crews of native laborers with knapsack sprayers. Drip oilers, in use previously, were removed because they were found to be an ineffective method of control. Spraying of barracks could be reduced, because of good larvicidal work, to three times weekly. Concentration was placed on larviciding, although some attempt was made to effect malaria control by clearing swamp areas close to the cantonment, by burning grass in low areas during the dry season, and by the drainage of swamps and the filling of small pits. Malaria control was enhanced to some extent by spraying native huts, starting in February 1945, after a case of malaria had been incurred in an enlisted man of the U.S. Navy. Residual spraying with DDT was instituted in April 1945, after the arrival of a sufficient quantity.

In September 1944, a parasite survey was made by the 202d MSD of the native population living around the airbase at Amapá. This was done to determine the size of the malaria reservoir. Surprisingly, only 2 cases of *P. vivax* infection were discovered among 760 natives examined. This extremely low index may have been due to the fact that the survey was performed during the dry season. The results do not, of course, reflect the earlier epidemic in 1942, when *P. falciparum* was reported to be the malaria parasite involved. This is to be expected, because, although *P. falciparum* produces the most acute disease, it is, probably because of this characteristic, the least likely to cause relapses. The low index of *P. vivax* infections was also due, probably, to the fact that the natives investigated lived in a small settlement around the base and well within the control zone covered by the larviciding crew. Moreover, all cases of malaria which had occurred in this native population had been treated by the base surgeon or the Brazilian Red Cross nurse on duty there.

Mosquito collections made by the 57th MCD and the 202d MSD also showed the malaria hazard to be low at the time, with only one *A. darlingi* found outside the controlled area, and *A. peryassui* and *A. pessoai*, neither of which are malaria vectors, predominating.

On the basis of these data, it was stated that the airbase at Amapá fortuitously had been located in a good area, from the standpoint of malaria control. This was said despite earlier remarks by the base surgeon that a worse area could not have been selected. Actually, considering its position in the Amazon basin, the location of the base 6 miles from Amapá village and about the same distance from the tidal marshes made the problem of control much simpler than would have been the case otherwise. As soon as control measures were instituted, the incidence of malaria was maintained at a minimum.

São Luís.—In the entire history of the U.S. Army airbase at São Luís, only one case of malaria was reported to have been incurred among Army personnel stationed there. The malaria situation was never serious at the base, and the routine control measures under the supervision of the base surgeon were ample to maintain malaria at a minimum.

The airbase of Tirirical Field was situated about 5½ miles southeast of the city of São Luís in the State of Maranhão, at 2°35′ south latitude and 44°14′ west longitude. Its altitude was about 174 feet above sea level. The city and the airbase were on a large island, lying in the mouth of an extensive river system, separated from the mainland by the Baía de São Marcos and the Baía de São José. Rainfall varies between 40 to 90 inches per year with most of the precipitation occurring between February and October. However, droughts do occur during which time the total rainfall per year remains less than 40 inches. Despite the proximity to the Equator, the climate is good, with a mean annual temperature of 83° F., and relative humidity of 80 percent.

The relatively high altitude of the base and a terrain affording good drainage lessened the possible malaria hazard. *Anopheles* mosquitoes of the species *A. darlingi* and *A. aquasalis* are prevalent in the low country of the mainland but not in the interior of the island. That malaria vectors were present near the shore of the island, however, was evidenced by a report of seven cases of malaria in one English family living on the beach and of the finding of many anophelines in that area.

An early sanitary survey of the base revealed little malaria potential. A few anophelines (unidentified) were found breeding in a ditch on the post and one adult *Anopheles* was captured. The use of mosquito bars and the mosquitoproofing of buildings were recommended. These were the only antimosquito measures applied until October 1943.

During that month, a large number of *Culex* mosquitoes appeared which were found to be breeding in overgrown ditches on the post. These ditches were oiled and later filled, and the number of mosquitoes soon diminished.

São Luís was visited by the commanding officer of the 57th MCD. in November 1943 and in January 1944. This officer recommended the continued use of bed nets during the rainy season, emphasized the need for maintenance of screening, the use of larvicidal measures against mosquitoes during the rainy part of the year, and the routine spraying of barracks twice weekly during the rainy season.

Larvicidal measures were put into effect by employing two natives to do occasional oiling when necessary and another small crew of Brazilians to operate a portable gasoline engine-driven spray apparatus. After the appearance of the case of malaria at São Luís, an additional survey was made by the commanding officer and two enlisted men of the 57th MCD. One of the enlisted men remained to supervise the malaria control program, consisting of larviciding, ditch clearing, and insecticide spraying, with very satisfactory results.

Fortaleza.—Adjacento Field was situated on rolling sandy terrain about 5 miles south of the city of Fortaleza. No malaria has ever been contracted there among U.S. Army personnel. This situation was due mainly to the fortuitous location of the base inland, away from the breeding places of *A. aquasalis.* Although considerable water existed during the rainy season in depressions around the airfield, these ponds and swamps afforded breeding only for innocuous anophelines, *A. argyritarsis*, *A. pessoai*, *Anopheles strodei*, and *A. albitarsis.* While *A. albitarsis* is an important malaria vector in the Natal area, its zoophilic habit makes it unimportant in malaria control in the State of Ceará.

Precautionary measures against malaria at Adjacento Field consisted of the use of mosquito bars, mosquitoproofing of barracks, and the use of nonresidual sprays. These measures were directed not only against malaria but also against pest insects as well. The base was always well sanitated.

Bahia.—Ipitanga Field was located about 21 miles southeast of the city of São Salvador in the State of Bahia, Brazil, at about 12° south latitude and 38° west longitude. The field was several miles from the coastline, separated from it by a series of dunelike hills running along the south and east. The Rio Ipitanga partially bounded the landing field, while swamps existed on nearly all sides of the base. Prevailing winds blew over the field from the southeast and east. Temperature ranges from 70° to 90° with an average of 77°. Precipitation totals about 77 inches per year with a rainy season similar to that in Recife.

The field was surrounded by depressions which became filled with water during the rainy season and served as mosquito-breeding foci. The field was also adjacent to a native village of several thousand population in which malaria was endemic. The Brazilian National Malaria Service conducted some survey and larvicidal work around the airfield in 1943, when the base was under construction, but this work was apparently not extensive.

Because of U.S. Navy administration and of the small number of Army personnel on the base, control measures by the U.S. Army against malaria could not be made definitive. Recommendations for malaria control in 1943 included drainage or filling of swampy areas on the base, larviciding operations with diesel oil, barracks spraying and mosquitoproofing, the use of the indoor movie theater, and the use of bed nets and of other individual protective measures for individuals required to work outside at night.

The U.S. Engineer Department employed a small squad of Brazilian laborers and also set up a series of drip oilers for larviciding standing waters. No further action was taken by the U.S. Army because the base was mainly under U.S. Navy control and the U.S. Army Medical Department had no activities there after November 1943. In August 1943, the Area Medical Inspector, South Atlantic Transport Division, Air Transport Command, accompanied a general staff officer of that Headquarters to Bahia on an inspection tour. These officers concluded that malaria was not a serious problem at the base and made recommendations for control similar to those made previously by the malaria control officer, USAFSA. In May 1944, a request was received from the commanding officer of USAF, at Bahia, for a malaria survey of the base. It was determined that a Navy entomologist was supervising malaria control at Ipitanga Field, and to avoid duplication of effort, no action was taken by this Headquarters.

After the U.S. Navy vacated Ipitanga Field in early 1945 and the U.S. Army took it over as a subpost of the Recife military area, attention was again given to malaria control. The base surgeon established liaison with the Brazilian National Malaria Service, and 10 Brazilian laborers were employed by the base engineer to work with this agency on the base and in adjacent areas, performing larviciding and semipermanent control. Repairs were also made to buildings to make them mosquitoproof, and barracks spraying and the use of bed nets were resumed.

In the history of U.S. Army occupation of Ipitanga Field, no cases of malaria were incurred among Army personnel. Records show four cases in civilians in the months of April through October 1943, and no cases after July 1954. No figures are available on the malaria incidence in Navy personnel, although some cases are known to have occurred.

Theater Medical Laboratory

On 6 January 1943, Captain Landis of the Air Transport Command was given the responsibility of establishing and supervising the Wing and area laboratory. This was later merged with the laboratory of the 200th Station Hospital at Recife. On 24 April 1944, Captain Kagan became chief of laboratory service and epidemiologist.

The laboratory had by this time become the theater medical laboratory and histopathology center. In June 1944, this laboratory was reorganized to include an Epidemiology Section, of which Entomology and Parasitology were subdivisions. On 14 July 1944, the 202d Malaria Survey Unit was given space in the laboratory and took complete charge of the Entomology Section. The unit also assisted the Parasitology Section in certain aspects of its work. During 1944, a total of 36,437 procedures were accomplished in the laboratory, of which 684 had to do with entomology and 5,730 with parasitology. In 1945, the number of procedures totaled 31,324, of which 5,901 related to parasitology, 2,032 being malaria smears. Only 62 insect identifications were performed, the medically important anthropods of the area having been largely recognized the previous year.

Achievements

In June 1945, the strength of the Command (USAFSA) reached 10,000. The "Green" Project (return of troops from Europe) was then in full swing. Although this represented the greatest number exposed to tropical health hazards in the history of the USAFSA, the incidence of malaria was close to the lowest for the entire period (table 18).[33]

TABLE 18.—*Malaria in U.S. Army Forces, South Atlantic, 1943–45*

[Rate expressed as number of cases per annum per 1,000 average strength]

Year	Malaria attacks (new plus recurrent cases)		Incidence of malaria (new cases only)	
	Number	Rate	Number	Rate
1943	133	21.4	113	18.2
1944	75	11.1	53	7.9
1945 [1]	27	8.9	16	5.3

[1] Data for January–June 1945.

The commanding general, Maj. Gen. Ralph H. Wooten was able to report, in July 1945, that through intensive application of permanent control measures, extracantonment sanitation in cooperation with Brazilian health agencies, and enforcement of malaria discipline, malaria had been practically eliminated from U.S. Army bases in Brazil.

EXTRAMILITARY RELATIONS

Liaison with various Brazilian agencies involved cooperative activity along the following lines:

1. Assistance in malaria control activities in areas adjacent to U.S. Army bases.

2. DDT made available both for control purposes and for experimental work.

3. Demonstrations in use of DDT.

Of the several Brazilian agencies involved in medical liaison with the USAFSA, three were especially important in relation to malaria:

1. The Brazilian National Malaria Service (Dr. Mario Pinotti).

[33] See footnote 5, p. 121.

2. The Port Health Service (Dr. F. Carneiro de Mendonca). This agency had to do with disinsectization and foreign quarantine.

3. Serviço Especial de Sáude Pública.

Close contacts were of course maintained with the Medical Departments of the Brazilian Army, Navy, and Air Force.

Insofar as malaria is concerned, the Division of Health and Sanitation of the Office of the Coordinator of Inter-American Affairs was perhaps the most important cooperating agency. Considerable aid was furnished the U.S. Army in malaria control work both at Belém and at Fortaleza.

The Brazilian National Malaria Service was especially helpful in areas where the Office of the Coordinator of Inter-American Affairs did not operate. At São Luís, Fortaleza, Natal, Recife, and Bahia, this agency furnished data to the malaria control officer, as well as to base surgeons. Control work by the U.S. Army in these areas was then coordinated with Brazilian activities. At Recife, the 202d MSD carried on joint experiments with Dr. Lacena, of the Brazilian National Malaria Service, concerning the use of DDT as a larvicide. Likewise, a "guarda" was loaned by this agency to the 202d MSD to collect epidemiological data. The data furnished by the Detachment were made the basis for treatment of infected natives by the Brazilian National Malaria Service. The 202d MSD also assisted this agency in planning residual spray experiments (with DDT) for the control of adult anophelines.

The SESP, at an early date, set up a program of permanent and temporary control measures around Belém and of barracks spraying at Amapá. Although control procedures at these points were later taken over by the 57th MCD, the SESP continued to furnish survey information of vital importance to the work of this group. The SESP also cooperated in two surveys at Ibura Field. In 1945, this agency invited the theater sanitary engineer, USAFSA, to conduct an inspection of their facilities in the Amazon Valley.

The most important achievement of a cooperative nature was the establishment, in January 1944, of an efficient system for disinsectization of aircraft coming from Africa. Brazilian national health authorities, Brazilian port sanitary personnel, the Rockefeller Foundation representatives in Rio de Janeiro, and the U.S. Army were jointly involved.

In 1944–45, important work was accomplished outside of military command under the auspices of the Inter-American Cooperative Public Health Services in Latin American countries.[34] *Anopheles pseudopunctipennis* was shown to occur on the west coast of South America from sea level to 11,000 feet. Its range was confirmed as including Bolivia, Chile, Colombia, Peru, and Ecuador, as well as parts of Mexico and most of Central America. *Anopheles darlingi* was identified from Bolivia, Brazil, Colombia, Guatemala,

[34] (1) Yeager, C. H.: Mosquito Work in the Other Americas. Proc. N. J. Mosq. Extermin. Ass. 32: 134–142, 1945. (2) Bishopp, F. C., and Stage, H. H.: A Review of Mosquito Work in a World at War in 1944. Proc. N. J. Mosq. Extermin. Ass. 32: 13–25, 1945.

Honduras, British Honduras, the Guatemalan boundary of Mexico, eastern Peru, and Venezuela. *Anopheles albitarsis* was listed from Brazil, Bolivia, Colombia, Trinidad, British Guiana, Venezuela, and Paraguay. *Anopheles albimanus* was confirmed for Ecuador, Venezuela, Colombia, Panama, Costa Rica, Nicaragua, El Salvador, Honduras, Guatemala, Mexico, Cuba, Haiti, and the Dominican Republic. Cuba and the British Colonies were not included in these particular investigations.

Permanent drainage projects were carried out in Guatemala, El Salvador, Honduras, Nicaragua, and Costa Rica.[35] While these were underway, temporary control measures included larviciding with paris green, diesel oil, and DDT, also DDT spraying in houses.

South American Countries

An informative account of malaria control work in most Central and South American countries during the war years has been prepared by Gabaldon.[36] Administrative organization, antiparasitic measures, and antianopheline measures are discussed. Budgets are compared for the years 1939 to 1943. Facts and figures appear to justify future emphasis on anopheline reduction or eradication. Exclusion and interception measures (spraying inside houses) are reported as very effective. Such information may be of great potential importance in possible future military operations, as well as in relation to various activities of a commercial and industrial nature, on which the continued prosperity of the Americas depend.

Part III. Experience in the Caribbean Defense Command

ORGANIZATION

General

The Caribbean Defense Command was activated 8 May 1941, with headquarters at Quarry Heights, C.Z.[37] General Orders No. 8, issued 29 May 1941, defined the Command as consisting of the "islands in or bordering the Caribbean Sea, the Guianas, Venezuela, Colombia, Ecuador and the countries of Central America (except Mexico)." The same announcement created three sectors to be known as the Trinidad Sector, the Puerto Rican Sector, and the Panama Sector.

[35] (1) Harris, R. R.: Malaria Control in Central America. Proc. N. J. Mosq. Extermin. Ass. 33: 154–158, 1946. (2) Bishopp, F. C., and Stage, H. H.: A Review of Contributions to the Knowledge of Mosquitoes around the World during 1945. Proc. N. J. Mosq. Extermin. Ass. 33: 123–147, 1946.

[36] Gabaldon, Arnoldo: Malaria Control in the Neotropic Region. *In* Malariology, edited by Mark F. Boyd. Philadelphia: W. B. Saunders Co., 1949, vol. II, pp. 1400–1415.

[37] A History of Medical Department Activities in the Caribbean Defense Command in World War II. Vol. 1, pp. 131–132, May 1946. [Official record.]

The Caribbean Defense Command was thus formed of the long-established, but recently expanded, PCD (Panama Canal Department),[38] together with the Puerto Rican Department, which had come into existence in May 1939,[39] and whose headquarters were located at San Juan, P.R., and which included the Virgin Islands. To this combination was added the Trinidad Base Command, and all the posts and installations, insular or continental, geographically associated. These included the various new bases to the southward, which had been established as a result of negotiations with the Netherlands and with Great Britain.

The practice of referring to "Atlantic" and "Pacific" Sectors within the PCD appears not to have been continued into the war years. The entire PCD thus became a single sector, of the same name.

This arrangement, however, was not permanent. The Caribbean Defense Command underwent a number of internal administrative changes before the end of the war, the essential features of which may be summarized, as follows:

Confusion arose almost at once as to the relation of the Trinidad Sector (and Trinidad Base Command) to the former Puerto Rican Department. This was clarified in June 1943, by the establishment of the Antilles Department, with Headquarters at San Juan, which eliminated the Puerto Rican Department, as such, and placed the Puerto Rican and Trinidad Sectors on an equal footing within the new administrative unit. This continued into 1944, when the two subordinate sectors were in turn eliminated and all posts in the Antilles came under the direct control of Antilles Department Headquarters.

The Sixth Air Force was a part of the Caribbean Defense Command but had the same area of control as the Command itself. It was administered by the Sixth Air Base Command.

Medical

For some time after the establishment of the Caribbean Defense Command, no centralized direction of medical affairs was authorized.[40] Each major subdivision of the Command continued to handle its own medical problems and to send reports directly to Washington, D.C. The surgeon of the PCD or the chief health officer of the Panama Canal were available for consultation in special cases.

The Corps of Engineers maintained a medical service for its civilian employees, which functioned side by side with the Army Medical Services.

The first step toward the establishment of an office of the surgeon for the entire Command came about on 14 June 1943, when Maj. (later Col.) Daniel Bergsma, MC, arrived from the United States to serve the headquarters staff, with special responsibility for venereal disease.

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[38] Before 1940, the Panama Canal Department was restricted to the Canal Zone.
[39] War Department Pamphlet 8–2, 2 Apr. 1943.
[40] Annual Report, Office of the Surgeon, Caribbean Defense Command, 1943.

On 13 October 1943, Brig. Gen. (later Maj. Gen.) Morrison C. Stayer, incumbent chief health officer for the Panama Canal, was designated as surgeon of the Caribbean Defense Command, and an "Office of The Surgeon" thus became established. After this date, most of the medical reports from both the Panama Canal and Antilles Departments passed through this headquarters for review and consolidation before being sent to Washington. This was a great advantage to the Caribbean Defense Command, as many decisions involving change of policy could be rendered by the Command surgeon, and the necessary procedures could be put into effect without waiting for directives from Washington, where there was not always complete understanding of practical conditions in the field.

By the end of 1943, General Stayer and his assistant, Major Bergsma, already familiar with the malaria situation in the Panama Canal Zone and adjacent territory, had made special malaria studies in both the Puerto Rican and Trinidad Sectors of the Antilles Department.

The Sixth Air Force served three "Areas" corresponding to the "Sectors" of the Caribbean Defense Command. Seventeen airbases were involved. In 1942, the situation for the Panama Area (seven bases) was as follows:

Name of base	*Medical officers*
Albrook Field, C.Z	6 (4 of these on duty status).
France Field, C.Z	4 (2 of these on duty status).
Howard Field, C.Z	2 (both on duty status). (Surgeons, 16th Air Base Group, Acting Base Surgeon.)
Rio Hato, R. de P	2.
Guatemala City	2 (on duty status from Howard Field and France Field).
Galápagos Islands, Ecuador	3 (all on duty status from Albrook Field).
Salinas, Ecuador	3 (all on duty status; 1 each from Howard Field, Albrook Field, and France Field).

In 1942, the situation for the Trinidad area (five bases) was as follows:

Name of base	*Medical officers*
Waller Field, Trinidad, B.W.I	1 medical officer.
Beane Field, St. Lucia, B.W.I	None (that is, Post Surgeon, not Air Force. Surgeon, 5th Bombardment Squadron here, however).
Hato Field, Curaçao, N.W.I	None (Surgeon, 59th Bombardment Squadron here).
Atkinson Field, British Guiana	(Surgeon, 44th Reconnaissance Squadron here.)
Zandery Field, Surinam	1.

In 1942, the situation for the Puerto Rican Area (five bases) was as follows:

Name of base	*Medical officers*
Borinquen Field, P.R	14 medical officers (hospital facilities for 290 beds).
Losey Field, P.R	9 medical officers (hospital facilities for 96 beds).
Benedict Field, St. Croix	(Surgeon, not of Air Force.) (Surgeon, 12th Bombardment Squadron here.)
Coolidge Field, Antigua	(Surgeon, not of Air Force.) (Surgeon, 35th Bombardment Squadron here.)
Vernam Field, Jamaica	(Surgeon, not of Air Force.)

In 1942, the personnel of the Sixth Air Force were not well provided for in the matter of medical care. This was particularly true in the field of preventive medicine, although reasonable protection was achieved through the environmental sanitation program of the Army Ground Forces. The Air Force was particularly vulnerable to malaria, because of frequent missions into and out of malaria areas. Infected Air Force personnel could also serve as new reservoirs, on return to base, as did troops of all organizations when evacuated from malarious territory.

PANAMA CANAL DEPARTMENT

The malaria control activities of the Caribbean Defense Command will be treated in two units, pertaining to the two Departments as finally constituted. These will be followed by a special section dealing with the Sixth Air Force.

As already stated, this Department represented an expansion of military activities normally limited to the Canal Zone, but which, in the interest of hemisphere defense required the establishment of numerous installations in adjacent territory. At its greatest expansion, the Department extended from about 20° north latitude to 5° south latitude and from 77° to 89° west longitude.

A brief statement concerning the malaria hazard, including facilities for control, will be given for each of the Republics or dependencies in which the Army operated. These statements pertain chiefly to conditions prevailing at the outbreak or during the early period of the war.

Countries and Dependencies Concerned

Guatemala.—National public health administration is a function of the Bureau of Public Welfare, which was organized by presidential decree in August 1941.[41] Its activities include special programs for malaria control.

In this country, the rainy season extends from December to May, while the remainder of the year is relatively dry.[42] The greatest rainfall is on the Atlantic side. Malaria is severe and almost universal on the coasts; it is also serious in the river valleys.

Early campaigns against mosquitoes were confined chiefly to oiling and dusting and were not especially effective. Drainage projects were few and insignificant as compared with the obvious need.

Anopheles albimanus is the principal malaria vector, being found on both coasts as well as in the Petén district. *Anopheles pseudopunctipennis*, however, is prevalent in the central highlands, while *A. vestitipennis* proved the major vector in the camps along the Cobán-Petén highway. *Anopheles darlingi* is found in Petén province and around Lago de Izabal.

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[41] Medical and Sanitary Data on Guatemala. Compiled by the Medical Intelligence Branch, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 15 June 1943.

[42] Report, Lt. Col. V. H. Cornell, MC, U.S. Army, subject: Sanitary Survey of Guatemala, 12-20 Mar. 1941.

It should be remembered that El Salvador has no Atlantic coastline. For various reasons, it was the southern (coastal) portion which was considered most important from a military standpoint. For example, El Salvador is the only port on the Gulf of Fonesca where the water is deep enough for fairly large ships to tie up.

This region is tropical. The dry season extends roughly from December to April. There is a great increase in malaria in the rainy season.

In 1941, malaria control in El Salvador was "in its infancy." Surveys by spleen palpation and blood smears had been made by Dr. Henry W. Kumm of the Rockefeller Foundation, and a drainage demonstration project had been conducted at San Miguel. Malaria was the great scourge of the country, beyond a doubt, but practical control measures had not been put into practice on an effective scale. It was necessary for military personnel to make provision for their own protection.

It is perhaps worth mentioning that El Salvador has the densest population of any area on the mainland in the Caribbean and Gulf regions.

Nicaragua.—The National Health Department is headed by the Secretary General who is also The Surgeon General of the Army. This Department, which replaced the Health Division of the former Ministry of Health and Welfare, has eight administrative subdivisions, including the Central Public Health Laboratory (also known as the National Institute of Health). There is a Rural Hygiene Division which attempted campaigns against malaria, before 1943, but with indifferent success.[47]

On the Pacific side, the rainy season continues from some time in May to early December. On the Atlantic side, the dry season is much shorter, or absent. In the more thickly populated western areas, the temperature is high, with April and May most depressing, due to cessation of the trade winds. The rainfall at San Juan del Norte is especially heavy.

A possible canal route exists up the Rio San Juan on the Atlantic side, through Lake Nicaragua and Lake Managua, and across a narrow strip of land to the Pacific.

Malaria is prevalent, and there is a constant reservoir in the native population, which lives almost entirely in unscreened houses. It was realized by the military authorities that any operations aimed at clearing the region along the Río San Juan would both increase population and improve breeding conditions for vector anophelines in that region. In the 1941 survey, Lt. Col. Virgil H. Cornell, MC, stated that malaria was a menace, all along the coasts, in the river basins and about the lakes.[48]

The principal vector, as in other Central American countries, is *A. albimanus*. *Anopheles aquasalis*, *A. pseudopunctipennis*, and *A. argyritarsis*

[47] Medical and Sanitary Data on Nicaragua. Compiled by Medical Intelligence Branch, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 7 Nov. 1942.

[48] Report, Lt. Col. V. H. Cornell, MC, U.S. Army, subject: Sanitary Survey of Nicaragua, 23 Feb.–1 Mar. 1941.

By 1943, more lasting control measures had been instituted in the environs of Puerto Barrios, Guatemala City, San José, and along the route of the Pan American Highway. Topographic surveys were also underway, as a basis for long-range, permanent improvements.

Honduras.—In 1941, the health department of Honduras was reported as rather poorly organized, with an inadequately trained staff.[43] From a sanitary standpoint, therefore, any military force had to be prepared to supply its own protection and facilities.

On the north coast, there is much rain. The period from February through June is most moderate in this respect. In the south, however, conditions are quite different, with two short rainy periods which fall in May and late October or November. In the mountainous areas, on the other hand, rain prevails from April to October. Malaria is serious in the north, which is characterized by many broad swamps; also in the south, though here the disease is more seasonal. Drainage is especially poor about the Gulf of Fonesca, and there is much malaria along the winding, lower courses of streams and rivers which flow into it. In the highlands, the disease occurs chiefly in persons "from the coasts."

In 1941, mosquito control had been practiced in "Company" areas and to a lesser extent in villages near them. Efforts at oiling and drainage were both so sporadic, however, that little good had resulted as extensive breeding areas nearby had been left quite undisturbed. By 1943, however, the Inter-American Cooperative Public Health Services had begun to function, and projects for malaria control were developed in several regions, including the ports of Amapala on the Pacific side and Puerto Castilla on the Atlantic coast. There was also provision for emergency malaria control in the camps of the workers on the Pan American Highway and on the Potrerillos-Pito Silo road.[44]

British Honduras, though within the general area of the Caribbean Defense Command, is not properly within the scope of this discussion. It is nevertheless of interest to note a British report for 1939.[45] During that year, 653 cases of malaria were admitted to public hospitals in the colony; 31 hospital deaths were ascribed to malaria, with 84 deaths in the colony as a whole. Outpatient cases treated at hospitals numbered 4,115.

El Salvador.—Although it is the smallest of the Central American States, El Salvador has a Ministry of Agriculture and Public Health which includes a Preventable Disease Division. The latter is organized into five subdivisions, one of which is concerned wholly with malaria problems.[46]

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[43] Report, Lt. Col. V. H. Cornell, MC, U.S. Army, subject: Sanitary Survey of Honduras, 1–7 Mar. 1941.

[44] Medical and Sanitary Data on Honduras. Prepared by the Medical Intelligence Branch, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 15 Sept. 1943.

[45] Medical and Sanitary Reports from British Colonies, Protectorates and Dependencies for the years 1939–1941. British Honduras (1939). Trop. Dis. Bull. 43 (Suppl.): 217–219, 1946.

[46] Report, Lt. Col. V. H. Cornell, MC, U.S. Army, subject: Sanitary Survey of El Salvador, 7–12 Mar. 1941.

are also present. Malaria reaches its highest incidence at the beginning of the rainy season (May and June) and again at the end (October to December) when optimum breeding conditions abound. Malignant tertian malaria predominates.

Costa Rica, 1941.—The government has a department of public health with a number of subdivisions. At least four of these have some interest in malaria. The Rockefeller Foundation and the Pan-American Sanitary Bureau extend advisory services.[49]

The long coastal areas were of the greatest interest from a military standpoint. The dry season extends from December into April. The rain on the Atlantic coast is heavier. Malaria increases with the wet season, the peak falling about 1 month after the peak of rainfall. Sixteen kinds of *Anopheles* have been found in Costa Rica, but only *A. albimanus* is an important vector.[50] Official mortality statistics for 1940 reported 916 deaths from malaria, or 140 per 100,000 for the entire country. Since 75 percent of the people live in the relatively healthy central plateau, this means a death rate approaching 500 per 100,000 in the coastal regions. (In the same year, the highest malaria death rate in the United States was 9.1 per 100,000 reported in Arkansas.)

With the assistance of the Rockefeller Foundation, considerable antimalaria drainage had been carried on, particularly in the province of Guanacaste.

Republic of Panama.—The Ministry of Public Health in 1943, through its Malaria Section, operated a Division of Malaria Studies. Its activities were directed chiefly toward antimosquito work. Eight projects, employing 366 nationals were being carried on,[51] and an intensive health education program was in operation. In addition, the Division of Sanitation had two technicians for malaria studies on the staff of its chief sanitary inspector.

The Division of Health and Sanitation of the Office of the Coordinator of Inter-American Affairs cooperated with the Republic of Panama on its malaria program, which consisted largely of drainage, entomological studies, ditch construction, larvicidal work, and ditch maintenance.

These agencies served the urban centers well, but many parts of the interior lacked any organized public health work. The United Fruit Company, however, had a comprehensive health program which included malaria and insect control.

The population is concentrated along the seacoasts and rivers. Certain large areas are sparsely populated. Malaria is the principal health problem, from both a civilian and a military standpoint. *Anopheles albimanus* is the

[49] Report, Lt. Col. V. H. Cornell, MC, U.S. Army, subject: Sanitary Survey of Costa Rica, 12–23 Feb. 1941.

[50] Medical and Sanitary Data on Costa Rica. Compiled by Medical Intelligence Branch, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 7 July 1943.

[51] Medical and Sanitary Data on the Republic of Panama and the Panama Canal Zone. Compiled by Medical Intelligence Branch, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 26 Nov. 1943.

principal vector with *A. punctimacula* in second place. Six other species are perhaps involved.

Clark and Komp[52] have shown that in certain villages of Panama, over a 10-year period, no seasonal variation in malaria occurred which could be correlated with seasonal rainfall.

Panama Canal Zone.—The chief health officer, Panama Canal Zone, is selected from the Army Medical Corps and serves for a period of 1 to 5 years.[53] His assistant is a civilian, who has direct charge of sanitation and malaria control. Field sanitation work operates by the Northern, Pedro Miguel, Panama Suburban, and Ancon-Balboa districts. For malaria control work in the Zone, certain geographic areas are allotted to the Medical Department of the Panama Canal. This is by mutual agreement between the chief health officer of the Panama Canal and the surgeon of the Panama Canal Department of the Army.

Antimosquito work had been diligently carried out for many years, but up to 1943 no effective method had been found to prevent anopheline breeding in Gatun Lake or outlying jungle streams, pools, or swamps. Neither could the flight of these mosquitoes into sanitated areas at certain seasons be prevented. Malaria was the chief cause of illness in the Canal Zone, though deaths were rare.

Precipitation in the Canal Zone tends to be considerably greater on the Atlantic side than on the Pacific coast. Average temperatures and relative humidity are not significantly different. The data in table 19 are instructive.

TABLE 19.—*Average temperatures, relative humidity, and precipitation in the Canal Zone, 1943–45*

Year	Precipitation		Mean relative humidity		Mean temperature	
	Atlantic	Pacific	Atlantic	Pacific	Atlantic	Pacific
	Inches	*Inches*	*Percent*	*Percent*	*Degrees F.*	*Degrees F.*
1943	126.25	60.80	80.7	83.6	80.4	78.7
1944	138.58	76.65	80.4	82.9	80.3	78.9
1945	132.12	63.85	80.3	79.3	80.8	83.0

The principal dry season starts in January and ends in April. During this period, mosquito breeding reaches a low ebb. The wet season begins in May and with some fluctuations lasts until December. The greatest mosquito (and malaria) menace comes with the change of seasons. Thus, the highest malaria rates are usually recorded in June or July, and the next highest in

[52] Clark, Herbert C., and Komp, William H. W.: A Summary of Ten Years of Observations on Malaria in Panama with Reference to Control with Quinine, Atabrine, and Plasmochin without Anti-Mosquito Measures. *In* A Symposium on Human Malaria. Edited by F. R. Moulton. Washington: Publication No. 15. American Association for the Advancement of Science, 1941, pp. 273–284.

[53] See footnote 31, p. 171.

December or January. In both cases, this is due to the abundance of shallow water, ideal for the rebreeding of anophelines. *Anopheles albimanus* has long been known as the principal vector.

The maximum number of troops on duty in the Canal Zone at any time probably did not exceed 70,000. These became widely scattered as the program for hemisphere defense materialized. At many automatic weapons and antiaircraft stations, the chief antimalaria procedure was the administration of suppressive Atabrine therapy. Some lots of Atabrine proved inferior in solubility. Attempts were made to safeguard men on night duty by spraying their uniforms with pyrethrum extract before a 2-hour detail, with inconclusive results.

Colombia.—Very few American troops were stationed in Colombia.

Ecuador, 1943.—The Ministry of Social Welfare, Health, and Labor included a public health system of undesirable complexity, which, for lack of centralized authority, had not functioned efficiently.[34] The average longevity in the country was only 32 years. Malaria was one of several diseases of military importance. Epidemics of plague, smallpox, and typhus occurred annually. Nevertheless, of 62,183 registered deaths in 1940, 4,847 were listed as due to malaria.

Anopheles albimanus and *A. pseudopunctipennis* are the proved malaria vectors, the first on the coast, the second in the mountain valleys. Drainage, ditching, and oiling had been carried out to some extent in the valleys, but, in the coastal zone, the numerous swamps could only be drained with great difficulty and excessive cost, and no progress had been made.

It appears certain that a large portion of the population suffers from malaria throughout the year, with inevitable loss of time and reduced capacity for work. The general backwardness of many parts of the country is due at least partly to chronic malaria. The greatest seasonal peak coincides with the termination of the rains, usually in May or June.

Galápagos Islands.—There are no anopheline mosquitoes on any of the islands.[35] The only culicine species recorded is *Aedes taeniorhynchus*, a potential vector of yellow fever and dengue. Military authorities took cognizance, however, of the possibility that both human gametocyte carriers and vector anophelines might be introduced in connection with the transport of troops and goods. This never occurred.

Peru, 1943.—Official public health work is controlled by the Public Health Division of the Ministry of Public Health and Social Welfare.[36] The Division has six administrative sections. Malaria control is a responsibility of the Section of "Technical Services," also of the Section of "Sanitary Campaigns."

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[34] Medical and Sanitary Data on Ecuador. Prepared by Medical Intelligence Branch, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 1 Oct. 1943.

[35] Medical and Sanitary Data on the Galápagos Islands. Prepared by Medical Intelligence Branch, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 8 Sept. 1943.

[36] Medical and Sanitary Data on Peru. Compiled by Medical Intelligence Branch, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 1 Sept. 1943.

The Rockefeller Foundation has collaborated for years with the Peruvian Government in the fight against malaria. Since 1942, the Institute of Inter-American Affairs has been a vital influence. Malaria surveys were carried out north of Lima, in the Chimbote area. Swamps were cleared, and technicians were trained for malaria control work.

The incidence of malaria is high in most of the country, but particularly so in coastal areas and deep-cut valleys where the chief vector is *A. pseudopunctipennis*. Control measures, chiefly by spraying, have been found very successful in certain valleys.

In jungle areas east of the Andes along the Amazon River, *A. albimanus* is thought to be the important vector. American military interests, however, were confined largely to the coast.

Development of Control in the Panama Canal Department, 1941–45 [55]

As contrasted with Pacific and African theaters, the PCD had seen malaria control campaigns for many years, going back to the work of Col. (later Maj. Gen.) William C. Gorgas in 1904.

When the Department was officially established, such activities came within the jurisdiction of the Department surgeon. Besides his organization, however, there continued to function the Sanitary Division of the Office of the Chief Health Officer, Panama Canal.

Until 1944, the malaria rate per 1,000 per annum among military personnel in the PCD continued to be at least twice the rate among employees of the Panama Canal. This was undoubtedly due to the fact that the soldiers operated away from home stations at least part of every year. The native reservoir of gametocyte carriers was always great and vector anophelines abundant. The problem was much aggravated in 1940, when emergency conditions required the troops to take to the field during the rainy season. Quinine was used as a prophylactic drug but with indifferent success. Only a very poor repellent, the English Dover's cream, containing oil of citronella, oil of cedar, and hard and soft paraffin was available. Pyrethrum in kerosene, 1 to 20, was the antimosquito spray, which had to be applied twice daily in all buildings. Protective clothing was used, and bed nets were required outside of sanitated areas. The system of mosquito control orderlies had already been instituted in the fall of 1940.

Construction work, which increased in 1941, often blocked ditches and otherwise created new mosquito-breeding areas. Col. Wesley C. Cox, MC, Surgeon, Panama Canal Department, stated: "The Field Sanitary Force oiled all impounded water, but areas of new danger were created almost faster than they could be oiled."

[55] Unless otherwise indicated, all data in the remaining section on the Panama Canal Department are based on the Annual Reports, Department Surgeon, Panama Canal Department, 1941–45, and the Professional History of Preventive Medicine in World War II, 1 January 1940 to 1 October 1945. The Panama Canal Department, vol. II. [Official record.]

Tents had to be used, even at permanent stations, to house newly arrived troops. It was practically impossible to mosquitoproof a pyramidal tent. Even buildings were difficult to keep mosquitoproof. One regiment's quarters had to be completely double floored to accomplished this.

All newly arrived units were given antimalaria instruction, but few took this seriously until taught by experience. For example, during combat training, the men rolled up their sleeves, opened their collars at night, and dispensed with head nets in order to see better. At antiaircraft positions, troops were observed sleeping beside their guns and other equipment, rolled up in their mosquito bars.

On the Atlantic side, malaria incidence increased as a result of a coral sand hydraulic fill, which prevented the tide water from entering the mangrove swamps. The mangroves were killed by the heavy deposit of sand, and this removed the shade. Thus an area which had previously supported only *A. aquasalis* became ideal for *A. albimanus*, the more important vector.

Many of these activities went on in close proximity to localities where the native population was 100 percent infected. Much malaria was also brought in by the thousands of civilian laborers, imported from the West Indies and from other Central and South American Republics.

The tide was turned in 1943 by the advent of the new repellents, the Freon-Aerosol bomb, and by Atabrine in sufficient quantities for issue to troops. Most important, of course, was an intensified educational campaign, including the use of posters and projection slides to acquaint every soldier and civilian with the seriousness of the fight against "Ann" or "Miss Anopheles."

It is of interest to note that the term "malaria discipline" was devised and first used in the PCD in 1941. The term caught on and was adopted by unit commanders everywhere.

Problems of 1941.—Since the inception of the defense period in 1939, ever-increasing number of troops belonging to the Panama Coast Artillery Command, the Panama Mobile Force, and the Air Corps were so stationed as to be living under field conditions, away from established posts or sanitated areas. The rates for malaria in 1940 and 1941 reflect this added risk as shown in table 20.

TABLE 20.—*Malaria rates for primary and recurrent cases among U.S. Army personnel, Panama Canal Department, 1939–41*

[Rate expressed as number of cases per annum per 1,000 average strength]

Diagnosis	1941	1940	1939
Primary malaria only	40.7	48.7	20.7
Primary and recurrent malaria	51.8	56.8	21.4

Rates by year, however, give but a poor understanding of the seasonal problems involved. Thus, for 1941, rains in May resulted in a considerable

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TABLE 21.—*Malaria rates for primary and recurrent cases among U.S. Army personnel, Panama Canal Department by month, 1941*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	Primary malaria	Recurrent malaria
January	37.3	19.4
February	42.7	12.0
March	23.5	11.5
April	28.0	8.7
May	22.7	9.7
June	50.9	7.8
July	40.9	13.2
August	33.0	12.0
September	102.7	13.0
October	43.5	12.5
November	37.4	10.2
December	27.2	10.7

increase in the primary malaria rate for June, while similar precipitation in August caused a high peak in September (table 21).

It is of interest to note that it is the primary rate which fluctuates significantly in response to vector activity. The recurrent rate, as is clearly seen, shows no consistent seasonal fluctuation.

The great height of the peak that occurred in September 1941 was due to a lapse of malaria discipline among units more or less new to the Department. In units where antimosquito and antimalaria discipline were kept up, no such rise occurred. All troops not living in barracks received quinine prophylaxis. A total of five deaths from malaria are recorded for 1941.

The following preventive measures involved all available procedures but were incomplete in some respects: Housing in screened barracks, wherever possible; use of mosquito nets or bars by all personnel not housed in screened barracks; use of head nets, gloves, and leggings whenever use of same would not interfere with the military duties to be performed; use of prophylactic quinine; antimosquito measures at all military installations and in an ever-widening circle around these installations (not planned in relation to flight range of vector); use of mosquito repellents, antimosquito sprays, oiling of standing water, and use of other larvicides.

Military personnel continued to be exposed to new infection in at least three ways: (1) Through duty at field positions, emergency airfields, and temporary camps; (2) through association with many chronic malaria carriers among the civilian population, and in the presence of anopheline vectors; and (3) through visits to native villages and establishment of temporary or common law relations with native women.

Problems of 1942.—In January, a number of military units arrived in the PCD and were assigned to combat positions in the interior of Panama. These were indoctrinated in malaria control, but the low malaria rates of the first 3 months were due more to the dry season than to malaria discipline. The rate for primary malaria dropped from 50.3 per 1,000 per annum to 28.1 between January and April, which doubtless contributed to a false sense of security. The real situation was demonstrated by maneuvers held during the first 2 weeks of April. Rains, which had begun in March, continued during the maneuver period. Many men contracted infection during these activities and during the weeks which followed. All troops were living under actual combat conditions during May and June; as a result, the primary malaria rate for the Department rose to 233 per 1,000 per annum and the recurrent rate to 25, giving a combined rate of 258. This declined gradually during the next several months reaching 90.4 by November.

Use of antimosquito cream, spraying of barracks with Pyrocide-20, and quinine prophylaxis for all men not quartered in mosquitoproof barracks constituted the control program for the period cited. This was manifestly insufficient.

An even more striking demonstration was furnished by the experience of a combat team of 4,000 which trained night and day under field conditions for almost the entire month of December. The primary malaria rate in this organization rose to 274.9. Even the Panama Mobile Force (of which the Combat Team was a part) had a rate of only 126.5 for the same period, while for the remainder of the Department the primary rate was only 32.1.

For the PCD as a whole, the rates for the year 1942 were: Primary malaria, 87.1; recurrent malaria, 24.6; total, 111.7.

During the first part of 1942, the majority of the troops in the field were under tentage. While barracks, hutments, messhalls, kitchens, and recreation halls were being constructed, tents were screened whenever possible. Galvanized screening rusted out very rapidly here, as in all humid tropical situations.

At several coast artillery positions, both barracks and hutments were provided. There was regular inspection, not only of the screening but also of the eaves, doors, roofs, and walls. Minor repairs, to stop all holes where mosquitoes might gain ingress, were carried out at once. A caulking compound, made of shredded paper, flour paste, sand, and cement, was found quite satisfactory for closing openings in eaves and cracks in sidewalls and proved very durable. Salvage screening was used for larger apertures.

The provision of screened recreation rooms proved of great importance, especially in field positions. The men could thus be protected during the evening hours, when the anopheline mosquitoes were most likely to feed. The same rooms served for instruction and study. All kitchens and messhalls in field positions were also mosquitoproof. During this particular period, the newer mosquito repellents were not yet available to the Department. "Stay-away" had been found effective but had been discontinued because of its toxicity to man.

For most of 1942, the contrast between permanent posts (sanitated areas) and outposts (unsanitated areas) was very great. The following rates (table 22) per 1,000 per annum are for primary malaria only.

TABLE 22.—*Malaria rates for primary cases only, in U.S. Army personnel, in permanent (sanitated) posts and outposts (unsanitated) areas, Panama Canal Department, January–November 1942*

[Rate expressed as number of cases per annum per 1,000 per average strength]

Month	Sanitated area	Unsanitated area
January	12.0	32.4
February	19.2	33.9
March	11.4	37.8
April	5.3	40.7
May	20.9	100.2
June	51.6	179.4
July	43.5	133.2
August	34.4	98.6
September	22.7	55.3
October	15.6	39.3
November	26.7	30.4

Again, if the rates are analyzed according to organizations with contrasting types of duty, the same facts are brought out. For example, the month of November showed a primary malaria rate of 53.9 per 1,000 per annum for the entire Panama Canal Department. However, the Panama Mobile Force, which carried out such duties as road and beach patrol and engaged in intensive unit training, had a rate of 116.5, while all other units enjoyed the relatively low rate of 34.2.

Several additional factors also contributed to the high malaria rate in 1942, which by June had reached 258 (primary and recurrent) per 1,000 strength per annum.

It was sometimes difficult or impossible to carry out effective mosquito control procedures during the course of construction, which, in itself frequently created new mosquito breeding areas, or, new construction work might actually block existing antimosquito drainage, which happened, for example, at the Majawar River and the Río Chilibrillo.

Again, whereas the Army was successful in sanitating an ever-widening circle around each military post, camp, or station in the Canal Zone, existing treaty arrangements with the Republic of Panama did not make it feasible for the Army to carry out antilarval measures in unleased extracantonment areas in the Republic.

For these and other reasons, more than usual reliance had to be placed on drug prophylaxis, bed nets, repellents, protective clothing, and avoidance of civil communities at night. Enforcement was hardly adequate.

The following recommendations were suggested in the Russell-Boyd report:[58]

1. That a medical officer, experienced and suitably trained in military malaria control methods, be made malariologist to the PCD, to organize, coordinate, and supervise military malaria survey and control work in the Department. (Possibly this officer could serve concurrently as malariologist to the Caribbean Defense Command. Such an organization had been suggested on 24 October 1942, in a letter from The Surgeon General to the Commanding General, Caribbean Defense Command.)

2. That an entomologist and a sanitary engineer trained in malariology be assigned to this antimalaria organization. These might be suitable officers already serving in the PCD, or, if requested, specially trained men available through the Office of The Surgeon General.

3. That, where not now in use, specific and detailed plans and spot maps for malaria control in each station in the PCD be prepared, with responsibilities and routine procedures clearly defined.

4. That the question be studied as to how to obtain active help from the Republic of Panama Health Department in dealing with extracantonment malaria, analogous to that already being given by the Canal Zone Health Department in extracantonment areas.

5. That every effort be made to maintain the current high efficiency of mosquitoproofing in all military stations of the PCD, that steps be taken to provide a more adequate supply of noncorrosive wire screen cloth of not less than 16 mesh, and that all construction be in accord with the principles of modern mosquitoproofing.

6. That, if possible, no more mosquito bars or bed nets, made of "buttercloth," "tobacco cloth," "cheesecloth," or other material impermeable to air circulation, be issued for use in such tropical areas as the PCD.

7. That ample quantities of Quartermaster issue mosquito repellent lotions (Indalone, replaced by Rutgers 612 as soon as available) be requisitioned for liberal use by troops in the PCD.

8. That much greater use be made of pyrethrum sprays to kill adult mosquitoes, especially in the early morning and evening hours, that ample supplies of the new Freon-pyrethrum insecticide dispenser be obtained, that the practice of issuing insecticide sprays only "within limit of funds available" be discontinued, that antimalaria supplies of all kinds, including paris green, oil, pyrethrum insecticides and repellents, be issued on an "as required" basis in such a malarious area as the PCD.

9. That measures for anopheline mosquito control on all new projects be carried forward concurrently with construction and with the same priority, and that care be taken in new construction not to increase the malaria problem by blocking drainage or by creating new breeding places.

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[58] Report, Dr. Mark F. Boyd and Lt. Col. Paul F. Russell, MC, to The Surgeon General, 5 Nov. 1942, subject: Malaria Tour in the Panama Canal Department.

10. That in order to reduce the large numbers of malarial infections now being acquired in towns and villages where the disease is prevalent by soldiers on pass during the usual leave hours from 1300 to 2300, the possibility be considered of changing leave hours in some stations so that they would come between 0800 and 1800.

11. That prophylactic, or in other words, suppressive treatment of malaria be reduced within the PCD to the greatest extent compatible with local conditions, and that it be administered on a specific rather than general basis, that is to say, applied only to those positions where the need for this emergency treatment can be demonstrated.

12. That the possibility be considered of treatment with Atabrine, by Army medical officers, of all laborers on Army projects who are quartered at night within close proximity to Army positions in the PCD.

In regard to No. 4 above, a plan was ultimately evolved by which the Coordinator of Inter-American Affairs would appropriate a sum of money, to be matched in part by funds appropriated by the government of Panama, for the purpose of carrying out a malaria control program in the Republic.

Successful conquest of malaria, 1943–45.—During 1943, an excellent standard for malaria discipline was maintained in the Panama Canal Department. Each barracks or hutment was served by a malaria control orderly whose duty it was to spray the building twice daily, between 0500 and 0530 and between 1800 and 1900, using a Freon-Aerosol dispenser. These orderlies also eliminated casual water in ruts, tire tracks or depressions, cleaned and maintained eaves drains and other drains or ditches near the barracks, and every 7 days oiled all casual water near the barracks that could not otherwise be eliminated. They performed inspections of doors, screens, and walls of barracks, making minor repairs on the spot, and reported major defects for action on the part of the unit commander.

Garnishing of salvaged canvas was used on inner surfaces of doors and along door jambs at field positions. Improvised caulking material composed of shredded paper, flour paste, sand, and cement continued to be useful, especially in sealing cracks at the eaves where corrugated roofing was used.

The general success of these efforts is registered in the malaria rate (table 23).

The peak figure for primary malaria, reached in June 1943, is trivial as compared with the previous year, and the small seasonal peak indicated for October is inconsequential. In general, it may be said that there was a steady decline of malaria throughout the year, as educational and enforcement measures became more and more effective.

Head nets, gloves, and leggings were prescribed for all guards and sentries on night duty. Between the hours of 1800 and 0630, antimosquito lotion was prescribed for all individuals visiting or passing through unsanitated areas. Mosquito bars were required in all table of organization type barracks even though there were screens. Kitchens, messhalls, and recreation halls were sprayed twice daily, at the same hours as the barracks. Motion picture theaters were sprayed between 0600 and 0700 and again before the start of the first performance.

TABLE 23.—*Malaria rates of primary and recurrent cases among U.S. Army personnel, Panama Canal Department, by month, 1943*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	Primary malaria	Recurrent malaria	Total malaria
January	63. 4	30. 9	94. 3
February	33. 9	26. 1	60. 0
March	19. 7	29. 8	49. 5
April	22. 2	22. 9	45. 1
May	24. 8	22. 3	47. 1
June	31. 4	16. 1	47. 5
July	19. 7	14. 7	34. 4
August	16. 2	12. 4	28. 6
September	13. 7	11. 8	25. 5
October	18. 0	11. 8	29. 8
November	15. 4	9. 3	24. 7
December	16. 5	7. 8	24. 3

Primary malaria in unsanitated areas, however, continued to show a rate more than twice as high as in sanitated areas. Recurrent malaria was always present, due chiefly to turnover in personnel. Chronic relapses occurred among Puerto Rican troops, then replacing continental units in the Panama Canal Department.

The conquest continued with increasing success through 1944 (table 24).

TABLE 24.—*Malaria rates of primary and recurrent cases among U.S. Army personnel, Panama Canal Department, by month, 1944*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	Primary malaria	Recurrent malaria	Total malaria
January	10. 1	12. 5	22. 6
February	8. 5	10. 9	19. 4
March	3. 4	4. 9	8. 3
April	1. 6	4. 6	6. 2
May	10. 8	5. 1	15. 9
June	14. 0	9. 8	23. 8
July	18. 0	5. 4	23. 4
August	8. 5	6. 3	14. 8
September	7. 2	4. 8	12. 0
October	4. 4	6. 8	11. 2
November	5. 0	5. 3	10. 3
December	2. 3	4. 3	6. 6

The inevitable seasonal fluctuations are still present, but the improvement over the previous year is evident at a glance.

One new, routine procedure adopted in 1944 was the spraying of screens in unsanitated areas with residual DDT. Also, water that could not be eliminated by filling or ditching was treated with a 5 percent solution of DDT in a 4 to 1 mixture of diesel oil and grade "c" fuel oil.

Malaria discipline was carried to greater efficiency than in 1943. The combined rate for primary and recurrent malaria for the year 1944 was reported as 14.5.

In 1945, the malaria rate fell still lower. The rate per thousand per annum for primary malaria became 5.8, for recurrent malaria, 3.4. The total rate, 9.2, was the lowest yet attained in the PCD, and it was the first time, since the PCD was established, that the rate among troops was lower than the rate for the Panama Canal (table 25).

TABLE 25.—*Malaria rates of primary and recurrent cases among U.S. Army personnel, Panama Canal Department, by month, 1945*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	Primary malaria	Recurrent malaria	Total malaria
January	4.0	5.9	9.9
February	2.1	4.1	6.2
March	2.9	7.2	10.1
April	3.9	4.7	8.6
May	9.6	4.8	14.4
June	8.4	1.2	9.6
July	5.3	3.0	8.3
August	5.4	0.9	6.3
September	8.2	1.2	9.3
October	5.6	1.3	6.9
November	6.5	2.2	8.7
December	11.9	3.5	15.5

It will be seen that seasonal peaks, though real, are without arresting significance.

Control measures remained much the same in nature as before. Filed reports refer to spraying all screens and screen doors as well as the interiors of occupied buildings, with monthly applications of 5 percent DDT in diesel oil. Freon-Aerosol dispensers were reserved for use in the destruction of adult mosquitoes.

At this time, responsibility was efficiently vested in three levels of authority. Each organization looked out for maintenance of buildings and drainage control in its own area. In all areas not maintained by organizations, the post engineers, working in cooperation with the Medical Department Field

Sanitary Force, constructed and maintained malaria control installations. The long-range (10-year) program was the responsibility of the Department engineer. Malaria control continued to be a "command responsibility."

The fact that the December rate tops that of May and June deserves special explanation. Malaria discipline is easiest to maintain when privileges are few. Thus, in the PCD, an exceptionally high standard prevailed during the first 10 months of 1945; however, as the rates for both primary and recurrent malaria remained low or went lower, it became increasingly difficult to enforce malaria discipline. The constant example of stricken comrades was lacking, and the men began to feel that the danger had been exaggerated. When no malaria occurred in an organization for several consecutive months, some relaxation of discipline was sure to follow. A real slump came during the last 3 months of 1945, when overnight and weekend passes were again instituted. Added to the usual increase of anophelines at the end of the dry season, this resulted naturally in an increase of primary malaria for December 1945.

A renewed emphasis on the instructional program followed. All men going on pass were instructed to use the issued repellents. It is greatly to the credit of both medical and line officers, commissioned and noncommissioned, that a "high sense of moral responsibility" was maintained. One report contains the comment: "Men free for the night wander far afield and when in certain environments cease to consider the dangers of malaria."

Recapitulation and comment.—Rather complete statistics are available for the Panama Canal Department regarding malaria cases over a period of years. Table 26 includes both primary and recurrent malaria among military personnel and represents the number of cases per annum per thousand average strength admitted to medical treatment facilities.

TABLE 26.—*Attack rates for malaria among U.S. Army personnel, Panama Canal Department, 1936–45*

[Rate expressed as number of cases per annum per 1,000 average strength]

Year	Rate	Actual war years	Rate
1936	45. 8	1941	51. 8
1937	44. 7	1942	111. 7
1938	35. 2	1943	42. 6
1939	21. 4	1944	14. 5
1940	56. 8	1945	9. 2

The relatively low rate for 1939 shows the effect of a consistent effort at control over a 4-year period, under rather stabilized conditions insofar as troop movements were concerned. The expansion of activities during the next 3-year period, involving as it did the establishment of small outposts, emergency airfields, and the like, away from sanitated bases, found reflection in the rather alarming increase in 1942, when the rate was more than double that of the previous year. Another factor was the influx of new troops who had no experience in dealing with malaria.

During the next 3 years, a full-scale control program was in operation, in which all available methods were employed. The results speak for themselves. Part of the decline in rate was of course due to the gradual abandonment of many minor outposts. On the other hand, the control program was sometimes handicapped by delays in delivery of insecticides and repellents because the Quartermaster was under obligation to meet the greater demands, in the far Pacific and elsewhere, which had first priority.

It is of interest to note that, during the latter half of 1942, the malaria rate for Panama Division employees of the Engineer Service, Caribbean Defense Command, was only 52.52;[59] undesirably high, of course, but less than half the rate for PCD military personnel.[60] The wide dispersal of the latter as compared with the relatively fixed location of the labor camps was presumably a factor.

The story of malaria in the PCD is also reflected in statistics from Gorgas Hospital, Ancon, C.Z., over a 3-year period. During 1942, this hospital handled 4,519 cases of malaria, which represented 13.2 percent of its total caseload. In 1943, the figure stood at 1,843, or 6.0 percent of all cases treated. In 1944, there was a still further reduction to 1,071, or 4.6 percent. These percentages represent actual diagnosis of malaria by blood smear.

Special Units, Organizations, and Projects

Field Sanitary Force

An important factor in keeping the malaria situation well in hand was the Medical Department Field Sanitary Force, also called the Field Sanitation Force. This organization, composed of civilian personnel, was especially efficient in carrying out malaria control measures in and about military areas. Such a statement is all the more significant when one realizes that the total strength of this unit in 1942 consisted of 3 sanitary inspectors and an average of 207 laborers (increased subsequently to 251).

The Field Sanitary Force was established in 1939 by the Office of the Surgeon, Panama Canal Department, and was made up largely of men from the West Indies, particularly from the island of Martinique.

Toward the end of the war, Panamanians came to predominate in the labor gangs, with the remaining West Indians serving as the backbone of the Force.

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[59] Letter, Lt. Col. R. J. Lorre, MC, Chief Surgeon, Panama Division, Engineer Service, Caribbean Defense Command, to The Surgeon General, U.S. Army, 30 Jan. 1943, subject: Medical History of the Panama Division, Engineer Service, Caribbean Defense Command, 1941–1942.

[60] (1) In 1906, the malaria death rate for employees of the Panama Canal and Panama Railroad was 745 per 100,000. Morbidity ran much higher, 82.1 percent of all employees being admitted to dispensaries and hospitals. By 1916, admissions had dropped to 1.6 percent and the death rate was 6 per 100,000. In 1942, the malaria rate rose to 2.45 percent, but was soon reduced again, and for 1945 stood at 1.26 percent. (2) Faust, Ernest Carroll: Malaria Incidence in North America. *In* Malariology, edited by Mark F. Boyd. Philadelphia: W. B. Saunders Co., 1949, vol. 1, pp. 749–763.

Working in close cooperation with the Field Sanitary Force was Maj. (later Lt. Col.) George W. Hamilton, SnC, who made the drainage survey for malaria control throughout the posts and outlying areas. Working both in office and field was Capt. Emery V. Smith, MC, assistant malaria control officer for the Department.

In 1946, the Field Sanitary Force was still engaged in control activities at airbases and subbases of the Caribbean Air Command, though with reduced personnel.

Army School of Malariology

Facilities for training specialized personnel had come into being at several points in response to pressing needs. Cooperating in these preliminary enterprises were the Tennessee Valley Authority, the Florida State Board of Health, the Rockefeller Foundation, and the Pan-American Highway Commission. The Army used these various facilities for training military personnel, but the scattered location of the training areas made instruction difficult and much time was lost in moving from place to place. The Surgeon General's Office finally succeeded in unifying these efforts through the establishment, at Fort Clayton, C.Z., of the Army School of Malariology.

Activation took place on 26 January 1944. Original authorized strength was 10 officers and 14 enlisted men, but this was increased on 1 April 1944 under Special Manning Table 8-40-PC to 11 officers and 49 enlisted men. Col. Charles G. Souder, MC, was appointed commandant.

Dr. John E. Elmendorf, Jr., of the International Health Division, Rockefeller Foundation, who had served 2 years as director of the Florida school, became assistant commandant.

The mission of the school was to train officers and units in Army methods of controlling malaria in endemic areas. To be eligible for training, Medical Corps officers were first required to complete a course in tropical medicine. Sanitary Corps officers (parasitologists, entomologists, and engineers) were especially selected by The Surgeon General. Enlisted men (from malaria control and malaria survey units) were carefully selected on the basis of their qualifications. Laboratory technicians were also trained. Officers were trained in groups of 25 to 30.

The course, which was of 4 weeks' duration, was designed to present actual problems and practical exercises in malaria control (fig. 26). Night operations were included as part of the instruction.

The staff, as constituted in July 1944, consisted of ten commissioned officers, including a clinical malariologist (Dr. Elmendorf), an entomologist, and a sanitary engineer, each with the rank of lieutenant colonel. An entomologist and a sanitary engineer, each with the rank of major, were also provided in the table of organization. The enlisted personnel included seven technical sergeants of whom three served as instructors in entomology and one in parasitology. In the grade of private there were also three instructors in entomol-

FIGURE 26.—Parasitology class, Army School of Malariology.

ogy and one in parasitology. The author personally attests that these eight enlisted instructors, carried as "sanitary technicians," did yeoman service. Most of these men had received civilian education equivalent to that usually found in commissioned personnel.

Experimental work under military auspices

Protective clothing.—Considerable attention was given to penetrability of cloth to the bites of disease-carrying mosquitoes. Byrd cloth, as tested against *A. albimanus* and *Aedes aegypti*, gave best results. If arm tests of any particular fabric showed that the latter permitted penetration either in the dry or wet condition, or when soaked with sweat, that fabric was discarded. The lasting quality of any fabric, under jungle conditions was, of course, considered of major importance.

It was recommended that any uniform designed primarily for protection against mosquito bites should be larger than ordinary and loose fitting. (Even so, the discomfort from lack of ventilation can be considerable.) No mosquito-proof garment was intended to replace repellents or malaria discipline in general, but rather to be used in combination with them.

Experiments utilizing DDT.—On 10 September 1943, Colonel Cox was sent 5 pounds of Gesarol (DDT) by air express, for trial use as a larvicide. Fifty pounds followed by ordinary shipment. Crankcase oil, also diesel oil No. 2, had been recommended as vehicles for application. This was the beginning of a series of field experiments, which led finally to large-scale treatment of extensive areas by airplane. Certain aspects of these experiments and field trials are summarized in paragraphs which follow:

The first significant studies on the experimental use of DDT as a larvicide were reported early in 1944. The following points seemed especially important:[61] (1) The new insecticide killed all larvae, both *Anopheles* and *Culex*, as determined by examination 24 hours after application (none of the control oils achieved this); (2) a 1-percent concentration ($\frac{1}{100}$ of a pound per acre) was quite as effective against mosquito larvae as a 5-percent concentration ($\frac{1}{20}$ of a pound per acre) (the stronger concentration was detrimental to fish and vegetation, while the 1-percent concentration appeared not to be); and (3) the lasting power of the larvicidal mixture is related to the character of the diluent and the method of application. Thus, a viscous oil mixture, distributed through marginal vegetation with a mop had a more enduring effect than a light oil mixture, applied with a knapsack sprayer. In the former case, a persistent film is renewed from the reservoir established at the margin. In impounded waters, such applications controlled anopheline breeding for 4 weeks.

Possible disadvantages were also noted: (1) Heating is necessary to put DDT into complete solution, especially with the higher viscosity oils, and (2) the 1-percent concentration killed practically all forms of insect life in the water. Since this included adult mosquitoes alighting on the water for oviposition, malaria control was augmented, but the destruction of many forms of fishfood might well have adverse economic effects. From a strictly military standpoint, this was not of immediate concern, but, in the interest of long-range conservation, it was destined to have a limiting effect on the general use of DDT in postwar years.

All of the field work, in connection with the tests described previously, was carried out by Capt. Emery V. Smith.

During the calendar year 1944, two reports were rendered on the hand application of DDT as a larvicide, and three on the distribution of DDT by airplane. Hand application related almost entirely to larviciding, but treatment from the air was aimed at control of adult mosquitoes as well. Toward the end of the year, a specially constituted board of officers, including Navy personnel, made preliminary tests on the efficiency of a 20-percent solution of DDT by weight in "Velsicol NR 70," distributed as an Aerosol spray by a specially equipped combat aircraft furnished by the Navy. Tests scheduled for 1945 included large-scale distribution of DDT in various solvents by multi-engined aircraft of the C-47 and B-25 type.

Various boards were appointed, augmented, modified, and superseded in the course of this work. It is not practical to list them all. A selected example will serve to illustrate procedure:

[61] Letter, Col. Wesley C. Cox, MC, Surgeon, Panama Canal Department, to The Surgeon General, U.S. Army, 2 Feb. 1944, subject: Report on Efficacy of a New Larvicide (DDT), inclosure thereto, 15 Jan. 1944, subject: Observations and Comment on the Efficacy of New Larvicide and Some Methods of Application.

In January 1945, a board of officers was appointed to study certain aspects of malaria control.[62] The personnel were as follows: Col. Charles G. Souder, MC, Army School of Malariology (Chairman); Col. Wesley C. Cox, MC, Headquarters, Panama Canal Department; Col. Harold E. Schneider, MC, Sixth Air Force; Lt. Col. Daniel Bergsma, MC, Headquarters, Caribbean Defense Command; Lt. Col. Alton H. Saxer, MC, Sixth Air Force; Maj. (later Lt. Col.) Charles L. Pierce, SnC, Panama Canal; Maj. Marshall Hertig, SnC, Gorgas Memorial Laboratory; Capt. Emery V. Smith, MC, Headquarters, Panama Canal Department, Recorder; and Dr. Herbert Clark, Director, Gorgas Memorial Laboratory.

Three technical consultants were also designated: Lt. Col. (later Col.) John Q. A. Daniels, MC, Maj. Tristram J. Cummins, Jr., CWS, and Capt. William N. Sullivan, SnC.

Included in the objectives of this study[63] were: (1) Action of various solutions of DDT against larvae and adult mosquitoes; (2) effectiveness of equipment devised for aerial distribution of DDT; (3) securing of information relative to the influence of terrain, meteorological conditions, type of equipment, and other factors on effectiveness of DDT; and (4) the effect of DDT on insects other than mosquitoes.

A preliminary report was rendered 31 March 1945 on tests carried out in the Republic of Panama between 23 January and 6 March 1945.

Certain aspects of DDT airplane spraying tests in Panama are summarized from a report by Lt. Col. Oliver R. McCoy, MC:[64]

The Army Air Forces Board arrived in Panama, 23 January 1945. These officers, from Wright Field, Ohio, and Orlando Air Base, Fla., were accompanied by five civilian consultants; four of these consultants were from the U.S. Department of Agriculture. These were assigned by a special board appointed by the surgeon of the Caribbean Defense Command. Colonel Cox served as project director.

Two malaria control units, 30 Medical Department enlisted men, and 12 enlisted men from the Army School of Malariology assisted in the work.

The Signal Corps set up a communications system and furnished photographers. A complete weather station was established at field headquarters.

The Army Air Forces Board took charge of application. The Panama Board evaluated results. Five plots in a jungle area east of Panama City

[62] Letter, Col. Hugh J. Deeney, AGD, Adjutant General, Office of the Department Commander, Headquarters, Panama Canal Department, to Col. Charles G. Souder, MC, Army School of Malariology (Chairman) and members of a Board of Officers, 23 Jan. 1945, subject: Appointment of Board of Officers to Study Certain Aspects of Malaria Control.

[63] Report, Col. Charles G. Souder, MC, Chairman, Board of Officers, to The Commanding General, Panama Canal Department, 31 Mar. 1945, subject: Preliminary Report of a Board of Officers Appointed to Study Certain Aspects of Malaria Control.

[64] Memorandum, Lt. Col. O. R. McCoy, MC, Director, Tropical Disease Control Division, Preventive Medicine Service, Office of The Surgeon General, U.S. Army, to Acting Chief, Preventive Medicine Service, Surgeon General's Office, 19 Feb. 1945, subject: Observations of DDT Airplane Spraying Tests in Panama.

were surveyed by the Corps of Engineers, and perimeter and diagonal trails were provided. Covering vegetation was about 100 feet above the ground. Preliminary mosquito counts were made from human bait at 20 stations in each plot and from a horse trap set in the center of each.

Almost complete elimination of adult mosquitoes was accomplished in all the areas treated. Larvicidal effects were tested by setting out pans of water containing *Aedes* larvae at ten points in each plot. Since *A. albimanus* larvae do not survive transportation, these were tested by exposure in the laboratory to water rendered toxic in the field. The larval kill depended on whether or not the spray penetrated the jungle covering.

The number and size of spray particles reaching the ground were determined by setting out slides, coated with magnesium oxide, at each station. From 1 to 5 percent of the material reached ground level.

Four plots were variously treated, using a variety of solvents. One plot was left untreated, as a control. All spraying was done between 0725 and 0745 hours, a period when there was little or no wind. The plane used was a B–25 (J) equipped with a grid outlet. Results indicated that this type of equipment was more satisfactory than any yet developed for spraying DDT in the field. Comparisons with exhaust Aerosol type of apparatus had not as yet been made.

Army Air Forces Board Project No. F–4095 was completed and reported on 11 April 1945. Large payload type aircraft had been used and various DDT solutions employed. These tests made use of a lake, a jungle area, two native villages, and six jungle test plots, all similar.

On 17 March 1945, a special board of officers was created to study further certain aspects of the problem. This board included four officers from the Sixth Air Force.

Using a C–47 plane with a carrying capacity of 800 gallons of DDT in diesel oil, the group conducted numerous tests in four distinct areas: (1) The Chilibre-Buenos Aires area, involving a river, lake and jungle area, (2) the Farfan swamp area, and (3) the old French Canal area.

Toward the end of the year, a special study was begun, involving four villages situated along the Atlantic coast, west of Fort Sherman, C. Z. All four were known as hyperendemic foci of malaria. The inhabitants of Piña were treated each week with the experimental drug SN 7,618 (chloroquine diphosphate). In Lagarto, the houses were sprayed or painted with a 5-percent solution of DDT in diesel oil. The village of Salud was sprayed from the air with the same preparation. Nuevo Chagres was left untreated, as a control. An expansion of this program was later put into effect.

The Gorgas Memorial Laboratory

Through the National Research Council and the Office of Scientific Research and Development, a number of problems relating to insect vectorship of disease were studied at various locations. Three projects of prime importance in the control of malaria were: (1) The development of insect repellents; (2) the development of efficient insecticides other than pyrethrum; and (3) the development of improved larvicides for the control of anopheline mosquito breeding.[65]

The Gorgas Memorial Laboratory, in the Republic of Panama, was in a favorable location for this type of work, not only because of climate and terrain but also because cooperation for military field studies was assured from the Panama Canal Department.

By memorandum of 24 April 1943, four Sanitary Corps officers were allotted for duty with The Surgeon General for the purpose of conducting these and other researches at the Gorgas Memorial Laboratory.[66]

Dr. Herbert C. Clark, Director of the Laboratory, acted as commanding officer of the group. The Army personnel, with dates of arrival and departures, were as follows:[67]

Personnel and date of arrival	*Status as of 1 November 1945*
Maj. Marshall Hertig, 15 June 1943	Still on duty.
1st Lt. (later Capt.) Alexander G. B. Fairchild, 8 April 1943	Still on duty.
1st Lt. (later Capt.) William C. McDuffie, 16 August 1943	Departed 11 June 1944.
1st Lt. (later Capt.) Roy Melvin, 4 October 1943	Departed 10 September 1944.
2d Lt. (later 1st Lt.) Harold Trapido, 4 July 1944	Still on duty.
1st Lt. Charles D. Michener, 15 December 1944	Still on duty.
T/4 Edson F. Fichter, 17 July 1944	Departed 20 October 1944.

It will be seen that the allotted strength of four officers, including one of field grade, was maintained throughout the period concerned. Capt. (later Maj.) Alexander G. B. Fairchild, SnC, had been a staff member of the Gorgas Memorial Laboratory for 5 years previous to his military duty. Capt. Roy Melvin and Lt. Charles D. Michener, who replaced him, were concerned with studies on chiggers. The DDT anopheline projects were directed by Capt. William C. McDuffie. His successor, 2d Lt. (later 1st Lt.) Harold Trapido, was chiefly concerned with the village malaria control project.

The headquarters of the unit were located in the Gorgas Memorial Laboratory in Panama City. The Institute's animal houses, the insectary with its colony of *A. albimanus*, and the services of laboratory personnel were likewise available for use.

In addition, the field station at Juan Mina, on the Chagres River just inside the Canal Zone boundary, was much used. Most of the repellent tests, the DDT anopheline work, and the village DDT spraying project were carried out from this point.

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[65] Memorandum, Col. J. R. Hudnall, MC, Director, Military Personnel, (Office of The Surgeon General,) to The Director, Military Personnel Division, Army Service Forces, 13 Apr. 1943, subject: Allotment of Officers to The Surgeon General for a Special Duty.

[66] Memorandum, Brig. Gen. Russell B. Reynolds, GSC, Director Military Personnel Division, Army Service Forces, for The Surgeon General, 24 Apr. 1943, subject: Allotment of Officers.

[67] Hertig, Marshall: Chronological History, Gorgas Memorial Laboratory Unit of Sanitary Corps Officers, 1943–45. [Official record.]

The expenses of the unit's various projects were covered partly by the Gorgas Memorial Laboratory and partly by funds provided under contracts between the Laboratory and the Committee on Medical Research of the Office of Scientific Research and Development. Certain supplies were furnished by the Army, as were two vehicles (but not their maintenance).

Helpful contacts were maintained with the chief health officer of the Panama Canal, the surgeon of the PCD, and the surgeon of the Panama Mobile Force. This gave opportunity for the officers of the unit to visit field installations and jungle outposts and to participate, with troops, in field tests of repellents and protective clothing.

Repellents Rutgers 612, dimethyl phthalate, and the Army's 6–2–2 mixture were tested against *A. albimanus*, *A. triannulatus*, and four species of *Mansonia*. All were found effective against both anophelines and culicines.

Early experiments with DDT dusts as larvicides were not encouraging, and emphasis was shifted to oil solutions and emulsions. It was brought out that since the effect of DDT in oil as a larvicide is very brief, its principal value lies in the practically 100 percent kill which can be achieved with very small quantities of the insecticide, such as one-fortieth to one-twentieth of a pound per acre.

Major Hertig and Captain Fairchild, as members of the board of officers serving under Colonel Souder, participated in the experiments on spraying DDT from aircraft under jungle conditions. Dr. Herbert Clark and members of the U.S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, from Orlando, Fla., and Washington, D.C., also served with this group.

Captain McDuffie carried out experiments in half-acre plots to determine the effects of DDT sprayed from the ground to control adult mosquitoes. In dense jungle, the beneficial effect lasted several days, while in open country the benefit was transient. The latter observation was supported by the subsequent work of Captain Fairchild in a cacao plantation at Almirante, Republic of Panama, where no effect was observable the day after spraying was carried out.

The village spraying projects conducted by Lieutenant Trapido deserves special comment. In 15 months of investigational work, he demonstrated the desirable effect of merely spraying the houses, which were built of cane walls with palm-thatched roofs.[illegible] There is obviously no way to render such dwellings mosquitoproof. Five percent DDT in kerosene was applied inside and out at intervals of 4 months to houses in the village of Gatuncillo, in the middle Chagres River area. Two adjacent villages were used as controls.

As measured by house catches and horse baited traps, a great reduction of anophelines was realized in the treated village and area close by. The degree of control improved with successive treatments. During the third 4-month

[illegible] Trapido, H.: The Residual Spraying of Dwellings with DDT in the Control of Malaria Transmission in Panama, With Special Reference to *Anopheles albimanus*. Amer. J. Trop. Med. 26: 383–415, July 1946.

period, the malaria transmission potential, as shown by captured *A. albimanus*, was reduced by 99.9 percent. Reduction in anopheline population was evident for at least 300 feet into the forest. At the end of the first year, a decrease of the malaria rate was also observed.[69]

Earlier work on projects sponsored by the Office of Scientific Research and Development had been carried on by Dr. Carl M. Johnson who studied malaria antigens and by Mr. Daniel M. Jobbins who investigated insect repellents.[70]

It should be remembered that much of the knowledge that was available concerning malaria in Panama at the outbreak of the war was the result of surveys and investigations carried on by the staff of the Gorgas Memorial Laboratory. The tenth and final report on a selected group of villages along the Chagres River was published in 1941.[71] Species of malaria parasites were found in the following proportions: *P. falciparum*, 72 percent; *P. vivax*, 22 percent; and *P. malariae*, 6 percent. More than half the population of the villages studied were positive for malaria one or more times during the year as shown by monthly surveys. Significant in the general findings is the conclusion that drug treatment, though it practically eliminates severe clinical malaria, cannot prevent an epidemic when unusually great numbers of the vector are present. It is, therefore, considered quite impossible to eradicate malaria parasites by such means, or even to reduce transmission to any great extent. It was established that quinine and Atabrine may be considered equally effective as antimalarial drugs but that the use of Plasmochin (pamaquine naphthoate), because of its toxic effects, requires close supervision.

The Pan American Highway

Along the Inter-American Highway, especially in Central America, the most important malaria vector is *A. albimanus*, with *A. pseudopunctipennis* a secondary vector at high altitudes.[72] From both a military and a civilian standpoint, it is important that halting places for travelers be made as safe as possible. Routine measures that render the large centers of population more or less mosquito free are not practiced in the smaller towns of the rural lowlands, which, therefore, remain a special hazard in this respect. Surveys begun in 1943 by the Pan-American Sanitary Bureau showed that the risk of contracting malaria exists for the most part below an altitude of 1,000 feet

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[69] In recent years, a degree of resistance on the part of the anophelines has been reported. This has proved to be due to a change of resting habits, whereby the mosquitoes no longer seek walls of buildings for resting purposes, and thus tend to avoid contact with the treated surfaces. True, physiological resistance, as in the housefly, has not been confirmed.—L.S.W.

[70] Letter, Henry E. Meleney, M.D., Consultant to the Secretary of War, to Members of the Central American Commission on Field Instruction in Tropical Medicine, 7 Apr. 1943, inclosure thereto, subject, Report of Tour of Central America For the Purpose of Surveying Tropical Diseases Conditions and Opportunities for Field Experience in Tropical Medicine.

[71] Clark, H. C., Komp, W. H. W., and Jobbins, D. M.: A Tenth Year's Observation on Malaria in Panama, with Reference to the Occurrence of Variations in the Parasite Index, during Continued Treatment with Atabrine and Plasmochin. Am. J. Trop. Med. 21: 191–216, March 1941.

[72] Jobbins, D. M.: Algunos problemas en el control de mosquitos en la carretera interamericana de Centro América. Bol. Ofic. san. Panam. 27: 819–826, September 1948.

and that only very restricted malaria centers exist above 3,000 feet. These isolated foci at higher altitudes did, however, increase in number during the construction period, because the infected laborers served as malaria reservoirs after returning home.

International conferences relative to the construction of an Inter-American Highway date from 1923.[53] Appropriations by the U.S. Congress began in 1925. The military value of the project was recognized after the bombing of Pearl Harbor, and on recommendation of Gen. Brehon B. Somervell, Commanding General, Army Service Forces, the War Department took over the responsibility of construction in Central American countries on 3 July 1942. Col. Edwin C. Kelton of the Corps of Engineers was placed in charge, with instructions to make the highway passable for heavy military traffic, in all weather, from the northern border of Mexico to the Canal Zone. This involved 459.7 miles of new construction, in addition to the improvement of 404 miles of existing road; 696 miles of all-weather road were already in use. When the project was discontinued for military purposes on 31 October 1943, approximately 600 additional miles had been made passable, with some 233 miles of road in Panama and Costa Rica still be to constructed. It should be pointed out that at no time was the completion of the project considered an urgent military necessity. It, therefore, received a very low priority both as to materials and shipping facilities.

The mileage to be constructed or improved under Army supervision was constituted as follows:

	Mileage
David, Panama, to La Concepción, Panama	15.0
La Cuesta to Piedras, Panama, to San Isidro del General, Costa Rica	129.8
San Ramón, Costa Rica, to Nicaraguan border	150.3
Nicaraguan-Costa Rican boundary to Dirlamba, Nicaragua	64.5
Sébaco, Nicaragua, to Honduran border	82.3
Honduras-Nicaragua boundary to Goascarán River on Salvador-Honduras border	91.8
Goascarán River to San Miguel, Salvador	36.0
San Cristobal, Salvador, to Guatemala City	100.0
Guatemala City to Mexican border	194.0
Total	863.7

Approximately 27,000 persons were employed by contractors and U.S. engineers. Of these 25,060 were Central American natives.

At the beginning of the project, Colonel Kelton requested that two officers from the Medical Corps be assigned for duty with his group, one to serve at San José, Costa Rica, the other at Managua, Nicaragua. At the time, it was contemplated that approximately 120 men would be stationed in Panama and Costa Rica, 100 in Nicaragua and Honduras. The total allotment of officers was accordingly increased by this number, and two medical officers of the rank of major, experienced in tropical diseases, were ordered to report to Headquar-

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[53] The Inter-American Highway, an Interim Report From the Committee on Roads, House of Representatives, U.S. Congress, 18 Dec. 1946.

ters, Pan American Highway, U.S. Engineer Office, Los Angeles, Calif., for duty in Central America.

A list of medical installations eventually utilized or established in connection with the project is shown in table 27.

TABLE 27.—*Medical installations, Pan American Highway*

Location	Type	Capacity beds	Assigned personnel	
			Officers	Civilian technicians
Panama:				
Boquerón	Dispensary	0	0	1
El Volcán	Infirmary	3	1	1
Costa Rica:				
Corredor	Dispensary	0	0	1
Sabalito	do	0	0	1
Potrero Grande	do	0	0	1
Buenos Aires	do	0	0	1
San Isidro del General	Hospital	25	1	3
Dominical	Dispensary	0	0	1
Macho Gap	do	0	0	1
El Empalme	do	0	0	1
San José	Hospital	25	4	10
San Ramón	Dispensary	0	0	1
Macacona	Hospital	25	1	3
Guacimal	Dispensary	0	0	1
Las Cañas	Infirmary	4	0	1
Bagaces	Dispensary	0	0	1
Liberia	Infirmary	4	1	1
La Cruz	Dispensary	0	0	1
Nicaragua:				
Managua	Infirmary	5	1	3
San Isidro	do	3	1	2
Esteli	Hospital	25	2	6
Ducuali	Infirmary	8	1	2
Honduras:				
San Marcos	do	[illegible]	0	1
El Banquito	do	3	0	1
Choluteca	do	11	1	3
Nacaome	Hospital	25	2	5
El Salvador:				
Santa Rosa	Dispensary	0	0	1

Source: Design and Construction of Pan American Highway, Corps of Engineers Historical Monograph, vol. 1, February 1946, p. [illegible].

Besides the officers assigned to Central American duty for the duration of the project, several others served the area on a temporary basis. Through the efforts of Col. (later Brig. Gen.) Leon A. Fox, MC, it was suggested that a limited number of medical officers, who had completed a course in tropical medicine, should be assigned to the area temporarily, for the dual purpose of serving the organization and gaining personal experience in the handling of tropical diseases.

This was made operative in March 1943; as a result, nine officers, selected by The Surgeon General, reported to the project medical director and were stationed at construction camps and other points where training facilities were suitable. By a system of rotation, each officer trainee was brought into contact with all tropical diseases and sanitary problems related to the project.

Climatological factors affected both engineering and health problems. In Central America, as stated previously, there is usually a wet and a dry season. As a rule, the dry season begins about the first of December and terminates in May. The rainy season of 1942 proved abnormally wet and long, in some localities extending to February 1943. By contrast, the rainy season of 1943 was abnormally dry.

In most years, western Panama and south Costa Rica receive a heavy rainfall. Toward the north and west, this diminishes, with Nicaragua and Honduras receiving the minimum. There is then a gradual increase through El Salvador and eastern Guatemala. In western Guatemala, heavy precipitation is the rule.

In general, the wet season is favorable to mosquito breeding throughout Central America. The heavy rains are not handled adequately by the drainage channels which effect control at other times, and fresh breeding places are thus created. By contrast, the dry season is unfavorable to adult mosquitoes and, though breeding goes on, the average female rarely survives long enough to become infected.

Early attention to malaria prevention was inclined to be haphazard. Dr. Henry E. Meleney,[74] Consultant to the Secretary of War, made an extensive tour of the Central American countries in 1943. In Costa Rica, at a new camp and hospital for Army engineers near Esparta, he found screen doors of messhalls opening inward and mosquitoproofing of buildings incomplete. At a similar camp near Las Cañas, he found windows of sleeping quarters furnished with shutters but not with screens. Gauze was used on doors instead of wire screens, and some doors had no springs; however, mosquito bars were in use.

Based on recommendation of the Pan-American Sanitary Bureau, protective sanitary measures were instituted in construction camps along the highway, particularly, in Nicaragua and Costa Rica. In Costa Rica, from 12 to 40 percent of all time lost by American labor had been traced to malaria. Ditching and the use of oil larvicides were emphasized.

In Nicaragua, DDT was used both as a larvicide for the spraying of buildings in the larger, newer camps along the Rama Road. This road branches from the Pan American Highway near Lake Managua and Lake Nicaragua and proceeds to the Atlantic Coast. Certain camps in Honduras received similar treatment. In all cases, control was adequate.

[74] See footnote 70, p. 192.

In the smaller, temporary camps, where expenditures for drainage could not be justified, larviciding, together with spraying and screening of barracks, gave reasonable control.

A special aspect of the problem was related to the large number of imported laborers who proved to be malaria carriers. Treatment was instituted, not only for those with symptoms, but for all carriers who could be discovered.

The malaria situation as of 30 June 1943 is well set forth in a letter from Colonel Kelton to the Chief of Engineers, U.S. Army.[75] The plan of medical care had been developed in accordance with recommendations of Colonel Fox who, acting for the Office of The Surgeon General, conducted a survey of medical conditions in November 1942.

The administration of the Pan American Highway in Central America operated as two units. The northern area, with headquarters at Managua, Nicaragua, included Guatemala, El Salvador, Honduras, and Nicaragua. The southern, or San José area, which included Costa Rica and Panama, was administered from San José, Costa Rica. The chief medical officer, who maintained headquarters at San José, had assigned to his staff one officer trained in entomology and malaria control, also a sanitary engineer, similarly specialized.

All personnel stationed in malarious areas were required to sleep under bed nets, but screening for barracks and messhalls was not at first available. Until this could be provided, mosquito netting was used in several places to screen messhalls. Citizens of the United States were required to take suppressive Atabrine therapy.

Local health agencies gave full cooperation in the control program.

Approximately 375 cases of malaria occurred between July 1942 and June 1943 among the 2,500 U.S. citizens on duty with the Pan American Highway in Central America. This 15 percent, however, occurred in less than half the total personnel, chiefly among those stationed at ports of entry, or on duty in hyperendemic areas, or engaged in survey work. It should also be noted that the worst malaria epidemic in 20 years occurred during this period in the countries concerned. Nicaragua and Honduras suffered most, chiefly because of a great scarcity of antimalarial drugs.

In the San José area (Costa Rica), employees lost time because of malaria[76] during every month that the project was in operation. In a period of 10 months, a total of 187 cases (by monthly increments) handicapped progress in this area alone.

Three-million-dollar plan for the Canal Zone

As mentioned elsewhere, a complete survey of all posts, camps, airbases, and stations within the territorial limits of the Canal Zone was made in 1943.

[75] Letter, Col. Edwin C. Kelton, Corps of Engineers, Director, Pan American Highway, U.S. Engineer Office, San José, Costa Rica, to The Chief of Engineers, USA, Washington, D.C., 23 Aug. 1943, subject: Medical Activities, Pan American Highway, Period From Initiation of Project to 30 June 1943.

[76] Design and Construction of Pan American Highway. Corps of Engineers Historical Monograph, vol. 1, February 1946.

The resulting maps showed all drainage systems, watercourses, and impounded bodies of water. The recommendations regarding malaria control involved three phases, based on relative urgency.

1. Projects requiring immediate action, to be completed as soon as possible and in any case within 2 years.

2. Projects to be completed in the near future, with an outside limit of 5 years.

3. Long-range projects, requiring completion within 10 years.

It was estimated that the entire plan would require the expenditure of approximately $3 million. When completed, this would accomplish complete sanitation (with reference to malaria control) for each military installation and its environs within flight range of the anopheline vector.

Funds for initial operations were made available in 1944, and the Department engineer was instructed to begin work 1 January 1945 on six projects, to meet immediate needs. These included the posts of Corozal, C.Z., Albrook Field, Fort Kobbe, C.Z., Howard Field, France Field, Fort Davis, C.Z., the Chiva Chiva Signal Corps area, and the outlying area of Albrook Field along the Fort Clayton, Corozal, Albrook Highway.

A sum of $280,000 was expended during the fiscal year 1945 for labor and approximately $120,000 for material. An appropriation of $400,000 was allocated for 1946, and an equal sum was approved for 1947.

Plans for 1947 included work at Fort Gulick, C.Z., Fort Sherman, Fort Clayton, and the Corozal Cemetery.

The surveys, on which these projects were based, are models of detail and include specific recommendations as to use of round tile, inverts, and culverts, in addition to showing each location where filling, regrading, and paving should be carried out.[77]

ANTILLES DEPARTMENT [78]

Climate, Topography, and Population

The Greater Antilles and Leeward Islands are generally similar in temperatures. The entire area lies in the belt of the northeasterly trade winds, which makes for an even temperature, ranging between 75° and 85° F. Precipitation may vary greatly, not only from island to island, but from year to year in the same locality. Heat and humidity are not oppressive except in sheltered areas, most of which are some distance from the coast. The "prickly heat season" in Puerto Rico extends from May to September, in typical years. Cuba has a definite rainy season which occurs in June and July. In Puerto

[77] These surveys and supplementary reports, together with the accompanying maps, appear as Exhibits A, B, and C of volume II, The Prevention of Disease in the U.S. Army During World War II—The Panama Canal Department.

[78] Except as otherwise indicated, all data in this section have been compiled from the Annual Reports, Medical Department Activities, Antilles Department, 1943–45.

Rico, at coastal levels, January through March are generally very dry, and the fall months are almost always wet. This was sharply reflected in the seasonal distribution of malaria and malarial mosquitoes. In other islands of the group, periods of no precipitation alternate with short periods of local showers. In Saint Croix, rains are rare, and only by drilling deep wells is it possible to obtain fresh water on this island.

Cuba is the only island with a fertile central plain. Its soil is derived from Laurentian granite, like that of the Appalachian region. The rest of the islands are more or less mountainous, with rather narrow coastal plains. Puerto Rico shows much heavy bodied clay and has a great deal of limerock and granite as well as scattered schist. Although generally semipermeable, its soil becomes highly impermeable where the sodium or saline content is high.

The relatively porous soils of the remaining islands owe their character largely to having been derived from lava. The role of coral in building these islands has been disputed. Except in the Bahamas, the importance of coral is considered questionable. Salt marshes and fresh water swamps characterize the coastal areas and contribute to mosquito production, with or without malaria.

Though Cuba and Haiti are somewhat less congested, human population is generally dense in the Caribbean. In most islands, the average is close to a thousand people per square mile. The Negroes, who outnumber the white population perhaps 300 to 1, at least in the past, have tended to be somewhat nomadic, shifting from island to island in small boats. This habit, added to socioeconomic and climatic similarities, has brought about a distribution of disease that is quite uniform throughout the area. Malaria ranks with tuberculosis, syphilis, and enteric infection as diseases of greatest importance. In Haiti, there is a high incidence of yaws.

With the exception of Cuba, the islands of the Antilles are the eroded tops of mountains or mountain ranges. Malaria was concentrated chiefly in the peripheral coastal plains with inland indentations along stream terraces. Malaria prevalence was greatest in Haiti and Saint Lucia, with the Dominican Republic a close third. These islands, Saint Lucia and Hispaniola, were similar to the three Guianas in this respect. In Puerto Rico and Trinidad, the incidence was somewhat lower but was still sufficient to make malaria a leading cause of death and in all probability the most common disabling illness.[79] In all eight places mentioned, it was a primary deterrent to economic development. Of the 7¾ million people living in these countries or dependencies, nearly 6 million were concentrated in the more intensely malarious portions.

Permanent malaria control measures must be extensive in scope, since two of the four common vectors (*A. albimanus* and the *A. aquasalis*-*A. tarsimacula*-

[79] Henderson, J. M.: A Discussion of Caribbean Malaria Control. J. Nat. Malaria Soc. 4: 189–200, September 1945.

tus complex) breed in a wide range of habitat, including temporary accumulations and saline waters.

Though rural rates are generally higher than urban rates, the problem is still acute in many principal cities. Lack of planned control by governments, long-effective flight range of certain vectors, abundance of breeding places, and general lack of protection against adult mosquitoes are contributing causes. Costly antilarval measures are economically feasible, however, in urban areas (in terms of per capita cost) whereas, in nonurban districts, they cannot be supported.

Such was the general background against which military malaria control in the Caribbean was carried to a successful conclusion.

Greater Antilles

Cuba.—In 1943, Cuba had practically no public health workers on a full-time basis. This tended to slow down any modern program for health improvement, though great strides had been made in the early years of the century, and these gains had not been lost.

Thus, in 1900, malaria was rampant, the mortality rate being 254 per 100,000 population. A National Department of Health was established in 1909, with a director of cabinet rank, and, by 1913–14, the mortality rate had fallen to 18. There were several epidemics in 1920 and 1934, and mild ones in 1916 and 1926. By 1941, however, the mortality rate was down to 4 per 100,000.[30]

The disease is endemic in all parts of the island but occurs most frequently in three regions: The valley of the Rio Cauto in the province of Oriente, the coastal regions of the province of Pinar del Rio, and the coastal plains of north Camagüey. *Plasmodium malariae* is rare. In some regions *P. vivax* and *P. falciparum* are equally common. In others, *P. vivax* predominates.

Five species of anophelines are native, but *A. albimanus* is the only vector of malaria. It is, however, the most common species. In and about Marianao (near Havana), mosquito breeding had been controlled for some years by the combined efforts of the Health Department and the Rockefeller Foundation. The important U.S. base was located at Batista Field, Cuba.

Jamaica, B.W.I.—Jamaica, the largest British Island in the West Indies, contains 4,404 square miles, of which about 646 are flat, consisting of alluvium, marl, and swamps. These areas are chiefly coastal. Bluffs, plateau country, and central mountains are encountered in succession as one penetrates the country.

Public health and medical services are combined in one department, of three divisions, one of which is devoted to communicable disease. Malaria control is included among five subdivisions in this division (1943).[31]

[30] Medical and Sanitary Data on Cuba. Prepared by Medical Intelligence Branch, Preventive Medicine Division, U.S. Army, 20 July 1943.

[31] Report, Maj. H. J. Banton, MC, U.S. Army, subject: Sanitary Survey of the Island of Jamaica, 20–21 May 1941.

The disease is most prevalent in certain coastal areas but may extend inland up to 2,000 feet. The chief vector is *A. albimanus*, which is found more abundantly during September, October, and November. Most of the cases of malaria occur between June and January. Areas most productive of the vector are the vicinity of Annotto Bay, Oracabessa Bay, Falmouth, Saint Anns Bay, and Montego Bay.

In 1940, the island had 17,441 reported cases of malaria, with 521 deaths, but very few were confirmed with smears. Malaria control followed modern methods but was handicapped by lack of funds. Nine hundred Canadian soldiers brought to North Kingston, in October 1940, used bed nets and repellents but slept in unscreened barracks. Eight cases of malaria occurred in this group within approximately 6 months.[82]

Tests have shown that in Jamaica, if an animal bait trap attracts more than five *A. albimanus* females per night, a critical concentration exists, and malaria transmission may be expected. During a 3-month period, within which this index was reached, 11 percent of the local people within 2 miles of a certain U.S. military installation reported chills and fever, and four military cases of malaria occurred.[83] Aerial spraying of DDT at biweekly intervals corrected the condition. Screening of quarters and proper malaria discipline were continued. It is interesting to note that under similar circumstances the critical *A. albimanus* index at Losey Field in Puerto Rico was found to be two rather than five; a rather special case.

American troops were stationed chiefly at Fort Simonds, Jamaica, B.W.I., and at Vernam Field.

Antimalaria activity here, as elsewhere, was divided into temporary and permanent control. Much of the latter did not get beyond the recommendation stage. The temporary control consisted of oiling small ponds (if not used by cattle for drinking purposes) and other accumulations of water in gullies. Paris green was used chiefly in areas devoted to rice and cane cultivation. The supply of paris green, particularly in 1943, was not always adequate. Beginning in 1944, oil was used only on the post. All extracantonment work was carried out with paris green and lime dust. Chiefly important in the good results achieved was the supervision of extracantonment control work by personnel of MCWA (Malaria Control in War Areas), U.S. Public Health Service. This was essential as three-quarters of the mosquitoes on the post were probably produced outside the base, in canefields and ricefields.

The routine educational program at Fort Simonds and Vernam Field consisted of lectures to all members of the command, together with special instruction to two members of each unit. There were only two cases in military personnel in 1944, one of which was recurrent. But in spite of this success

[82] Medical and Sanitary Data on Jamaica and the Clayman Islands. Prepared by Medical Intelligence Division, Preventive Medicine Service, Office of The Surgeon General, U.S. Army, 12 Aug. 1943.

[83] Thompson, G. A.: Anopheline Threshold of Malaria Transmission Noted in Jamaica. Pub. Health Rep. 65: 689–696, May 1950.

from a military standpoint, the island still remains dangerously malarious.

According to Colonial Reports,[54] there was a sharp outbreak of malaria in the Bull Bay area, 10 miles east of Kingston, early in 1950. During the same year, government hospitals and dispensaries reported a total of 17,826 cases of malaria. The need for cooperation between the U.S. military and island authorities would thus still be very great in the case of any future operations. The Colonial Report for 1946 [55] gives 4,011 hospital admissions with 161 deaths, with outpatient attendances for treatment numbering 14,014.

Haiti (Hispaniola).—Although the United States did not maintain bases on this island, a few remarks on the malaria situation are in order. According to Caldwell's report on malaria control in the Dominican Republic,[56] malaria is present everywhere, increasing especially in the spring and fall, when rainfall is greatest. *Anopheles albimanus*, a versatile breeder, is the principal vector. The malaria work of the government is assisted by the Institute of Inter-American Affairs. Surveys carried out between 1941 and 1944 showed that 0.8 to 38.0 percent of the population have parasites in their blood. Spleen rates, by communities, ranged from 0 to 42.8 percent. In 1,374 positive blood smears, the various types of *Plasmodium* occurred as follows: *P. falciparum*, 72.8 percent; *P. vivax*, 17.2 percent; *P. malariae*, 4.7 percent; and mixed, 5.3 percent.

In the Republic of Haiti, recent surveys showed that 86.6 percent of all malarial infections are caused by *P. vivax*. Mixed infections accounted for 2.6 percent. These included a few triple infections. Three species of anophelines are found, *A. albimanus*, *A. grabhami*, and *A. vestitipennis*.[57] The first is present everywhere.

The population is almost entirely Negro and numbers approximately 2 million. No reliable vital statistics are available, but so far as malaria is concerned, clinical manifestations are usually conspicuous only in infants. The higher mountain valleys and the southwest slopes, with scanty rainfall, appear to be malaria free.

Puerto Rico.—Puerto Rico is an island of approximately 3,534 square miles, with an equable climate and a population of 2.2 million persons. *Anopheles albimanus* is found everywhere except on the central mountainous ridge. The possibility of eradicating this species has been much discussed. A marked reduction in breeding activity between January and April could perhaps be made the basis for procedure. A campaign, consisting of larviciding and residual spraying for adults, might be started at any point and continued around the island, with the mountains on one flank and the sea on

[54] Colonial Annual Reports, Jamaica. London: His Majesty's Stationery Office, 1950, pp. 62–63.

[55] Medical and Sanitary Reports from British Colonies, Protectorates and Dependencies for the years 1939–1941. Jamaica, 1940. Trop. Dis. Bull. 43 (Suppl.): 225–227, 1946.

[56] Caldwell, J. D.: Malaria Control in the Dominican Republic. Puerto Rico J. Pub. Health & Trop. Med. 21: 198–200, December 1945.

[57] Paul, J. H., and Bellerive, A.: A Malaria Reconnaissance of the Republic of Haiti. J. Nat. Malaria Soc. 6: 41–67, March 1947.

the other. A test program on the smaller island of Vieques has been suggested.[88]

Puerto Rico, being an American possession, was very naturally the center of military organization and administration for the Antilles Department. The Army had installations at Borinquen Field, Camp Tortuguero, Fort Buchanan, where the Antilles General Depot was located, Fort Brooke, Camp O'Reilly, Losey Field, Henry Barracks, and Fort Bundy,[89] together with a large number of lesser installations largely for coastal defense or for antiaircraft protection, of which Camp Ensenada Honda may be mentioned as an example.

The problems of malaria control at these several bases will be treated at some length in the sections which follow.

The Lesser Antilles (Leeward and Windward Islands)

The Lesser Antilles included the British Windward Islands, the British Leeward Islands, the French West Indies, and the Netherlands West Indies.

Besides Trinidad and Tobago, the British Windward group includes Barbados, Grenada, Saint Vincent, Saint Lucia, and Dominica. Principal administrative units of the British Leeward group are the British Virgin Islands, Antigua (with Barbuda and Redonda), Montserrat, and Saint Kitts-Nevis (with Anguilla).

The French West Indian islands consist of two colonies, Martinique and Guadeloupe, with a number of small islands governed as dependencies from the latter.

The Netherlands West Indies lie in two groups; Curaçao, Aruba, and Bonaire lie off the north coast of Venezuela. The second group is situated to the north of Saint Kitts, in the British Leeward chain, and include Saint Eustatius, Saba, and Saint Martin.

In a 1943 survey, Barbados was reported free from malaria. Otherwise, the disease was considered to be generally present throughout the Lesser Antilles, with *A. albimanus* and *A. aquasalis* serving as the principal vectors.[90] Malaria is a year-round disease in this part of the world, though most prevalent during and after the rainy season. Blackwater fever has been reported in Martinique and Guadeloupe.

The Virgin Islands of the United States.—The principal islands are Saint Croix, Saint Thomas, and Saint John. On the island of Saint Croix, the population is largely rural, except for the two small municipalities, Christiansted and Frederiksted. On the island of Saint Thomas, the population

[88] Henderson, J. M.: The Eradication of *Anopheles albimanus* in Puerto Rico—an Ecologic Discussion. Mosquito News 8: 45–49; 97–101, June and September 1948.

[89] History of Medical Department Activities, Antilles Department, Preventive Medicine. [Official record.]

[90] Medical and Sanitary Data on the Lesser Antilles. Prepared by Medical Intelligence Branch, Preventive Medicine Division, Surgeon General's Office, U.S. Army, 15 Feb. 1943.

centers briefly in the town of Charlotte Amalie. Saint John is sparsely populated.[21]

Malaria occurs usually in the benign, tertian form. The vector is *A. Albimanus* which is widely distributed. Although the U.S. Virgin Islands had suffered epidemic malaria in the 1930's, they were free from indigenous malaria during the war years. The few cases among military personnel were shown to be imported. Only small numbers of *A. albimanus* were found on Saint Thomas and Saint Croix during surveys conducted in 1944.

The Army installation on Saint Croix was Benedict Field. Camp Harwood, on the island of Saint Thomas, was a gun position at an elevation of about 1,000 feet. It would have been safe even if a malaria problem had existed elsewhere on the island.

Antigua.—Because of the early fall of France, U.S. bases and outposts were located chiefly in British (and Netherlands) territory. It is not possible to include detailed information concerning each of the islands where troops were stationed. Antigua, one of the Leeward Islands, and Saint Lucia, one of the Windward group, may be cited as examples:

The British Island of Antigua has an area of 108 square miles and a population of approximately 35,000. The climate is drier than in most of the West Indies, with an average rainfall of only 43 inches. August through October is the hot, rainy season. Fresh ground water is soon mixed with the sea water which infiltrates the substructure. For this reason, the island suffers from an inadequate water supply.

Both *A. albimanus* and *A. tarsimaculatus* (*A. aquasalis*) are present. Malaria follows the rainfall. In 1936, when precipitation was 74 inches, there were 3,459 cases of malaria, with 40 deaths. In 1939, when only 33.06 inches of rain fell, the number of cases was 1,173, the number of deaths, 8.[22]

The area on Parham Harbour, utilized as a U.S. Army base (Coolidge Field and Antigua Base Command), was at first believed to be in a dangerous location. Winthorpes Village, a Negro village of some 300 inhabitants, jutted into the center of the area on Parham Harbour, from the West. In his 1941 survey, Colonel Fox recommended either that Winthorpes Village be relocated or that U.S. forces be given complete jurisdiction over its sanitation. Careful investigation by John M. Henderson, Sanitary Engineer, (R), of the MCWA, failed, however, to confirm Colonel Fox's suspicions. The daily tidal character of the great mangrove swamp nearby apparently rendered its water unsuitable for any significant breeding of *A. albimanus*.

Military communications show very light infection among troops for 1943, during which year the total number of cases was 16. Six of these were primary and ten recurrent, with the probability that the majority of the in-

[21] Medical and Sanitary Data on the Virgin Islands of the United States. Compiled by the Medical Intelligence Branch, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 26 Oct. 1942.

[22] Report, Lt. Col. Leon A. Fox, MC, U.S. Army, subject: Sanitary Survey of Antigua, British West Indies, 17-21 Feb. 1941.

fections were contracted off the base, which was rather constantly exposed to westerly winds. Main infective areas on the island of Antigua were Freetown, Bethesda, Liberta, Old Road, Urlins, and Johnsons Point. The city of Saint Johns was practically malaria free, in spite of a fairly high percentage of vector anophelines. The British Colonial Government health officer was active in 1944, with engineering projects aimed as mosquito reduction. Military reports for that year listed 10 malaria cases of which 6 were primary and 4 recurrent. All these cases occurred during the first 10 weeks of the year, the majority in newly arrived troops from Puerto Rico.

Antigua was known to be moderately malarious before it was used as a U.S. base. British reports list 1,450 cases in 1940 and 474 in 1941. In 1941, there were nine deaths.[93]

Saint Lucia.—The British Island of Saint Lucia, 230 miles north of Trinidad, has an area of 233 square miles. It lies approximately midway between Saint Vincent to the south (also British) and the French island of Martinique, which is almost due north.

Although rough and mountainous, the island is very fertile, and all forms of tropical agriculture thrive. Sugar and other products are exported. The narrow river valleys are subject to great landslides, with occasional economic disaster. Precipitation exceeds 100 inches per annum in the mountainous interior, sometimes decreasing to near 40 at the coast.

Floods are rare but drought is unknown. The first 4 months of the year tend to be the driest.

The temperature ranges between 70° and 90° F., and the northeast trade winds are an almost constant influence. At Castries, which has an elevation of approximately 845 feet, the wind direction is so constant that a one-directional airstrip is sufficient.

Racially, the population is largely Negro or mixed Negro and white. Small numbers of East Indians are found, and still fewer of European descent. Before the onset of the war, malaria had always constituted the main health problem on Saint Lucia and in most years stood higher than all other reported causes of death.[94] It doubtless caused more noneffectiveness than all other diseases combined.

The U.S. Army base at Vieux Fort, likewise the Navy base at Gros Islet, were potentially unhealthy spots. Sixty-five percent of the nearby native population showed malaria parasites, a higher percentage than in any other parts of the island.

In 1940, according to British reorts,[95] the recorded incidence of malaria showed an upward trend. This was due, it is believed, not to greater prev-

[93] Medical and Sanitary Reports from British Colonies, Protectorates and Dependencies for the years 1940–1941. Antigua, 1941. Trop. Dis. Bull. 43 (Suppl.): 224–225, 1946.

[94] Report, Lt. Col. Leon A. Fox, MC, U.S. Army, subject: Sanitary Survey of St. Lucia, British West Indies, 1941.

[95] Medical and Sanitary Reports from British Colonies, Protectorates and Dependencies for the years 1940–41. St. Lucia, 1940. Trop. Dis. Bull. 43 (Suppl.): 252–253, 1946.

alence of the disease, but to increased attendance at dispensaries, some of which had just been established. For the year 1940, 11,323 patients were treated at dispensaries and 146 were hospitalized; of these, 6 died. Deaths attributed to malaria throughout Saint Lucia numbered 161.

Because of this background, it is rather remarkable that the Army construction camp, established in 1941, enjoyed almost complete freedom from malaria. The neighboring town of Vieux Fort had a high malarial rate. The construction camp, however, was to windward of the town; also, early steps were taken to fill Vieux Fort Swamp. This procedure tended to benefit not only Vieux Fort but also the cantonment site, which lay to the northwest. At top development, the construction force numbered about 500 continentals and their dependents, and some 3,000 local laborers. During the first 6 months of operation, there were only four cases of malaria. Saint Urbain Swamp and Coconut Grove continued to breed mosquitoes, but these were not very near the infected areas.[96] It was reported[97] that the malaria rate at Vieux Fort dropped 70 percent over that of previous years as a result of the work of the construction force at Beane Field.

A real scare was experienced in 1942 when the laboratory reports showed an incidence in military units of 700 per 1,000. This proved to be due to errors on the part of the technician who had interpreted artifacts and blood platelets as malaria parasites.

The British Government is continuing malaria control work in the Castries District and elsewhere.[98]

Guadeloupe.—The French island of Guadeloupe supports three species of anophelines: *A. albimanus*, *A. aquasalis*, and *A. argyritarsis*.[99] Only *A. aquasalis* is considered an important vector. It enters houses in great numbers, especially in the evening. The larvae occur in grassy pools, overgrown irrigation channels, rock pools, and flood savannas, all more or less brackish. *Anopheles emilianus* Komp is considered a synonym.

Trinidad

This most southerly island of the West Indies lies about 10 degrees north of the equator. It contains over 2,000 square miles. The population is close to 450,000, predominantly Negro. There are at least 150,000 East Indians, and a considerable number of Chinese. The island is very fertile, and the natural resources are great.

The northern fourth of Trinidad is mountainous. Many streams flow southward, through low, sometimes rolling country. Coastal and inland swamps are numerous. Trade winds serve to mitigate the heat somewhat,

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[96] History of the Caribbean Health Service from Inception to 1 Apr. 1942, St. Lucia.

[97] Letter, Lt. Col. T. W. E. Christmas, MC, Medical Director, Trinidad District, to the Assistant Chief Health Officer, Caribbean Division, N.Y., 18 May 1942, subject: Malaria Rate at St. Lucia.

[98] Colonial Annual Reports, St. Lucia. London: His Majesty's Stationery Office, 1948.

[99] Floch, H., and Abonnenc, E.: Les moustiques de la Guadeloupe. Genre *Anopheles*. Publ. Inst. Pasteur Guyane No. 106, 1945.

especially between November and May. Precipitation varies greatly, but, in general, the hotter and wetter season extends from May to October, the cooler and drier season from November through April. The annual rainfall at Port of Spain averages 63.66 inches.

Malaria is the most serious health problem in Trinidad. Up to 1941,[100] there had been no complete malaria survey of the island, but it was known that all types of the disease were present, estivo-autumnal being the most common. Blackwater fever also occurred in sharply defined areas.

Because of incomplete knowledge, it was recommended that a certain amount of basic research be accomplished before large-scale, expensive control projects should be launched. The Rockefeller Foundation assisted in these investigations.

Together with Tobago Island, Trinidad boasts 13 species of *Anopheles*, of which *A. aquasalis* is the most important vector, with *A. bellator* the chief transmitter in zones of heavy rainfall.[101] As described elsewhere, *A. bellator* breeds in wild bromeliads which grow attached to branches of the immortelle trees, high off the ground. It should be pointed out that before its vectorship was conclusively demonstrated by Rozeboom and Laird,[102] Dr. Eric de Verteuil[103] of Trinidad, in 1934, presented convincing epidemiological evidence that *A. bellator* was almost certainly a transmitter of malaria.

Anopheles aquasalis, which favors brackish water swamps is the long-recognized vector along the coast. Both *Anopheles neomaculipalpus* and *A. albitarsis* are suspected of being minor vectors. Surveys have shown that *A. aquasalis* may migrate as much as 5 miles inland, over rough country.

The main area used by U.S. Army Forces lay 20 miles east of Port of Spain. It included approximately 22 square miles and sloped southward from the foothills. The Army also acquired rights to wharfage in Port of Spain harbor, a recreation area on Saline Bay, and some 2½ square miles of savanna in the west central part of the island. The Navy area was in the extreme northwest. The principal U.S. Army base was Fort Read, Trinidad, B.W.I., including Waller Field. (At times there was autonomous control of the Waller Field area by the Air Corps.) The Antilles General Depot and the Trinidad Subdepot were also located at Fort Read.

Bromeliad malaria still continues to be serious in Trinidad.[104] On the cacao plantations, immortelle trees are planted at rather wide intervals to give desirable shade. In the dry season, these trees lose their leaves. The situation results in more light and less humidity than prevails in the natural forest, so

[100] Report, Lt. Col. Leon A. Fox, MC, U.S. Army, subject: Sanitary Survey of Trinidad, British West Indies, 1941.

[101] Stage, H. H., and Gillette, H. P. S.: Observations on Mosquitoes and Malaria Control in the Caribbean Area. Part III—Trinidad. Mosquito News 7: 157–159, December 1947.

[102] Rozeboom, L. E., and Laird, R. L.: *Anopheles (Kerteszia) bellator* Dyar and Knab as a Vector of Malaria in Trinidad, British West Indies. Am. J. Trop. Med. 22: 83, 1942.

[103] De Verteuil, E.: Administration Report of the Surgeon-General for the Year 1934. Government Printing Office, Port of Spain, Trinidad, British West Indies.

[104] Downs, W. G., and Pittendrigh, C. S.: Bromeliad Malaria in Trinidad, B.W.I. Am. J. Trop Med. 26: 47–66, January 1946.

that *A. bellator* breeds at lower levels and thus has easy and frequent contact with plantation workers. Although *Anopheles* breeds in 22 species of the 30 bromeliads found on immortelle trees, only one species, *Gravisia aquilega* (which is second in abundance), is of outstanding importance. Surveys showed that this species contained five times as many larvae per tree as any other of 10 species studied. Whereas this might seem to facilitate control, unless workmen are well skilled in discriminating among the species of bromeliads, much labor can be wasted on the spraying or removal of relatively harmless forms. *Wittmackia lingulata* and *Hohenbergia stellata* are usually included in eradication programs because of the close resemblance of the three species.

Because immortelle trees are dangerous to climb, especially after a rain, the use of phytotoxic sprays has become standard procedure, copper sulfate being the most satisfactory to date. Furthermore, hand removal is more expensive, even with cheap labor. Also, spraying accomplishes far more rapid results. It does not harm the immortelle trees, or the cacaos. One thorough treatment of an area is believed to be sufficient for 5 years. From a long-range standpoint, the replacement of the immortelle trees with windbreak plantings of other species would be a most desirable procedure for discouraging the breeding of *A. bellator*. At present, this anopheline is scarce in all parts of Trinidad, which has a low rainfall. The highest spleen rates are found in the north-central part of the island, where the annual rainfall is between 91 and 110 inches, and *A. bellator* the principal, if not the only vector species. Both *A. aquasalis* and *A. neomaculipalpus* occur within the region and should be viewed with suspicion.

South American Mainland

The jurisdiction of the Caribbean Defense Command included Venezuela and the Guianas. The various bases in Brazil pertained to the South Atlantic Command.

Venezuela.—Venezuela has been thoroughly studied and reported on. The area of the country is 912,050 square kilometers, on which live a little less than 4 million people. The population is described as 20 percent white, 8 percent Negro, 7 percent Indian, and 65 percent of mixed blood.

The coastal plain, backed by a range of mountains, is called the Costa-Cordillera. Here, 77 percent of the population live on 18 percent of the total land area. South, from the Costa-Cordillera, extends the Llanos. This region, bounded on the south by the Río Orinoco, contains 36 percent of the land area and supports 20 percent of the population. South of the Río Orinoco lies the Guayana, with 46 percent of the land area, but with only 3 percent of the population.

The rainfall of Venezuela ranges rather uniformly from an average of 39 inches in the north to an average of 79 inches in the south. The wet season occurs near the middle of the year.

The most malarious region is the Llanos, which contains many rivers subject to flooding, and numerous pools, ponds, and lagoons. Although the Guayana also has many rivers, many of them contain water of such high acidity (low pH) that *A. darlingi* is prevented from breeding in them.

All three species of *Plasmodium* occur. In persons under 5 years of age, *P. vivax* is found more often than *P. falciparum*. Above this age group, the relation is reversed. Infections with *P. malariae* are relatively few. The annual malaria death rates exhibit a 5-year cycle. Since 1920, these have been more favorable, due to the general improvement in standards of living in the Llanos area. Since 1945, there has been general house spraying with DDT in all areas accessible by car.[105]

Of the 29 species of *Anopheles* found in Venezuela, only *A. albimanus* and *A. darlingi* are considered important vectors, with *A. pseudopunctipennis* of secondary importance in the mountains. *Anopheles darlingi* transmits malaria in all three zones, but *A. albimanus* is a vector only in the Costa-Cordillera. It is less anthropophilic than *A. darlingi*.

Entomologists believe that *A. albimanus* was introduced by shipping, from Central America.[106] Another possible vector is *A. triannulatus* which has been found naturally infected with oocysts.[107]

Altitude strongly limits distribution.[108] Thus *A. aquasalis*, by its preference for brackish waters, is limited to coastal levels. By contrast, *A. albimanus* ranges up to 1,725 feet, *A. darlingi* to 2,975 feet, and *A. pseudopunctipennis* to 3,280. There is considerable adaptability in regard to rainfall. One locality with an annual mean precipitation of 17 inches supports *A. albimanus*, *A. pseudopunctipennis*, and *A. punctimacula*. Yet both *A. albimanus* and *A. punctimacula* have been found associated with *A. darlingi* in an area with an average annual rainfall of 106 inches.

In Venezuela, the growing of rice creates a special problem in malaria control. Both *A. albimanus* and *A. pseudopunctipennis* breed freely in the flooded fields.[109] The former is the chief and proved vector. La Vectoria suffered a severe outbreak in 1943, and Cagua a similar outbreak in 1944. In the first, no breeding of *A. albimanus* could be discovered outside of the ricefields; in the second, only 1 percent of the collected larvae were taken from other situations. Shortage of better larvicides reduced control measures to sawdust and kerosene, which did not prove satisfactory. Legislation was eventually passed which forbade cultivation of rice by artificial irrigation near towns, except under permit

[105] Gabaldon, A.: The Nation-Wide Campaign Against Malaria in Venezuela. Tr. Roy. Soc. Trop. Med. & Hyg. 43: 113–160, September 1949.

[106] Gabaldon, A., and Cova-García, P.: Zoogeografía de los anofelinos en Venezuela: I. Los dos vectores principales. Tijeret. sobre Malar. 10: 19–32, 1946.

[107] Gabaldon, A., and Cova-García, P.: Zoogeografía de los anofelinos en Venezuela: II. Los vectores secundarios y los no vectores. Tijeret. sobre Malar. 10: 78–127, 1946.

[108] Gabaldon, A., and Cova-García, P.: Zoogeografía de los anofelinos en Venezuela: III. Relaciones con el Terreno y Clima. Tijeret. sobre Malar. 10: 164–179, 1946.

[109] Berti, A. L., and Montesinos, M.: Cultivos de arroz en relación con la malaria: el problema en Venezuela. Cuad. verde Com. ejecut. 3a Conf. Interamer. Agricultura No. 52, pp. 1–32, Caracas, 1946.

from the Division of Malariology. Such permits required proper leveling of the land and specified that each 4 days of flooding be followed by 4 days of draining and that larvicides must also be used. Permits were not issued for land that could not be dried out in 4 days.

British Guiana (Demerara).—This colony extends about 500 miles from north to south with an average width of perhaps 200 miles. The population is comparatively small and is found in the rather narrow coastal plain, which is very fertile. That portion which is below high tide is protected by seawalls. Sugarcane and rice culture prevail. The intermediate zone, which extends southward, produces diamonds, gold, and bauxite. Great masses of highland lie in the western and southern parts. There are many waterfalls.

A very high relative humidity renders the jungle areas oppressive, but a sea breeze makes the vicinity of Georgetown more tolerable.

The coastal population is a mixture of Negroes, Chinese, Portuguese, and East Indians.

Malaria in British Guiana has always been severe.[110] Deaths from malaria in 1946 stood at approximately 2 per 1,000 per annum. The disease ranked second as a reported cause of death in 1939, following pneumonia; but, if undefined fevers are taken into account, it probably deserved first place. In 1941, it was so reported. All forms of the *Plasmodium* are present. Blackwater fever occurred more frequently than in any other Atlantic base used by the Armed Forces.

Anopheles darlingi, *A. albitarsis*, and *A. aquasalis* are all involved, with *A. darlingi* the leading vector.

The control problem is complicated because there are two dry seasons and two wet seasons, with not much time between for a definite malaria program. British reports for 1941 speak of malaria being "greatly decreased" because of abnormal and prolonged drought. Nevertheless, government agencies hospitalized 1,356 cases (77 deaths), and 4,359 outpatient cases were handled. In the Colony as a whole, 288 deaths were registered as due to malaria in 1941.[111]

The site selected for the U.S. military base was a sandy elevation, 22 miles south of the city of Georgetown on the east bank of the Demerara River between the mouths of two tributaries, the Madewini River and the Hauraruni River. It was necessary to remove a rambling, native village (Hyde Park), which lay on low ground along the Demerara, and resettle the inhabitants outside the area. It became the policy to keep native habitations away from the windward side of camp.[112]

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[110] Stage, H. H., and Gigliolí, G.: Observations on Mosquito and Malaria Control in the Caribbean Area. Part II. British Guiana. Mosquito News 7: 73–76, 1947.

[111] Medical and Sanitary Reports from British Colonies, Protectorates and Dependencies for the Years 1939–1941. British Guiana, 1941. Trop. Dis. Bull. 43 (Suppl.): 215–217, 1946.

[112] Medical and Sanitary Data on British Guiana. Compiled by the Medical Intelligence Branch, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 19 Sept. 1942.

The expected vector, *A. darlingi*, was not recorded about the site of the U.S. base in 1941, but *A. aquasalis* was. This species bred in the tidal swamps along the Demerara River. Such swamps were present all along the waterfront, and breeding also took place in borrow pits, along the road. However, a drainage and filling program was launched to eliminate breeding places, and only about 20 cases of malaria occurred among construction forces during the first 9 months of operation. There was one death, in July 1941.

At the labor camp at Hyde Park, an attempt was made to segregate chronic malaria carriers from nonimmunes. At first, these were housed three-quarters of a mile from the construction camp. Later, they were moved to the boundaries of the base.

Throughout the next 3 years, malaria control work was continued, with emphasis on maintenance of established ditches and oiling of various swamps. In December 1944, at the request of the surgeon of the Caribbean Defense Command, the 392d Medical Composite Unit of Trinidad made mosquito and parasite surveys with reference to the detection of both malaria and filariasis.

The incidence of malaria at Atkinson Field never reached higher than 30 per 1,000 per annum for any month of 1944, and during the last quarter, no case of primary malaria was reported. The majority of all 1944 cases were contracted off the base.

Surinam (Dutch Guiana).—The low coastal belt is patterned with tortuous rivers, influenced by tides. South of this is a triangular area of savanna country, with the broad base lying west. Still further south are highlands, with mountain peaks rising to above 3,000 feet.

Four seasons are recognized: The long rainy season from April through July; the long dry season from August through November; the short rainy season covering December and January; and the short dry season during February and March.

U.S. military interest was much concerned with the production and transportation of aluminum. The mines at Moengo and Paranam, the airport at Zanderij, and the port city, Paramaribo, which is also the capital, represented areas in which health problems might be important.

Colonel Fox considered health conditions better in Surinam than in French or British Guiana, due, in his opinion, to more effective administration.[113] Population pattern is scarcely an explanation, as Surinam has all the racial elements of the other colonies in addition to many Javanese, who constitute over 20 percent of the whole. The climate is no more salutary.

Malaria is endemic throughout Surinam, though not uniformly. In general, the malaria curve follows the rainfall curve.

Morbidity charts show a decided peak after the beginning of the long rainy season (May 15 to August 15) and a lesser peak about the end of the

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[113] Report, Lt. Col. Leon A. Fox, MC, U.S. Army, subject: Sanitary Survey of Dutch Guiana (Surinam), 6–14 Sept. 1941.

short wet season November 15 to February 15. Cyclic outbreaks of epidemic proportions also occur.

Wolff[114] considers that the movements of populations seeking employment during the years of economic crisis (1932 and 1933) served to distribute malaria more widely in Surinam.

In some areas, infection is perhaps universal, with a partial immunity tolerance. Disease, under such conditions, may be thought of as a "lapse from immunity." General Fox, in palpating the abdomens of 47 children estimated to be in the age group "6 months to 3 years" found only one enlarged spleen, but this is certainly not typical, since Wolff reports spleen rates among tribal populations as ranging from 20 to 100 percent. The carrier rate among bush Negroes is believed to be 100 percent.

Wolff discriminates between the coastal region, in which malaria is moderately endemic, and the interior, where the endemicity is high. In the interior, the estivo-autumnal type predominates.

The anopheline fauna of Surinam is rich in species. According to van der Kuyp,[115] collections made in 1946 included *A. darlingi* Root, *Anopheles darlingi* var. *paulistensis* Galvão, Lane and Correa, *A. aquasalis* Curry, *Anopheles oswaldoi* Peryassú *Anopheles triannulatus davisi* Paterson and Shannon, and *A. nuñez-tovari* present in Surinam. (The variety *A. darlingi paulistensis* is not considered distinct by all entomologists.) *Anopheles aquasalis*, *A. bellator*, *A. darlingi*, and *A. albitarsis* are among the potential vectors, with *A. darlingi* most dangerous in the interior, and *A. aquasalis* the principal offender on the coast.

Before the war, mosquito control measures were limited, though the companies operating the bauxite mines made serious effort in the immediate vicinity of their activities.[116]

French Guiana.—As in Surinam, malaria is widespread.[117] It is especially common in the penal colonies and mining camps. East Indians are frequent sufferers, but the bush Negroes enjoy relative immunity and are rather refractory to clinical attacks. In 1935, blood smears examined at the Institute of Public Health in Cayenne showed 72 percent *P. falciparum*, 20 percent *P. vivax*, 6 percent *P. malariae*, and 2 percent mixed infections.

According to Floch,[118] *P. falciparum* malaria is now everywhere more prevalent than *P. vivax*. This is in marked contrast to the findings of Marcel

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[114] Wolff, A. E.: Malaria in Surinam. Bol. Ofic. san. panam. 23: [illegible], April 1946.

[115] Van der Kuyp, E.: Preliminary Report on the Subgenus *Nyssorhynchus* (Diptera, Culicidae) of Surinam (Dutch Guiana). Docum. neerl. et indones. de morbis trop. 1: 67–69, 1949.

[116] Medical and Sanitary Data on Surinam. Prepared by the Medical Intelligence Branch, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 27 May 1943.

[117] Medical and Sanitary Data on French Guiana. Compiled by the Medical Intelligence Branch, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 29 May 1942.

[118] Floch, H.: L'endémo-épidémie palustre en Guyane française. Institut Pasteur de la Guyane et du Territoire de l'Inini. Publ. No. 163, October 1947. Abstr: Trop. Dis. Bull. 45: 749–750, September 1948.

Léger [119] in 1917, when 68 percent of all infections were reported to be due to *P. vivax* and only 28 percent to *P. falciparum*. Present figures, representing blood examinations over an 8-year period, give *P. falciparum* 81 percent, *P. vivax* 17 percent, and *P. malariae* 1.5 percent. Either Léger's data were not representative or the various population movements of subsequent years have substantially altered the endemic reservoir. Epidemic manifestations, it should be pointed out, occur in the dry season.

Of the principal vectors, according to Floch, *A. darlingi* constitutes 91 percent of the mosquitoes taken in houses, while *A. aquasalis* makes up 46 percent of those captured outside. *Anopheles darlingi* is a fresh water breeder, while *A. aquasalis* is found in brackish situations.

In 1943, the city of Cayenne was reported to be fairly free of anophelines, partly because of drainage projects but also because of favorable winds.

Development of Control in the Antilles Department

General information

For the Antilles Department as a whole, malaria was at first one of the greatest causes of noneffectiveness. By 1945, it ranked among less important categories.[120] This was due, of course, to continuous and close attention to all aspects of the control program. At any time, all gains could easily have been erased if preventive measures had been relaxed. Throughout the war, in the same overall area, morbidity and mortality rates in civilian populations continued high.

Civilian reports for the year 1941 show that malaria was a problem in various Caribbean locations. In Dominica, 4,579 cases were reported, with 58 deaths.[121] In Saint Vincent, malaria accounted for 550 cases, with 2 deaths.[122] In Turks and Caicos Islands, there was an epidemic.[123] In Montserrat, malaria was on the increase, and a serious outbreak occurred in the windward area near the Farm River. Thirty deaths from malaria occurred in the Island that year.[124] Malaria was mild in the Virgin Islands (Great Britain) with only 9 inpatients and 413 outpatients reported.[125] The previous year Grenada had suffered an epidemic, with 10,383 cases and 97 deaths, in eight districts.[126]

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[119] Léger, M.: Le paludisme a la Guyane Française: Index endémique de diverses localités. Bull. Soc. path. exot. 10: 740, 1917.

[120] See footnote 89, p. 208.

[121] Medical and Sanitary Reports from British Colonies, Protectorates and Dependencies for the years 1939–1941. Dominica, 1941. Trop. Dis. Bull. 43 (Suppl.): 228–230, 1946.

[122] Medical and Sanitary Reports from British Colonies, Protectorates and Dependencies for the years 1939–1941. St. Vincent, 1941. Trop. Dis. Bull. 43 (Suppl.): 257–258, 1946.

[123] Medical and Sanitary Reports from British Colonies, Protectorates and Dependencies for the years 1939–1941. Turks and Caicos Islands, 1941. Trop. Dis. Bull. 43 (Suppl.): 220–221, 1946.

[124] Medical and Sanitary Reports from British Colonies, Protectorates and Dependencies for the years 1939–1941. Montserrat, 1941. Trop. Dis. Bull. 43 (Suppl.): 242–243, 1946.

[125] Medical and Sanitary Reports from British Colonies, Protectorates and Dependencies for the years 1939–1941. Virgin Islands, 1941. Trop. Dis. Bull. 43 (Suppl.): 246–247, 1946.

[126] Medical and Sanitary Reports from British Colonies, Protectorates and Dependencies for the years 1939–1941. Grenada, 1940. Trop. Dis. Bull. 43 (Suppl.): 249–251, 1946.

In Trinidad and Tobago, malaria continued to occupy first place among diseases responsible for civilian ill health and disability.[127] The number of cases actually reported in 1941 was 15,385, but as the disease was not notifiable, this was only an indication of the much greater number of people who presumably were ill. Deaths for that year numbered 484 as compared with 431 in the previous year.

Reports for 1942 were encouraging or ominous, according to locality. For the Puerto Rican Sector, general health was considered good except for high venereal and malarial rates. The latter incided at the rate of 73 per 1,000 Army personnel per annum in April 1942. This represented a marked increase over that of the same month of the previous year. This was believed due to unseasonal rains, to increase in the number of native troops, many of whom were already infected, and to increased dispersion of troops. Although mosquito netting was available in satisfactory amounts, wire screening was scarce. Troops not on posts were given quinine as a prophylactic measure. This is of interest, since quinine soon became too scarce for even therapeutic use, except in special cases.

Only two military cases of malaria were reported in May 1942 from Antigua, though civilian malarial rates were high. No drug prophylaxis was used there.

Malaria was reported as unknown in Aruba with but few cases in Curaçao, all contracted before arrival.

High malarial rates, as expected, were reported from Trinidad, where sleeping under nets was made mandatory. Troops on jungle duty, away from posts, were given malaria prophylaxis. Antimalaria sanitation in Trinidad was the responsibility of the district engineer.

Before September 1943 and to some extent thereafter, mosquito control was handicapped by lack of a regular supply of insect sprays and larvicidal oil. All installations were screened, and the screening inspected and repaired weekly. Temporary repairs with netting, cloth, rags, or lumber were frequently necessary until replacement screening became available. Bed nets were issued, and periodic inspection employed to insure proper use and repair. Most of the cases of malaria occurred among personnel serving as night guards. Although head nets and gloves were issued, enforcement of their use proved difficult or impossible. At this time, repellents were not available.

Up to the year 1943, conditions in Puerto Rico gave the Antilles Department considerable concern. The background was not encouraging. The disease was known to kill approximately 2,000 inhabitants on the average per year. The Insular Health Department records for 1940 showed 23,758 cases in 1940 with 1,817 deaths. For 1941, the figures were 23,484 cases and 2,282 deaths. This represented rates of 1,228.7 and 124.6 per 100,000. For 1942, the rates were 1,009.8 and 99.4, respectively.

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[127] Medical and Sanitary Reports from British Colonies, Protectorates and Dependencies for the years 1939–1941. Trinidad and Tobago, 1941. Trop. Dis. Bull. 43 (Suppl.): 263–266, 1946.

Malaria ranked as one of the chief causes of disability among Armed Forces in the island in 1942, but as a minor cause in 1943, a tribute to the fidelity with which the military authorities had applied whatever control measures were available.

The Insular Health Department, of course, did its share, but with limited funds. In their program, emphasis was placed largely on treatment of patients to reduce mortality and to eliminate foci of infection.

An important phase of the Army's control program was the continual survey of anopheline densities. Gratifying reductions were noted as a result of both temporary and permanent control measures at (and near) Camp O'Reilly, Fort Buchanan, P.R., Camp Tortuguero, and Losey Field. Studies of anopheline breeding areas and field surveys to obtain epidemiological data were carried out during 1943 at three other installations on Puerto Rico, also at Benedict Field, Saint Croix, and Fort Simonds.

A new type of malaria report card was introduced in January 1943, greatly facilitating the assembling and analysis of data. Classification of primary and recurrent cases was made relatively easy, in accordance with the following pattern:

1. *Camp.* Individuals who did not leave their home station during the 30 days before illness.

2. *Camp* and *pass.* Individuals who were out of camp on overnight pass from 8 to 30 days before illness.

3. *Camp* and *different night station.* Individuals who left camp to assume duty at a different station during night hours.

4. *Maneuvers.* Individuals who participated in field maneuvers from 8 to 30 days before illness.

5. *Civilian life.* Individuals who entered the Army 8 to 30 days before illness.

Cases of *vivax* malaria were considered relapses if there was a history of previous malaria within 12 months. With *falciparum* malaria, 6 months was the limit used.

If a change of station occurred within 7 days before the onset of illness, the case was considered as of the old station. When changes occurred from 8 to 30 days before onset, the case was attributed to the station where the greater portion of the time had been spent.

Such a careful analysis made it possible to be much fairer in evaluating the effectiveness of antimalaria programs at various posts. For example, in earlier reports, many cases were attributed to Henry Barracks, simply because they were diagnosed there. Of the 34 cases hospitalized at Henry Barracks during the first 6 months of 1943, 32 proved to have been contracted off the post. This was in harmony with anopheline catches, which had been low for some time.

Sanitary Corps officers were generally assigned as post malaria control officers. Where extensive control projects were undertaken, two Medical

Department enlisted men with special qualifications were assigned to each station hospital for malaria control duty. Antimalaria housekeeping measures were their chief responsibility.

During November and December 1943, data on mosquito densities and mosquitoproofing standards were systematically collected at many posts. To determine the "intra-cantonment adult mosquito index," mosquitoes were collected each week from a representative number of occupied buildings and classified as to anopheline and nonanopheline. To determine the "mosquito-proofing index," a representative number of buildings were visited, and defects were recorded. This stimulated both interest and action. In many cases, a reduction of the mosquito index to zero was attained.

The year 1944 was fortunate from the malaria standpoint.[128] The incidence of the disease was low, not only among Army personnel, but also among natives in unsanitated areas. The dry season, combined with a natural, cyclical low point for the region, supplemented the effects of a well-developed antimalaria program.

In the Puerto Rican Sector, the attack rate for January 1944 was 13 as compared with 63 for January 1943 and 142 for January 1942. For February 1944, the ratio was 6:48:104; for March 6:25:99; and for April 4:7:73.

Improvement in the Trinidad Sector was less striking, but in general parallel; the attack rate for January 1944 was 53.6 as compared with 51 for January 1943 and 69 for January 1942. For February 1944, the ratio was 22:53.1:57; for March 27:66:74; for April 20:35:49. It should be pointed out, of course, that in Trinidad the peak of the malaria season occurs in late summer. Thus, the attack rate in August for 1942 was roughly 105 per 1,000 per annum. In August 1943, this had been reduced to approximately 66. In the Panama Canal Department, the attack rate for January 1944 was 22.6; for February, 19.4; for March, 8.3; for April, 6.2. These figures include both primary and recurrent malaria (table 24).

By 1945, the problem became one of maintaining the preventive measures which had brought about the gratifyingly low rate then prevailing among military personnel. High morbidity and mortality rates were still characteristic of civilian populations in the Antilles Department.

Costs were decreasing, as emphasis was then on maintenance of drainage ditches rather than on their construction.

The larvicide principally used was an emulsion composed of 3 parts water to 1 part diesel or fuel oil, with DDT added to the oil ingredient.

Both larviciding and spray killing of adults were then being handled by plane, the large capacity C-47 being found most practical. Much hand larviciding could thus be eliminated, and hitherto impenetrable areas covered. Residual effects lasted up to 6 weeks.

Spraying of barracks and civilian homes with DDT at bimonthly intervals had become established practice.

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[128] Essential Technical Medical Data, Caribbean Defense Command, April 1944.

Individual control measures assumed renewed importance on posts where strengths were being cut, and environmental control measures were becoming no longer feasible from an economic standpoint. A continuing educational program was therefore necessary.

Administration

On 4 December 1942, a Department malaria control officer was appointed by the commanding general to function under the Department surgeon. His duties were to coordinate all malaria control activities at Army posts and to collaborate with agencies in charge of extracantonment malaria control programs. This officer traveled extensively, inspecting projects and advising post engineers, post surgeons, and commanding officers.

The advisory function was broadened before the end of the year by the establishment of a Department malaria control board, consisting of the Department malaria control officer, a representative of the U.S. Public Health Service, and a representative of the District Engineer's Office. Post commanders made full use of the services of this board and thus insured that their plans and projects were in accord with the best malaria control principles.

The U.S. Public Health Service, of course, did not operate extracantonment projects in connection with every post. For other posts, it was arranged that the District engineer should be responsible in carrying out extracantonment projects formulated by the respective post commanders. The advice and assistance of the Department malaria control board was available at all times. Thus, each post was assured the proper combination of intracantonment and extracantonment control work to meet its particular needs.

Medical Department officers who held the title of "Malaria Control Officer" in the Office of the Surgeon, Antilles Department, included:

Maj. Louis Gonzales, MC, 15 December 1943 to 26 May 1944.
Capt. Rafael Rodriguez-Molina, MC, 26 May 1944 to 23 June 1944.
Maj. Leonard B. Dworsky, SnC, 23 June 1944 to 1 November 1944.
Capt. Francis B. Frost, SnC, 1 November 1944 to 18 January 1945.

Puerto Rican Sector

Although the division of the Antilles Department into two Sectors was not continued to the end of the war, it will be convenient to present the essential material in this manner.

In 1943, the Puerto Rican Sector included 12 stations. The eight Ground Force stations were:

Post of San Juan, including station hospital, P.R.
Camp O'Reilly, P.R.
Fort Buchanan, P.R.
Henry Barracks, P.R.
Camp Tortuguero, P.R.

Saint Thomas, V.I.
Antigua, B.W.I.
Jamaica, B.W.I.

The Air Force stations were four:

Borinquen Field, P.R.
Losey Field, P.R.
Benedict Field, St. Croix, V.I.
San Julián, Cuba.

The Air Force station at San Julián, Cuba, was added after the 1942 report, representing an increase of five stations over 1941.

MALARIA PROBLEMS, 1941–43

The malaria situation in the Puerto Rican Department, at the beginning of the war, is summarized in table 28.

TABLE 28.—*Malaria data for U.S. Army enlisted personnel in Puerto Rico, continental troops, and insular troops, 1941*

[Rate expressed as number of cases per annum per 1,000 average strength]

Category	All enlisted personnel	Continental troops	Insular troops
Strength	18, 359	6, 376	11, 983
Days lost	18, 877	5, 869	12, 008
Incidence:			
Number	1, 648	494	1, 191
Rate	92	77	99

During the first 30 weeks of 1942, the malaria attack rate of troops in Puerto Rico had reached 114 per 1,000 strength. For the first 21 weeks of the same year, the figure stood at 74.2 per 1,000 strength in Panama. The rate of primary malaria in the PCD for the 4 weeks ending 26 June 1942 was 233.1 per 1,000,[illegible] in spite of the fact that the Caribbean Defense Command had been utilizing all the malaria control measures thus far developed for use by troops. It became essential that The Surgeon General should have firsthand information regarding malaria problems and control methods in these areas.

It was therefore arranged that Lt. Col. (later Col.) Paul F. Russell, MC, in company with Dr. Mark F. Boyd, of the Rockefeller Foundation, both experienced malariologists, should proceed to San Juan, during September 1942, and make a similar journey to the PCD, in October 1942, for the purpose of obtaining the desired information.

[illegible] Letter, Col. John A. Rogers, MC, Executive Officer, Office of The Surgeon General, to The Commanding General, Services of Supply, 31 Aug. 1942, subject: Malaria Control.

The Puerto Rican survey disclosed that some cantonments had achieved rates of 250 per 1,000 strength during 1941 and 1942.[130] Good cooperative relations existed between the Army, the U.S. Public Health Service, the Insular Health Department, and the Work Projects Administration, but specific plans for intracantonment and extracantonment control for each installation were yet to be developed. The Insular Health Department had made no sustained effort to deal with the menace of the civilian reservoir living outside cantonments, and the Army had been slow in assuming its full responsibility for intracantonment control. Some of this had been compensated for by the activity of the U.S. Public Health Service, which lent considerable aid of an emergency nature, but it had been understood from the beginning that the prime responsibility of the U.S. Public Health Service was extracantonment control and that the Army was expected to look after intracantonment control in all its phases.

The Russell-Boyd report resulted in specific recommendations to the effect that the Army assume full responsibility for intracantonment control, including larviciding and drainage. The antimalaria program of the Army in Puerto Rico had up to this time been limited to screening, minor ditching and oiling, pit-filling projects, and the use of bed nets, protective clothing, and suppressive drugs. Some survey work had been in operation since 1 June 1942. The recommendations advocated greater use of pyrethrum sprays to kill adult mosquitoes, also that bed nets be included in the screening inspection.

Most significant was the suggestion that a full-time malaria control officer, with suitable assistants, be appointed for the Puerto Rican Department and that he be placed on the staff of the Department surgeon. Considerable time was to elapse before this was achieved.

The sanitation of the entire Puerto Rican Sector in 1942 was reported good, "except for the presence of malaria vectors throughout the year, especially at Fort Buchanan, Losey Field, and Camp Tortuguero." The same memorandum states that the development of auxiliary airdromes along the coastal plain of the island of Puerto Rico had appreciably increased the seriousness of the malaria problem.

Most of the U.S. military posts in Puerto Rico were located on the coastal plain, where malaria is endemic. Fort Buchanan, Losey Field, and Camp Tortuguero presented the greatest problems. In hyperendemic areas nearby, the spleen rate in children between 2 and 10 years was permanently over 50 percent.

In the Salinas area, which was used for military maneuvers, the annual attack rate among some 10,500 men was between 200 and 300 per 1,000 in 1941.

The temperature in Puerto Rico varies from 72° to 86° F., so that mosquito production never ceases because of cold. Seasonal temperatures do affect

[130] Letter, Col. John A. Rogers, MC, Executive Officer, [Office of the Surgeon General, U.S. Army], to The Adjutant General, [War Department], 22 Oct. 1942, subject: The Control of Malaria in Puerto Rico.

mosquito production, nevertheless, as shown by the fact that adult emergence usually drops sharply in mid-December and continues relatively low for 2 or 3 months, the rate of larval development being reduced about 50 percent. Malarial infections tend to fall off 4 to 6 weeks after adult emergence is checked.

More important than temperature, of course, are the seasonal variations in rainfall. Increase in precipitation is reflected in higher mosquito counts and more malaria. A third factor in *A. albimanus* production is shade. When the sugarcane becomes sufficiently tall, *A. albimanus* tends to be replaced by *A. grabhami*.

Surveys carried out among civilian populations revealed a parasite rate between 20 and 40 percent, especially along the southern coast. Some 2,000 deaths due to malaria were reported annually. With limited funds, the Insular Health Department's program consisted of (1) treating patients to reduce mortality and eliminate foci of infection, (2) antilarval work in a number of hyperendemic districts, and (3) permanent engineering projects in selected districts where the problem was most severe.

Military reports for 1941 and 1942 in Puerto Rico show annual incidence rates among enlisted personnel of 84 and 86 per 1,000, respectively. The latter portion of 1942 showed marked improvement, however, particularly at Fort Buchanan, where a rate of 45 per 1,000 prevailed in October, November, and December as compared with 213, 137, and 273 for the corresponding 3 months of 1941, 1940, and 1939.

This degree of success in controlling malaria at Fort Buchanan was attributed chiefly to screening, insecticiding, and malaria discipline since the anopheline density had been reduced appreciably only in central areas of the somewhat sprawling post. Viewed in retrospect, it seems probable that larviciding and drainage also helped, but such opinion was not held at the time by those responsible for current reports.

Even after the numbers taken in bait traps had become considerably lower, the malaria hazard remained great; however, a reduction in the number of malaria carriers was effected by the evacuation of the small village of Colonia Santa Ana. At the same time, many old troops were transferred, thus eliminating a goodly portion of the human reservoir. Increased efforts were also put forward to detect the carriers among new inductees and to prevent these cases from becoming centers of infection among the troops.

At Losey Field, Fort Buchanan, and Camp Tortuguero, wastelands and pasturelands contributed extensively to anopheline breeding, and wet fields of sugarcane were also important in certain instances. Irrigation channels and reservoirs, streams and cutover mangrove swamps characterized the vicinity of Losey Field. At Fort Buchanan, the worst breeding areas were manmade, in that hydraulic fill had blocked certain natural drainage outlets, creating scattered bodies of shallow, impounded water. At Camp Tortuguero, large areas of waste marshland, formerly in cane, produced many anophelines. The marshy fringes of Laguna Tortuguero were next in importance. At

Camp O'Reilly, old sugarcane ditches, in addition to at least four small streams, were sources of breeding.

PROBLEMS AT SELECTED POSTS

Camp Tortuguero.—As stated previously, this post was surrounded by extensive sugarcane fields and large bodies of standing water. Within the camp boundaries were Laguna Rica, Laguna Tortuguero, and a seepage area at the base of a hill. Five hundred acres or more of marshland lay to the east of the camp, and there were several nearby "barrios," practically surrounded by canefields. The nearby towns of Vega Baja, P.R., and Manatí, also malarious, were frequently visited by troops.

Within the camp, malaria control was accomplished by oiling all breeding places or dusting with paris green. Ditching, drainage, and filling were also employed. All buildings used at night were screened. The use of mosquito bar and of Freon Aerosol was made compulsory. Routine inspections, also group instruction and demonstrations were employed. Informative posters concerning individual precautions were placed in hutments. Weekly catches of mosquitoes were made in occupied hutments to test the efficiency of the program.

Camp O'Reilly.—War Department Training Circular No. 108, dated 21 September 1943, had its influence in the Caribbean as elsewhere. A report from Camp O'Reilly mentions the appointment of antimalaria details by all organizations and their training by the post malaria control officer. Barracks were regularly inspected and scored as to the defects found. These reports were sent to post headquarters, and each organization was notified by the post commander as to the defects recorded.

The prevalence of mosquitoes at Camp O'Reilly was likewise reduced by both intracantonment and extracantonment drainage and by extensive larviciding. The malaria rate for 1942 was only 113 per 1,000 average strength per year, and for 60 percent of the months of 1943, less than 20 per 1,000 strength. The construction of permanent linings in ditches and watercourses upon the post was a feature of the control activities.

An important step in the sanitation of Camp O'Reilly was the relieving of one Sanitary Corps officer, in 1943, of the duty of mess inspection and the utilization of this officer, as post malaria control officer, to work in cooperation with the post engineer.

The 1944 Annual Report, Department Surgeon, Antilles Department, compares the malaria rate for 1942, which was 113 per 1,000 per annum, with 30 per 1,000 per annum for 1943 and 6 per 1,000 per annum for 1944.

This was accomplished entirely before the availability of DDT and resulted from conscientious attention to many things. Particularly influential was an exhibit, opened in April 1944, at the 326th Station Hospital, which all enlisted men of the command were required to visit in groups of ten.

Explained and demonstrated were the use of the mosquito bar, how to tuck it well under the mattress, how to repair holes by mending or patching; likewise the use of head nets, gloves, leggings, and repellent. The use of Panama inverts, and side slabs, and the sodding of banks with Bermuda grass were pictured, also dusting, oiling, and cleaning of ditches. The work of both military and U.S. Public Health personnel, within and without the cantonment, was likewise shown.

Losey Field.—The largest and most uncontrollable breeding areas at Losey Field and Camp Tortuguero were eventually reduced or eliminated by drainage construction, carried out by the U.S. Public Health Service and the Work Projects Administration,[131] chiefly in 1943. Previous to this, Losey Field had posed a difficult problem. The area, covering about 240 acres, was purchased by local donations and given to the government. Useless for agriculture, because of its swampy nature, the land is only 20 feet above sea level. The distance to the sea is about 1½ miles. Cost of drainage could not be other than excessive. The Insular Health Department spent approximately $70,000 in malaria control in the Losey Field area in 1941, which included 92,707 lineal feet of pipe in subtile drainage, and $800 per month for oiling and spraying.

Borinquen Field, P.R.—At this base, malaria control was at first confined largely to the use of screens and mosquito bars. The malaria rate rose, until, in July 1942, it had reached 100 per 1,000 per annum (as compared with 62 for July 1941).

Vigorous measures were instituted, including a program of filling, draining, and oiling. Bajura Pond, a sea-level swamp at the northeast corner of the base, very difficult to drain, was eventually taken care of by dusting once a week from the air with a mixture of alum (or lime) and paris green.

The malaria rate for July 1943 was only 6 per 1,000 per annum. For the balance of the year, only 9 cases were reported, and most of these were among coastguardsmen quartered off the post or in soldiers who had been on pass in malarious territory.

MISCELLANEOUS REPORTS FOR 1944

Reports for 1944 (in some cases referring to work accomplished in 1943) showed that the situation was well in hand.

At Fort Bundy, where DDT began to be used in October 1944, the number of malaria-transmitting mosquitoes taken in surveys ranged from one-fourth to one-tenth the number found in previous months, as, for example, 739 collected in November 1944 versus 9,235 collected in September 1944.

At Losey Field, 15 cases of malaria were contracted among troops undergoing training in the Salinas Training Area; but these were proved to be the result of relaxed malaria discipline, and corrective measures were immediately

[131] Letter, John M. Henderson, Sanitary Engineer, (R), Federal Security Agency, U.S. Public Health Service, San Juan, P.R., to Lt. Col. Paul F. Russell, MC, Office of The Surgeon General, 19 July 1943, subject: Civilian and Army Malaria Morbidity by Months in Puerto Rico.

instituted. Suppressive Atabrine therapy was also authorized for troops in the Salinas Training Area.

At Fort Buchanan, the malaria problem was practically eliminated by a combination of all available procedures and by cooperation between U.S. Engineer Department, post engineer, U.S. Public Health Service, Work Projects Administration, and other agencies. Drainage, larviciding, attention to barracks, and malaria discipline, all had a part. Post malaria control officers (Sanitary Corps) discharged the following duties:

1. Supervision of post engineer larviciding and minor ditching crew. (This function was somewhat nominal. On most posts, including Fort Buchanan, such crews worked directly under the authority of the post engineer.)

2. Supervision of four malaria control technicians who were concerned both with the control programs of the post and of the Antilles General Depot areas.

3. The collection, tabulation, and review of data relating to mosquito control.

4. The review of data secured from malaria patients.

5. Supervision of and participation in the malaria control education program for troops.

6. Regular inspection of all intracantonment breeding areas and the recommendation of corrective measures.

7. The inspection of sleeping quarters of troops.

8. The preparation of all required reports on malaria control.

At Camp Tortuguero, conscientious attention to all aspects of the problem continued to create a better record. Chief difficulty at this post was the condition of quarters for troops, where separation of boards due to excessive rainfall and changeable weather caused many cracks capable of admitting mosquitoes. The post engineer kept a permanent repair crew employed at mosquitoproofing work.

Results of the use of DDT larvicidal dust, also of 5 percent DDT in No. 2 diesel oil, were beginning to be observed.

At Henry Barracks, the malaria problem was reported as "minimal" in 1944. About three-fourths of the area of the post had been improved that year with 1,500 linear feet of half round acres (estimate) drained, but this is not considered to have had a real bearing on malaria, as Henry Barracks enjoyed a very good record from 1941 on.

CONCLUDING STATEMENT

The decrease of malaria in the Puerto Rican area during the course of the war may be illustrated by the statistics in table 29, from the 161st General Hospital, Fort Brooke.[128] No cerebral malaria was recorded at this hospital.

[128] Professional History of Internal Medicine in World War II, the Antilles Department. [Official record.]

The prompt establishment of adequate antimalaria control measures, including the institution of malaria discipline, was believed to be the factor influencing the rapid decrease in the incidence of malaria among Army personnel.

Adequate malaria control was not accomplished until sometime in 1943, after which a rapid decrease in malaria incidence took place. Through most of 1942, malaria rates in Puerto Rico remained undesirably high. Colonel Russell, who visited the island during 1942, recorded conditions as "distressingly bad." Even minor repairs of barracks, necessary for mosquitoproofing were not given proper attention on many posts until the last 6 months of 1943.

TABLE 29.—*Admissions for malaria, 161st General Hospital, San Juan, P.R., 1942–45*

Diagnosis	1942	1943	1944	1945 [1]	Total
P. vivax	871	180	101	23	1, 175
P. falciparum	117	46	24	7	194
P. malariae, mixed, and unclassified	4	1	1	0	6
Total	992	227	126	[2] 30	1, 375

[1] Includes first 9 months only of 1945.
[2] Data are believed to include both primary and recurrent cases.

The role played by the Malaria Control in War Areas, U.S. Public Health Service, in Puerto Rico, especially during the critical 1942–43 period, was very great. For a number of reasons, the Army did not achieve proper organization for adequate malaria control until sometime in 1943, and preventive medicine units did not actually take the field to any extent until 1944. Tardy recognition of these organizational needs not infrequently resulted in the assignment of unsuitable personnel for control work, and lack of proper planning in the selection of campsites can probably be traced to the same source. Meantime, MCWA, with its self-contained units or "teams" was chiefly responsible for the functioning of the joint Army malaria control program as it was then constituted.

Trinidad Sector [133]

CONSTRUCTION PERIOD

The first and foremost problem confronting the U.S. military authorities in the Caribbean was the construction of bases to receive large numbers of U.S. troops. This task fell to the Corps of Engineers and was administered by Districts.

Of these, the Trinidad District was perhaps the most important from the malaria hazard standpoint. Toward the end of December 1940, Lt. Col. (later

[133] Data on civilian malaria and its vectors have been included in the previous section on countries and dependencies.

Lt. Gen.) David A. D. Ogden arrived in Port of Spain as district engineer, accompanied by 2 officers of the Corps of Engineers and 36 civilian employees. This group supervised the construction of the various bases involved. Much native labor was employed. Port of Spain served as headquarters for all work in the Trinidad District.

Three areas were recognized, the British Guiana Area, which contained Atkinson Field, the Saint Lucia Area, which contained Beane Field, and the central or Trinidad Area, administered from Fort Read. Included under the Trinidad Area were Fort Read, Waller Field, a number of auxiliary airfields, certain fixed defense units of the Caribbean Defense Command, and the permanent docks.

The Trinidad Area gave greatest concern, as two endemic centers were involved. One of these centers consisted of the coastal swamps, which were breeding places for *A. aquasalis*. The other endemic center was in the highlands, where there is plenty of rainfall, and proved to be due to the abundance of *A. bellator*, a hitherto suspected but not proved vector. As mentioned previously, these mosquitoes are treetop breeders. Proof of the natural infection of *A. bellator* was brought forward by Dr. Lloyd E. Rozeboom [134] and Mr. Raymound Laird of The Johns Hopkins University who arrived in Trinidad in May 1941 and found the first naturally infected *bellator* in July 1941.[135] Their findings were later confirmed by Downs and Shannon [136] of the Rockefeller Foundation, while engaged in making a malaria survey of the Island.

During the first 9 months of operations, there were 48 cases of malaria in Trinidad among construction forces, with 1 death.[137]

Draining, filling, and anti-*bellator* measures were conspicuously effective in reducing anophelines as compared with culicines. In June 1941, the ratio between anophelines and culicines was 1 : 1, in December 1 : 9. This is probably not too significant, however, as *A. oswaldoi*, a nonvector, appears to have contributed substantially to the former count.

MALARIA IN MILITARY PERSONNEL, 1941–45

At the 359th Station Hospital, Fort Read, previously designated as the 41st General Hospital, a total of 1,142 primary and recurrent cases were admitted.[138] These were classified as follows:

	Number
Plasmodium vivax	807
Plasmodium falciparum	308
Plasmodium malariae	1
Mixed infections	12
Unclassified	14

[134] Dr. Rozeboom received the Bailey K. Ashford Medal of the American Society of Tropical Medicine in recognition of his work on *Anopheles bellator*.

[135] See footnote 102, p. 206.

[136] Downs, W. G., Gillette, H. P. S., and Shannon, R. C.: A Malarial Survey of Trinidad and Tobago, British West Indies. J. Nat. Malaria Soc. Suppl. 2: 5–44, 1943.

[137] See footnote 96, p. 205.

[138] See footnote 90, p. 202.

Four cases of cerebral malaria were recorded, all due to *P. falciparum*. One failed to recover, the only death from malaria in the Antilles Department.

During 1942, there were approximately 1,150 cases of malaria in U.S. Army forces in the Trinidad Sector, but by 1943, mosquito control programs had begun to yield generally satisfactory results. However, in many locations, detailed information as to the species concerned, their habits, and ecological requirements was incomplete or lacking. In such cases, the attack on the problem had to be general, which usually meant some waste of funds, materials, and manpower.[139]

The Trinidad Sector and Base Command had the benefit of a malaria control laboratory located not far from the sector surgeon's office.[140] Built in 1942, this laboratory served, directly or indirectly, the entire sector, which was over 1,000 miles long. Besides the Dutch Islands of Aruba and Curaçao, this included Las Piedras and Puerto La Cruz on the mainland of Venezuela, the Venezuelan Island of Patos, British Guiana, the British Islands of Trinidad and Saint Lucia, also Surinam (Dutch Guiana), and Rochambeau Field in French Guiana.

Throughout its history, the laboratory was directed by a commanding officer who, with one exception, was a medical officer malariologist. (In early 1945, this post was held by an engineer.) The parasitologist and the entomologist originally assigned to the laboratory remained with the organization until its deactivation. Until near the end of 1944, an engineer also served in close cooperation with the central staff.

The functions of the laboratory were defined as follows:

1. To identify specimens of larvae and adult mosquitoes from the various bases and submit reports.
2. To examine blood smears of all malaria cases.
3. To make field investigations of control procedures.
4. To collect, assemble, and interpret data submitted by hospitals and field personnel.
5. To disseminate newer technical information regarding control methods and procedures.
6. To provide other technical assistance.

A more complete account of the laboratory will be given in a later section entitled "Special Units, Organizations, and Projects."

A rather complete study of the Trinidad Sector was carried out by General Stayer. The program which he outlined was put into effect and operated as follows:

Local surgeons were made responsible for malaria control as well as sanitation for their own posts and camps. Each local surgeon outlined the projects

[139] Letter, Col. R. E. Shum, A.G.D., Adjutant General, Trinidad Sector and Base Command, to Commanding Officers, All Posts, Camps, Stations, and Bases (Ground and Air Forces), Trinidad Sector and Base Command, attention: Surgeons and Post Engineers, 26 Jan. 1943, subject: Mosquito Control.

[140] Annual Report, Surgeon, Trinidad Sector and Base Command, 1942.

FIGURE 27.—Gypsy moth sprayer in use against bromeliads.

he believed necessary for the control of malaria in his area and submitted plans to the engineers for estimates. Funds were provided by the district engineer, with the local post engineer completing the project under the technical supervision of the local surgeon.

As indicated previously, the malaria control laboratory undertook to identify mosquitoes sent in by fieldmen and to give advice on species control. This service was somewhat hampered by the frequent removal of experienced personnel for service at other points. The loss of Lt. Wilbur G. Downs was particularly regretted by the Sector surgeon.

The problem of *A. bellator* was considered worst at Fort Read, in the center of Trinidad. It was said that, even if the entire Fort Read area were covered with concrete, the malaria problem there would not be affected.

This was an exaggeration, but the statement is significant. The possibility of felling the immortelle trees, hauling them away, and burning them to destroy the bromeliads was rejected because of expense. More practical was the training of crews to climb the trees and cut out the bromeliads. The eventual employment of pressure pumps to spray the bromeliads with copper sulphate, which is toxic to the epiphytes, had to await the arrival of suitable machinery from the United States. The U.S. Department of Agriculture was instrumental in arranging the shipment from Greenfield, Mass., of a Bean power sprayer, formerly used in combating gypsy moth depredations in New England (fig. 27).

The type of malaria control employed at each location depended upon the nature of the particular base. Thus, within the Trinidad Sector, U.S. installations fell into three categories, according to probable permanence. Six were 99-year leased bases. These were Fort Read, Edinburgh Air Base, Green Hill Cantonment, Port of Spain, British Guiana Base Command, and Saint Lucia Base Command.

Bases held only for the duration of the war included five individual stations in Surinam, an airbase in French Guiana, and the two Dutch Islands, Aruba (Camp Savaneta) and Curaçao (Camp Suffisant).

Small outposts, of indefinite number and permanence, were scattered throughout the Trinidad Sector and though occupied by relatively few men constituted a distinct health problem of their own. Malaria discipline was chiefly counted on in these situations. A single exception was La Lune, Trinidad, where mosquito breeding was limited to a restricted area along one border of the camp. Clearing and larviciding measures were found to be economically feasible and greatly reduced the mosquito problem.

At bases to be held only for the duration of the war, control measures depended on the anopheline fauna. On Aruba and Curaçao, no malaria problem existed. During the construction of the airbase in French Guiana, drainage, larviciding, and spray killing of adult mosquitoes were employed to protect the construction crews, which entered the area late in April 1943. On recommendation of the Trinidad Base Command, native labor camps and Puerto Rican labor camps were moved to 1 mile from the U.S. camp. So far as can be ascertained, construction was suspended before completion of the work, the base was never activated, and only a very restricted malaria control program was ever in operation at the base.

Of the five temporary stations in Surinam, only Zanderij Field saw an extensive larvicidal and drainage program. Camp Paranam and Camp Moengo were served through programs carried out by the local aluminum companies. In general, larvicidal work was instituted whenever field inspection showed the breeding of anophelines.

At the six bases of the 99-year class, long-range plans as well as emergency measures were, of course, important. Each of these installations is discussed separately in the section which follows.

CONTROL PROGRAMS AT BASES UNDER LONG-TERM LEASE [144]

Edinburgh Air Base, Trinidad, B.W.I.—Drainage for malaria control could not be accomplished until general purpose drainage had been completed, and this was slow. Larvicidal control within the base, however, was excellent. Beginning in September 1943, the base was operated by Navy personnel, and the 80th Construction Battalion was assigned there. As long as Army personnel remained at this establishment, a cooperative program of mosquito control was in effect. The 80th Construction Battalion provided necessary equipment, such as dragline and bulldozer, while the post engineer furnished larvicidal control and labor to man the equipment.

[144] Annual Report, Surgeon, Trinidad Sector and Base Command, 1943.

Port of Spain, Trinidad, B.W.I.—The post extended for about a mile along the Port of Spain waterfront and ranged from one-quarter to one-half a mile wide. Normal filling and grading took care of all greater breeding areas, and larvicidal work covered the rest. To protect adequately all parts of the post, permission was secured to extend control measures into British property known as the Kings wharf area. Control appears to have been nearly complete. For months at a time, inspectors were unable to find anopheline larvae.

Green Hill Cantonment, Trinidad, B.W.I.—This cantonment suffered a high malarial rate in 1942. A large, coastal swamp, closely adjacent, was the source of the anopheline vector. Accordingly, in February 1943, the district engineer was directed to provide a nonclogging, self-cleansing outlet from the swamp to the ocean and to install a tide gate. This was completed in July 1943, leaving the swamp entirely dry.

Green Hill Cantonment was built in a coconut plantation. This resulted in ditch maintenance being more expensive than usual for a post this size. In spite of this, excellent standards were maintained.

Fort Read, Trinidad, B.W.I.—It was not until April 1943 that a larviciding program was started for the control of ground-breeding mosquitoes. Earlier in the year, it was believed that the tree-breeding *A. bellator* was the only malaria vector of consequence in the vicinity. The disclosure by the field inspection program that *A. aquasalis* was breeding extensively nearby caused considerable revision of control procedures. It was found that not only was this species present in the salt marshes 13 miles away but that it had adapted itself to a salt-free environment and was breeding successfully in fresh water pools throughout the Fort Read area (fig. 28). It then became necessary to cover approximately 25 square miles of territory with larvicide each 7-day period. A Sanitary Corps officer was assigned to cooperate with the staff of the post engineer in carrying out this program. There was a lack of labor, transportation, and of competent supervision, but these problems were gradually solved, and, by 1 September 1943, good control over ground-breeding mosquitoes had been achieved. Minor drainage projects were carried out here and there to eliminate repeated larviciding.

As for the control of *A. bellator*, because of delay in the shipping of high-pressure spray machinery, it became necessary to resort to a hand-cutting program for the elimination of bromeliads. During the last 3 months of 1943, a strip, nowhere less than one-quarter mile wide, was cleared around all cantonment areas. This involved climbing some 70,000 immortelle trees. An allotment of $102,000 from Headquarters, Caribbean Defense Command, was nearly all used for this purpose.

British Guiana Base Command.—An excellent program was initiated in 1942 and supplemented in 1943 by a certain amount of new ditching to connect several springs and streamlets with the main outfall. The maintenance of the system, however, proved excessively expensive. In 1944, steps

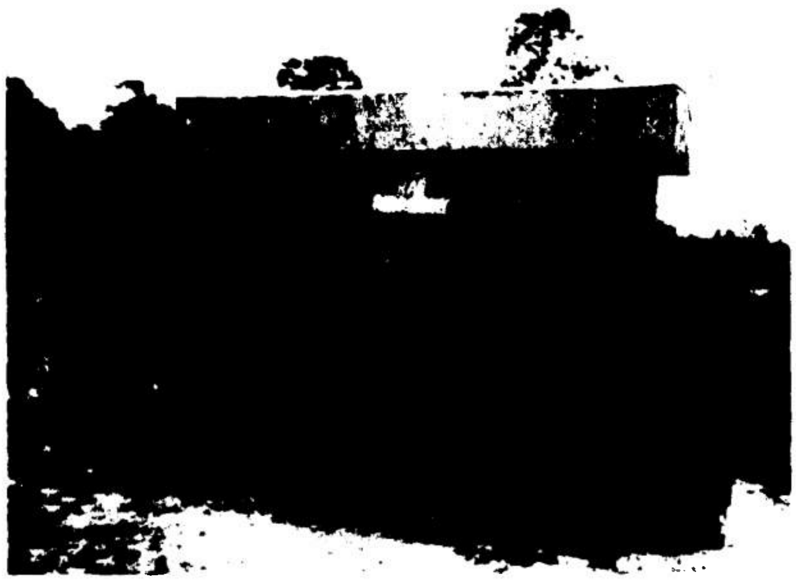

FIGURE 28.—Dawn trap used in mosquito survey at Fort Read, Trinidad, B.W.I.

were taken toward the installation of permanent tidal gates which would prevent tidal water from entering areas adjacent to the Demerara River. Homemade tidal gates had been in operation on all outfall drains fronting the river since 1942.

Saint Lucia Base Command.—Much swamp filling, drainage, and clearing work were accomplished during the construction period. Subsequent extension of the drainage and filling, together with a well-administered larvicidal program, made Saint Lucia relatively mosquito free in 1943. It was only necessary to extend the permanent construction work to cut down maintenance costs.

The incidence of malaria among military personnel on Saint Lucia in 1943 was approximately 45 per 1,000 per annum; by 1944, this had been reduced to 8 per 1,000 per annum. Flushing of certain swamps with sea water and emphasis on individual protective measures were considered responsible for a good share of the improvement.

Special Units, Organizations, and Projects

Caribbean Health Service during construction of bases.—The London treaty of 27 March 1941, confirming an exchange of notes, dated 2 September 1940, gave the United States 99-year leases to sites in British possessions for the construction of Army, Navy, and Air Force Bases. The sites were located in Newfoundland, the Bermudas, the Bahama Islands, British West Indies, Jamaica, Antigua, Saint Lucia, Trinidad, and British Guiana.[142] It will be seen that the majority of these locations fell in malarious territory.

Construction of these bases became the responsibility of the Corps of Engineers, U.S. Army, and an Eastern Division, Corps of Engineers, was created to carry out this work. In the Caribbean, the work was carried on by districts which did not always have the same boundaries or designations throughout the war. For example, the Jamaican District, at one time distinct, came under the Puerto Rican District in 1943. The Army Air Base in Antigua, most southerly project of the Puerto Rican District in 1942, appears in later documents as falling in the Trinidad District along with Saint Lucia and British Guiana.

The medical officers who first served each base deserve great credit for their comprehension of the malaria problem and for their early attention to preventive sanitation.

The special problem in Trinidad, relating to malaria transmission by *A. bellator*, breeder in bromeliads, in treetops, was investigated and eventually controlled.

Malaria attack rates for the Caribbean area in 1942 ranged between 50 and 180 per year per 1,000 average strength as compared, for example, with the low and high attack rates in Liberia, 429 for September and 1,340 for December 1942, respectively.[143] It was found difficult to protect troops away from fixed installations or troops newly arrived in a highly malarious area where they must live under field conditions while constructing a base. The relative success achieved in keeping Caribbean rates within bounds would seem to be due in no small part to the fact that, in general, bases were completed by small groups of engineers and other professional personnel, using much native labor, before substantial numbers of military personnel were brought there.

The Engineer Service, Caribbean Defense Command, took a firm attitude regarding malaria prevention in 1941–42.[144] Regulations were posted and rigidly enforced. These pertained to use of bed nets, quinine prophylaxis, mosquitoproofing of barracks, use of insecticide spray, individual protective measures, care of tin cans, discouragement of excessive use of alcohol, maintenance of drainage ditches, and oiling of breeding places. In general, it can be said that the work of construction was not seriously hampered by the malarial rate prevalent in the labor force.

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[142] See footnote 96, p. 205.

[143] Reba, John W. H.: Malaria, Its Prevalence, Control, and Prevention in the Africa-Middle East Area. (Official record.)

[144] Medical History of the Panama Division, Engineer Service, Caribbean Defense Command, 1941–42.

The 392d Medical Malaria Control Detachment.—For the southern half of the Antilles Department, the history of malaria control is very largely the history of the 392d Medical Malaria Control Detachment.[15]

This organization, referred to in most documents as the "Malaria Laboratory," serviced Trinidad, Saint Lucia, British Guiana, Surinam, and French Guiana. There were a number of changes, both in organization and in personnel between its inception in 1942 and the end of 1944, but, as of 1 November 1944, the organization became known as the 392d Medical Composite Unit (Malaria Control). On 21 March 1945, the name was changed to 392d Medical Malaria Control Detachment. The commanding officer of the laboratory served also as the sector malaria control officer, or assistant Department malaria control officer, or, during the period when the laboratory served only Trinidad, as the base malaria control officer.

Commanding officers of the Malaria Laboratory were as follows: Capt. Melvin D. Robinson, MC, arrived 9 March 1943, departed 19 December 1943; Capt. Eli C. Ridgway, MC, arrived 23 December 1943, departed 9 March 1945; Capt. (later Maj.) Donald C. Senges, SnC, arrived 26 April 1945, departed 15 November 1945; and 2d Lt. Stanley F. Yolles, SnC, November 1945 through 10 January 1946. The parasitologist was Mrs. Tamarath K. Yolles, from the opening of the laboratory in 15 January 1943 to December 1945; the entomologist, Lieutenant Yolles, from the opening of the laboratory, 15 January 1943 to January 1946. Slides on all cases of malaria reported from all hospitals in the sector were checked in this laboratory. An able group of enlisted technicians operated an insectary, identified entomological specimens, maintained records and files, performed necessary chemical work, and assisted in malaria control activities. Two of these technicians functioned on detached service at the British Guiana Base Command.

First located in Saint Clair cantonment, immediately adjacent to the office of the sector surgeon, the Malaria Laboratory was moved to Fort Read, 12 May 1944, where more space and better facilities were available. Added office space, a classroom, an animal house, and a dressing room for native dippers were among the features provided. From the inception of the laboratory until activities were transferred to Fort Read, continuous courses were given for all medical officers arriving in the area, also for selected groups of nurses. Instruction concerned the diagnosis and treatment of malaria, as well as the identification of anopheline and culicine mosquitoes.

Beginning 3 May 1943, the sector Malaria Laboratory initiated a course for enlisted technicians in the laboratory diagnosis of malaria. Thick smear technique was emphasized. Surgeons at the various posts were urged to select personnel and recommend them for this training.

All hospitals in the sector were required to submit a thick and a thin blood smear on each case diagnosed as malaria. These were stained and examined in the sector Malaria Laboratory, and reports were made to the hospitals.

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[15] Annual Report, 392d Medical Malaria Control Detachment, 1942–45.

Consistently recurring error from any station was indication for sending the station technician to the sector Malaria Laboratory for intensive training in slide diagnosis. This practice resulted in a great reduction in percentage of error.

The central organization maintained a slide library of all malaria patients in the sector. Each incoming case was recorded on an organizational chart which provided a running picture of malaria control efficiency for each location as well as for the sector as a whole.

Most of the malaria in the Trinidad Sector was of *vivax* type. The 1943 annual report from this sector shows *P. malariae* occurring in negligible amount, but throughout 1943 the percentage caused by *P. falciparum* gradually increased from 13.8 percent in January to 33.3 percent in November. There was a corresponding decrease in the percentage of *vivax* cases, from 86.3 to 64.9. Typical of attempts to reduce human reservoirs was a malaria survey conducted at Green Hill Cantonment on 500 natives living near the base. Any person with a positive spleen or positive blood smear was treated with Atabrine.

The entomological aspects of the work of the sector Malaria Laboratory deserve special comment. Continuous larval surveys were carried on at each base, as were weekly adult mosquito collections. Enlisted men of either the Corps of Engineers or the Medical Department supervised the native collectors. These were guided by a simple, nontechnical manual, which explained methods of collecting, packing, and shipping of adult and larval specimens. Identification work was performed at the sector Malaria Laboratory, to which all collected specimens were sent. Collectors were required to fill out data forms, thus contributing to knowledge of breeding, feeding, and resting habits. Identifications were reported back to the surgeon of the base concerned, with comments on the relative importance of the species and preferred methods of control.

Many inspections and surveys were made by the malariologist and by the parasitologist, also by the engineer, separately or in combination with the entomologist. These involved areas in British Guiana, Surinam, French Guiana, Saint Lucia, and Trinidad.

Other sanitary agencies.—Antilles Department medical laboratory at San Juan, shared with the 392d Medical Malaria Control Laboratory, at Fort Read, the credit for considerable research work related to sanitation.[180] A third agency, the Anglo-American Caribbean Commission, also deserves comment in this connection:

> This body was created on 9 March 1942 for the purpose of encouraging and strengthening social and economic cooperation between the United States of America and its possessions and bases in the area known geographically and politically as the Caribbean area, and the United Kingdom and British Colonies in the same area, and to avoid unnecessary duplication of research in these fields * * *.

[180] A History of Medical Department Activities in the Caribbean Defense Command in World War II, vol. 2.

The agency was located in Trinidad, at Port of Spain. General health and living conditions received considerable attention on the part of this advisory group, which consisted of three members from each of the two countries. Its relation to malaria and malaria control was indirect, through its interest in the overall program of sanitation.

Airplane dispersal of DDT in the Antilles Department.—Larviciding by means of airplanes had been undertaken with some success before the availability of DDT. At Losey Field, plane dusting with a paris green mix was used to treat a second growth mangrove swamp in the extra reservation area in 1942: L-1 or L-4 observation biplanes were used. A similar procedure was followed in 1943 to protect the Navy San Patricio housing development, along with Fort Buchanan which was nearby. A Navy "duck" (amphibian) plane was first employed, but it could not fly low enough because of its pontoons. A "moth" monocoupe was later substituted, with better results. Caking of the mix, deterioration of paris green, and variable breezes, even in the early morning, accounted for wide variation in the control achieved, but the experience was valuable.

Operations using DDT were first carried on at Camp Tortuguero, and (somewhat later) at Fort Bundy. At Fort Bundy, the breeding areas were off the post, in mangrove swamps and jungle, and included portions of the Las Palmas river valley and the Río Daguao valley, where ground larviciding measures had not proved successful.

After initial trials, reliance was placed chiefly on airplane application, supplemented by hand dusting and minor drainage. Before this, in the wet season, control was never satisfactory, and malaria in civilian laborers had somewhat handicapped the construction of the base. In spite of extensive larviciding, bait trap catches of *A. albimanus* had ranged up to 144 per night, per trap. The substitution of airplane spraying for all other control procedures in the Río Daguao valley and lower mangrove portion of the Las Palmas river valley achieved remarkable and gratifying results.

Several points were established which were of great interest at the time:

1. Spraying of DDT in diesel oil can be carried out in wind up to 18 to 20 miles per hour. This is impossible with paris green dusting.

2. Eight to ten trips per day, in familiar areas, constitute the normal service which might be expected of one pilot, using an L-4 Cub type airplane. (In actual practice, the usual number of trips per day was five or six.)

3. This provides for a daily coverage of 1,000 acres and spreads from 200 to 250 gallons of spray solution. (When the formulation became stabilized at 5 percent DDT in diesel oil, the rate of application was one-half gallon or more per acre.)

4. A swath 30 feet wide can be satisfactorily treated by flying 15 feet above the mangrove, in moderate wind.

5. Larvicidal action remained in effect about 5 days.

In mid-February 1945, there were moderately heavy rains at Fort Bundy. Under former control programs, this would have led to a rise in mosquito densities. However, efficient pumping and drainage systems were then in operation, and there was also an application of DDT in diesel oil by the L–4 Piper Cub. As a result of these combined measures, trap collections during the last week of the month averaged only 0.6 specimens. During certain months, the operation of the light plane was hampered somewhat by the frequency of strong winds; nevertheless, low bait trap collections were maintained.[107]

Even first results at Fort Bundy were so promising that the program was expanded to include Fort Read, Fort Simonds, and Atkinson Field. Some spraying was done with 10 percent DDT in diesel oil, but, in most of the applications, a 5-percent solution was used. One quart of solution, equivalent to 0.1 pound of DDT per acre, proved adequate.

Early applications were made with an L–4 Piper Cub plane, equipped with a Husman-Longcoy spray apparatus. Later, a larger liaison-type L–1 plane was used and finally a C–47, capable of carrying two removable 250-gallon tanks. Intervals between spray operations varied from 3 to 8 weeks or longer, depending on anopheline density and the nature of the season and terrain. In all cases, however, excellent control was achieved, and, wherever operations were on a sufficient scale to permit the reduction or elimination of ground control activities, very significant savings in costs were realized. At Fort Bundy, a permanent drainage project to cost approximately $277,860 had been canceled, and alternative procedures became mandatory. Aerial larviciding proved to be the answer. In Trinidad, the cancellation of a similar undertaking, estimated to cost $423,000, made aerial larviciding necessary. It was, of course, successful.

In Trinidad, superior results were obtained by having the pilot cover the area to be treated in a decreasing spiral, rather than in parallel swaths. Two or three spiral flights, starting at the perimeter, were required to disperse the amount of solution allotted for the acreage concerned. This appeared to result in a more even distribution of insecticide than parallel flights.

The original plan called for the airplane spraying of only some 2,000 acres directly associated with Waller Field. As actually carried out, however, the project included the entire Fort Read area, a tract of approximately 5,000 acres. This was slightly rolling terrain, partially cleared of dense jungle around the various buildings of the post. Scattered through the heavy jungle were more or less cleared areas which functioned as primary breeding sites. Complete, permanent drainage for this acreage would have cost in the vicinity of $2½ million. Control for 1 year, by use of a C–47 type plane, scarcely exceeded $20,000. The degree of efficiency achieved is indicated by a total of only 1.24 *Anopheles* adults per collection during the peak of the rainy season

[107] Essential Technical Medical Data, Caribbean Defense Command, February and July 1945.

in June. One year before, without airplane spraying, the figure stood at 60.2 adults per collection.

In territory requiring great maneuverability of the plane, the L-4 and L-1 types were superior, though somewhat more expensive to operate than the C-47.

As a result of the Department surgeon's inspection of bases in Cuba and Jamaica in December 1945, it was recommended that a second C-47 plane be requested for use in DDT spraying in the Antilles Department. With one plane based at Borinquen Field and the other at Waller Field, it was felt that long flights could be eliminated and that advantage could be taken of optimal weather conditions. Also, in the event of a breakdown, the remaining plane might still continue to serve the area.

Special studies on methods for dispersal of insecticides by aircraft made use of the 119th and 125th Malaria Control Units which had completed training in Panama, 17 November 1944. The technical assistance of these units proved very valuable. Although originally designated for service in Pacific areas, both units were held in Panama until 15 July 1945, a delay in movement of 3 months over orders previously issued. These units had previously served in the Antilles Department and were attached to the Army School of Malariology on a temporary basis. By General Orders No. 34, Panama Canal Department, they had been redesignated on 2 May 1944, as the 119th and 125th Malaria Control Detachments.

Recapitulation and comment.—In the Antilles Department, it was necessary to locate many of the bases in low, marginal areas where extensive mosquito breeding was inevitable. Temporary control measures were usually instituted along with first construction operations. Overall plans for the base provided for more permanent control measures.

In general, malaria rates were high during the first year, gradually dropping to a tolerable level as major engineering operations were completed. In 1944, it was possible for many posts to maintain satisfactory control with routine preventive practices and a larviciding program. In the same year, the use of the airplane for dispersal of DDT made possible the treatment of areas hitherto inaccessible and greatly cut the labor cost in many localities where a large labor force had previously been required. An airplane can cover in a few hours territory which requires days to treat with ordinary ground equipment. Certain costly, permanent work which had long been planned was postponed or abandoned in favor of treatment from the air. Although many biological scientists have seriously questioned the ultimate effect of continued air dispersal of DDT on the fauna and flora of the regions involved, there can be no doubt that economic advantage clearly justified this procedure during the latter portion of the war.

As discussed previously, most of the preliminary work with airplane dispersal was conducted at Fort Bundy. With former methods, in spite of the combined programs of the Army and the U.S. Public Health Service, animal bait traps located on swamp margins continued to give anopheline catches that were undesirably high. For a brief period, this reached over 1,000 specimens per night owing to heavy rainfall. Salinization ditches were used to reduce breeding in a mangrove swamp to the south of the base, and a pasture, directly west, was served by a pumping station with a drainage and diking system. Aerial larviciding was employed as an added measure, especially over mangrove swamps lying to the southwest. When an uninterrupted 7-day cycle was maintained, the anopheline catch remained close to zero. Similar results were obtained by the Navy in treating the Brugal Swamp, near San Juan.

Spraying of the walls and ceilings of native huts on or near military areas with 5 percent DDT in kerosene was also tried. This, of course, was aimed at reducing the number of infected mosquitoes. Surfaces so treated retained their toxicity for at least 2 months.

Older insecticides were also made effective by improved techniques. U.S. Public Health Service personnel developed oil emulsions to replace straight oil as a larvicide. More effective, and less costly, the emulsion larvicide was much used at Losey Field, where an M–4 chemical warfare apparatus was employed in its preparation.

PROBLEMS OF U.S. ARMY AIR FORCES IN THE CARIBBEAN DEFENSE COMMAND

Sixth Air Force [140]

The predecessor of the Sixth Air Force was the 19th Composite Wing, which had been activated in 1929 and was stationed at France Field, on the Atlantic side of the Canal Zone. The airbase at Albrook Field, on the Pacific side, was opened in 1932. During the 1930's, all medical service to these troops was provided by officers and men on duty in the PCD and assigned either to Albrook or France Field.

Approximately 40 emergency landing fields were available in the Canal Zone and Republic of Panama. Some of these were merely unimproved pasture lands, but others, with various improvements, became of military importance, with attendant medical problems. Some time was to elapse, however, before the idea of establishing a ring of outlying bases changed the basic concept of defense from that of destroying planes over the Canal Zone to one of preventing any enemy from coming within striking distance of it.

To develop needed additional airbases, and to service them, the Service Command, Caribbean Air Force, was brought into being on 18 September 1941.

[140] Except as otherwise indicated, all data in this section have been compiled from the Medical History of the Sixth Air Force, 1929–42.

One week later, three Service Area Commands were established; namely, the Panama Service Area Command, the Puerto Rico Service Area Command, and the Trinidad Service Area Command. The Service Command had control of all Air Corps Stations, Air Corps Bases, and Air Depots in the Caribbean Defense Command, including all service personnel, service units, and fixed installations thereon located. Combat units were thus left free to engage in training or fighting, as occasion might demand. As a matter of record, it should be stated that the Panama Area Service Command never operated under an approved table of organization and was eventually absorbed by the Service Command itself.

Under a reorganization in February 1940, the 19th Composite Wing was made to include the Panama Air Depot, in addition to a number of newly activated units. The first use of the term "Air Force," in connection with these units was in November 1940, when the Panama Canal Department Air Force was activated and assigned to Albrook Field. Certain Signal and Ordnance Corps components were included, in addition to all units making up the 19th Composite Wing. Maj. William B. Wilson, MC, was designated on 27 January 1941 as Surgeon, Panama Canal Department Air Force.

Major Wilson was replaced by Lt. Col. Ernest F. Harrison, MC, who arrived in Panama, 19 October 1941, and was announced as Surgeon, Caribbean Air Force, 2 days later. Maj. (later Col.) John B. Herman, MC, formerly Surgeon, Albrook Field, became assistant surgeon. Practically all of the planning, organization, and supervision of medical services during 1942 fell to these two officers. This was, of course, the year of greatest expansion and development. In February 1942, Colonel Harrison visited, in person, Curaçao, Aruba, Trinidad, Surinam, Saint Lucia, Antigua, Saint Croix, Puerto Rico, the Dominican Republic, Haiti, Cuba, Guatemala, Nicaragua, and Costa Rica.

The subsequent history of the Panama Canal Department Air Force was as an integral part of the newly formed Caribbean Defense Command, the headquarters of which were activated 8 May 1941, at Quarry Heights. All Air Forces of the Panama Canal Department, together with those of the Puerto Rican Department and the Trinidad Base Command, were immediately combined into the Caribbean Air Force.

Because the Caribbean Air Force had been given practical autonomy by the commanding general of the Caribbean Defense Command, it became necessary to clarify the division of medical responsibility. In February 1942, the Army Ground Forces of the Panama Canal Department, Puerto Rican Department, and Trinidad Base Command retained responsibility for environmental sanitation, veterinary inspections, all quarantine measures, new water supply projects, medical supply and related inspections, and also for general hospitalization and evacuation to general hospitals.

All other medical service of the Air Force operated independently for the next year and a half. It will be seen that long-range, permanent projects for malaria control remained in the hands of the Army Ground Forces which were responsible for "environmental sanitation."

On 6 March 1942, the Caribbean Air Force was redesignated the Sixth Air Force. Colonel Harrison, as surgeon, headed the medical section of that headquarters.

The Trinidad and Puerto Rican areas required the Air Force to face a more serious malaria problem than had been encountered in Panama. Whereas permanent drainage, filling, and construction projects had rendered the Canal Zone relatively safe, a large number of new stations and outposts throughout the Antilles were being established in wholly unsanitated surroundings, insofar as malaria was concerned. In some regions, 80 percent of the native population were infected. It is not strange that the primary malaria rate skyrocketed from the old average of 70 per 1,000 per annum (Panama Canal Department) for the years 1940 and 1941 to a peak in June 1942 of 233 per 1,000 per annum in military personnel.

During this year, numerous airbases, airdromes, and air warning outposts were established. This defense system involved Air Force installations from Guatemala to Peru and from the Greater and Lesser Antilles to the Galápagos Islands in the Pacific. The Panama Area included airbases at Albrook Field, Howard Field, France Field, Río Hato, Guatemala City, Salinas, Ecuador, Galápagos Islands, and David, R. de P., with auxiliary airdromes at Chame, Aguadulce, La Chorrera, and La Joya, all in the Panamanian Republic.

The Puerto Rican Area included the airbases at Borinquen Field, Losey Field, Benedict Field, and Coolidge Field.

The Trinidad Area included airbases at Waller Field, Beane Field, Hato Field, Zanderij Field, and Atkinson Field.

The further establishment of numerous aircraft warning stations made the malaria problem much more real. Many of these were quite isolated and could only be reached by boat, after a 48-hour trip. Organization of the Medical Detachment, 558th Signal Aircraft Warning Battalion, dated from 7 March 1942. When this battalion was disbanded and replaced by the 516th Signal Aircraft Warning Regiment, the Medical Detachment was increased to 9 officers and 67 enlisted men (eventually to 93). Dispensaries were operated at Howard Field, Quarry Heights, and Fort Gulick.

By September 1943, evacuation facilities had been much improved, permitting the medical officers to spend more time on inspection trips and the supervision of sanitary maintenance. As a result, the incidence of malaria was reduced to rates comparable to those found in more sanitated areas. In accordance with published orders, Atabrine prophylaxis was discontinued in October 1944. It was believed that the malaria rate did not increase, because of the vigilance of the men in carrying out all other measures for malaria prevention.

As an outgrowth of the organizations listed above, the 554th Signal Aircraft Warning Battalion was activated 25 November 1944.

The Medical Service of the Sixth Air Force inevitably became interested in the dispersal of DDT from airplanes for the control of insect vectors of disease. Various tests and achievements within the territory of the Caribbean Defense Command have been discussed previously. These results, and similar reports of success in many theaters, led the Office of the Air Surgeon, Washington, D.C., to propose the activation and training of Air Force insect control units. Such units were to consist of certain experienced flying personnel trained in low-level flying, together with malariologists, entomologists, and sanitary engineers, in addition to necessary ground and supporting elements.[149] Notice to this effect was sent the surgeon of the Sixth Air Force on 3 May 1945. It is not known if any such units were ever activated for service in the Caribbean Defense Command.

The Air Transport Command

The Caribbean Wing (later redesignated the Caribbean Division) of the Air Transport Command became of greatest importance during the latter half of the war. It had its malaria problems, but, being forewarned, was forearmed and of course made use of well-developed and already sanitated facilities. Excellent general malaria control and individual discipline were reported from Atkinson Field,[150] only two cases of malaria having occurred over an extended period. The flight surgeon carried on a program of medical education here as at other bases. Transient personnel were briefed daily with particular stress on malaria. Suppressive treatment, individual preventive measures, and the use of the Aerosol bomb were given emphasis. A 4-hour malaria course for officers and enlisted men was repeated every few months.

At Waller Field, only one case of malaria was reported during 3 months. Bed nets were required and barracks were sprayed, though the efficiency of the latter might be doubted as, at first, open barracks prevailed and only Aerosol insecticide was available for much of the time. Spraying time was increased in an attempt to compensate for this. For the last 3 months of 1944, there was no malaria among Air Transport Command personnel at Waller Field. As reported on 1 January 1945, mosquitoes were few, a reflection of the efficiency of the insect control program. The post was well drained, the barracks well screened, all screens were inspected at least once a week, and a continuous program of oiling, spraying, and clearing was in operation.[151]

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[149] Letter, Brig. Gen. Charles R. Glenn, Deputy, The Air Surgeon, to Surgeon, Sixth Air Force, 3 May 1945, subject: Transmittal of T/O and T/E for Insect Control Unit.

[150] Medical Historical Report, Caribbean Wing, Air Transport Command, From Its Inception through 30 June 1944, subject: Medical Problems, Atkinson Field, British Guiana.

[151] Medical Historical Report, Caribbean Division, Air Transport Command, 1 July–30 Sept. 1944, subject: Malaria, 1107th AAF Base Unit, Waller Field, Trinidad.

The Caribbean Air Command, 1946

The malaria rates among personnel in the Caribbean Air Command for September 1946 are shown in the following tabulation:

Unit (including subbases)	*Rate per 1,000 per annum (all recurrent)*
Albrook	5.1
Howard	5.6
France	21.1
Borinquen	6.5
Panama Coastal Frontier	5.2
Caribbean Coastal Frontier	4.3
Entire Command	4.72

No clinical malaria was present at the Panama Air Depot, Rio Hato, Beane Field, Coolidge Field, Vernam Field, Atkinson Field, Waller Field, or their satellites.

It will be noted that no primary malaria occurred. During the previous month (August 1946), the primary rate for the Caribbean Air Command was 5.6; for September 1945, it had been 9.6.

The good results shown in this particular report reflected the assumption of part of the control work by post engineers. This work had previously been performed by hiring laborers who were paid out of Medical Department funds.

Airplane spraying of DDT was also beginning to make itself felt. By this time, such procedure had become routine at Howard Field, France Field, and Río Hato Air Field in the Panama coastal frontier area. In the Caribbean coastal frontier area, airplane spraying was being used when necessary. At all outpost stations, individual protection was emphasized.

COOPERATING ORGANIZATIONS (NONMILITARY)

The Rockefeller Foundation

The history of malaria control in this area during the war years was intimately involved with the previous and continuing activities of the International Health Division of the Rockefeller Foundation.[156] Malaria surveys, field studies, and control activities were carried out in Puerto Rico from 1920 to 1936. In 1924 and from 1940 to 1943, surveys and field studies were conducted by the Foundation in Haiti. From 1928 to 1933, Jamaica had received similar attention. There were Foundation malaria projects in Costa Rica, 1928–40; Honduras, 1927; Nicaragua, 1920–25; Panama, 1926–39; El Salvador, 1934–42; Cuba, 1935–42; British Guiana, 1938–46; Trinidad, 1941–46; and Colombia, 1929, 1932–48.

[156] Annual Reports, Rockefeller Foundation, 1920–1948.

U.S. Public Health Service—Malaria Control in War Areas [153]

The office of MCWA was established in February 1942 [154] to organize a control program which would utilize the resources of the Work Projects Administration and State health departments, supplemented by direct operations on the part of the U.S. Public Health Service when other resources were inadequate. Control work outside military reservations was closely integrated with that carried on by military authorities within the boundaries of the various posts. Operations began 17 March 1942.

Insofar as the Caribbean Defense Command was concerned, activities centered in Puerto Rico and, to a lesser extent, in Jamaica.

By the end of 1941, the Navy had begun the vast Roosevelt Roads Naval Base, and Puerto Rico became strategically important in many ways. It was a base for antisubmarine operation by both sea and air.[155] Military installations were located for tactical and strategic purposes, of course, and this usually involved localities where both hyperendemic malaria and infected mosquitoes were to be found. All Army posts except Borinquen Field were poorly located in this respect, as were the two major naval bases at Ensenada Honda and Vieques. Night duty was especially hazardous at coast artillery, searchlight, and antiaircraft installations. One-third of the first group of marines sent to Vieques island came down with malaria within 3 months after landing there.

During 1941, an attempt was made, utilizing Work Projects Administration labor, to carry out antimalaria work near military bases. This effort, sponsored chiefly by the Insular Health Department, came to very little because of material and equipment shortages and lack of trained personnel. The malaria attack rate in military personnel continued to rise.

When MCWA began operations in Puerto Rico, it was agreed with the Insular Health Department that all antianopheline projects around military bases would be carried out directly by the U.S. Public Health Service. This enabled local funds to be concentrated chiefly on malaria control in rural areas and civilian population centers, with particular emphasis on the provision of antimalarial drugs.

Malaria Control in War Areas confined its first work to the vicinity of the four major Army posts and the two naval bases mentioned previously. The Army posts were Fort Buchanan, Losey Field, Camp O'Reilly, and Camp Tortuguero. The Army and Navy did as much intracantonment work as possible, while the U.S. Public Health Service devoted itself primarily to extracantonment activities.[156]

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[153] Much additional information concerning Malaria Control in War Areas is scattered throughout other portions of this section and need not be duplicated here.

[154] Malaria Control in War Areas, 1942–43, p. 34. *In* Summary of Activities, Office of Malaria Control in War Areas, U.S. Public Health Service, 1943–46.

[155] Pratt, H. D., and Stephens, P. A.: History of MCWA Operations in Puerto Rico, 1942–1946. [Official record.]

[156] Belten, J.: The Prevention of Malaria Among the Military Forces in Puerto Rico. Bol. Asoc. méd. Puerto Rico 35: 89–96, March 1943.

Four types of extracantonment control were available, all calculated to reduce the numbers of mosquito larvae. These were the (1) use of paris green (a stomach poison), (2) use of oil (acts primarily on respiratory organs), (3) drainage projects (designed to remove water before a generation of mosquitoes can be produced), and (4) filling operations (to eliminate depressions in which water often stands).

Manmade breeding places were very common. At Fort Buchanan, the incidental filling of drainage ways had caused flooding into old pasture lands, sugarcane fields, and mangrove swamps. At Camp O'Reilly, a network of roads (without culverts) at the very center of the encampment had dammed the ditches and thus formed breeding places, while borrow pits and old stream channels, not filled in, produced mosquitoes in the immediate vicinity of the barracks. At Ensenada Honda, also, roadbuilding and general leveling had blocked many drainage courses, and the constant efforts of over a hundred laborers were required to keep conditions from becoming a menace.

At Fort Buchanan and Losey Field, subsoil tile was first employed in drainage projects. Later, however, centrifugal pumps were used in low-lying areas, not only to lift water from below sea level but also to facilitate drainage from land not more than 3 feet above sea level. The water was led off through large, open, outfall canals.

Larviciding crews were employed in the afternoons on minor drainage work, whenever winds became too strong to do effective dusting with paris green. During the more active breeding season, water was not allowed to go undrained or untreated in any place for more than a week, as this time represented the development period of a mosquito generation under favorable conditions; 2 days for the eggs, 1 day for each of the four larval stages, and 1 day for the pupa.

It was difficult to evaluate the merits of larviciding and drainage as compared with measures aimed directly at the adult mosquito. Because of improvements in types of mosquito traps, nightly counts of captured adult anophelines sometimes rose, even when field control conditions were becoming increasingly effective. Certainly the "safe index" under one set of conditions cannot be taken as reliable in another setting, though the MCWA did use an index of "5" as a tentative aiming point for keeping malaria at a minimal level.[157]

Mosquitoproofing of barracks, supplemented by spray killing of the few mosquitoes which succeeded in entering buildings, must receive a great deal of credit for reducing malaria transmission but only in partnership with attacks made concurrently on the breeding grounds of the vector hosts. It would be unfair to state that antiadult procedures were chiefly responsible for marked

[157] Henderson, J. M.: Antimalaria Measures for the Protection of Military Personnel in Puerto Rico and Their Applicability to Civilian Malaria Control. Puerto Rico J. Pub. Health & Trop. Med. 20: 419–445, June 1945.

decreases in the incidence of malaria among the troops. Also important is the fact that apparent decreases in malaria usually needed interpretation. Early morbidity reports did not distinguish between primary attacks and recurrent conditions, whereas later reports did. Intelligent comparisons required careful study.

A point of interest brought out in the Bolten report [158] is that larviciding, usually advocated where drainage cannot yet be undertaken, was rarely effective in Puerto Rico until after a certain amount of preliminary drainage had been accomplished. This reduced the breeding areas to a point where real control might be accomplished with the facilities available. Otherwise, in spite of a good larvae kill (90 percent with paris green), materials and labor were often wasted.

A malaria board was formed, consisting of the Antilles Department malaria control officer, a representative of the Corps of Engineers, U.S. Army, and the Chief of Operations, MCWA. This board visited various U.S. Army posts throughout the Caribbean, including those in leased territory. One outcome of this visit was the institution of an extracantonment program in the vicinity of Fort Simonds in 1944. Unusual rainfall late in 1945 created a special problem here, which was met by weekly spraying from the air with 5 percent DDT in diesel oil, utilizing a plane based on Borinquen Field.

In 1945, the U.S. Public Health Service carried out an urban malaria control project at Ponce in cooperation with the Insular Health Department and the Puerto Rican Work Projects Administration. The next year saw a DDT residual spray project at Santa Isabel.[159]

The MCWA field station in Puerto Rico rendered monthly reports on its activities for the entire period, 1942–45. These were submitted to the Division of States Relations, U.S. Public Health Service, until that Division became part of the Bureau of State Services, after which reports were sent to that office.

In the fall of 1945, the MCWA notified both the Army and the Navy that it proposed to close out its operations in Puerto Rico. Both arms of the service, however, requested that the U.S. Public Health Service continue its operations, modified in accordance with need and availability of funds. This was approved by the Federal Security Administrator, after which a joint malaria control organization was established. The administrative body was the Joint Army-Navy-Air Force-U.S. Public Health Service Malaria Control Committee, to be known later as the Joint Army-Navy-Air Force-U.S. Public Health Service Malaria Control Board. This agency continued to function until about midyear 1950. The coordination of intracantonment and extracantonment activities under this arrangement appears to have been excellent.[160]

After the war, the "Malaria Control in War Areas Program" of the U.S. Public Health Service was superseded by the "Extended Malaria Control Pro-

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[158] See footnote 156, p. 241.

[159] See footnotet 155, p. 241.

[160] Annual Report, Surgeon, U.S. Army Forces, Antilles, 1949.

gram."[161] Whereas the first was calculated to protect military personnel from malaria indigenous in war areas, the second was devised to forestall the possibility of the transmission of malaria from returning servicemen to civilian populations. Residual spraying of houses with DDT was undertaken in Puerto Rico on an experimental basis. The village of Playa de Humacao was sprayed three times at intervals of 6 months. Blood film surveys over the period concerned showed a drop in positive percentage from 5.8 in November 1944 to 0.9 in November 1945. In the unsprayed village of Loíza Aldea, the percentages were 4.7 and 3.8, on corresponding dates. These desirable results of the residual spray program are all the more striking since *A. albimanus*, the principal vector, seldom remains within houses except for a few hours during the night and thus has no extended opportunity to acquire a lethal dose of DDT.

Inter-American Cooperative Health Services

A force affecting at least indirectly both the health of troops and the health of civilian labor in the American Tropics was the Institute of Inter-American Affairs. Key defense areas and those producing critical war materials received particular attention.[162] The establishment and supervision of airbases, the protection of rubber workers in the Amazon, and the sanitation of camps for highway and railroad workers all furnished occasion for activity, especially in the field of malaria control.

The malaria program was part of a concentrated health campaign entered upon jointly by 18 American Republics, including the United States. At a meeting of American foreign ministers in January 1942, the importance of the mobilization of vital forces was recognized, and, 1 month later, the Health and Sanitation Division was established in the Office of the Coordinator of Inter-American Affairs. It became the responsibility of this Division to extend and amplify the work done by the Rockefeller Foundation (International Health Division) and the consultant services of the Pan-American Sanitary Bureau.

The Institute of Inter-American Affairs was a corporate unity, set up by the Coordinator of Inter-American Affairs to administer funds and execute cooperative agreements between the United States and other American Republics. Funds, voted by the U.S. Congress, were assigned to the Institute for administration. By mutual agreement, each republic formed a cooperative health service, as an integral part of its National Department of Health. Any project, such as malaria control, was the joint responsibility of the field representative of the Health and Sanitation Division of the Institute of Inter-American Affairs and a representative of the National Department of Health of the republic concerned. Technical field parties sent from the United States

[161] Link, V. B.: A Preliminary Report on Malaria Control by DDT Residual Spraying. J. Nat. Malaria Soc. 6: 124–130, June 1947.

[162] Dunham, G. C.: Malaria Control Activities of the Institute of Inter-American Affairs. J. Nat. Malaria Soc. 3: 31–38, March 1944.

were supplemented by local personnel. Funds and equipment were also supplied from both sources.

Towns in the Republic of Panama which lay along the Inter-American Highway and the Trans-Isthmian Highway received malaria control sanitation under a continuing project directed by the Chief Health Officer, the Panama Canal. In that connection, the Chief Health Officer acted as representative of the Office of the Coordinator of Inter-American Affairs. The benefit to the military was obvious, as many of these towns were close to military installations, and were visited frequently. Two objectives were sought: the reduction of the gametocyte reservoir and the reduction of the adult anopheline vector population.

Though conceived in response to an emergency situation, the machinery set up by the Inter-American Cooperative Public Health Services was destined to develop a pattern for continued, cooperative effort in the field of international public health. The translation into Portuguese of "Practical Malariology,"[163] a National Research Council publication, for the benefit of malariologists working in Brazil, is an example of postwar activity on the part of the Institute of Inter-American Affairs.

MISCELLANEOUS MATTERS

Allocation of DDT

When DDT was available in pounds, rather than tons,[164] very careful calculations were made to insure a fair distribution to all theaters. For example, recommended allotments out of the 50,000 pounds available for larviciding purposes in April 1944 were as follows:

	Pounds		*Pounds*
Southwest Pacific	12,000	Caribbean Defense Command	1,500
South Pacific	12,000	South Atlantic	500
China-Burma-India	10,000	Central Pacific	500
North Africa	10,000	Continental United States	1,000
Middle East	2,000	Special use	500

The Caribbean and South Atlantic Commands together were thus allotted only 2,000 of the 50,000 pounds, or 4 percent. This does not mean that the malaria problems of these areas had become trivial, but rather that the majority of troops therein were at established posts, protected by permanent control measures, a situation which contrasted sharply with the shifting conditions imposed by combat activities in undeveloped countries.

[163] See footnote 8 (4), p. 126.

[164] Memorandum, Maj. O. R. McCoy, MC, Director, Tropical Disease Control Division for the Quartermaster General, attention: Maj. Allan R. Kemp, 30 Mar. 1944, subject: DDT for Mosquito Larvicide Use.

Anopheline Vectors West of the Andes

On the west coast of South America, three species of *Anopheles* are important.[165] *Anopheles albimanus* occurs mostly below 900 feet but has been recorded from altitudes as high as 5,000 feet. The egg of this species is somewhat resistant to drying and survives at least in the moister mud, throughout the rainless season. *Anopheles pseudopunctipennis* is never found at sea level. Its range extends from around 300 to something less than 10,000 feet. *Anopheles punctimacula* is found from sea level to 5,000 feet and is often associated with the culture of rice. As it prefers animals to man, it is responsible for the transmission of human malaria only when relatively abundant.

In Colombia, [166] *A. darlingi*, *A. albitarsis*, *A. punctimacula*, *A. pseudopunctipennis* and *A. neivai* have been found naturally infected.

In Peru, *A. pseudopunctipennis* is the principal vector, but *A. punctimacula* probably also plays a part.[167] The latter species was known in Peru before 1942 but is now common in the district of Lima and appears to be increasing. Surveys published in 1944 reported sporozoites in the salivary glands of at least six specimens.

By means of precipitin tests, the source of blood contained in the stomachs of captured female mosquitoes may be determined. In Peru, *A. punctimacula*, which is found only in the coastal region, is definitely a human feeder wherever it occurs. The two races of *A. pseudopunctipennis*, however, differ in this respect. The form which predominates on the eastern slope of the Andes is markedly androphilic, but the coastal variety is much less so.[168]

In a certain malarious coastal village of Peru, the local form of *A. pseudopunctipennis* has been shown to prefer almost any common domestic animal to man, and the donkey above all others.[169]

Anopheles pseudopunctipennis is, however, the chief vector in Chimbote, Peru.[170] This industrial port, which rose to importance in 1942, was surveyed at that time. Of 472 children between the ages of 5 and 12, 9.1 percent showed parasites in their blood; 24.6 percent had enlarged spleens. *Anopheles pseudopunctipennis* larvae were abundant in lagoons north and east of the town. *Anopheles punctimacula* was present but in such small numbers as to be considered of no significance.

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[165] Castillo, R. L.: Los vectores de paludismo de los paises de la Costa pacifica de America del Sur y su control. Rev. Kuba 5: 101–105, July–August 1949.

[166] See footnote 28, p. 134.

[167] Villalobos, C. E., and Valderrama Delgado, A.: El *Anopheles punctimacula* en el Peru. Pub. de la Dir. Gen. de Salubridad, Lima, 1944.

[168] Corradetti, A.: Osservazioni sulle preferenze alimentari dell'*Anopheles pseudopunctipennis* e dell'*Anopheles punctimacula* nel Peru. Riv. di parassitol. 9: 129–135, 1948.

[169] Sasse, B. E., and Hackett, L. W.: Note on the Host Preferences of *Anopheles pseudopunctipennis*. J. Nat. Malaria Soc. 9: 181–182, June 1950.

[170] Westphal, E. A., and Horton, R. K.: Malaria Control Work in Chimbote, Peru. Bol. Ofic. san. panam. 25: 798–800, September 1946.

Other Activities of Antimalaria Organizations

The malaria survey as well as the malaria control teams in every area were at times hard pressed to keep abreast of seasonal demands. On other occasions, these technically trained units found themselves with leisure time. Several possibilities presented themselves: (1) Where line troops were in the vicinity, to utilize malaria personnel in giving instruction on malaria discipline; and (2) where facilities existed, to expand the training of survey and control personnel so as to include a knowledge of other parasitic and tropical diseases, insect-borne and otherwise, together with the techniques of their prevention and control. The latter procedure was followed somewhat informally in certain cases, on the initiative of the officer in charge, and with the approval of his immediate superior. The development of the modern preventive medicine company, with its broad interest and responsibility for survey, instruction, and control, stemmed from such beginnings.

CHAPTER V

North Africa, Italy, and the Islands of the Mediterranean

Justin M. Andrews, Sc. D.

Malaria reached its highest level in the North African theater in 1943. According to data obtained from tabulations of individual medical records, there were (excluding readmitted cases) 731 cases of malaria in 1942; 32,811 in 1943; 23,985 in 1944; and 5,765 in 1945. The total malaria attack rates (excluding readmitted cases) per annum per 1,000 average strength were 31.89 in 1942; 71.84 in 1943; 36.92 in 1944; and 16.29 in 1945. It is believed that the high rate in 1943 was due to poor malaria discipline, imperfect Atabrine (quinacrine hydrochloride) supply, and inadequate malaria organization. By 1945, when these defects had been corrected, the rates had lessened considerably.[1]

The most important vector of malaria was *Anopheles labranchiae labranchiae*. Principal gametocyte reservoirs were rural Arab populations and Italian prisoners of war in North Africa, civilian refugees, Italian prisoners of war, impressed Yugoslav laborers, and Italian cobelligerent troops in the remainder of the theater.

The special antimalaria organization as it finally developed was strongly centralized. The Malariologist, North African theater, commanded a detachment of malarologist officers. These were attached to major commands in which they gave technical direction to malaria survey and control detachments. An airplane dusting and spraying-flight detachment was responsible operationally to the theater malariologist.

In Africa and Sicily, main reliance was placed on the physical improvement of streams, oil larviciding, and spray killing with pyrethrum. In Sardinia, Corsica, and Italy, these measures were supplemented and finally overshadowed by the aerial application of paris green and DDT as larvicides and of DDT as a residual building spray. Insect-proofing of buildings was practiced as screening supplies permitted. Personal protective measures were directed throughout the theater and their use stimulated by special training and subsequent reminders. In 1943, all troops were ordered to take Atabrine in suppressive doses. That policy was liberalized in 1944 by exempting troops

[1] Except as otherwise indicated, the data presented in this chapter are based on the following three sources: (1) Annual Report, Medical Section, North African Theater of Operations, U.S. Army, 1943. (2) Annual Report, Surgeon, Mediterranean Theater of Operations, U.S. Army, 1944, vols. 1 and 2. (3) Final Report of the Preventive Medicine Officer, Mediterranean Theater of Operations, U.S. Army, 1945.

in areas where the malaria hazard was negligible. During 1945, suppressive Atabrine therapy was directed only for troops in areas where malaria was an uncontrolled danger.

MILITARY DEVELOPMENT

On 14 August 1942, Lt. Gen. (later General of the Army) Dwight D. Eisenhower was directed by the Combined Chiefs of Staff of the Allied Nations to accomplish the control of North Africa from the Atlantic to the Red Sea and thus to secure positions from which direct attacks could be launched against the southern flank of the European Fortress.

Allied Force Headquarters

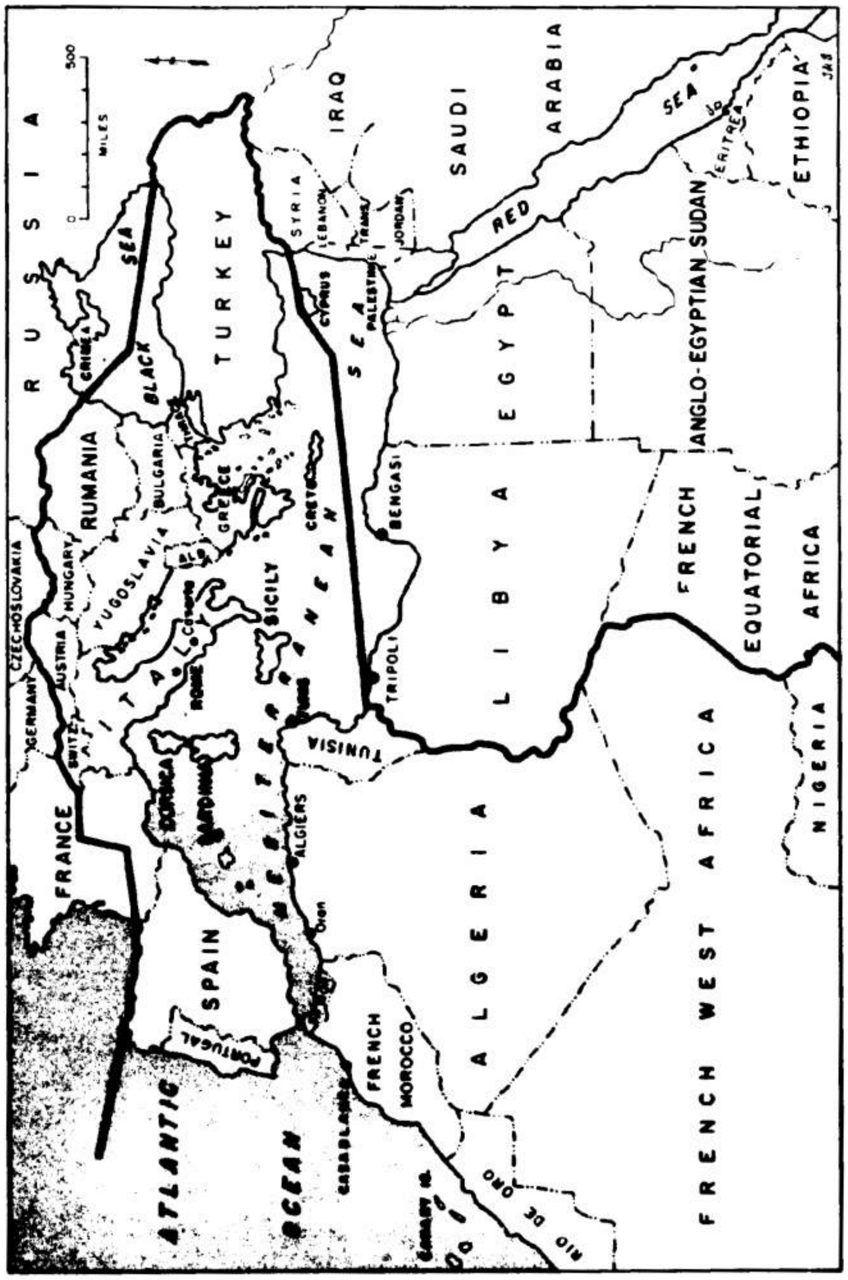
The tactical planning for the intitial operation was begun in London by British and U.S. staff strategists, the latter detailed from the Planning Section, Headquarters, ETOUSA (European Theater of Operations, U.S. Army). On 12 September 1942, this group was officially designated AFHQ (Allied Force Headquarters) and was expanded suitably to function thereafter as a general headquarters. It consisted of general and special staff sections, each of which included British and U.S. personnel and was intended primarily for policy making, planning, and coordination.

North African Theater of Operations, U.S. Army

The British, however, developed their component of AFHQ as an operating as well as a coordinating agency and, with the prompt capitulation of the North African countries and the establishment and expansion of base section organizations, it became apparent that Americans also would have to provide for the centralized administrative and operational supervision of troops. For that purpose, another headquarters known as NATOUSA (North African Theater of Operations, U.S. Army) (map 11) was activated on 4 February 1943. Both AFHQ (American Section) and NATOUSA headquarters operated with the same personnel, though the latter organization required many additional members. They were located initially at Algiers, but during the summer of 1944 they moved to Caserta, Italy.

Services of Supply and Communications Zone, NATOUSA

On 15 February 1943, all supply operations were delegated by NATOUSA to a service of supply echelon with headquarters in Oran. A year later, 24 February 1944, the functions of SOS (Services of Supply), NATOUSA, were expanded to include those of a communications zone organization, and NATOUSA became, from the standpoint of Medical Department function, a planning and consultative agency. Services of Supply, NATOUSA, moved to Caserta during the summer of 1944 and was redesignated COMZONE (Communications Zone), on 1 October 1944.



MAP 11.—North African Theater of Operations, 1944.

Mediterranean Theater of Operations, U.S. Army

Concurrent with the absorption of southern France into ETOUSA on 1 November 1944, the designation of the North African theater was changed to MTOUSA (Mediterranean Theater of Operations, U.S. Army). COMZONE, MTOUSA, was inactivated 20 November 1944, and MTOUSA thereafter assumed responsibility for all operational as well as planning functions.

Operations

The invasion and occupation of Morocco and Algeria, both malarious countries, involved American and British forces. Operations began on 8 November 1942; 3 days later they had been terminated successfully.

The campaign to the east started at once and again American and British troops participated. The struggle for Tunisia was fought over intensely malarious terrain and was not concluded until 12 May 1943.

Sicily, second only to Sardinia in malaria morbidity according to Italian malariologists, was secured by the Seventh U.S. Army and the British Eighth Army. It was a short but bitter contest lasting 38 days, from 10 July to 17 August 1943.

Canadian and British forces started pouring across the Strait of Messina into Italy on 3 September, and, on 9 September, the Fifth U.S. Army landed on the Salerno-Paestum beaches. This was the first of a series of operations destined to lead U.S. soldiers through many highly malarious sections of Italy.

On 8 September, Italy surrendered to the Allied Forces and, within the following month, Sardinia, always the blackest spot on the Italian malaria maps,[2] was liberated by Italian divisions. Corsica was taken at about the same time by Free French troops assisted by American Rangers. Both of these islands were developed intensively as bases from which Army Air Force and Royal Air Force airpower was beamed into Nazi-held northern Italy and southern France.

Fifth U.S. Army troops drove steadily northward up the west coast of Italy. Naples was occupied 1 October and the Volturno River was crossed during the month. The northern advance slowed down with the coming of winter. A firm but tight beachhead was established at Anzio-Nettuno on 22 January 1944. German defenses forced a stalemate until 11 May when a combined offensive launched by the Fifth U.S. Army and the British Eighth Army broke the deadlock.

The Fifth U.S. Army pushed on through the flooded plains of Fondi and Pontinia, historically famed for their malaria hyperendemicity, and, on 25 May, made contact with VI Corps troops from the northern beachhead. On 4 June, Rome was occupied. During the ensuing month, U.S. and British forces continued to drive the enemy northward to a point beyond Leghorn. By the end of the year, the two armies had engaged some 28 German divisions

[2] War Department Technical Bulletin (TB MED) 178, July 1945.

in defense of a line extending across the Italian peninsula, roughly from La Spezia to Ravenna.

On 15 August, the Seventh U.S. Army, composed of U.S. divisions and attached French troops, invaded southern France successfully. The area occupied and exploited by U.S. troops was nonmalarious.

Allied Forces in Italy massed below the Gothic Line until the spring of 1945. On 14 April, their final offensive was launched which took them across the malarious Po River flood plains and into the industrialized areas of northern Italy. On 2 May, this operation was concluded. Contact was made with partisan troops from Yugoslavia, and on 7 May Nazi Germany surrendered unconditionally.

Base Sections

Numerous base sections, area commands, or equivalent organizations were developed for the support of the armies. They were occupied for varying periods of time. The more important ones were located at Casablanca, Morocco; Oran, Algiers, and Constantine, Algeria; Bizerte, Tunisia; Palermo, Sicily; Naples, Leghorn, and Bari, Italy; Cagliari, Sardinia; Ajaccio, Corsica; and Marseille, France (map 12).

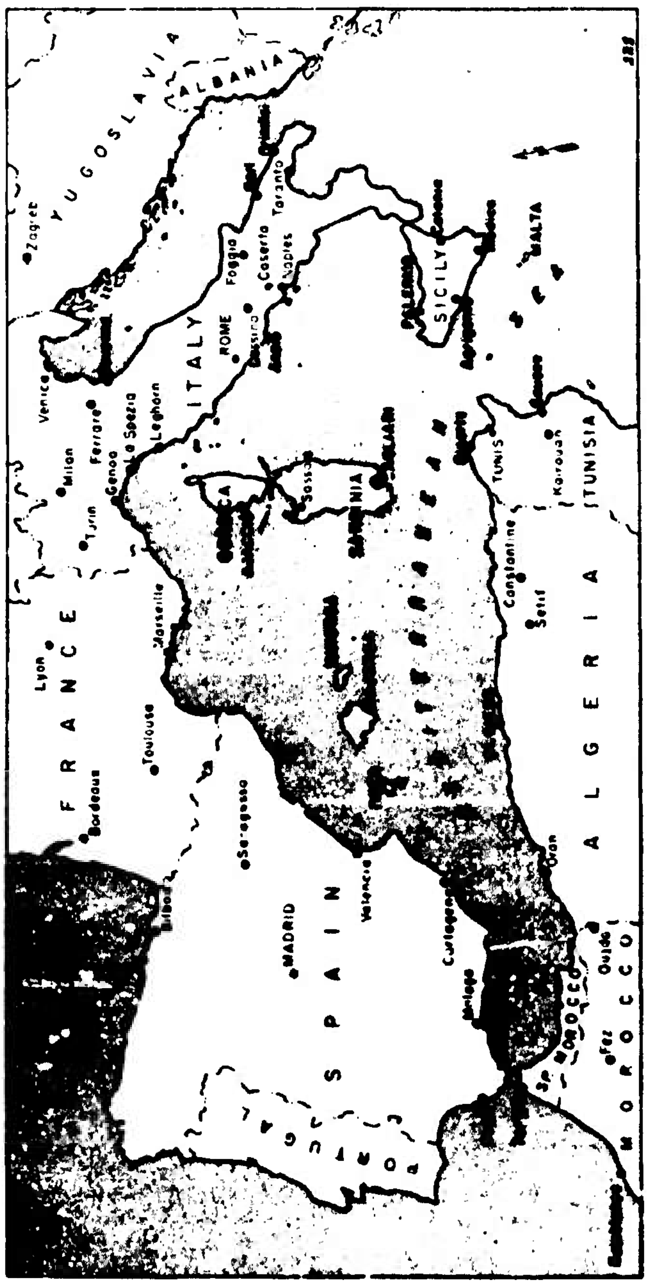
Air Force Installations

Medium bomber facilities were developed mainly on the satellite airfields around Foggia. Light bombers also operated from that side of Italy and from the southwestern coast and from Sardinia and Corsica. Fighter fields were more transient and widespread. They were established throughout the occupied sections of the theater, moving forward as fast as security precautions permitted, though a few units were left in the rear areas to carry on shore patrol, air-sea rescue, and counteraerial combat duties.

AREA CHARACTERISTICS

Geography

The limits of NATOUSA were defined to include the Iberian Peninsula, southern France, Italy, Switzerland, Austria, the Balkans, Turkey, the areas of French, Spanish, and Portugese influence in West and North Africa, and the intervening islands of the Mediterranean (map 11). The actual military operations occurred mainly in the coastal areas of Morocco, Algeria, Tunisia, Sicily, Sardinia, Corsica, Italy, and southern France. All points in the theater were within 900 air miles of Algeria. The entire area lies 30 degrees or more north of the Equator and is, therefore, within the Temperate Zone and has definite winter and summer seasons.



MAP 12.—Principal cities of base sections, area commands, or equivalent organizations, NATOUSA (MTOUSA), 1944.

Climate

Temperatures suitable for the transmission of *vivax* malaria (daily average of 60° F., or higher) occur from late April to November in North Africa, Sicily, and Sardinia.

In Italy and Corsica, the season is shorter, commencing in May or June and ending in October. The presence of semihibernating anophelines in occupied houses and animal shelters throughout the winter months suggests the possibility that infections may be transmitted as late as December or early January.

Temperatures high enough for the development of *falciparum* malaria (daily averages of 70° F., or higher) ordinarily start in June in Morocco and Algeria and in May or June in Tunisia, Sicily, and probably Sardinia. This period terminates in September in Morocco, Algeria, and Sicily but not until October in Tunisia. In Italy, north of Rome, average daily temperatures of this magnitude are not frequent enough to permit the development of *falciparum* parasites in mosquitoes, and *falciparum* malaria in man is correspondingly rare.

Average yearly rainfalls vary from 15 to 30 inches throughout coastal North Africa, Sicily, and Sardinia. In Italy and Corsica, they may be slightly higher. The midsummer months—June, July, and August—are dry or nearly so, particularly in North Africa. Most of the rain falls from October through March.

Surface

The clay soil on the hillsides of North Africa is notable for its lack of ability to absorb water. Vegetation is scarce, evidence of erosion abundant. Water runoff is, therefore, sudden and of great volume. Rivers and streams are swollen, torrential, and fast moving in the spring. By July, they are mere trickles connecting occasional shallow pools or are dried up entirely. In Sicily, Sardinia, Corsica, and Italy, there is a larger proportion of perennially flowing streams, as the water-holding capacity of the earth is somewhat greater. Many of the mountains are higher, their slopes support more prolific plantlife, and snow remains on them for longer intervals. Seepage and runoff into ravines and streams continue over more extended periods of time than in North Africa.

Native Reservoirs of Infection

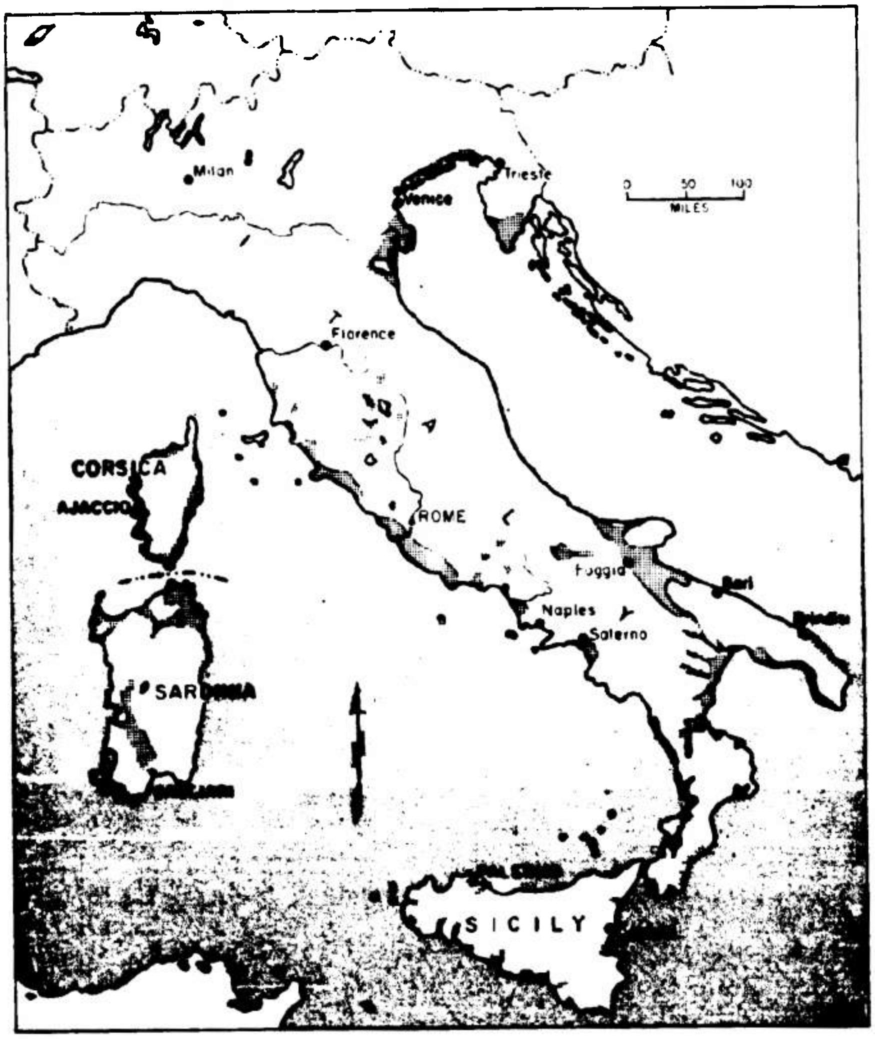
Ordinarily, some 90 percent of the inhabitants of the North African countries are Arabs. With the declaration of war, however, Europeans flocked to Africa to evade the ravages of the conflict. In some instances, the populations of the larger cities doubled in size. The normal European component is predominantly French, but Italians and Spaniards have come into North Africa in such numbers that Italian or Spanish is heard in certain places as frequently as French. These immigrants and refugees contributed little, however, to the malaria potentialities of the region.

The indigenous Arabs of the coastal areas are predominantly plain dwellers, living in close association with agricultural pursuits. Thus, malarious natives—the reservoir of infection for mosquitoes—were most abundant in rural sections along the coast and on the fertile river flood plains extending between the ranges of the Atlas Mountains. Basic dissimilarities in languages, religion, personal hygiene, and other customs impose strong barriers against intermingling with foreigners. Even among themselves, the Arabs are very clannish and, except in cities, had little tendency to associate closely with U.S. troops.[3] This tribal isolation protected U.S. troops against transmission of vermin and diseases ordinarily acquired by direct contact but had no effect in preventing malaria, as it was virtually impossible to avoid siting camps and bivouac areas within mosquito flight range of Arab villages.

While there was some evidence of Arabic participation in the racial stock of Sardinia, Sicily, and, to a less extent, southeast Italy, its influence was never sufficient to hinder fraternization with Allied personnel. The two islands were as much a part of the Fascist State as the peninsula itself and, like it, were peopled predominantly by its nationals. In spite of their previous political affiliations, the Italians as a group and as individuals manifested strong amity for the Americans and appeared to enjoy their company.

The bombing and shelling of cities had resulted in widespread destruction of homes and dislocation of the Italian population. The terrified inhabitants moved into underground shelters or out into the country where they lived in caves, barns, public buildings, under bridges, or wherever they could find protection from the weather and bombardment. Many of them had left their homes precipitately and were, therefore, destitute, hungry, and lacking in sufficient clothing. They had no medical service and were as accessible to mosquitoes as the beasts of the field. In time, they constituted a huge reservoir of gametocyte carriers. In their desperate efforts to obtain the necessities of life, they tended to come into close association with Allied troops and thus facilitated the transmission of malaria. In addition to refugees, the areas were jammed with thousands of demobilized Italian soldiers. Many of these had seen service in the Balkans, North Africa, Ethiopia, Italian East Africa, and Sardinia, where they had experienced malaria from which they relapsed repeatedly. A large proportion of these ex-soldiers and of other young male civilians were formed into Italian labor units which lived and worked in close proximity to U.S. and British bivouac areas. They required extensive and continued treatment for malaria and must have contributed largely to local mosquito infection (map 13).

[3] Personal observations of the author who supervised malaria control activities on a theaterwide basis in North Africa, Sicily, Italy, Sardinia, and Corsica, from May 1943 to January 1945.



MAP 13.—Distribution of malaria in Italy, Sicily, and Sardinia, 1944, and in Corsica, 1943.

In Sardinia, the potentialities of the highly infected civilian population were enhanced by the presence of some 200,000 Italian troops and Yugoslav laborers impressed by the Axis. They had been there for two malaria seasons. Their military organization had disintegrated completely, and they were scattered all over the island, living from hand to mouth as best as they could.

They suffered severely from malaria, and numerous deaths were ascribed to this disease. Many were employed as guards and laborers by U.S. military organizations and thus increased the likelihood of local anopheline infection.[4]

The Corsicans are of French and Italian ancestry. They are extremely independent people and did not associate with U.S. and British soldiers as extensively as did the natives of Italy, Sicily, and Sardinia. Historically, the island is reputed to be highly malarious (map 13). It is the custom of coastal plain farmers to move their families from the lowlands up into the hillside and mountain villages to escape the heat and fever of the summer months. This suggests that a considerable number of gametocyte carriers exist normally among the native Corsicans. To this must be added the infection potentialities of the 5,000 Yugoslav laborers imported from Sardinia. Most of them arrived at the height of the relapse season, and many were taken directly from the ship to the hospital with malaria attacks. They were ordinarily quartered in small camps adjacent to Allied establishments.

Because of the paucity of malaria survey detachments in NATOUSA and the necessity of using them as malaria control units, no widespread systematic effort was made to determine spleen and parasite rates in native populations adjacent to U.S. troop installations. Occasional spot surveys supported the ever-present clinical evidence of malaria morbidity with which gametocytes and consequent local mosquito infection must have been associated.

Vectors

The most important vector of malaria in the North African and Mediterranean theaters was *Anopheles labranchiae labranchiae* Falleroni 1926 (fig. 29). In North Africa and Sicily, the map of its distribution was virtually that of the river systems in the plains. It was found generally in permanent sunlit, vegetated, clear waters. Pools, backwaters, along the indented edges of streams and rivers, collecting basins, poorly maintained irrigation ditches, canals, seepages (especially from leaky irrigation systems over grassy areas), wells and cisterns, foxholes, founts, and fresh-water lagoons with peripheral marshes, all supported larval growth of this species. During the early part of the season, this species was found predominantly in the flooded areas adjacent to permanent bodies of water. As these flooded areas contracted during the summer, the larvae were found mainly in pools, edges of rivers, streams, and seepages. As the process of natural drying went still further, *A. l. labranchiae* invaded the neglected irrigation systems and wells. It is a versatile, adaptable species tenaciously maintaining itself in fresh and brackish water, being limited principally by low temperatures, shade, pollution, turbidity, high salt content, and brisk flow.

[4] Because of the general practice of maintaining many of these infected individuals close to U.S. troops, one harried malariologist referred to them as "our mobile pool of gametocyte carriers."

[5] War Department Technical Bulletin (TB MED) 125, December 1944.

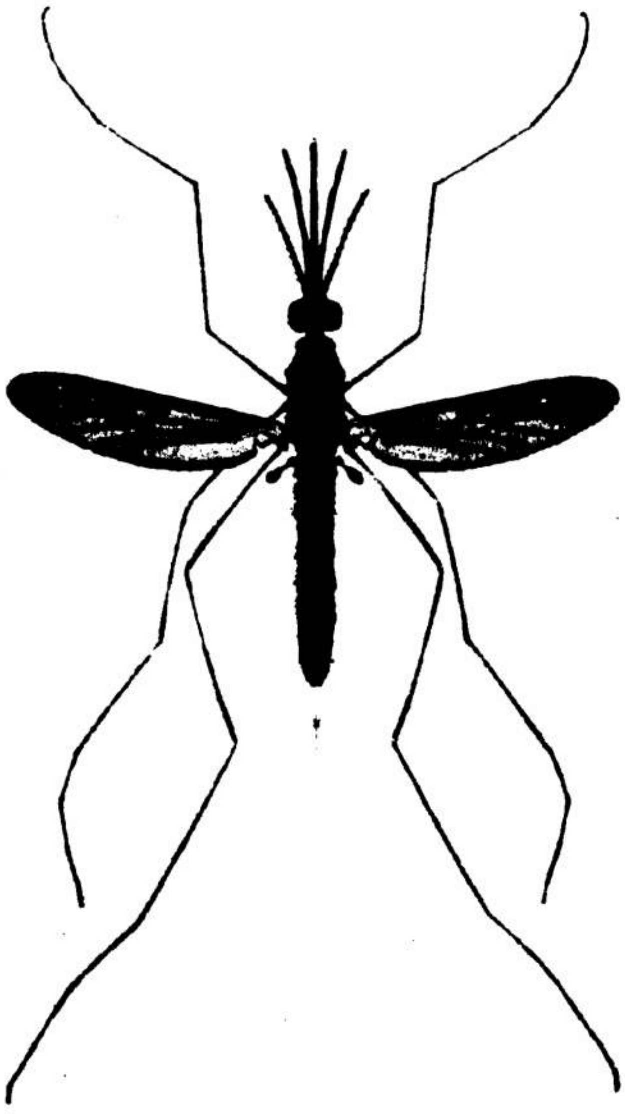


FIGURE 20.—Adult female of *Anopheles maculipennis* Meigen. This mosquito is identical in appearance with *Anopheles labranchiae labranchiae* Falleroni, principal vector of malaria in the north African and Mediterranean areas. (From J. Hyg., Lond. 1: 451, 1901.)

FIGURE 30.—Enemy-demolished pumping station near Licola, northwest of Naples.

In Italy and Sardinia, the larvae grew abundantly not only in rivers and streams but also in water held by unmaintained canals, ditches, tank traps, slit trenches, foxholes, shell and bomb craters, subterranean shelters, gun emplacements, and the extensive flooded areas purposely inundated by the Germans (figs. 30 and 31). This type of destruction resulted in flooding enormous areas of farmland, as shown in figure 31. Many of these areas became mosquito producing. The natural drainageways in Italy, Sardinia, and Corsica were obstructed by the residues of demolished bridges and hastily built bypasses and fords. These interferences with natural flow created many additional breeding places for *A. l. labranchiae*. On the northeast coastal plain of Corsica, several large lakes with marginal swamps added to the breeding acreage.

The adults of this species bite both man and domestic animals and rest in houses and animal shelters. During the winter, they could be found in small numbers in houses in Morocco. In Italy and Sardinia, they were encountered frequently in houses (especially unoccupied upper rooms) and in concrete pillboxes and strongpoints. They were difficult to find in the winter months in Algeria and Tunisia. In the summer, they were excessively numerous in occupied houses, stables, pigsties, and poultry shelters, especially in untreated areas of Italy, Sardinia, and Morocco. On certain occasions, their densities were so great that estimates of their numbers would be as high as 1,000 or more per square yard of wall surface.

The only other anopheline species presumed to be of vectoral importance were *Anopheles sacharovi* (*elutus*) Favre 1903, and *Anopheles superpictus*

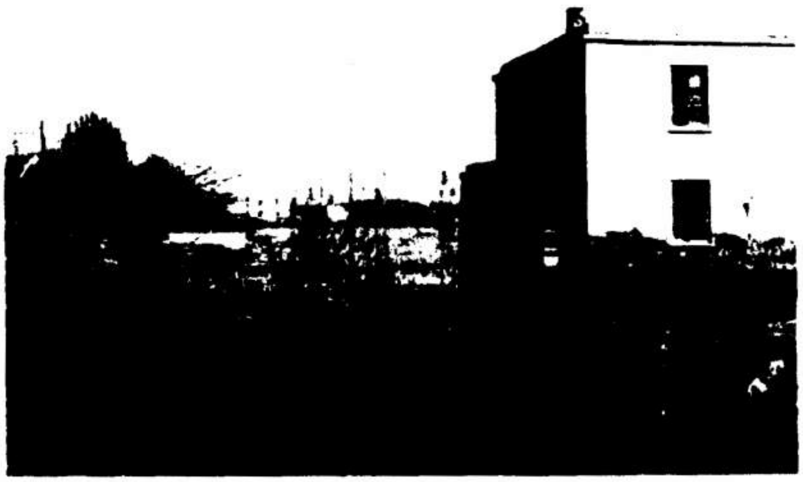


FIGURE 31.—Flooded area near Licola, showing high water mark on the side of the farmhouse.

Grassi 1899. *A. sacharovi* is a coastal form which tolerates somewhat higher salt concentrations than does *A. l. labranchiae*. It was found in the vicinity of Naples and on Corsica but never in any abundance. *A. superpictus*, a species which breeds in highly aerated running streams in the mountains and foothills, was of negligible importance from a numerical standpoint.

MALARIA EXPERIENCE

The total monthly diagnosed malaria rates (provisional) per 1,000 per annum for the theater from 1942 through 1945 are shown in table 30. This portrays well defined but distinctly different trends in a series of three exceptionally interesting annual malaria experiences.

Experience in 1942

Malaria acquired during the last 2 months of the year was minimal, and most of this came from coastal Morocco north of Casablanca.

Experience in 1943

The situation in 1943 was one of a susceptible and inadequately prepared military population exposed to hyperendemic malaria. A suppressive treatment schedule of 0.2 gm. of Atabrine, on 2 nonconsecutive days per week, was

TABLE 30. *Incidence of malaria, by months, in the U.S. Army in the Mediterranean (formerly North African) theater, 1942–45* [1]

[Preliminary data based on sample tabulations of individual medical records and summaries of statistical health reports]
[Rate expressed as number of cases per annum per 1,000 average strength]

Month	1942 [2]		1943		1944		1945	
	Number of cases	Rate	Number of cases	Rate	Number of cases	Rate	Number of cases	Rate
January			517	24.95	1,392	29.11	759	19.25
February			214	10.28	2,214	46.61	636	15.98
March			60	2.24	4,098	72.11	988	20.60
April			86	2.89	4,222	80.24	1,077	28.23
May			180	4.85	3,022	56.67	1,139	31.20
June			1,847	47.82	4,691	89.75	1,002	25.81
July			4,806	112.00	4,341	81.26	639	23.67
August			8,516	191.50	4,897	90.78	392	15.32
September			6,047	129.78	4,870	73.88	111	7.90
October			6,235	122.03	3,270	60.96	32	2.96
November	67	8.58	2,550	53.24	2,030	38.04	21	2.41
December	664	43.92	1,753	34.85	1,235	25.48	4	.88
Total	731	31.89	32,811	71.84	40,682	61.67	6,800	20.52

[1] The 1942–43 data represent incidence; it consists of new cases admitted for malaria and cases in which malaria appeared as a secondary diagnosis. The 1944–45 data are in terms of total malaria attacks, which is comprised of cases readmitted for malaria as well as new primary and secondary cases.

[2] No troops were present in the theater before November 1942.

ordered on a theaterwide basis effective as of 22 April.[6] This order was not enforced for the following reasons:[7]

1. The widespread prevalence of acute intestinal manifestations following the third dose.
2. Misinformation regarding its effects.
3. A lack of comprehension as to its value.

Base sections in Morocco and Algeria achieved some measure of environmental protection against the disease, but combat troops were sorely beset by malaria.

By the time the Sicilian campaign started, hospital admissions for malaria in Tunisia were on the increase. For this reason, many troops scheduled to participate in the campaign failed to embark. Others reached Sicily, but some 700 to 800 of them came down with the disease within incubation periods too short to have been due to infection contracted on the island. During the Sicilian campaign, 9 July to 10 September 1943, hospital admissions for malaria (21,482) exceeded battle casualties (17,375).[8] The new cases could be attributed largely to the failure to call for more than one of the three malaria

[6] Circular No. 38, Headquarters, NATOUSA, 20 Mar. 1943.

[7] Long, Perrin H.: A Historical Survey of the Activities of the Section of Preventive Medicine, Office of the Surgeon, MTOUSA, 3 Jan. 1943 to 15 Aug. 1945. [Official record.]

[8] Report, Malaria in the Sicilian Campaign 9 July to 10 Sept. 1943, Office of the Surgeon, AFHQ, 21 Oct. 1943.

survey and control units which had been earmarked and readied for the invasion. This one unit arrived on D+4, but the troops advanced so rapidly that no antimalaria operations could be organized en route. Even after they were established in Palermo, there was more work than one unit could handle effectively. As a result, the troops were denied adequate environmental protection against anophelines.

Poor malaria discipline in both North Africa and Sicily also accounted for much of the morbidity. The remainder was caused primarily by failures in Atabrine supply. These occurred on board ship (lack of coordination between Army and Navy), at rations' breakdown points (where Atabrine was to be issued with the rations), and among forward combat elements for tactical reasons. This last is always inevitable to some degree. Thus, the malaria debacle in Sicily was the result of inefficient malaria control supply, poor malaria discipline, and a quantitatively inadequate special antimalaria organization. The malariousness of Sicily was well known and control and survey units had been prepared to accompany the invading forces, but the Seventh U.S. Army Command would not permit these units to proceed to Sicily in time to render effective aid during the invasion.

The malaria rate reached a maximum in August 1943 of 192 cases per 1,000 per annum which represented about 8,500 cases; this coincided more or less with the end of the Sicilian campaign on 17 August. This overall theater rate fails to reflect faithfully the extent of the malaria morbidity experienced by elements of the Seventh U.S. Army during the campaign. As shown in table 31, weekly rates of diagnosed malaria among II Corps troops are reported to have risen to over 1,700 per 1,000 per year. Corresponding rates of "fever

TABLE 31.—*Admission rates, by weeks, hospital and quarters, for malaria and FUO (fever of undetermined origin) in the Seventh U.S. Army, by major command, during the Sicilian campaign, 16 July–20 August 1943* [1]

[Preliminary data based on sample tabulations of individual medical records]
[Rate expressed as number of cases per annum per 1,000 average strength]

Week ending—	Divisions		Corps troops, II Corps		Army troops, Seventh U.S. Army		Consolidated Seventh U.S. Army	
	Malaria	FUO	Malaria	FUO	Malaria	FUO	Malaria	FUO
16 July	24	26	53	65	50	92	30	37
23 July	50	91	411	220	53	99	92	108
30 July	47	284	163	724	202	288	109	337
6 August	54	453	723	804	428	606	250	556
13 August	185	397	1,734	1,063	514	419	485	483
20 August	40	202	1,090	434	683	570	338	332
Total	63	234	727	582	382	401	232	322

[1] The average strengths for the weeks indicated were respectively, as follows: Divisions, [illegible]; Corps troops, II Corps, [illegible],157; Army troops, Seventh U.S. Army, 47,[illegible]; and consolidated Seventh U.S. Army, 1[illegible].

of undetermined origin," a collective diagnostic term which included indeterminate proportions of malaria, sandfly fever, and other unrecognized pyrogenic disorders, were as high as, or higher than, the malaria rates.

Because of the rapid increase in the number of cases, the Seventh U.S. Army adopted a suppressive treatment schedule of 0.1 gm. of Atabrine 7 days a week starting on 14 August 1943.[9] This increased dosage was well administered and tolerated. It was continued for about 3 weeks and probably accounted for the drop in the rate in September to 130 per 1,000 per annum. The relatively high rate in October was the result of the Salerno landings made by the Fifth U.S. Army on 9 September: discipline in taking suppressive Atabrine became lax in the heat of battle and at a time when mosquito transmission was still occurring.

With the coming of cold weather, the rates dropped off rapidly. As will be pointed out in the following paragraphs, many more infections not manifested in 1943 undoubtedly were contracted during the fall months of that year but were suppressed by Atabrine and remained dormant during the winter months. By the end of the year, 32,811 new cases were recorded, an annual rate of about 72 per 1,000. The number of recurrent cases is not known, but it is surmised that the new cases constituted 90 percent or more of the total malaria attacks. Since the primary cases reported during the winter and spring months of 1944 were practically all contracted during the previous season, the rate of transmission in 1943 must have been much higher than the hospital admission rates indicated. About 19 percent of the year's infection were *falciparum* malaria, 48 percent were *vivax* malaria, 1 percent were quartan, less than 1 percent were the mixed type, and 32 percent were undetermined as to type.

Experience in 1944

Troops were well established on the Italian mainland by 1944. Suppressive Atabrine, 0.6 or 0.7 gm. per week, was ordered as of 1 May on a theaterwide basis except in areas which were nonmalarious or where malaria was considered by the area surgeons to be under control.[10] The breakthrough at Anzio on 25 May permitted troops to push north through the flooded Pontine marshes. The advance continued across highly malarious coastal lowlands, passing through Civitavecchia, Tarquinia, Orbetello, Grosseto, and Piombino. DDT was sprayed in forward areas, sometimes in advance of artillery units. With the advent of winter, troops were operating in the mountains north of Pisa and Florence and were out of malarious country. Throughout this period, additional U.S. forces (largely Air Corps) were occupying the insalubrious islands of Sardinia and Corsica.

Table 30 shows a sharp rise in spring cases with a rate of 80 per 1,000 per annum in April 1944. While many of these cases were relapses of infections

[9] See footnote 7, p. 262.
[10] Circular No. 12, Headquarters, NATOUSA, 28 Jan. 1944.

contracted the previous year, a large proportion (approximately 40 percent) gave histories of no previous malaria. A few of these may have been contracted during the spring months, but the majority of these primary attacks undoubtedly represented late 1943 infections either suppressed by Atabrine or showing extraordinarily long incubation periods typical of certain strains of *vivax* malaria. The proof of this assertion rests on the observation that little or no spring malaria occurred in divisions entering the theater during the late winter of 1943–44. Indeed, their early cases were invariably in replacement or attached personnel from other divisions which had seen service in the 1943 campaigns. Thus, while 40,682 represents the total number of cases recorded for the year, a rate of about 62 per 1,000 per annum, most, if not all, of the 15,348 cases occurring before June are attributable to infections acquired during the 1943 season. In all probability, many of the relapses appearing after the beginning of June also should be referred back to 1943. Of the laboratory-diagnosed cases, about 5 percent were *falciparum* malaria, 92 percent were *vivax* malaria, less than 1 percent were quartan, and the balance was of undetermined types. Only in Sardinia was the species distribution substantially different: 21 percent *falciparum* malaria, 72 percent *vivax* malaria, and the remainder undetermined. The farther north the troops went in Italy, the fewer *falciparum* cases were reported; they were rare north of Rome.

Experience in 1945

The 1945 season saw a marked reduction in the size of the Mediterranean theater. North Africa was split off and placed under the command of the U.S. Army Forces in the Middle East. The islands of Sicily, Sardinia, and Corsica ceased to be of operational importance, and their military personnel were returned to the Italian mainland. For all intents and purposes, malaria control operations were restricted to Italy in the vicinity of Naples and Rome, around the Army Air Force areas in the Foggia region, in the Arno Valley from Leghorn to Florence, in the Ancona-Timini sector on the northeast coast, and in certain sections of the Po River Valley. While the danger from malaria exposure was considerably less than during the previous two seasons, the fact that troops were generally scattered throughout the malarious areas of Italy during 1945 constituted a situation of potential seriousness.

The Atabrine policy for this year called for suppressive medication only in areas designated as malarious.[11] With the exception of one instance in the Po River Valley where the Fifth U.S. Army specified a few dangerous areas, suppressive treatment was limited to an occasional unit having an unduly high malaria rate or to individuals recovering from an attack.

The start of 1945 found Army troops ensconced in the Apennines north of Florence, preparing for the final offensive into the Po River Valley. After the highly satisfactory 1944 season, it was anticipated that the rise in cases

[11] Circular No. 54, Headquarters, MTOUSA, 9 Apr. 1945.

in the spring of 1945 would be less than in the preceding year. This prediction was fulfilled as the months passed. The peak appeared in May, when a rate of 31 per 1,000 per annum was recorded. Some apprehensiveness was felt concerning the possible effects of the Po River offensive, especially if it slowed down, on malaria prevalence in the troops. Fortunately, the campaign was a short one. The abrupt cessation of hostilities on 8 May 1945 permitted the Army to establish the bulk of its troops in the southern Alps, the remainder occupying isolated areas throughout the Po River Valley. Thus the rise in case number, which had been anticipated in June, failed to materialize. On the contrary, there was a steady drop in the incidence which was quite phenomenal in the light of existing conditions.

With the capitulation of the German armies in Europe, redeployment of U.S. troops to the United States and to the Pacific theaters was initiated promptly. However, while this movement was going on, approximately one-half the theater strength—Air Force and Service troops—was established in malarious areas. As the Army divisions were redeployed, they were required to occupy some of the more dangerous areas while staging. It is believed that the intensive work accomplished by the War Department malaria control units, in addition to the widespread use of DDT as a residual house spray, played a significant role in keeping malaria casualties to a minimum. During the 1945 malaria season, there was a total of 6,800 cases reported in the theater, a rate of 20.5 per 1,000 per annum. Again, as in 1944, the type of malaria was predominantly *vivax* as shown by the following species distribution for the year: 2 percent *falciparum* malaria, 97 percent *vivax* malaria, quartan rare, and the remainder type unspecified.

Primary Malaria Rates

As reported previously, malaria control officers believe that the best appraisal of their efforts and fortune are the trends of new or primary malaria rates. Field malariologists gathered this information more or less independently in NATOUSA during 1943 and more systematically in MTOUSA during 1944 and 1945. On the basis of personal interviews with patients or from forms filled in by medical officers on the wards, they determined from each patient his unit assignment and history of previous malaria. On 1 July 1944, the Medical Section, COMZONE, NATOUSA, required its hospitals and separate dispensaries to use a supplemental communicable disease report in addition to the weekly statistical health report. The new form indicated whether or not patients were assigned to the command to which the hospital was responsible and whether or not the condition for which they were hospitalized (including malaria) was a primary or a subsequent episode. This relieved the base section malariologists of an onerous task and provided better and more extensive operational information for their use. The Medical Section continued to require this report from its base section hospitals and dispensaries after COMZONE had been inactivated.

Table 32 shows a comparison of primary and total malaria attack rates for the months where reasonably dependable data were available. It was admittedly not possible to ascertain the exact amounts of malaria transmitted each year; nevertheless, certain calculations based on reasonable assumptions indic[illegible] at least the relative degrees of transmission each year. According to the t[illegible]ter malariologists, the primary rate per 1,000 for 1943 was probably somewhere in the sixties; for 1944, somewhere in the thirties; and for 1945, it was probably less than ten.

Civilian Malaria Experience in Italy

The relatively favorable military malaria experience in Italy poses the question whether the low Army rates were due to effective control efforts or to nothing more than the good fortune of being present when the malaria potential was reduced abnormally. The answer to such an inquiry would be given by a determination of malaria prevalence in the civilian population at the time of Army occupation. Data concerning malaria morbidity and mortality in the years from 1939 to 1945 in Italy are meager and imperfect, but, such as they are, they tend to indicate a violent upsurge of epidemic malaria among civilians, particularly in the war-torn areas.

TABLE 32. *Primary and total malaria attack rates in MTOUSA, hospital and quarters, per 1,000 per annum by months, 1944–45*[1]

Month	1944		1945	
	Primary attack rates	Total attack rates	Primary attack rates	Total attack rates
January		29	7	19
February		47	6	16
March	..	72	9	21
April		80	15	28
May	39	57	17	31
June	48	70	12	26
July	54	81	13	24
August	64	91	8	15
September	54	74		8
October	38	61		3
November	19	38		2
December	12	25		1
Total	-	62		21

[1] (1) Primary rates are based on malariologists' reports for May and June 1944; on COMZONE, MTOUSA, Supplemental Communicable Disease Reports thereafter. (2) Total rates are based on Statistical Health Reports (Form WD MD 86ab).

Before 1939, malaria was on the downgrade in Italy.[17] At the turn of the century, annual case rates of about 1,000 and death rates of 40 to 50 per 100,000 prevailed. Their steady descent thereafter was interrupted by World War I but reached alltime lows of 126 cases per 100,000 in 1939 and 1.1 deaths per 100,000 in 1940. This was due to the large-scale agricultural development of low, fertile coastal areas. Extensive land reclamation drainage (bonification) by gravity and pumping systems was practiced. This not only abolished large acreages of potential anopheline production but freshened the soil as a result of rainfall and drainage. Thus, it eliminated the dangerous carrier, *A. sacharovi*—a brackish-water breeder—from numerous sections where it had flourished previously. Furthermore, confining the water in these coastal lowlands to drainageways made it possible to apply paris green cheaply and effectively where this supplementary measure was indicated.

During the early years of the war, from 1939 to 1942, malaria increased as shown by the annual malaria morbidity rates per 100,000 reported as follows:

Year	*Rate*
1939	126
1940	137
1941	1[illegible]
1942	178

Actual rates were undoubtedly much higher as the imperfections of peacetime malaria case reporting are always enhanced during wars.

Official vital statistics for the country were not available after 1942; such figures as could be gathered were fragmentary and provisional. From them, it appears that the "heel" area of Italy showed little change in malariousness during the war years. This was the section of the country least disturbed by active warfare. On the other hand, the southwest coastal provinces and those in the northeast (Po River Valley) experienced reported increases of from 2 to 20 times their prewar malaria case burden. From Terracina, Fondi, Gaeta, Cassino, and neighboring rural settlements came reports of hyperendemic and fatal malaria. Similar accounts came from the provinces constituting the Veneto area through which the final offensive of the war was pushed. These are the areas where the hand of Mars was laid most heavily, where flooding, shelling, bombing, and digging in multiplied natural opportunities for anopheline production. Meteorologic influences also favored increased anophelism, but this effect was not productive of such high malaria morbidity rates in the Allied forces as occurred in the neighboring civilian population.

In summary, the evidence indicates that (1) in the face of epidemic malaria prevalence among the Italians in 1944 and 1945, the incidence of malaria in U.S. troops remained relatively low; and (2) the degree of success

[17] Statistics and other information regarding malaria prevalence among Italians were supplied by the Istituto Superiore di Sanita, Roma.

achieved in military malaria control was accomplished in spite of and not because of natural forces.

ANTIMALARIA POLICY AND ORGANIZATION

As in all theaters, antimalaria policy and organization evolved slowly. Until the late spring months in 1943, the malaria control program was in the stage of planning, formulating, obtaining local malaria intelligence, liaison with civilian health agencies, and general development which necessarily precedes the physical organization phase.

Initial Stage

A malaria advisory board was established by the Director of Medical Services, AFHQ, under the chairmanship of Brig. E. R. Boland, the consulting physician (British).[13] All nationalities locally concerned in the problem were represented in its membership which included Lt. Col. Perrin H. Long, MC, Consultant in Medicine, NATOUSA, and, later, the Preventive Medicine Officer and Malariologist, NATOUSA. This group inventoried and assessed malaria control facilities existing in the theater, set the policy for theaterwide suppressive medication, suggested that civilian health agencies be subsidized to provide environmental malaria control for Allied troops around camps and bivouac sites, considered the various malaria problems as they arose in the theater, and made recommendations regarding their solution.

During the early days, Colonel Long acted in the capacity of preventive medicine officer and concerned himself actively in laying the basis for the future antimalaria activities. He held conferences with British and French malaria control representatives and worked out an arrangement with civilian health agencies whereby they were to assume responsibility for the bulk of environmental malaria sanitation in extramilitary areas. Plans were made for a theaterwide suppressive Atabrine therapy program. Requests for special antimalaria personnel and supplies were placed with the War Department. Combat units commenced troop training in malaria control discipline. Exploratory survey operations were launched. Limited control activities—drainage and larviciding—were conducted in those areas where year-round anopheline production occurs. These were directed by Medical Corps or Sanitary Corps officers under the supervision of base section medical inspectors. By the end of May 1943, four survey and four control units had arrived from the United States and had been assigned to various base sections for duty. They immediately commenced malaria survey activities in and about Army installations and acted in advisory and inspectoral capacities with regard to antimalaria activities conducted by the various Army units within their own camps and those carried on by civil organizations insofar as they affected Army personnel

[13] See footnote 7, p. 262.

On 9 June 1943, a theater malariologist and an assistant theater malariologist were designated. The organization to which they belonged, a malaria control detachment recently arrived from Liberia, ultimately became the malaria control headquarters unit for the theater.

Policy Development and Expression

The pattern of administrative responsibility in malaria control as it finally developed was as follows: Malaria control policy and general administrative procedure in NATOUSA (MTOUSA) originated in the medical section of the theater headquarters, with the theater surgeon, the chief of preventive medicine, and the theater malariologist. These were expressed in circulars and administrative memorandums published from AFHQ and NATOUSA (MTOUSA) headquarters. They specified or clarified such considerations as (1) relative responsibilities of various commands in areas jointly occupied by Allied troops,[14] (2) dates for the beginning and ending of malaria control operations,[15] (3) personal preventive measures and suppressive medication, the basis for and method of issuing Atabrine and quinine for suppressive purposes to static and moving troops, (4) the designation of malarious and nonmalarious areas, the theater malaria control organization, (5) command responsibilities for malaria control, (6) allotment of malaria control supplies to individuals and units, (7) enlisted men antimalaria details, (8) malaria control instructions, (9) proper use of personal and environmental preventive measures,[16] the unrestricted use of DDT,[17] and (10) application for airplane dusting service.[18] These directives or pertinent parts of them were republished by subtheater commands.

Supplies

Estimates of theater requirements for malaria control supplies were made and their distribution within the theater suggested in the Preventive Medicine Section of the Surgeon's Office. These were sent to the engineer and quartermaster sections of the theater headquarters, where unfailing cooperation in effecting the recommendations was always evidenced. During each month of the active malaria control season, supplies on hand, in transit, and due into various major depots were inventoried by the malariologist and were reported to the theater surgeon. By this means, a reasonably current picture of the status and the flow of supplies throughout the theater was maintained.

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[14] Administrative Memorandum No. 21, AFHQ, 17 May 1944, subject: Allocation of Responsibility for Malaria Control Measures.

[15] See footnote 10, p. 264.

[16] Circular No. 72, Headquarters, NATOUSA, 29 May 1944.

[17] Letter Order to all concerned, by command of Lt. Gen. Jacob L. Devers, 29 Aug. 1944, subject: Insecticides.

[18] Administrative Memorandum No. 23, AFHQ, 28 May 1944, subject: Allocation of Responsibility for Malaria Control Measures.

Theater Malariologist

The theater malariologist administered the special malaria control organization.[19] He was responsible to the Surgeon, NATOUSA, through the Chief, Preventive Medicine Section, Office of the Surgeon, NATOUSA, and maintained close operational liaison with Col. Paul F. Russell, MC, Chief, Malaria Control Branch, Allied Control Commission, and Brig. George MacDonald, RAMC, British Consultant, Malariologist, AFHQ. Special antimalaria unit situation-and-status reports were submitted to the theater surgeon each month by the malariologist. On his recommendation, malariologists and units were moved as needed from one theater subdivision to another. Efforts were made to distribute the antimalaria units' technical information pertaining to malaria and its control which arrived in the Medical Section, Headquarters, North African theater.

Special Organization for Malaria Control

The organization consisted of a provisional malaria control headquarters unit, War Department malaria survey and control detachments, and a section of a ferrying squadron used to operate dusting and spraying airplanes. In addition, each company, battery, or similar unit maintained enlisted-man malaria details as directed by War Department Circular No. 223, dated 21 September 1943.

It is impossible to assign accurately the proper amount of credit due to the "enlisted-men" or unit antimalaria details for their malaria control achievements because no systematic accounting of their efforts is available. The details were trained and in many instances were supervised by the special malaria control organization. They were mentioned frequently in the local malariologists' reports, but no routine recording of their activities—separate from malaria control accomplishments in general—was ever required or made. It is known, however, that while these were variable in quantity and quality, their aggregate effect must have been very considerable. This was true especially in Fifth U.S. Army areas and in Army Air Force installations.

It was interesting to note that, in the Air Force installations during 1944, these antimalaria details were made up exclusively of Medical Department personnel (except in antiaircraft artillery units) and they worked under the

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[19] On 9 June 1943, Col. Loren D. Moore, MC, commanding, and Lt. Col. Justin M. Andrews, SnC, 2655th Malaria Control Detachment, were attached to the Medical Section, Headquarters, NATOUSA, for duty as malariologist and assistant malariologist, respectively. Shortly thereafter, Colonel Moore was incapacitated by rheumatoid arthritis and ultimately returned to the Zone of Interior.

On 24 July 1943, Col. Louis L. Williams, Jr., USPHS, arrived and was designated theater malariologist. He was stricken with coronary disease on 31 July and thus became unavailable for duty.

On 21 September 1943, Col. Paul F. Russell, MC, arrived and was designated theater malariologist.

On 4 March 1944, Colonel Russell left theater headquarters to become Chief, Malaria Control Branch, Allied Control Commission, and Colonel Andrews was designated theater malariologist.

On 9 January 1945, Colonel Andrews was returned to the Zone of Interior for redeployment. Maj. Thomas H. G. Aitken, SnC, was designated theater malariologist, a position which he retained until after the capitulation of the enemy troops in northern Italy on 9 May 1945 direct supervision of medical officers.[20] This practice was not in conformity with War Department Circular No. 223 which specifies that antimalaria details will be made up of Medical Department soldiers only in medical units. The circumstances which urged this departure from the directive were that: (1) Many Army Air Force units were composed entirely of special technicians with full-time duty responsibilities; (2) Army Air Force medical units were so generously manned that they could afford to supply the men without detrimental effect upon the fulfillment of their primary functions; and (3) the malaria survey and control units scheduled for the Army Air Force were delayed in arriving and it was essential for the Army Air Force malariologist to contrive some sort of working organization to take on the task of providing environmental malaria control. In spite of this contravention of Medical Department policy, the arrangement turned out to be an admirable one. Indeed, it is doubtful if as much work was accomplished, in proportion to total strength, by enlisted-men antimalaria details in other major commands during 1944.

Headquarters unit.—This unit consisted of four officers and seven enlisted men.[21] In the early spring of 1944, it became a provisional NATOUSA organization with 13 officer and 20 enlisted-man position vacancies. Officer members were available for attachment to surgeons' offices in base section, Army, and Army Air Force headquarters for duty as malariologists. These malariologists had technical direction of the malaria survey and control units assigned or attached to their respective headquarters. As long as considerable numbers of U.S. troops were maintained in Africa, they coordinated the work of French health agencies doing malaria control in the neighborhood of military installations. Through the malariologists, malaria survey and control unit activities were reported in prescribed form to the surgeon of the organization to which the unit was attached or assigned. Each month, the weekly unit reports, together with accounts of malariologists' activities, were consolidated by the local malariologists and submitted to the local surgeon. These monthly reports were then sent by the latter through channels to the theater surgeon.

Local antimalaria units.—As of 1 July 1943, there were four malaria survey units and four malaria control units in the theater, in addition to the 2655th Malaria Control Detachment. There were no malariologists other than the theater and assistant theater malariologists. By the end of the year, one more survey unit and three more control units had arrived and eight officers (six Medical Corps and two Sanitary Corps) reported in the theater for duty as assistant malariologists. They were assigned to the 2655th Malaria Control Detachment as authorized overstrength pending approval of the revised table of organization for that unit.

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[20] See footnote 3, p. 256.

[21] The 2655th Malaria Control Detachment (Ovhd) was originally activated by the War Department as Medical Detachment 2655 to supervise malaria control activities in and around Army installations in Liberia.

During 1944, 10 more control units were activated and trained in the theater. They were commanded by officers trained in the United States and sent over for that purpose. One more survey unit arrived completely trained. On 1 November, two control units were lost to the theater when ETOUSA took over all U.S. troops remaining in France. Thus, the antimalaria organization reached its maximal strength during the malaria season of 1944; as of 15 August, as shown in chart 8, it consisted of 6 survey units and 17 control units and 14 administrative malariologists, 12 of whom were assigned to the 2655th Malaria Control Detachment.

At the close of the 1944 season, when it was realized that the theater would no longer have commitments in North Africa, Sicily, Sardinia, or Corsica, it was decided to reduce the antimalaria organization both in personnel and units. The officer strength of the 2655th Malaria Control Detachment was cut from 13 to 6, and the antimalaria units were reduced from 17 to 10 control units and from 6 to 1 survey unit. Redeployment of officers took place during the winter months. The 10 oldest units were disbanded in February by War Department order, and all but three officers were returned to the United States. This drastic reduction occasioned considerable concern regarding the security of the malaria program. In order to safeguard it, authorization was obtained from MTOUSA to organize three provisional malaria control units. In addition, two of these units were authorized an overstrength of 14 enlisted men and 1 officer, making a total of 25 enlisted men and 2 officers. Where possible, an attempt was made to obtain men from the old units disbanded in the springs; this policy was successful in retaining about 30 percent of the trained personnel.

Airplane dusting and spraying detachment.—This detachment consisted of American and British pilots in the 327th Ferrying Squadron, Mediterranean Air Transport Service. They operated under the technical direction of the Malariologist, NATOUSA (MTOUSA), an arrangement requested by the Commanding General, Mediterranean Air Transport Service, and concurred in by the AFHQ committee of consulting malariologists consisting of the British Consultant Malariologist, AFHQ, the NATOUSA Malariologist, and the Tropical Disease Consultant, Royal Air Force.[22] In 1944, the U.S. contingent consisted of 9 pilots and 22 enlisted men; in 1945, of 9 pilots and 18 enlisted men; at no time were more than 6 pilots operating planes. They were equipped with two L–5 observation planes, three PT–17 (Stearman) trainers, all of which were equipped for dusting in 1944 with one modified for oiling in 1945, and ten A–20 (Boston) light bombers, four of which were equipped for oiling and six for dusting.

From administrative and operational viewpoints, it was advantageous to base aircraft and flying personnel at as few points as possible. In 1944, practically all the dusting and spraying in Italy was done from Capodichino Airport, though planes and pilots were attached for brief periods to Foggia Main

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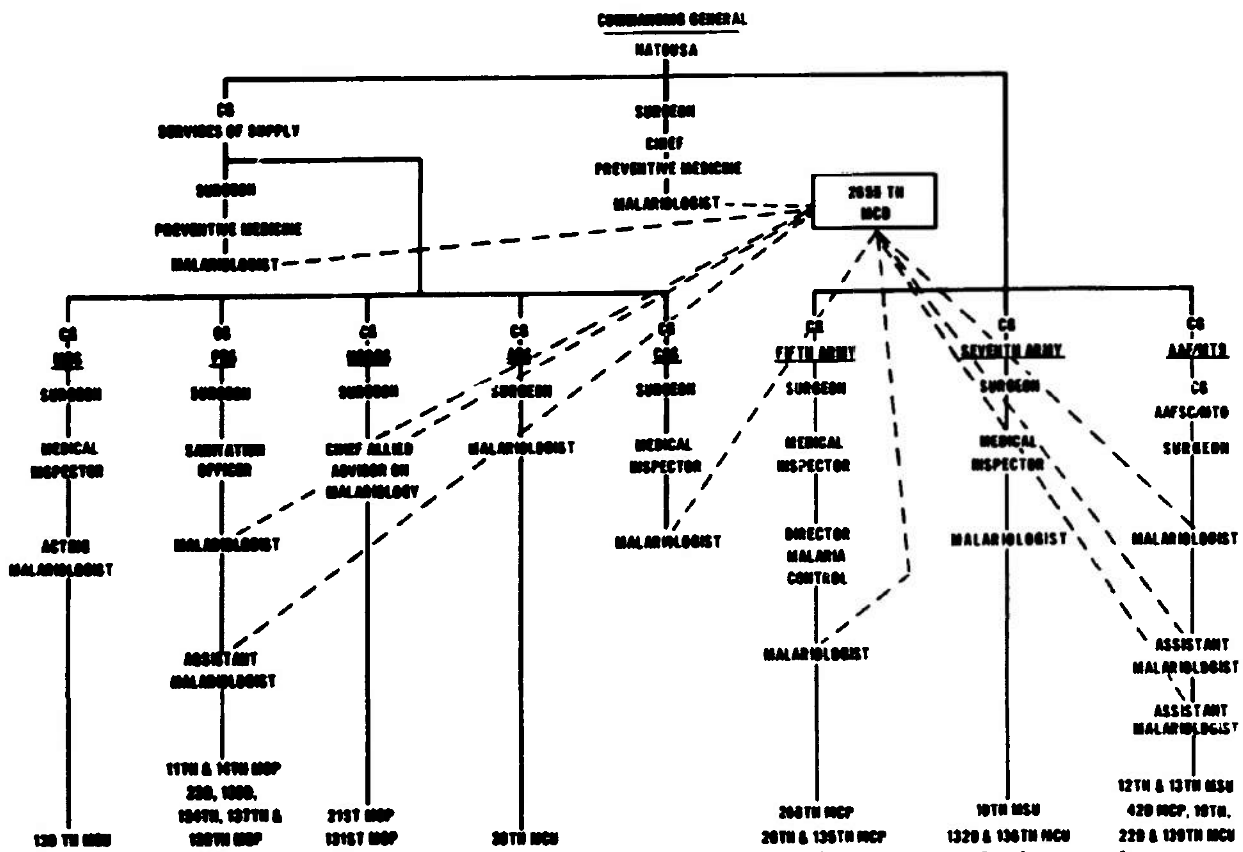
[22] Letter, Commanding General, AFHQ, to Commanding General, Mediterranean Allied Air Forces, 28 June 1944, subject: Malaria Control by Airplane Dusting.

CHART 8.—*Special malaria control organization, North African theater, 15 August 1944*[1]



[1] Broken lines indicate special technical channels in addition to usual technical channels through surgeons of major commands.

Airport in east Italy and at Castiglione del Lago Airfield in central Italy. Other separate installations remained for the entire season in Sardinia and in Corsica. In 1945, a home base was maintained at Capodichino with advance bases set up in northern Italy in the Leghorn-Pisa sector and in the Rimini-Verona area.

ANTIMALARIA ACTIVITIES

Training

The need for troop understanding of and familiarity with the procedures of malaria hygiene and sanitation was clearly recognized by Colonel Russell, theater malariologist, during the latter months of 1943. He urged the development of an Allied, theaterwide, malaria control teaching project as a winter activity for antimalaria personnel. This was directed forthwith[23] and the Allied Force Malaria Control School became an active entity in the early months of 1944 (fig. 32).

As finally established, this school was set up in three related but virtually autonomous sections, American, British, and French. Each section director outlined and supervised the presentation of courses suitable for personnel in his section. Some interchange of lectures was made among the British, American, and French schools held in Algiers. At the suggestion of the Surgeon, AFHQ (British), interallied dinners for the students of various nationalities were featured periodically in Algiers.

The basic faculty of the American Section of the Allied Force Malaria Control School was composed of members of the 2655th Malaria Control Detachment (Overhead). These officers were given a preliminary training course by the assistant theater malariologist in Algiers late in 1943. As they were attached to their respective posts, they conducted schools similar to the one in Algiers. Most of these were held during January, February, March, and April. All arrangements for announcements, issuing attendance orders, messing and billeting, and transporting student officers and men were made through regular channels by the malariologists, assisted in field and teaching duties by officers from malaria survey and control units. Certificates were generally awarded at the successful completion of these courses, so that suitable records might be made in the 201 files or service records of the individuals attending.

Three types of courses were given, modeled after those in Algiers, but with special divergencies and emphases as dictated by the situation. Course One was designed for officers of the medical-inspector type who had administrative interest in malaria control. This course dealt with clinical, epidemiologic, and preventive aspects of malaria. Guest lecturers were invited to participate and, especially in Algiers, strengthened the content of the presentation. Course Two was designed for laboratory officers and technicians. Train-

[23] Training Memorandum No. 52, AFHQ, 22 Nov. 1943, subject: Allied Force Malaria Control School.

FIGURE 32.—Allied Force Malaria Control School at Anzio-Nettuno beachhead.

ing was given in the making and staining by various methods of thick blood films and the identification of the various stages and species of the malaria parasites. Course Three was designed primarily for enlisted men who were to serve as antimalaria details, although it was attended also by line officers detailed as antimalaria officers. It consisted of brief, didactic training in the principles and demonstration of the procedures used in malaria control practice.

American Section schools were held in Algiers, Oran, Bizerte, Palermo, Cagliari, Naples, Caserta, Foggia, Bari, San Severo, Cerignola, Spinazzola, Manduria, and at the Anzio-Nettuno beachhead (fig. 33).[24] According to the local malariologists' reports, 7,540 officers and enlisted men received training at these schools. This was about 1.2 percent of the total U.S. strength at the time the schools were conducted and represents a substantial troop contact. It was recognized that educational efforts should not stop with the expiration

[24] The school at the Anzio-Nettuno beachhead deserves special comment. It was the largest (more than 2,000 officers and enlisted men were trained there) held in 1944 and was conducted literally under fire at all times. The hospital area seemed the least dangerous one available, so the didactic teaching was presented there in a double-ward tent liberally covered with red crosses. Not until the first day's class arrived—armed to the teeth!—did it occur to the instructor that the picture of the completely accoutered students going in and out of the tent and lounging around it during the 10-minute "breaks," if taken by a German photoreconnaissance plane, might be justifiably interpreted as evidence of a breach of the Geneva conventions and serve as the basis for a deliberate attack on the hospital area! Nothing of the sort ever happened, but it took 3 long days to get the order countermanded requiring all combat soldiers to carry arms at all times—so that the students could come to school unarmed. This was the more remarkable because the hospital area, according to the uncannily accurate reports of Radio Roma, was under special surveillance at the time.

FIGURE 33.—Group at Anzio-Nettuno beachhead receiving field instructions in malaria control. Hospital area appears in background.

of a school project. Accordingly, some 51 miscellaneous lectures were given by assistant malariologists to military audiences totaling more than 6,500.

Inasmuch as so many persons connected with malaria control had received extensive schooling during 1944, comprehensive training was unwarranted in 1945 and a modified educational project was proposed. This consisted of 1-day schools held by local malariologists and assistants for (1) officers entrusted with antimalaria instruction of troops or who supervised the activities of enlisted-men antimalaria details, and (2) enlisted men of the unit antimalaria details. In the main, these schools were held during March and April just before the malaria season.

The courses for officers included the history of malaria in the theater, a prognosis of the malaria hazard and problems for 1945, the duties and interrelationships of antimalaria personnel, antimalaria education of troops, the training and use of unit antimalaria details, where and how to get supplies and equipment, and the 1945 theater policy for suppressive Atabrine therapy.

The courses for enlisted men dealt with the importance of malaria, utilizing the "Graphic Portfolio on Malaria"—War Department Graphic Training Aid 8–4, which gives a brief description of anopheline and culicine mosquitoes and their comparative bionomics, malaria control procedures to be practiced by enlisted-men antimalaria details, care and use of equipment, and demonstration of mosquito-collecting, house-spraying, oil-larviciding, and ditching techniques.

A special course was offered to officers and technicians in the Air Force Group Aid Dispensaries. These units were in the process of being equipped with microscopes, and a majority of the technical personnel assigned were inexperienced in the preparation and interpretation of thick blood films for malaria diagnosis.

These schools were held in Naples, Rome, Grosseto, Siena, Leghorn, Pisa, Florence, Cattolica, Torre Maggiore, Foggia, Cerignola, Spinazzola, Bari, Manduria, and in the mountains of the Fifth U.S. Army sector, north and west of Florence.

According to the reports of local malariologists, 6,130 officers and enlisted men received training in these courses. This amounts to about the same troop contact as was achieved in 1944.

In addition to the formal training activities, awareness of the malaria problem and of the necessity for unremitting continuity in malaria control was stimulated by announcements and reminders conveyed both by radio and unit newssheets, by the use of roadside markers indicating the boundaries of malarious areas, by malaria control posters, and by the booklet entitled "This is Ann." Most of the posters came from the States (War Department, Medical Department Item Nos. 7J770-01 to 12, inclusive), although a few originated in the theater and were reproduced by engineer mapping units. Certain of the illustrations in "This is Ann" were enlarged and printed by civilian contract in Italy. The posters and pamphlets were usually in evidence in messhalls, dayrooms, and on company bulletin boards.

Survey Activities

These were minimized in NATOUSA and MTOUSA from necessity rather than choice. The number of malaria control detachments in the theater was never great enough to provide and supervise environmental control measures on a really adequate scale. Consequently, it appeared advisable to use malaria survey detachments as malaria control detachments during the malaria seasons. In some instances, the malaria survey detachments were authorized to draw enough extra vehicles and equipment to make them operationally equivalent to control units; in others, provisional malaria control detachments were formed, by theater directive, from replacement personnel, commanded by the extra officer (parasitologist) from malaria survey detachments and equipped as malaria control detachments.

Furthermore, a considerable body of information regarding the distribution of malaria and anophelism existed in each country and island occupied. While these data were not always up to date, nor as nearly accurate as might be desired, they were generally useful. It seemed pointless, therefore, to engage in detailed explorational surveys except on those rare occasions when information from local civilian sources was not available. Consequently, the bulk of survey activities was inspectoral.

Splenometry.—Spleen palpation as a rapid measure of malaria endemicity was not widely employed, although limited and isolated observations were made in nearly all base sections, armies, and Army Air Forces. A total of

5,110 individuals, mostly children, were examined, of whom 12 percent were reported to have enlarged spleens. *Local* spleen rates varied from 2 to 43 percent.

Parasitology.—More parasite examinations were made in relation to either troop strength or the number of malaria survey detachments in 1943 than in either 1944 or 1945. This was due largely to the necessity of checking the blood-film examinations of hospital laboratories staffed with personnel not yet experienced in the recognition and identification of malaria parasites. Epidemiologic studies based on parasite-positive slides were not possible except on a small and unsatisfactory scale. The rapid movement of units and individuals and the possibility of protracted incubation periods (resulting from suppressive Atabrine therapy), during which multiple exposures in various places may have occurred, made these efforts unproductive in discovering where infections were contracted. They did point, however, to a rather selective prevalence among truckdrivers, railroad operators, cooks and kitchen helpers, attendants in antiaircraft, searchlight and locator posts, and among members of similar details in which duty exposure after dark was the common factor.

During 1943, more than 12,000 blood smears were examined by survey unit personnel in the theater. The lack of homogeneity as to time, place, sampling, and technique precludes drawing statistical conclusions from these data. As expected, tertian infections appeared to predominate in the early summer months and estivo-autumnal infections in the late summer and fall. About 75 percent of the total examined were survey slides made from troops, prisoners of war, or natives (mostly children). The remaining smears were from hospital patients, the majority of whom were suspected of having malaria from clinical evidence. Of the total, 11.5 percent of the blood films were positive.

In 1944, over 14,000 smears were examined, of which only 3 percent were positive. Some of the examinations were from civilian or Italian military surveys; the others were made to check hospital laboratory malaria diagnoses.

In 1945, there were no parasitologic surveys due to the fact that all survey units but one were deactivated in the spring. The one remaining survey unit operated in the capacity of a control detachment. Accordingly, the control detachments were obliged to train their own mosquito inspection teams. In general, these consisted of two men per detachment. Lacking diagnostic equipment, it was impossible to differentiate anopheline larvae and adults.

Entomology.—As explained previously, most of the mosquito survey activities were inspectoral rather than explorational. The following species of anophelines were reported by various malaria survey units in the North African and Mediterranean theaters:

Anopheles algeriensis Theobald
Anopheles claviger bifurcatus Meigen
Anopheles hyrcanus pseudopictus Grassi
Anopheles labranchiae atroparvus van Thiel

Anopheles labranchiae labranchiae Falleroni
Anopheles maculipennis maculipennis Meigen
Anopheles marteri Senevet and Prunelle
Anopheles melanoon melanoon Hackett
Anopheles plumbeus Stephens
Anopheles sacharovi (*elutus*) Favre
Anopheles superpictus Grassi
Anopheles turkhudi (*hispaniola*) Liston [25]

Other members of the *maculipennis* complex were probably encountered but were not recognized because of the paucity of survey personnel and equipment.

Control Activities

No environmental control measures of a truly permanent nature were attempted in NATOUSA except a relatively small amount of land fill. It is probable that much of the open ditching may have had certain semipermanent control values if the requisite maintenance work was done on it each year. Generally speaking, each Army unit was responsible for locating and controlling all anopheline breeding and performing other antimosquito measures within the limits of its installation, and, in many instances, for a mosquito flight-range radius beyond.

In North Africa, an effort was made during 1943 to utilize civilian health agencies for carrying on larviciding, clearing, and minor hand drainage beyond the military area limits to the extent of two kilometers. Base section commanders were authorized by NATOUSA directive to draw from U.S. military sources transportation, nonmedical supplies, and facilities for malaria control as dictated by circumstances in each base section and to expend up to 500,000 francs ($10,000) a month for civilian labor and miscellaneous items for the same purpose. This idea had merit, and where the base section commanders, surgeons, and preventive medicine officers took a constructive interpretation of the directive, the supplemental control activities thus generated had definite values both to military and local civilian populations.

Unfortunately, none of the North African health agencies, with the possible exception of the one in Morocco, had an experienced malaria control organization large enough to take on the task of environmental malaria control around Allied military installations. In Algeria, it was customary for larvicidal and drainage improvement operations to be performed by one national agency, the Service de la Colonisation et de l'Hydraulique, under the technical direction of another agency, the Service de la Santé Publique. The Eastern Base Section

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[25] (1) Russell, P. F., Rozeboom, L. E., and Stone, A.: Keys to the Anopheline Mosquitoes of the World, With Notes on Their Identification, Distribution, Biology, and Relation to Malaria. Philadelphia: The American Entomological Society, The Academy of Natural Sciences, 1943, pp. 56–61. (2) Ross, E. S., and Roberts, H. R.: Mosquito Atlas. Part II. Eighteen Old World Anophelines Important to Malaria. Philadelphia: The American Entomological Society, The Academy of Natural Sciences, 1943, pp. 37–38.

included parts of both Algeria and Tunisia which made it necessary to deal with two different national health departments. These circumstances naturally led to complications and misunderstandings in planning, responsibility, execution, and finally, in reimbursement.

Larviciding.—The treatment of anopheline breeding places to destroy larvae was practiced on a more extensive scale than any other single control method. The more frequent areas of mosquito production were small streams and ditches. In many of these areas, the entire water surface was covered by floating and emergent vegetation, and mosquito breeding extended from bank to bank; in others, plant growth was marginal, and larvae were found only along the edges, especially in relation to small vital floatage. In either case, supplementary clearing and cleaning were needed to make larviciding applications effective. These physical operations must have had considerable destructive effect upon the larvae themselves.

Petroleum oil, usually No. 2 diesel, was the larvicide of choice for ground application. Paris green was not generally available until 1944, but, in spite of considerable promotion and instruction in its use, the unit antimalaria details did not employ it to any great extent and showed a strong preference for oil. Probable reasons are that oil was much more available due to its general distribution for purposes other than larviciding, it required no mixing or trips to a mixing plant, it was not a poison, and the oil sprayers were mechanically superior to the rotary hand dusters usually supplied. In certain base sections, some paris green hand dusting was done by or immediately under the supervision of the special malaria control organization. An immense amount of paris green was spread by airplane in Italy, Sardinia, and Corsica during 1944 and in Italy in 1945. During the spring of 1944, DDT made its appearance in the theater. As a larvicide, it was used almost entirely in an experimental way both from the ground and by airplane. In 1945, 5 percent DDT in oil was used extensively as a larvicide applied both from the air and from the ground.

For the most part, various types of hand pressure sprayers were used to apply petroleum products. Continuous drip oilers were set up over streams in many parts of the theater. In one base section, a power oil sprayer was developed by utilizing a M3A1 Chemical Warfare decontaminating unit mounted on a 2½-ton 6 x 6 truck chassis (fig. 34). This was actually a homogenizing pump developing up to 500 pounds pressure and was used to deliver a finely dispersed mixture of one part of oil in three parts water. Less oil was necessary for a given area when applied by this apparatus, the area was oiled in a shorter time than by hand-operated equipment, and the oil was forced below the water surface where it continued to come up under and around vegetation for periods of 2 or 3 weeks, so that its effect lasted longer than surface spraying.

Airplane larviciding.—Probably the first utilization of airplanes in dispersing larvicides in NATOUSA was made in Morocco during the summer of

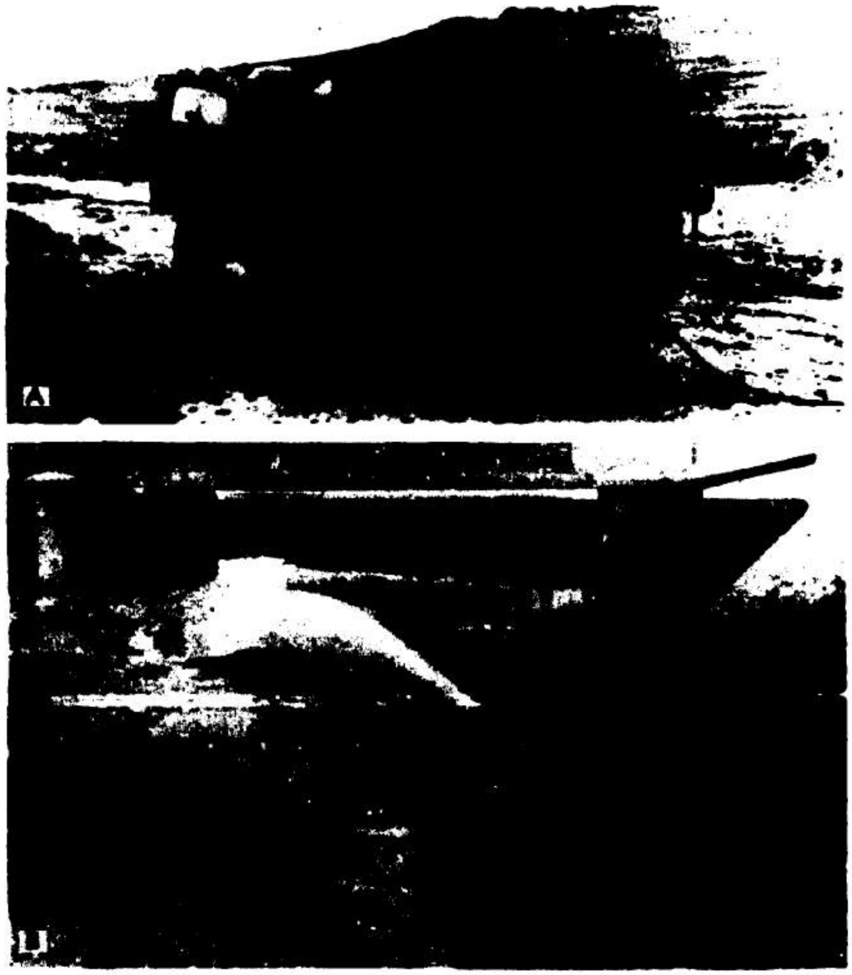

FIGURE 24.—Power oil sprayer used to apply petroleum products. A. Decontaminating unit, mounted on a truck chassis, used to spray a mixture of diesel oil and water into mosquito breeding places. B. This method of oil-water application is especially effective and long-lasting in areas where emergent and floating vegetation is abundant, as the larvicide is forced into and below mats of vegetation.

FIGURE 35.—A-20 airplane dusting paris green over flooded areas northwest of Naples.

1943.[26] Planes and pilots for this purpose had been requested from the States early in the year. It was late September, however, before the six pilots—three of them experienced in crop dusting—reported for duty, and even later before the three PT-17 (Stearman) trainers, modified for dusting, were assembled and ready to fly. By that time, the mosquito-breeding season was nearly over so the planes were flown only for a small amount of experimental dusting. Some replacement parts for the dusting attachments had been sent over with them, but no repair or maintenance items for the aircraft arrived nor were there any in the theater. With the prospect of providing malaria protection in 1944 through the flooded Pontine and other bonifications and in malarious Sardinia and Corsica, it was necessary to enlarge the scope of the aerial-dusting facilities considerably beyond those afforded by three small trainer planes, any one of which might be grounded indefinitely by a cracked spark plug or a flat tire. It was obviously desirable to provide more and larger planes which could be serviced within the theater. The A-20 (Boston) light bomber was finally selected because of its flying characteristics and availability (figs. 35 and 36), and a B-17 was dispatched to the States to obtain a load of PT-17 motors, tires, wheels, instruments, and other replacement parts.

[26] The base section commander had forbidden use of paris green as a larvicide by Army personnel because he was misinformed as to its toxicity to men and domestic animals. The local stores of paris green were, therefore, made available to the Moroccan public health service, representatives of which proceeded to spread the paris-green-road-dust mixture with an old French bomber which had been condemned long before as unairworthy. The time came when this ancient aircraft could no longer get off the ground, whereupon the local Navy air surgeon took over the mission using a modified L-4 Cub. He succeeded in getting in his flying time while he dusted effectively portions of two large swamp areas near Army campsites.

FIGURE 36.—A-20 dusting planes flying in formation. A. Planes flying over inundated Volturno bonification area. The speck at the upper right is an observation plane checking and directing the operation. B. Planes flying over the Plain of Cassino. The furthest plane is not yet discharging dust. The battered Monastery is atop the mountain peak to the left; at right, Hangman's Hill and numerous water-holding shell holes, bomb craters, and various other anopheline breeding places in foreground. Most of these were inaccessible because of landmines. The area required treatment because the road traversing it to the north was a vital supply line.

Theaterwide airplane dusting and spraying service was developed in 1944 and continued the following year. At the request of the Theater Surgeon, AFHQ directed the Mediterranean Allied Air Force to provide adequate planes and pilots for malaria control purposes.[27] This responsibility was delegated by the Mediterranean Allied Air Force through the Army Air Force Service Command to the Mediterranean Air Transport Command. This organization placed a detachment of one of its ferrying squadrons virtually at the disposal of the theater malariologist. The crop dusting pilots, assisted by special malaria control organization personnel, supervised the structural modification of the A–20's to convert them to dusting and oiling planes.

Working arrangements were as follows: Requests for airplane dusting or spraying service were transmitted to the theater malariologist. As soon as practicable, he or one of his representatives visited the area and, accompanied by the local malariologist, made an aerial and ground inspection of the terrain to be treated. The amount of materials required for each week was then computed, and decisions were made regarding responsibility for transporting, mixing, and planeloading of larvicidal materials. The local malariologist provided a map for the pilot showing the exact area to be covered. The job was then scheduled for a particular day each week and copies of these arrangements circulated to all agencies concerned. Thereafter, the work proceeded as arranged until cancellation. Planeloading was generally handled by some element of the special malaria control organization.

In 1944, nearly 900,000 pounds of 25 percent paris green in lime and 7,000 gallons of oil (mostly No. 2 diesel with varying contents of DDT) were applied by airplane for American and British malaria control. During 1945, about 250,000 pounds of paris green mixed with diatomaceous earth (1:3 for American use) or cement (1:6 for British use) and roughly 72,000 gallons of 5 percent DDT in oil were dispersed by plane in the theater.

These quantities of paris green and DDT mixtures required large-scale mixing facilities. In 1944, they were contrived by base section engineers from an old Italian ammunition plant located in a cave near the Fair Grounds outside Naples (fig. 37). This factory was provided with motor-driven, steel tumblers loaded from a platform overhead. These containers discharged mixed dust into steel barrels on rollers below. Ample facilities were available for the dry storage of paris green and lime as well as mixed dust. Both 25 percent and 10 percent mixtures were prepared at this plant, the former for airplane and the latter for hand-duster applications. Plant capacity was 8 tons of mixed dust per 8-hour day.

In 1945, American larvicides were prepared by one of the malaria control units working in the Solvay plant at Rosignano (fig. 38). The 25 percent paris green mixture in diatomaceous earth was blended in revolving steel drums formerly used for manufacturing chloride of lime. The plant capacity was

[27] Letter, the Commanding General, AFHQ, to the Commanding General, Mediterranean Allied Air Force, 23 Mar. 1944, subject: Malaria Control Dusting Airplanes for 1944.

FIGURE 37.—Paris green mixing plant near Naples.

5 to 15 tons per day. DDT solutions (5 percent in diesel oil or kerosene) were prepared in one of several large stills previously used for making trichlorethylene. Each of these had a capacity of 1,200 gallons and was equipped with a set of agitator paddles which rotated at the rate of 60 r.p.m. Oil or kerosene was pumped in through pipes connected to large storage tanks outside the building. DDT concentrate, dissolving in the proper amount, was added through a hatchway in the top of the still. After thorough mixing, the solution was drawn off through a tap at the bottom directly into 55-gallon drums. These stills had a capacity of about 2,400 gallons per day. Because of the ease of production, the malaria control unit also prepared large quantities of 5 percent DDT in kerosene for use as a residual insect-killing spray to be applied within houses by various units.

The MTOUSA airplane malaria control project abundantly demonstrated the feasibility of using large fast planes for applying larvicides. When the program was begun, this principle had not been employed to any extent, and its practicability was flatly denied by numerous "swivel-chair" pilots. The A-20 (Boston) light bomber [28] proved to be an admirable vehicle for dust and oil applications to large, unobstructed water areas. These planes were used

[28] This bomber is powerful and surprisingly maneuverable in the hands of a skilled pilot and has visibility advantages over the B-25. Its radius of round-trip operation without refueling is about 200 miles. It can carry 3,000 pounds of dust, discharging it in 20 minutes, or 300 gallons of oil which can be discharged in from 3 to 15 minutes of flying time, according to the diameter of the discharge vent.

FIGURE 38.—Filling 55-gallon drums with freshly mixed 5 percent DDT in kerosene (or diesel oil) prepared in the Solvay plant, Rosignano, Italy.

to dust large marshy and ponded areas in Corsica, vast inundated acreages in coastal Italy, the extensive canal systems in western Italy, and along the troop-jammed highways of the Po River delta area (fig. 39).

The enthusiasm of theater malaria control personnel for the A-20 did not preclude the utilization of small planes for the precision treatment of small areas or winding streams, the course of which could not be followed by the larger aircraft. L-5 (Grasshopper) liaison planes, UC-61 (Fairchild) observation planes, and PT-17 (Stearman) trainers were all tried (fig. 40).[30]

[30] Of these, the Stearman trainer plane was by all odds the best. It is powerful, tough, maneuverable, and has had excellent pilot visibility, as the cockpit is open. It has a work radius, without refueling, of from 100 to 150 miles. It carries 500 pounds of dust which it discharges in 7 minutes, or 55 gallons of oil which are released in about 6.5 minutes at a speed of 90 miles per hour. The L-5 was also satisfactory for minor plane dusting or spraying operations, but it lacked the power and maneuverability of the PT-17. The UC-61 was considered undesirable for these purposes—though it was used more or less extensively by the British—as it is underpowered and has limited pilot visibility.

FIGURE 39.—A-20 airplane discharging DDT in oil over a small canal near Pisa.

FIGURE 40.—PT-17 (Stearman) spraying a canal in Italy with DDT in oil.

Experience in 1944 demonstrated the desirability of covering large areas with several A–20's flying in echelon formation (fig. 36) so that an entire area could be covered with a single loading of larvicide. This avoided the necessity of having to leave for more dust or oil and returning to find different wind and air current conditions, as well as having to resume operations at an uncertain point somewhere near the place where the previous load ran out. Formation flying was found to be best directed from a liaison plane overhead, utilizing radio intercommunication with the pilots in the work planes. By this means, the effects of crosswinds could be noted, pilots ordered to the right or left, bare spots covered, and so on. The A–20 treatment of large canals was also performed more effectively under the direction of an aerial observer, as the A–20 pilot cannot see behind him to gage the effects of wind drift on the spray or dust cloud.

Airplane dusting was carried out at weekly intervals in accordance with the general principle of applying larvicides of temporary effectiveness at least once during each consecutive period of larval development. Aerial oiling schedules were placed on a weekly basis also, but this was because of administrative convenience. No data are available to show how long the DDT applications were effective in Italy. It is possible but unlikely, judging from experiences reported from other areas,[20] that some residual effect was established after several weekly treatments on the same area.

Adult mosquito killing.—This activity was conducted systematically in Morocco during 1943, where it constituted a major and very effective means of mosquito reduction, especially when larvicidal measures were conducted simultaneously in the area.

This program was unique in that women were employed to conduct the spraying operations because of the ruling by the local pasha and the French civilian comptroller that men would not be permitted to enter Arab dwellings. Despite fear to the contrary, European women were easily obtained and proved to be more conscientious, careful, and steady sprayers than men. The total number of native dwellings involved in the inspection and spraying program in the whole sector is not known, but it must have been very large. The frequency with which the buildings were sprayed varied greatly, depending upon the findings of the inspectors. An indication of the cost and efficiency of this program is gained from data submitted from the Rabat area where, from 7 June to 31 July, five women sprayed 7,090 huts at a total labor cost of $564, or $0.08 per dwelling. Mosquito counts in these houses before the spraying program averaged 500 to 800 mosquitoes per hut; at the end, 5 to 10 mosquitoes per hut.

Less extensive uses of spray killing both with liquid insecticide and Aerosol dispensers were made in other portions of the theater. While they could not be used in the most forward section of combat areas, they probably achieved

[20] War Department Technical Bulletin (TB MED) 200, February 1946.

their maximum utilization in Army areas where both the antimalaria units and the unit antimalaria details sprayed houses and animal shelters in newly occupied sections.

In the summer of 1944, the use of DDT as a residual house spray in Italy, Sardinia, and Corsica was begun. This measure came to be of increasing importance in malaria control technique, especially in areas where the possibilities of other environmental control practice were either not practicable or did not yield immediate health benefits. DDT residual spray was used for the control of all pest and disease-carrying insects. The DDT was mixed with kerosene to make a 5-percent solution and was packaged either in 5-gallon or 55-gallon containers at central points. The Fifth U.S. Army drew the mixed product from its supporting base section and distributed it with printed instructions as to its use to various units, a moiety of which made their own application. In virtually all other installations, the DDT solution was issued to units but was applied for them by specially trained individuals or by teams using power sprayers. The latter arrangement was decidedly more efficient than the former, which was necessitated by the relatively vast dispersion of Army units. The basis of distribution in Air Corps units was 30 gallons per 1,000 men per month; in all other organizations, 5 gallons per company as needed, issue dates being determined by actual observations of insect prevalence. By NATOUSA directive, liquid insecticide and 5 percent DDT and kerosene were made available late in August "without restriction and in sufficient quantity to control disease-bearing insects throughout the theater." [31]

Its spectacular success in 1944 as an adult mosquito killer led to its utilization on an even grander scale in 1945 in Italy, where it was credited by the theater malariologist as being the most important item in malaria control operations during the season. More than three and one-half times as much DDT was applied to walls by malaria control units in 1945 than had been used similarly during the previous year. Spraying was commenced in March to kill the overwintering anopheline females. After the initial application, unit buildings were resprayed every month and the surrounding civilian houses about every 3 months. Later in the season, it was felt that it would be more profitable to increase the protected zone by another half-mile to a mile rather than to respray previously treated houses; in this way very large areas of countryside were blanketed with DDT. It was also discovered that, in order to get adequate control, it was necessary to treat every shelter in the control zone, otherwise small foci of adults continued to exist in the untreated structures.[32] Although DDT house spray was distributed on the basis of 30 gallons per 1,000 men per month in 1945, it was always available and units needing additional amounts could always draw them.

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[31] See footnote 17, p. 270.

[32] In a few instances, however, it was necessary to restrict the amount of spraying. Thus, in certain sections of the Po River Valley where sericulture is practiced, DDT was applied only to civilian pigsties, stables, and other outhouses as the silkworms which were raised in the homes would have otherwise been destroyed.

DDT replaced Freon pyrethrum to a considerable extent as an insecticide in 1945. During the previous year, the special malaria control organization used 11,217 bombs, whereas in 1945 only 1,716 were reported to have been used and these by Army units during the Po River Valley offensive when it was necessary to treat houses quickly; later, the units went back and resprayed the houses with DDT.

Physical operations.—These were extensively conducted throughout the theater in 1943 to eliminate mosquito breeding and to permit more effective application of oil larvicides. Vegetation and obstructions were removed and residual pools often eliminated in order to enhance the speed of waterflow. In some instances, temporary dams were constructed to permit periodic flushing of streams. In 1944, the total amount of stream training, drainage, and land fill was greatly increased in Italy, Sardinia, and Corsica. In Corsica, a tremendous mileage of ditch and stream clearing, new ditching, and stream channelization was accomplished. Large areas were dewatered which, according to local inhabitants, had not been dry before in the memory of man. The mosquito population was so reduced that Corsican families moved from their summer homes in the hills down to the coastal plains before the advent of cold weather.

The enormous amount of physical operations was accomplished mainly by Italian and Yugoslav military labor. Companies of Italian infantry or quartermaster service troops were attached to malaria control units for operational control. These Italian organizations drew their own rations, messed, and sheltered themselves. The companies varied in size, averaging from 125 to 150 officers and men, but about a third were concerned in company administration and were not, therefore, available for work. In Corsica, Yugoslav labor companies were used similarly. The men in these units had been taken from their homes and country by the Germans as forced labor to work in Sardinia. When transported to Corsica, these labor companies were commanded by Italian officers and noncommissioned officers—whom they heartily detested—were malnourished, dispirited, and plagued by recurrent malaria. When the Italian officers were replaced with Americans and the Slavs were well fed and given proper medical service, their morale rose rapidly and they became, by all accounts, the most effective and dependable source of labor available in the theater. Italian civilian labor was employed on contract projects by the Allied Control Commission in Salerno and eastern Italy. Their work was also satisfactory as long as it was subject to U.S. officer inspection.

The responsibility of the Corps of Engineers for environmental control was accepted whenever its units were available from other duties.

Three Corps of Engineers projects were of considerable magnitude and were coordinated with the program of the special malaria control organization to such an extent that they merit particular mention.

During the spring months of 1944, while the Fifth U.S. Army headquarters were located at Sparanise (a small village located near Naples), one battalion from each of five general service engineer regiments, together with the entire regimental heavy equipment, was made available for malaria control. One of the regimental officers, an experienced malaria control engineer, was detailed as liaison officer with the medical section of the Army headquarters. Together with the Commanding Officer, 28th Malaria Control Detachment, he surveyed the entire Army rear area north of the Volturno River, noting those situations where major earthmoving machinery and pumpage could be used to advantage. These jobs were then allotted to the various regiments by the Army engineer, and the indicated repairs were undertaken. This continued until engineers were needed for the push to Rome. No record of accomplishment is available, but the work included such operations as filling tank traps, shellholes, bomb craters; lowering culverts; removing obstructive bridge-demolition residues and bypasses; bridge improvement and construction; major canal repairs; and installation of heavy duty pumps which involved running electric powerlines for many miles. Much of this had to be done in heavily mined and boobytrapped areas. The engineers succeeded in reducing the water in the northern Volturno area to its normal level in time to permit civilians to plant the dewatered acres in the spring of 1944. It is no exaggeration to state that the U.S. Army engineers, with the tremendous manpower and equipment facilities at their disposal, accomplished more in a few weeks than the impoverished Italian citizenry could have hoped to do in as many years.

At the Anzio-Nettuno beachhead, the VI Corps engineer undertook responsibility not only for drainage improvement but for larviciding and spray killing in a considerable portion of that besieged area with the technical assistance of special malaria control organization representatives. This continued until the beachhead forces were joined with other elements of the Fifth U.S. Army on the advance to the north.

In the Salerno-Paestum area, where the invasion training center was situated during the summer of 1944, an engineer combat regiment cooperated with the special malaria control organization of the Army and the Navy in a joint program of malaria prevention. Men from this regiment, using explosives, carried out rapid but effective ditching for a distance of several miles thus dewatering a large and potentially dangerous area. This could not have been accomplished otherwise with the facilities at hand in time to have favored the health of the troops training nearby.

Insect-proofing.—Since screening is virtually nonexistent in North Africa, all the buildings requisitioned by the Army in 1943 were without this protection. The scarcity of Army screening materials that year restricted their use to latrines, kitchens, messhalls, and breadboxes. Thus insect-proofing was employed primarily as an antifly rather than as an antimosquito measure. Some screening of hospitals was permitted, complete in certain instances, limited in others to spaces mentioned above and to one or two wards for patients with insect-borne diseases. Salvaged mosquito bars were used extensively for screening purposes. In 1944 and 1945, the situation was greatly improved. Screening materials were provided and used on an adequate scale throughout the theater.

Personal protective measures, except medication.—Bed nets were utilized more faithfully than any other individual protective measure. By theater directive, they were available from 15 April to 30 November.[33] Some units requested them for use (against pest mosquitoes) during the winter months. They were not used by forward elements in combat as it was impracticable for these troops to carry or set up bed nets until they were back in rest areas. Where there was little or no supervision by officers, such as with truckdrivers or railroad operators on the road, it was not uncommon to find that bed nets and other essentials for personal protection against malaria were not in the possession of the individuals inspected.[34]

The wearing of protective clothing was limited usually to long trousers and sleeves rolled down after dark. Shorts and shirts without sleeves were prohibited except during the hours of daylight. Some outfits wore leggings all the time. Head nets and mosquito gloves were rarely used and were not even nominally required by the theater in 1944 as items of personal protection.

Repellents were amply available but their maximum antimalaria values were never realized. Unless mosquitoes were numerous enough to constitute an annoyance, it was unusual for officers or enlisted men to use repellent as instructed. All kinds made their appearance at one time or another in the theater. Dimethyl phthalate or 6-2-2 appeared to be least objectionable to the soldiers and was effective against *A. labranchiae labranchiae.*

Much time and effort went into the indoctrination of officers and soldiers in NATOUSA regarding the use of personal protective measures against malaria, but in spite of all these endeavors it was known from night inspections that personal protection was more or less neglected except in those units where command interest enforced malaria discipline. This indifference was strikingly apparent as soon as the troops passed Rome advancing to the north. It was due, presumably, to the rumor that malaria did not exist north of the Eternal City.

An excellent feature of the Fifth U.S. Army malaria control program was the use of antimalaria officers and malaria control committees.

The antimalaria officers were appointed from nonmedical personnel in each corps, division, regiment, battalion, and separate company. It was the duty of the antimalaria officer to inform himself about the status of malaria and its control in his organization, to attend and participate in the deliberations of the malaria control committee to which he belonged, to acquaint his commanding officer with the malaria problem of the Unit, and to see that all necessary malaria control measures were being enforced.

[33] See footnote 10, p. 264.
[34] See footnote 3, p. 283.

Malaria control committees were formed in each corps, division, regiment, and battalion. The membership of each corps and division committee consisted of the medical inspector, the engineer, and the antimalaria officer of their respective echelons. Regimental and battalion committees were composed of their surgeons and antimalaria officers. The function of each committee was to bring together information concerning the phases of malaria control represented by the respective committee members. Thus, at periodic meetings, the medical inspector contributed information about current malaria prevalence and the activities of the Medical Department antimalaria personnel. The engineer was concerned primarily with environmental control and the mapping of malaria and malaria control data. The antimalaria officer discussed malaria control in general but was especially charged with noting how well the individual preventive measures were being enforced. Their findings were reported to the commanding general or officer. To an Army operating in a malarious area, this type of conference was most helpful as it brought together in all echelons the three branches of service—command, engineering, and medicine—most intimately concerned in the prevention of malaria. It is believed that this device did much to sustain malaria consciousness and integrated control effort while the Army was exposed to the military hazard of malaria. The various Army Air Force commands employed malaria-discipline officers in virtually the same capacity as the antimalaria officers mentioned previously.

Suppressive medication.—As indicated previously, the Malaria Advisory Board, AFHQ, was influential in formulating suppressive medication policy for the theater.[35] The British were insistent upon universal, theaterwide administration of Atabrine (except to flying personnel who, they felt, should receive quinine) at a scheduled dosage of 0.2 gm. after the evening meal upon Monday and Thursday. This was contested in principle by the American membership for the following reasons: (1) It was American policy to depend primarily on environmental sanitation and not on chemical prophylaxis, except in active, tactical situations; (2) a high rate of toxic reactions, such as were manifested in the group of Ohio State University, Columbus, Ohio, students placed upon a controlled experiment of suppressive therapy under the auspices of the National Research Council, might occur, which, if true, would damage seriously the program of chemical suppression; and (3) with the numbers upon such therapy, the administrative details of providing the Atabrine to forward combat units would be difficult and the drug would arrive in an irregular manner and the program would suffer accordingly. The British minimized the force of these objectives, and the French agreed heartily with the British point of view. A compromise was finally effected whereby the procedures outlined above were to be followed, with the proviso that if environmental malaria control was found to be so effective in static areas that suppressive medication was

[35] See footnote 7, p. 282.

not needed, the commander in chief would decide whether or not the latter measure would be continued in main areas.

Suppressive Atabrine therapy was commenced 22 April 1943.[30] Practically no complaints of reactions were received following the first and second doses, but following the third, a well-nigh incredible wave of incapacitating, toxic episodes was reported. These involved nausea, vomiting, cramps, diarrhea, and, in some instances, febrile temperatures for a day or more following the third dose of Atabrine. All grades of severity were noted and many individuals experienced no symptoms whatever. A rather typical example of the incidence of toxic reactions encountered is shown in the following data recorded by the 59th Evacuation Hospital (table 33).

TABLE 33—*Incidence of toxic reactions from Atabrine at the 59th Evacuation Hospital, 1943*

Type of personnel	Toxic Atabrine reactions			
	After the 3d dose (30 April) (200 mg.)		After the 4th dose (3 May) (100 mg.)	
	Number	*Percent*	*Number*	*Percent*
Officers	51	57	51	24
Nurses	53	60	53	20
Enlisted men	375	50	373	22
Medical patients	136	76	138	18
Surgical patients	151	33	140	11
Venereal disease patients	126	16	70	4
Prisoner-of-war patients	64	12	79	5

Source: Long, Perrin H: A Historical Survey of the Activities of the Section of Preventive Medicine, Office of the Surgeon, MTOUSA, 3 Jan. 1943 to 15 Aug. 1945. [Official record.]

The experience in basic service troops was quite similar to that recorded in the officers and enlisted men in the detachment noted previously, with the exception that Negro troops showed a very low incidence of toxic reactions.

The experience in forward areas was very different from that in base sections. In II Corps troops, suppressive Atabrine therapy was begun 4 April 1943 because malaria was increasing in the 1st Infantry Division which was then engaged in combat. The third dose was followed, in the 16th Infantry Division, by less than 5-percent moderate or severe toxic reactions, all of which passed off rapidly. In the 32d Field Artillery Battalion, about 10 percent of the personnel were affected, while in divisional headquarters some 25 percent suffered from toxic reactions. The reactions in II Corps troops were definitely less frequent than those in base section personnel. A similar story subsequently was gained from the 9th and 34th Infantry Divisions and the 1st Armored Division. The British reported similar toxic disturbances with the same curious tendency of having fewer reactions in units which were in forward areas.

[30] See footnote 6, p. 292.

After this experience, the Malaria Advisory Board, AFHQ, was called into immediate session. It decided that 0.2 gm. was too large a dose of Atabrine and unanimously recommended that 0.1 gm. be taken on Monday, Tuesday, Wednesday, and Thursday of each week. Remarkable effects immediately were ascribed to this change in dosage, and many reports of decreased toxicity were received. However, the divisions in II Corps which had begun suppressive therapy early in April did not receive this order and continued upon the dosage of 0.2 gm. twice a week, on Tuesdays and Thursdays. This corps reported also an almost total lack of continued reactions so that the conclusion reached was that tolerance to suppressive Atabrine therapy was developed if the drug was continued, regardless of the type of dosage used.

The spring and summer experience with suppressive Atabrine had precisely the effect on the program of suppressive medication which the medical consultant had feared and expressed before the Malaria Advisory Board, AFHQ. For every individual who reacted physiologically to the early doses, there were several others who experienced similar psychogenic—but none the less incapacitating—episodes. Actually, when the smoke had cleared away, it was apparent that most of the affected people were able to develop a tolerance to the drug rather promptly if daily doses of 0.1 gm. or less per day were used. The proportion which remained continuously sensitive was less than 1 percent. Nevertheless, as a result of the widespread distress, numerous officers and men feared Atabrine and would go to any lengths to avoid taking it. They rationalized their deliberate and unauthorized discontinuance of the drug on many bases. The rumor spread that Atabrine was a cause of impotency. The yellow skin infiltration was regarded by the soldiers as jaundice and an indication of grave liver damage from which they might never recover.

Medical officers unconsciously sabotaged the program by expressing, in the presence of enlisted men, their doubts of the prophylactic value of Atabrine. Many of the troops worked and were quartered in large cities such as Algiers, Oran, and Casablanca, or in other areas where mosquitoes were scarce or absent. Neither officers nor enlisted men could see any use in taking Atabrine under these conditions, and the theater regulation was not enforced. These irregularities in taking suppressive Atabrine were evidenced abundantly by the frank admissions of malaria patients interviewed by malariologists and by the casual comments of officers in messes regarding the bottles of Atabrine on the tables before them. Thus, the proportion of troops taking Atabrine regularly in 1943 is not known nor, consequently, the role of chemical suppression in the picture of malaria morbidity which developed in 1943 and in early 1944.

A natural result of the uncertain, vacillating, poorly enforced Atabrine policy in 1943 was the evolution of a more rational directive for 1944.[37] By

[37] See footnote 10, p. 264.

this time, more information regarding the suppressive efficiency and lack of toxicity of Atabrine was available. The period 1 May to 15 October was designated as the malaria season. All areas were to be considered malarious unless otherwise designated, by the area commander concerned and upon the advice of his surgeon. Nonmalarious areas were designated as those in which malaria did not occur and areas where control measures had effectively removed the likelihood of malaria transmission. All military personnel were directed to take one 0.1 gm. tablet of Atabrine per day for either 6 or 7 consecutive days a week while in areas which had not been designated as nonmalarious.

The flexibility and adaptability of this directive, reinforced by troop training regarding the use of Atabrine, resulted in considerable improvement in Atabrine discipline during the first half of the 1944 malaria season. Some difficulty was experienced when soldiers who had been taking Atabrine regularly came into "nonmalarious" rest areas; that is, Rome, where Atabrine was not provided automatically with the rations. This defect was corrected promptly. The most serious impediment to the Atabrine program developed as the result of successful environmental control operations. The combination of low malaria rates and negligible anophelism made the enforcement of suppressive atabrinization—and other personal protective measures as well—seem useless to officers and enlisted men alike. Thus, during the late months of the malaria season in 1944, compliance with suppressive Atabrine regulations was not as extensive as earlier in the year.

In 1945, the policy was liberalized further by making Atabrine suppressive medication (0.1 gm. per day) compulsory only in specially designated areas.[28] Several such areas in the Po River Valley were thus specified by the Commanding General, Fifth U.S. Army. Otherwise, Atabrine consumption during the year was limited to occasional units having unduly high malaria rates or to individuals recovering from attacks. The 1945 directive was thoroughly rational and enforceable and, judging from the results, the most successful of the suppressive Atabrine policies developed during the 3 years.

Research

The personnel in the special malaria control organization were not able to devote much time to research. This was due not to any disinclination to engage in such activities but to a lack of opportunity. During the winter and early spring of the year, typhus control, malaria control training, and preseasonal control activities occupied the time of its members. After the transmission season commenced, no time for anything but control work remained. The theater was fortunate in having available in the Allied Control Commission (later Allied Commission) certain specialists (made possible through

[28] See footnote 11, p. 265.

the cooperation of members of the field staff of the International Health Division of The Rockefeller Foundation), highly skilled in particular phases of malaria control, who were able to devote their entire time to working out problems suggested by individuals occupied with actual malaria control responsibilities. Reference is made to the monthly reports of the Demonstration Unit, Malaria Control Branch, Allied Control Commission.

The following abstracts are based upon investigations made during 1944 and 1945 by members of the special malaria control organization and the Allied Control Commission.

1. Determination of toxicity of 5 percent DDT in kerosene to 33 members of power spraying teams exposed 6 hours per day, 6 days per week, from 1 to 21 weeks each. No evidence of intoxication was adduced from histories, physical examinations, and laboratory tests in a general hospital.

2. Analysis of admission and disposition sheets to determine what proportion of cases originally diagnosed as fevers of undetermined origin and febricula were finally diagnosed as malaria. Of 150 cases in the Fifth U.S. Army discharged to duty during each of the following months—June, July, August—of 1944, 35 percent were definitely diagnosed as malaria, 19 percent remained as fevers of undetermined origin or febricula, and the remainder were distributed among respiratory, gastrointestinal, and miscellaneous disorders.

3. Development of the A–20 as a spray plane for the application of DDT in liquids. This involved experimentation: (1) with M–10 CWS wing tanks which were discarded because of their mechanical difficulties; (2) the utilization of auxiliary fuel cells (332-gallon capacity) and airscoops leading to an atomizing chamber whence the spray was conducted through a discharge tube to the tail of the ship and released; and (3) a special 300-gallon tank, from which equalized flows were obtained irrespective of variations in the hydraulic head within the tank, and an atomizing apparatus consisting of a truncated, conical airscoop fitted over a simple discharge pipe so that the distance between the end of the pipe and the terminal orifice of the scoop could be altered to vary droplet size and pattern.

4. Development of the PT–17 (Stearman) as a spray plane for the application of DDT in liquids. This utilized a 55-gallon steel drum as a reservoir with flow-equalizing equipment and with an atomizing apparatus similar to those used on the A–20.

5. The variable spray patterns and droplet spectra developed by the A–20 and the PT–17 aircraft under varying conditions of temperature, wind direction, size of outlet, and adjustment of atomizer.

6. The dust pattern developed by the A–20 with 25 percent paris green-in-diatomaceous-earth mixtures under conditions of varying wind directions and amounts of dust in hopper. Great unevenness in spread, particularly of paris green particles, was noted.

7. A study of winter DDT house spraying and its concomitant effect on anophelines and malaria in an endemic area.[39] A single application of 5 percent DDT in kerosene (83 mg. of DDT per square foot) made in midwinter to all houses and outhouses in a certain area with virtually no other antimalaria measures in effect resulted in reduction in anopheline densities, frequency and size of enlarged spleens, and parasite rates (table 34).

TABLE 34.—*Results of winter DDT spraying in an endemic area, 1945*

Area	Average anopheline larvae per 10 dips	Average anopheline adults per square yard	Spleen		Parasite rate[2]
			Average size	Rate[1]	
	Number	*Number*	*Value*	*Percent*	*Percent*
Area treated with DDT:					
May	0.21	0.003	1.6	43	22
August	.02	.04	1.2	25	1
Untreated area:					
May	18.60	41.84	1.9	56	18
August	4.00	185.54	2.2	63	41

[1] Percentage of persons in any particular age group, or area, in whom the spleen can be felt by palpation.
[2] Percentage of persons in any particular age group, or area, in whom malaria parasites can be found.

Other Activities

During the winter months, the special malaria control organization was used predominantly for troop training in the principles of malaria prevention. Some of the malariologists and antimalaria units were employed in 1943–44 to combat the typhus epidemic which threatened Naples and the Fifth U.S. Army. At least one survey unit operated prophylactic stations in Naples during the winter. The remaining individuals and detachments were kept occupied in mapping, making watered-area surveys, overhauling equipment, consolidating records, and in accomplishing such preseasonal control operations as were possible. Thus during the season when malaria transmission was at its lowest ebb, the antimalaria personnel was serving usefully and in accordance with its prescribed functions.

As the theater malaria control organization expanded, increasing need was felt for discussing technical and administrative problems, for evaluating certain procedures, and for exchanging program information. To some degree, this was accomplished during the periodic visits of the theater malariologists to malaria control and survey units. It was evident, however, by the end of the 1944 malaria season, that a pooling of the highly specialized experiences

[39] (1) Soper, F. L., Knipe, F. W., Casini, G., Riehl, L. A., and Rubino, A.: Reduction of Anopheles Density Effected by the Preseason Spraying of Building Interiors With DDT in Kerosene, at Castel Volturno, Italy, in 1944–45 and the Tiber Delta in 1945. Am. J. Trop. Med. 27: 177–200, March 1947. (2) Aitken, T. H. G.: A Study of Winter DDT House-Spraying and Its Concomitant Effect on Anophelines and Malaria in an Endemic Area. J. Nat. Malaria Soc. 5: 169–187, June 1946.

of the malariologists attached to major commands would be invaluable toward making future operations more effective. With the object, therefore, of integrating, coordinating, and improving MTOUSA malaria control activities, of interchanging information, and of broadening the perspective of each malariologist by acquainting him with the experience of his fellows, the officer members of the 2655th Malaria Control Detachment were requested to attend and participate in a malaria control conference at Naples during November 1944. Sessions were held daily for 10 days. The program included a summary of theaterwide malaria control accomplishments and reviews of individual program experiences which were followed by group discussion and criticism. Presentations were also made concerning malaria control research projects which were being undertaken. A compilation of abstracts of the program was made and distributed later to those interested.

The results of the conference justified completely the time and expense involved in holding it. The participants had developed individual points of view which they propounded with great self-assurance and defended competently. The deliberate scrutiny and evaluation of each policy and procedure resulted in the resolution of certain generalizations concerning military malaria control which summarized the views of the malariologists. Some of them are presented in the following section.

CONCLUSIONS AND SUGGESTIONS FOR THE FUTURE

The following conclusions regarding NATOUSA (MTOUSA) malaria control experience and recommendations for future practice are not intended to reflect adversely on individuals concerned in their development. They are presented only with the object of improving military malaria prevention. Some of these reflect the deliberations of the malariologists at their 1944 meeting in Naples; others are the considered reflections of the author based upon his experience in NATOUSA and MTOUSA as assistant theater malariologist and then theater malariologist.

1. Physical noneffectiveness due to malaria did not threaten significantly the success of military operations in this theater. If the invasion of Sicily had been accomplished less swiftly, it is likely that malaria casualties might have become a source of embarrassment to the Commanding General in the fulfillment of his mission.

2. The principle of assigning command and operational responsibility to the theater malariologist in addition to his consultant duties worked very well in this theater. It centralized the program administratively as the theater malariologist was then in position to attach malariologists to major commands, to control essentially the attachment of antimalaria units, to supply airplane larviciding service where needed, and to advise concerning special malaria control supplies for the theater.

3. Military malaria control has all the diversity of practice inherent to civilian malaria control in addition to numerous other variable circumstances which do not occur in peacetime antimalaria operations; for example, static versus mobile populations, restricted versus expanding territories, service versus combat and flying troops, and the great increase in manmade mosquito breeding places due to topographic damage resulting from combat. Therefore, it is not feasible to plan or operate on a highly regimented basis; it is better in the long run to permit the local malariologists as much independence and liberty in developing and adapting their programs to prevailing conditions as is consistent with general theater coordination.

4. Didactic malaria control training is necessary as an initial incident in the educational process, but the process must be a continuous one in which the school is the beginning and not the end. Efforts at motivating military personnel to avoid exposure to malaria and of compensating for necessary risks must be maintained as long as the hazard of infection exists.

5. More malaria control enlightenment of line officers is needed, especially to promote a clear understanding of what their enlisted-men antimalaria details are supposed to do. This is especially true of commanding officers, particularly of company grade.

6. A greater utilization of medical supervision—perhaps through the medium of sanitary technicians—in unit malaria control would contribute greatly to the effectiveness of the program. By War Department Circular No. 223, dated 21 September 1943, enlisted-men details were to be composed mainly of nonmedical department personnel and were under the direct command of junior line officers who did not know how to use them. If the enlisted-men details could be placed under the technical direction of the medical officer, they might be used to much better advantage.

7. It was the considered opinion of the assembled malariologists, most of whom were medical officers, that, in MTOUSA, primary malaria control emphasis should be placed on: (1) Environmental control measures, (2) the use of bed nets, (3) protective clothing and repellents, and (4) suppressive medication. It is quite possible that groups of malariologists from other theaters would have given entirely different priorities to these activities.

8. The subject which provoked the most vigorous and sustained controversy in the malariologists' conference was the question of how much malaria control should be done for troops by the special malaria control organization and how much troops should do for themselves through the medium of enlisted-men antimalaria details. Except for the general proposition that *both* enlisted-men details and antimalaria units were needed, there was no general agreement as to their relative importance and dependability. In this theater, it was certainly true that malaria control could not be left entirely to enlisted-men details. The individuals assigned to this duty in many instances had little or no interest in it; many of them had other duty assignments that not infrequently superseded malaria control. Some of the men were inefficient and lazy. Frequent changes

occurred due to promotion, transfer, or the unpredictable notion of their commanding officers, so that there was much turnover and discontinuity in their work. They were commanded by officers who often were not well-indoctrinated with the importance and nature of their malaria control responsibilities.

Nevertheless, most of the environmental control (mainly DDT spray killing) in forward areas was done with enlisted-men details, and some of them performed magnificently under fire. The commanding officers of forward troops are rarely convinced of the urgency of malaria control units and are more prone to consider them unnecessary liabilities which have to be rationed, sheltered, and guarded. Thus, it is necessary under these conditions to depend primarily on the enlisted-men details, enhanced, where possible, by trained malaria unit personnel.

On the other hand, it was the general experience in this theater that in the relatively static rear areas a much higher quality of diversified malaria control program could be carried on through the use of native labor, labor troops, or of consolidated enlisted-men details working under the direction of malaria control unit personnel.

9. It was generally believed by the malariologic personnel in this theater that the malaria survey units and malaria control units as defined in 1944 were too small to accomplish their objectives efficiently. They were dependent upon larger units for rations and billets, and an unreasonably high proportion of their enlisted men component was needed for unit administration. It was suggested that several units might be attached to a higher coordinating headquarters for more effective utilization of unit personnel, or that larger, more self-sufficient units be organized. In 1945, the tables of organization and equipment for a medical battalion headquarters which might be used to consolidate antimalaria units were published, but this action was too late to be of use in MTOUSA. Since the end of the war, self-sufficient preventive medicine companies have been authorized, the functions of which include malaria survey and control.[46]

[46] (1) Tables of Organization and Equipment 8–500, 23 Apr. 1944. (2) Tables of Organization and Equipment 8–500, 18 Jan. 1945. (3) Tables of Organization and Equipment 8–117, 12 May 1950.

CHAPTER VI

Africa-Middle East Theater

John W. H. Rehn, Ph. D.

In Africa and the Middle East, U.S. military strength was small, and troops were spread over an enormous territory. Although some combat occurred within the area, American activities, with the exception of air combat forces, were fundamentally those of transport, supply, and liaison. Tortuous supply routes, particularly for air transport, necessitated numerous bases. Many of them were of an emergency or secondary character, and were lightly staffed. While some portions of the area were as malarious as any in the world, others were nonmalarious. As geographic, climatologic, and biologic conditions were very diverse, the programs developed were, in general, to meet local conditions. Administrative commands and boundaries were frequently changed, so that a decentralized method of malaria control and prevention was followed.

The discussion of malaria in the Africa-Middle East theater [1] is divided into a general consideration, supplemented by more detailed accounts of activities in Liberia and in the Persian Gulf. This division has been made because of biologic and administrative differences in these areas and because of limitations of available information.

The Liberian area had considerable contact with Central and other West African areas. Moreover, more detailed information is available for it and certain other small areas than is obtainable for the whole region. The Persian Gulf area, in addition to its geographic separation, differs significantly from all the other areas and within itself shows considerable diversity. Each of these areas was an independent command for at least a portion of the period covered.

In addition to a discussion of the general development there has been appended a brief résumé of the growth of the Air Transport Command and associated service commands. Because of their virtually independent development, a combined account might present a confused picture.

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[1] Except as otherwise indicated, data in this chapter are derived from: Billick, E. W., and Vickery, E. L.: History of the Medical Section, Africa-Middle East Theater, September 1941 to September 1945, vols. I and II. [Official record.]

MILITARY DEVELOPMENT

General Considerations

On 13 September 1941, the President of the United States, in a memorandum to the Secretary of War, requested that arrangements be made at the earliest practicable time for the establishment and operation of depots in the Middle East for the maintenance and supply of American aircraft and all types of ordnance furnished the British in that area. The U.S. Military North African Mission was immediately formed and sent to Egypt, where it arrived in Cairo on 22 November 1941. Contact was made to select housing, develop plans, and choose sites for bases. British, civilian, and captured records and reconnaissance surveys of Eritrea, Egypt, Anglo-Egyptian Sudan, and Palestine were utilized. In Egypt, the projects included ordnance shops as well as engineer and signal repair installations. Smaller scale activities of a similar type were planned for Palestine. At Port Sudan and in Eritrea, it was proposed to have Air Corps repair depots, ordnance repair shops, a naval base, and port facilities.

Since the United States was at that time a nonbelligerent, the Army could not build and staff the proposed installations itself, but it was responsible for the planning and supervision. The President had written: "The British authorities should be consulted on all details as to location, size and the character of depot and transport facilities. Their needs should govern."

The Japanese attack on Pearl Harbor changed the status of all U.S. Army activities. Construction was accelerated, militarization of the Mission between 10 April and 19 June 1942 was accomplished, and the region was consolidated into a theater of operations known as USAFIME (U.S. Army Forces in the Middle East). Service commands were organized in the various areas. The Iranian Mission was included among USAFIME. When Egypt was jeopardized by the campaign in the desert in June 1942, the Trans-Africa Road Reconnaissance Party made an investigation of a supply route across Africa on the southern fringe of the Sahara Desert from Khartoum in the Anglo-Egyptian Sudan to Lagos, Nigeria. Seven out of ten of the reconnaissance party contracted malaria. Fortunately it was not necessary to develop this alternate route.

The U.S. Army Middle East Air Force was established on 28 June 1942 and on 12 November was designated the Ninth Army Air Force, while the U.S. Army Ground Forces in the Middle East was organized on 16 August 1942.

A reorganization on 11 August 1942 resulted in the forming of the Eritrea, Delta, Levant, and Persian Gulf Service Commands (map 14). The Libyan Service Command, which originated on 7 December 1942, functioned until the end of May 1943 (map 15) and was then divided into base commands.

MAP 14.—U.S. Army Forces in the Middle East, jurisdictional map, 1942.

By 13 May 1943, all organized resistance in North Africa had ended. Preventive medicine, with the problem of malaria control topping the list, had been of the greatest importance in all operations.

The base commands established in the former Libyan Service Command were disbanded in September and November 1943. The Suez Canal Port Command was discontinued as a separate entity, and all were reabsorbed into the Delta Service Command.

In September 1943, the U.S. Army Forces in Central Africa were incorporated into the USAFIME and redesignated the West African Service Command. U.S. Forces in Liberia came into the theater without a change of name. The Persian Gulf Service Command was split off to form an independent command in December 1943 (map 16). Thus, activities were spread from Senegal in the west to Iran in the east. The Air Transport Command,

MAP 15.—U.S. Army Forces in the Middle East, jurisdictional map, 1943.

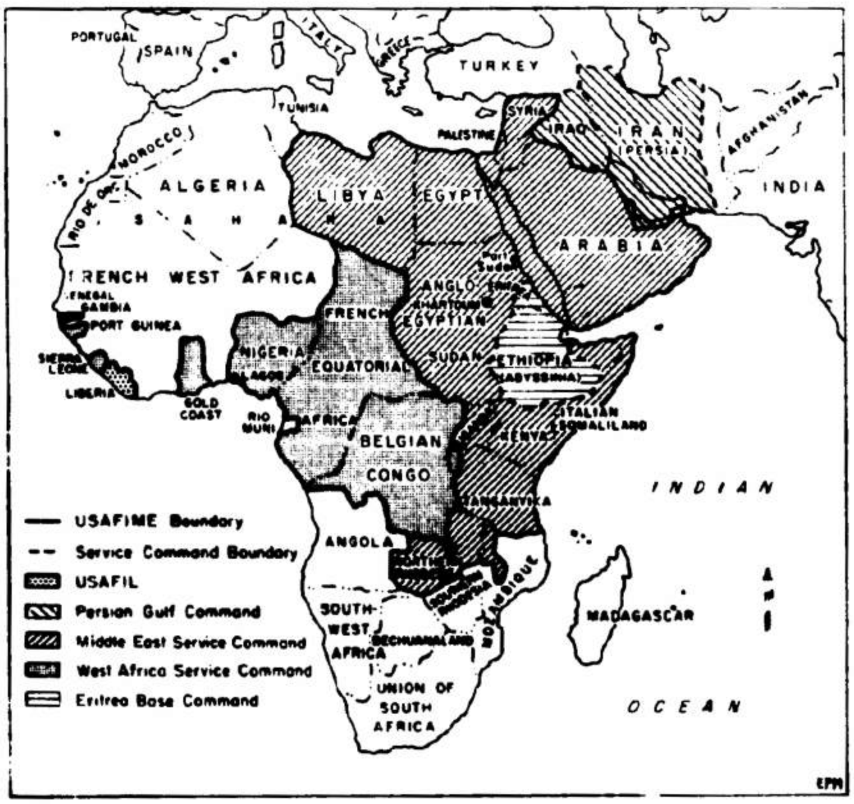
with its isolated bases across the continent of Africa, added to the malaria problems of the theater.

General retrenchment followed in 1944. Malaria was under control in most of the theater. Active fighting had moved far enough from the Middle East to render the theater of USAFIME one of communications rather than of combat. The original Delta Service Command changed into the Middle East Service Command on 16 February 1944. U.S. Forces in Eritrea regained a certain amount of independence later in the year, when they were again designated the Eritrea Base Command (map 16).

Early in 1945, the jurisdiction of USAFIME was greatly expanded. The ater boundaries were extended to include not only the whole continent of Africa and the Middle East but also a sector of Antarctica with its apex at the South Pole. The name of the theater was changed on 1 March 1945 to the Africa-Middle East theater. Those installations in French Morocco, Algeria, and Tunisia which joined the theater in March were organized into the North African Service Command.

A reduction of theater activities occurred as a result of victory in Europe, but it did not eliminate air traffic to India and China. It greatly stimulated air travel from Europe to the United States by way of North Africa.

After 2 September 1945, V-J Day, the Africa-Middle East theater proceeded on a rapid reorganization program, and by the end of the year most of the troops had been withdrawn.



MAP 16.—U.S. Army Forces in the Middle East, jurisdictional map, 1944.

Air Transport Command in Africa

The U.S. Government was interested in the delivery of airplanes to the Allies in the Middle and Far East. For this purpose, Pan-American Airways had been commissioned to establish a route for the transportation of aircraft by way of Africa to the Middle East. The route passed from Brazil to Liberia, through the Gold Coast, Nigeria, Anglo-Egyptian Sudan, Egypt, and Eritrea (map 17). Later, it was extended through Aden to India. By 15 December 1942, the Air Transport Command was operating the full route.

When the British Eighth Army was driven eastward to the Nile Delta

Map 17.—Air communications, U.S. Army Forces, Africa and the Middle East, 1941–45.

in the spring of 1942, the vulnerability of this air route became apparent. The War Department decided to find an alternate route and chose one which extended from Natal, Brazil, to Ascension Island, to French Equatorial Africa, the Belgian Congo, Uganda, and Abyssinia to Aden, and this grouping of airbases was organized as the U.S. Army Forces in Central Africa.

During 1943, the Air Transport Command grew and became more firmly established in Africa and Asia Minor. The Africa-Middle East Wing was reorganized into a North African Wing and a Central African Wing.

U.S. Army Forces in Central Africa closed the partly developed Southern Trans-African Air Route in 1943. Its activities came under the jurisdiction of USAFIME on 15 September 1943.

The Central African Division, Air Transport Command, was inactivated and closed its stations in June and July 1945, and the West African Service Command was inactivated on 30 June 1945. Remaining activities were placed under control of the North African Service Command.

U.S. Army Forces in Liberia

The mission of U.S. Army Forces in Liberia was to construct and maintain airfields and associated transport facilities. In August 1941, the U.S. Government contracted to establish aerial service through points in Africa. Construction was started at Roberts Field, Liberia, and continued until 31 December 1942, when all material was turned over to the U.S. Army Forces. The original plan to use Bathurst and Gambia, British West Africa, was abandoned in late 1941, and material was directed to the shores of Fisherman Lake, Liberia.

A defense agreement was signed by representatives of the United States and the Liberian Government on 31 March 1942. The first task force arrived in June 1942 and was concerned with airfield construction and with preparing for the larger defense force. The other task force arrived on 11 March 1943. In addition, the Liberian Government was assisted in reorganizing, training, and equipping the Liberian Frontier Force.

On 26 February 1946, the U.S. Army Forces in Liberia was inactivated.

Persian Gulf Command

On 27 September 1941, as the result of a Presidential directive, the U.S. Military Iranian Mission was established to include the Iranian Engineer District, North Atlantic Division, and to supplement the efforts of the British in the Persian corridor. The mission arrived in Baghdad, Iraq, on 30 November 1941.

Entry of the United States into the war did not at first alter the organization setup, but the territory of the U.S. Iranian Mission was changed to exclude India on 4 April 1942.

The activities of the U.S. Military Iranian Mission included the construction or reconstruction of approximately 1,000 miles of all-weather road; the building and operation of airplane, truck, and barge assembly plants; and the development of port facilities.

The U.S. Military Iranian Mission was discontinued on 24 June 1942, and the area was redesignated and established as the Iran-Iraq Service Command of USAFIME. On 13 August 1942, the Iran-Iraq Service Command was redesignated and established as the Persian Gulf Service Command with its geographic limits fixed as embracing Iraq, Iran, and those parts of Arabia that border on the Persian Gulf. In order to facilitate control and supervision, it was divided into territorial areas on 1 September 1942. The Persian Gulf Service Command was put under the jurisdiction of the Services of Supply, USAFIME, when the latter was established on 4 November 1942, and was relieved of this assignment on 20 January 1943.

After the Teheran Conference, the Persian Gulf Service Command was redesignated the Persian Gulf Command and was removed from the jurisdiction of USAFIME. At this time, U.S. military activities in all of Saudi Arabia came within the jurisdiction of USAFIME.

The mission of the Persian Gulf Command—the transportation of materiel to the U.S.S.R. from Persian Gulf ports across Iran—was declared accomplished on 1 June 1945. Effective on 1 October 1945, this command became a subcommand of the Africa-Middle East theater known as the Persian Gulf Service Command. The Persian Gulf Service Command closed suddenly, and all personnel were evacuated on 31 December 1945.

AREA CHARACTERISTICS

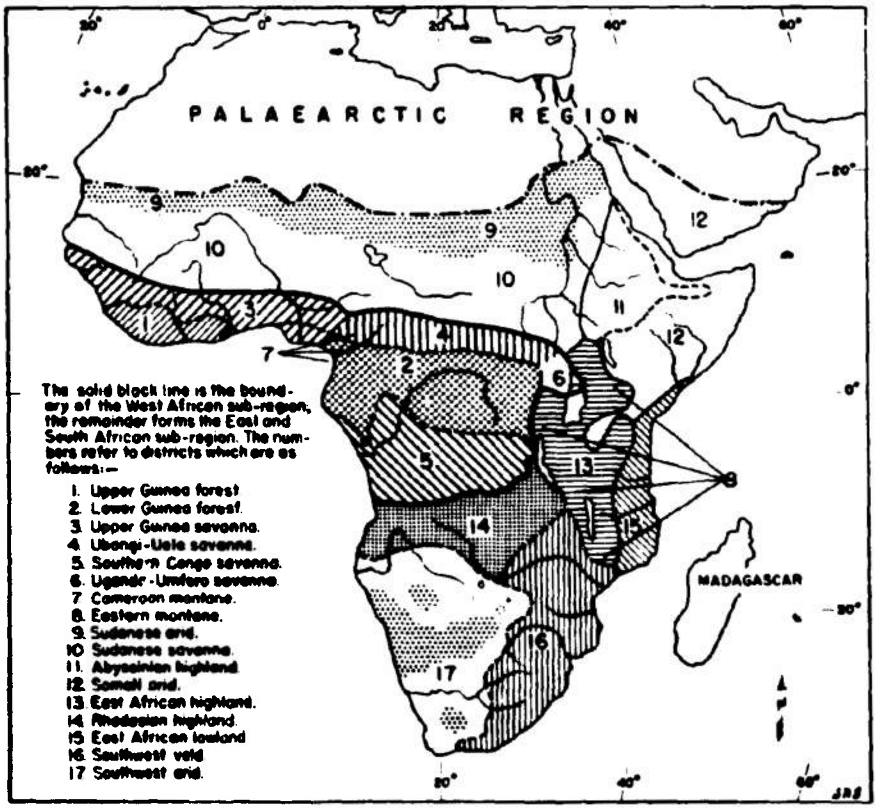
The Africa-Middle East area may be divided for purposes of description into two regions, Ethiopian (Africa) and Palaearctic (map 18).

Ethiopian Region

The tropical African area may be divided into a number of distinct biologic areas.[3] The most important of these is the immense West African region. Within this and the East and South African regions, secondary divisions are readily evident. Because of the large number of distinct biologic areas and the sparse troop population present, detailed statements concerning all these divisions are not required here. However, generalizations and discussion of features at some points of troop concentration may be of interest.

The coast of West Africa is bordered by a wide belt of virgin tropical forest, which, however, is broken by the clearings of the local population. To the north, the forests continue in open savanna woodlands, grassland interspersed

[3] Geographical Handbook Series, French Equatorial Africa and Cameroons, Great Britain Admiralty. Naval Intelligence Division. December 1942.



MAP 18.—Regional map of Africa.

with isolated groups of trees, and forest-fringed river courses. The region then passes into the Sudan Plain which is covered with deciduous brush and thorn.[3]

In the Sudan itself, there are two distinct areas, the southern forest, which has an average rainfall of 40 to 50 inches a year and which is composed of plains overgrown with deciduous trees, and the more northern districts, with rainfall of 20 to 40 inches a year, characterized by thornbush-covered plains.

The rainy season begins in the coastal districts in April and continues to the middle of July. This, in turn, is followed by gradually decreasing rains succeeded in October by a short rainy season. The driest period of the year is from December to March.

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[3] Martens, O., and Karstedt, O. (editors): The African Handbook, A Guide to West, South, and East Africa. 2d edition. London: George Allen and Unwin, Ltd., 1938.

In the Dakar area, French West Africa, rainfall is relatively light (from 25 to 30 inches a year), and summers are warm.

In Liberia, the humidity generally is high. The dry season, extending from December to March, definitely is the hottest. The wet season, which extends from April to November, while not cool, is less hot. Throughout this area, seasonal differentiation is into the wet and dry seasons, rather than into summer and winter.[4]

The Gold Coast has a hot and damp climate. Rainfall, however, is less than in other regions of the coast. The dry and rainy seasons are clearly defined. The latter starts in March and continues until about the end of June. A short and comparatively dry season ensues until the beginning of September, when the rains recommence and continue until the end of October. The dry season lasts from November to March.[5]

In Nigeria, the coastline is backed by a belt of swamp and mangrove forest from 10 to 60 miles in breadth which is intersected by the various arms of the Niger and other large rivers and streams. Beyond the forest zone is a broad section of more or less open country, consisting of savanna and parklike land. Most of the country is an undulating plateau which rises to an average of about 2,000 feet and is interspersed with isolated hills.

The Belgian Congo is a broad belt of almost impenetrable primitive forest stretching with scarcely a break to about the fourth degree of south latitude. This virgin forest is bounded to the north and south by parklike land, brush, and grass savannas.

Palaearctic Region

In the Palaearctic Region of the Africa-Middle East area, a number of distinct zones may be recognized. In a general broad category can be placed all the area bounding the southern and eastern shores of the Mediterranean. This semiarid land occupies a strip between the coast and the interior deserts. As exemplified by Palestine, although the actual time of arrival of the rains varies from place to place, conditions are as follows: There is seasonal rainfall, beginning about the middle of October and lasting until the middle or end of March. During April, there are a few spring showers, and from then until the end of October there is practically no rain. The country has really only two seasons—winter and summer. Throughout this country, January is the coldest, and August the hottest, month of the year. In general, the relative humidity is highest during the rainy season and lowest in May and October. Along the actual coast, the humidity is high throughout most of the year.

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[4] Strong, Richard P. (editor): The African Republic of Liberia and The Belgian Congo. Based on the Observations Made and Material Collected During the Harvard African Expedition, 1926–1927. Cambridge: Harvard University Press, 1930, vol. I.

[5] Fitzgerald, Walter: Africa: Economic and Political Geography of Its Major Regions. New York: E. P. Dutton and Co., Inc., 1930.

The general Nile drainage area, at least that portion occurring in Egypt, is an intensely agricultural section which has numerous problems peculiar to itself. Irrigation undoubtedly is one of the main factors contributing to the presence of malaria in this region.

In the Persian Gulf area, three major distinctions may be made. The first of these is the actual coastal area, where littoral conditions contribute greatly to the malaria problem. Inland, one first finds large reaches of arid or semiarid lands in which malaria is not widespread but is confined to those areas in which irrigation is practiced or in the vicinity of oases and wells. Continuing further inland, one reaches the mountainous and plateau section. In this area of the country, which is well watered, malaria is present but usually not hyperendemic. Irrigation, as well as the many natural waterways and basins, supplies the potential and actual breeding location for the various *Anopheles* vectors of malaria.

Tables 35 and 36 show average temperature and precipitation at selected localities. These give some approximation of meteorologic conditions at some of the more important centers of troop concentration.

LOCAL POPULATION

Throughout the areas, local populations represented several races and numerous distinct tribal stocks. In West and Central Africa, various indigenous tribes of Negroid stock, employed as unskilled labor, were closely associated with American troops. The degree of association varied from intermittent to almost constant, depending upon the condition at the particular base. In some cases, local residents were not allowed in the controlled areas except while working, but in other localities entire villages lay in close proximity to troop quarters.

In Northeast Africa, posts and camps were usually situated along transport and communication lines, in or near towns or cities. Here, again, the resident population (Egyptian, Arabian, and Hamitic) was utilized for labor. There must have been considerable contact during working hours under a variety of conditions. In the Levant, conditions resembled those in northeast Africa.

The Persian Gulf area, with its problems of transport and supply, necessitated close contact with the resident population. Here, labor forces and such skilled personnel as were available were utilized by the Army. Without doubt here, too, there was close contact with the indigenous population.

Living conditions among all types of population, whether Negroid, Arabian, Persian, or other, were generally substandard. There was a lack of even the most elementary sanitation, and health conditions were, in general, poor. Malaria control was usually nonexistent. In some areas, malaria was looked upon as the will of Allah and, therefore, beyond the means of mere mortals to comprehend or control. Adding to this the diversity of *Anopheles* vectors and their varied breeding habits, one can understand why malaria was a major

TABLE 35.—*Average rainfall in inches at selected localities,*[1] *for various time periods*

Locality	January	February	March	April	May	June	July	August	September	October	November	December	Total	Number of years
Teheran, Iran	1.7	1.1	2.0	1.4	0.6	0.1	0.2	0	0.1	0.3	0.9	1.2	9.5	27
Bushire, Iran	2.7	1.9	1.0	.5	0	0	0	0	0	.1	1.4	2.9	10.4	44
Baghdad, Iraq	1.2	1.3	1.3	.9	.2	0	0	0	0	.1	.7	1.2	7.1	33
Haifa, Palestine [2]	6.1	3.5	2.1	1.0	.3	0	0	0	.1	.8	3.6	6.4	23.9	9
Aden, Arabia	.3	.2	.5	.2	.1	.1	0	.1	.2	.1	.1	.1	1.8	39
Abbassia (near Cairo), Egypt	.4	.2	.2	.1	0	0	0	0	0	.1	.1	.3	1.3	35
Khartoum, Anglo-Egyptian Sudan	0	0	0	0	.1	.3	1.8	2.6	.7	.2	0	0	5.7	23
Bathurst, Gambia	0	0	0	0	.2	3.0	10.9	19.6	10.0	3.7	.2	0	47.6	36
Freetown, Sierra Leone	.4	.3	1.2	4.1	11.5	20.1	35.6	36.6	28.5	12.6	5.1	1.4	157.2	46
Firestone Plantation, Liberia [3]	1.4	2.7	4.8	6.7	12.9	19.9	19.8	21.2	26.7	17.2	7.7	3.4	144.6	17
Accra, Gold Coast	.7	1.0	1.8	3.7	5.7	7.0	1.7	.6	1.0	1.9	1.5	.7	27.2	32
Lagos, Nigeria	1.1	2.1	3.7	5.8	10.5	18.6	10.7	2.8	5.3	7.8	2.6	.8	71.6	29

[1] Precipitation data were taken from World Weather records and Smithsonian Miscellaneous Collection, volume 79, 1944.
[2] Kliger, Israel J.: Epidemiology and Control of Malaria in Palestine. Chicago: The University of Chicago Press, 1930.
[3] Annual Report, Malaria Control Activities at Roberts Field, Liberia, 1943.

TABLE 36.—*Average temperature in degrees Fahrenheit at selected localities* [1]

Locality	January	February	March	April	May	June	July	August	September	October	November	December	Total	Number of years
Bushire, Iran	57.9	59.0	65.5	74.1	82.4	86.1	89.6	90.2	86.5	79.5	70.1	61.5	75.2	44
Baghdad, Iraq	48.9	53.8	61.2	70.5	81.0	90.0	94.4	94.4	88.0	77.9	63.1	52.6	73.0	31
Haifa, Palestine [2]	55.8	57.4	60.4	66.6	72.1	77.2	80.8	81.7	79.7	75.0	66.7	58.5	69.3	8
Aden, Arabia	76.3	77.1	79.5	83.3	87.1	89.4	87.9	86.5	87.9	83.8	79.7	77.2	82.9	40
Abbassia (near Cairo), Egypt	54.3	57.0	62.4	69.4	75.9	81.1	82.8	82.0	77.4	73.0	65.3	57.7	69.8	53
Khartoum, Anglo-Egyptian Sudan	72.5	75.2	81.0	88.2	92.5	93.4	89.6	87.8	89.2	88.9	82.0	74.7	84.6	21
Freetown, Sierra Leone	81.3	82.3	82.4	82.4	81.5	80.3	78.6	77.9	79.1	80.1	81.2	81.4	80.7	46
Roberts Field, Liberia [3]	75.5	81.8	82.0	82.0	82.0	79.5	76.8	76.3	77.8	79.0	80.7	79.4	79.4	2
Accra, Gold Coast	79.7	80.3	81.3	81.1	80.0	77.5	75.7	74.7	76.2	78.3	79.8	80.1	78.7	32
Lagos, Nigeria	80.9	82.2	83.3	82.5	81.8	79.3	78.0	77.7	78.4	79.5	81.4	81.5	80.5	29

[1] Precipitation data were taken from World Weather records and Smithsonian Miscellaneous Collection, volume 79, 1944.
[2] Kliger, Israel J.: Epidemiology and Control of Malaria in Palestine. Chicago: The University of Chicago Press, 1930.
[3] Annual Report, 27th Malaria Control Detachment, 1945.

problem in much of the area. Because of lack of education, information, and initiative, many other diseases were also widespread.

MALARIA ENDEMICITY AND POTENTIALITIES

Africa and the Middle East are well known for their areas of malaria endemicity. Before American occupation, antimalaria work and malaria surveys had been carried on throughout considerable portions of this territory; however, there is not sufficient information to present an accurate map. The effect of malaria on this area is difficult to measure.[6] Enough work has been done and enough experience gained to show that malaria occupies a high place, if not the foremost, among the infective diseases causing mortality and morbidity in the indigenous populations. It plays an outstanding part in hindering the progress and social development of the people and in retarding the advancement of industry and trade. Up to the time of World War II, the prevention or control of malaria, with some notable exceptions, had been attempted only in populations inhabiting comparatively circumscribed areas, in urban districts, in large engineering or industrial projects, or in some areas of European farming settlements. In British colonial territories antimosquito measures had been practiced in the main townships.[7] In and around airports, considerable antimosquito measures were attempted.[8] Elsewhere, some steps had been taken to break the mosquito-man-mosquito cycle of the parasite in European homes by the use of screening, bed nets, and insecticidal sprays.

Africa as a whole is highly malarious. There are, however, portions of the Union of South Africa, vast stretches of the Sahara Desert, and various mountain areas in which malaria is definitely absent. *Falciparum* malaria is the most important variety in tropical Africa.

The entire Mediterranean coast of Africa is malarious, ranging in degree from low to high endemicity. Malaria extends southward into the great desert in several isolated oases. Throughout the huge Nile drainage system, malaria is endemic. Around the Suez Canal and on both shores of the Red Sea, it is also endemic. This condition extends down most of the coastal lowlands of east Africa. One main exception is the desert area of British and Italian Somaliland. The West Coast of Africa is also notoriously subject to malaria.

Throughout the great west African region, which encompasses primarily the Guinea forest belts and associated savanna land, malaria reaches hyperendemic proportions. Endemicity gradually tapers off until it is completely absent in the southern reaches of the Sahara Desert. West Africa has a sinister

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[6] Malaria Under African Conditions. Quart. Bull. Health Organ., League of Nations 5: 110–112, March 1936.

[7] Lord Hailey: African Survey, A Study of Problems Arising South of the Sahara. Issued by the Committee of the African Research Survey Under Auspices of The Royal Institute of International Affairs. New York: Oxford University Press, 1939.

[8] Development of a Medical Service for Airline Operations in Africa. War Med. 3: 484–497; 619–634, May-June 1943.

reputation in the matter of health. In this area, malaria is probably the most important cause of morbidity, inefficiency, and premature deaths. Nearly every member of the indigenous population is infected with malaria early in life.

Throughout British East Africa, malaria is prevalent but does not reach the proportions found in west Africa. The plateau section, although mildly malarious, does not offer suitable conditions for the hyperendemicity found further to the west. These conditions prevail in a southerly direction past the points where American troops were stationed.

Throughout the Levant, malaria is present to a varying degree. Some areas of hyperendemicity are known, but for the most part, moderate to slight endemicity is the rule. A considerable amount of antimalaria work was done in these countries before they were occupied by American troops.

In the Persian Gulf area, malaria is widely prevalent and often highly endemic, especially in the low coastal regions.

In addition to these generalities, the following more detailed information on areas where troops were stationed is of interest.

French West Africa

In the Dakar-Rufisque area of French West Africa, from 24 to 54 percent of blood smears from local residents were positive for *Plasmodium*.[9] Gametocyte indices averaged 6 percent in total examined and 28 percent in children between the ages of 5 and 10 years. On the Yoff Peninsula, surveys among the indigenous population showed 90 percent infectivity with a 6-percent gametocyte index. Of 407 positive blood smears, *P. falciparum* was identified in 388, *P. malariae* in 25, and *P. vivax* in 6. Twelve blood smears showed mixed infections.

Liberia

Liberia is a country where malaria reaches hyperendemic proportions. Parasite surveys[10] included individuals living on or near the Firestone Rubber Plantation, where control measures had been in effect (tables 37 and 38).

Parasite surveys were made in 1942 in villages near troop installations,[11] and, of 2,648 blood smears studied, 50 percent showed *P. falciparum;* 5.2 percent, *P. malariae;* and 2 percent, *P. vivax*. Similar examinations made in August 1953 revealed 161 out of 687 smears, or 23 percent, positive for malaria parasites.

[9] Report, Maj. Alva J. Floyd, MC, Asst. Malariologist, USAFIME, to Commanding General, USAFIME, Cairo, Egypt, attention: The Chief Surgeon, 4 Nov. 1944, subject: Report of Malaria Control Activities at U.S. Army Installations in West Africa, 1941–1944. Part IV, French West Africa.

[10] (1) Barber, M. A., Rice, J. B., and Brown, J. Y.: Malaria Studies on the Firestone Rubber Plantation in Liberia, West Africa. Am. J. Hyg. 15: 601–633, May 1932. (2) Medical and Sanitary Data on Liberia. Compiled by Medical Intelligence Branch, Preventive Medicine Division, Office of The Surgeon General, U.S. Army, 17 Nov. 1943.

[11] Annual Report, U.S. Army Forces in Liberia, 1943.

TABLE 37.—*Malaria parasite index, Liberia, 1941*

Age groups	Number examined	Percent positive
3 to 4 months	4	50
5 to 11 months	3	100
1 to 4 years	33	97
5 to 8 years	36	94
9 to 12 years	49	96
13 to 15 years	16	88
16 years and over	670	75
All ages	811	78

TABLE 38.—*Malaria parasite index, Liberia, 1942*

Age groups	Number examined	Percent positive
Infants	6	83
Children	35	71
Adults	380	34
All ages	421	38

In accordance with the usual findings in hyperendemic areas,[12] a high proportion of the infants (83 percent) and children (71 percent) were found infected, the adults having a materially lower parasite rate (34 percent). Similar relationships were observed between gametocyte prevalence and age. The infants showed a much higher prevalence (50 percent) than children (3 percent) or adults (1 percent). Numerous other surveys substantiated these findings.[13]

British West Africa

The Gold Coast is also subject to hyperendemic malaria. Surveys of children in the region have shown about two-thirds of them to be infected with *P. falciparum* and to have gametocyte rates exceeding 15 percent.[14]

The annual malaria rate for European personnel of the British Army in the Accra District in the period from 1 September 1941 to 31 August 1942

[12] Report, Maj. Justin M. Andrews, SnC, to Chief Health Officer, 5 July 1943, subject: Malaria Investigations and Recommendations for Malaria Control at Roberts Field Area.

[13] Annual Malaria Report, 1944. (Report of Malaria Control at U.S. Army Installations in West Africa, 1941–1944, Part III: Liberia, West Africa, Headquarters, Medical Composite Units (Malaria Survey and Control Units), 15 Jan. 1945.)

[14] Report, Maj. Elliston Farrell, MC, to the Commanding General, USAFIME, Cairo, Egypt, attention: The Chief Surgeon, 1 Nov. 1944, subject: Report of Malaria Control at U.S. Army Installations in West Africa, 1941–1944. Part II. Gold Coast British West Africa.

was 102.6.[15] From 50 to 75 percent of the children from 2 to 10 years of age in the district villages had enlarged spleens. Children under 5 years of age invariably were found to have gametocyte rates of 90 percent or more.

Egypt

During the period from August to December 1936, a survey was made of three general areas in Egypt:[16] The valley of the Nile, including Fayum; the Oasis of Siwa in the Western Desert: and the Suez Canal Zone. Malaria was found to be widespread in the Nile Valley: no locality of Lower Egypt proved to be malaria free. Both the parasite rates and the percentage of enlarged spleens were low in many places, but in villages near rice plantations or large bodies of fresh water they were usually high. High parasite and spleen indices were found in the Siwa Oasis and in the Suez Canal Zone. *P. vivax* predominated in the majority of localities, but *P. falciparum* occurred in nearly all parts of the territory. *P. malariae* was not found in the Nile Valley and was rare in other Egyptian areas. The spleen index was generally lower than the parasite index. The villages in Lower Egypt (the Delta, between Cairo and the Mediterranean) had an average parasite index of 7.2. The average parasite index of all examinations was 21.1 percent—an index probably too high to be representative of the whole valley.

Palestine

General surveys throughout various portions of the country obtained the following figures:[17] Among Jews, the *Plasmodium* index was 4.6 percent and the enlarged spleen index, 20.1 percent; among Arabs, the *Plasmodium* index was 12.5 percent and the enlarged spleen index, 62.5 percent; among Bedouins, the *Plasmodium* index was 32.5 percent and the enlarged spleen index, 58.8 percent. In Palestine, surveys made between 1922 and 1924 showed the relative frequency of various types of malaria to be: *P. vivax*, 69.13 percent; *P. falciparum*, 29.30 percent; and *P. malariae*, 1.57 percent. In epidemic periods, however, as for instance in 1922, the findings were: *P. vivax*, 58.6 percent; *P. falciparum*, 40.3 percent; and *P. malariae*, 1.1 percent.

Iran

In Iran,[18] blood surveys in 1934 showed from 10 to 25 percent of the population to be harboring malaria parasites. Examination of 5,000 patients during a 6-month period (from the middle of May to the middle of November)

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[15] Report, Maj. O. J. S. Macdonald, Indian Medical Service, to Brig. Gen. James S. Simmons, MC, Director, Preventive Medicine Division, Office of the Surgeon General, 1 Dec. 1943, subject: Summary of Report on Malaria in the Accra District.

[16] Barber, M. A., and Rice, J. B.: Survey of Malaria in Egypt. Am. J. Trop. Med. 17: 413–436, May 1947.

[17] Kligler, Israel J.: Epidemiology and Control of Malaria in Palestine. Chicago: The University of Chicago Press, 1930.

[18] Greenfield, G.: Beitrag zur Frage der Malaria in Persien. Arch. f. Schiffs-u.Tropen-Hyg. 39: 257–260, June 1935.

disclosed 48 percent as having had malaria, 75 percent of which was caused by *P. vivax*, 20 percent by *P. malariae*, and 5 percent by *P. falciparum*. Surveys made while American troops were present showed the proportions of the various kinds of malarial infection as follows: [19] *P. vivax*, 80 percent; *P. falciparum*, 14 percent; *P. malariae*, mixed, and unclassified infections, 6 percent. No surveys were permitted in Azerbaijan and Caspian areas of northern Iran which were under Russian control.

VECTORS

In the Africa-Middle East area, at least 75 species of *Anopheles* have been recognized. Some of these are rare, and many do not transmit malaria. The malaria vectors have received considerable study, and a wealth of information about them has been published. The following species of *Anopheles* are believed to be of importance in the transmission of malaria in Africa-Middle East areas occupied by American troops:

Anopheles claviger bifurcatus Meigen 1904 is found in Europe, northern Africa, Asia Minor, and Turkestan. Larvae breed in marshes, rock pools, wells, and cisterns. In Palestine, this species commonly enters houses and bites humans freely. Elsewhere, it rarely enters houses or feeds on man. It is the most important urban vector of malaria in Palestine and Syria but is not considered important in other areas.

Anopheles funestus Giles 1900 is widely distributed throughout tropical and South Africa, occurs as far north as Abyssinia, and is found on Madagascar and Mauritius.

A. funestus usually breeds in large or fairly permanent bodies of clear water, such as swamps, weedy banks of streams, rivers, ditches, protected lake shores, or long-standing seepages. Some shade is usually preferred, but not deep forest shade. As the breeding places of *A. funestus* are often more permanent than those of *A. gambiae*, the former tends to be associated with endemic rather than epidemic malaria.

The adults readily enter houses in large numbers where they feed on human blood. Work in Kenya has revealed that 40.8 percent of the blood meals examined were positive for human blood and that over 58 percent of those showing any definite reaction reacted only to human blood. Preference for the blood of Africans was suggested by the results of some experiments. Other work has shown that *A. funestus* is attracted more strongly to a human sleeping in a confined space than in the open. In all-night catches, it was found that the greatest number of females entered quarters at about 2300. Although *A. funestus* adults may be taken as far as 4½ miles from the nearest breeding place, 80 percent are found within a ½-mile radius of this site.

[19] A Narrative History of Medical Activities in the Persian Gulf Command. [Official record.]

A. funestus is an important vector of malaria, although often secondary to *A. gambiae*, where both occur. The following natural infectivity rates represent the percentage positive for sporozoites in the salivary glands: Sierra Leone: Kissy, 4.1 percent; Liberia: Firestone Plantation, 1.9 percent; Nigeria: Gadau, 3.5 percent; Ibadan, 6.9 percent; Lagos and vicinity, 12.8 percent; and Belgian Congo: Stanleyville, 4.2 percent. Many areas in East and South Africa show rates which vary from 0.2 to 27 percent.

Anopheles gambiae Giles 1902 is found throughout tropical Africa and in South Africa except in the desert regions and high mountains; it is also found in Arabia, Madagascar, Reunion, and Mauritius. It has invaded and has been driven out of Egypt and Brazil.

A. gambiae larvae are found in puddles, shallow ponds, borrow pits, hoofprints, and ditches in sun or light shade.

A. gambiae feeds mainly on human blood, and enters dwellings in large numbers in most regions where it is prevalent. In some towns, it is the only domestic *Anopheles*, and, in many areas, it may represent 95 percent of the domestic *Anopheles* population. In regions where *A. funestus* is also common, the two species together usually constitute 90 percent or more of this population.

Much research work on *A. gambiae* indicates a strong preference of resting females for inhabited dwellings. However, appreciable numbers may enter houses unsuitable as resting places, in order to feed and then leave. Observations in Kenya determined that this species had an anthropophilic index of 78 percent. At Lagos, 82 percent gave positive reactions for human blood even in examinations made of specimens caught in buildings in which both cattle and humans were sheltered. It has been found that where the species is abundant it frequently feeds in the early hours of the evening. At Lagos, all-night catches showed that while biting took place from sunset until sunrise, the peak of biting activities occurred between 0200 and 0400. This species has been found biting freely out of doors during the time of activity. Adult dispersal of at least one-half a mile is common, and at times individuals have been found as far as 3 miles from their breeding place.

A. gambiae and *A. funestus* are the two most important malaria vectors in the Ethiopian region. (Both are also important vectors of filariasis.) The following records show natural infectivity rates for this species and represent the percentage positive for *Plasmodium* sporozoites in the salivary glands: Sierra Leone: Freetown, 8 percent; Kissy, 11.2 percent; Liberia: Firestone Plantation, 3.5 percent; Nigeria: from 7.4 to 9.6 percent; Yaba, 4.6 percent; Lagos and vicinity, 6.6 percent; Ibadan, 13.1 percent; and central and east Africa, various stations, 0.7 to 11.5 percent.

Anopheles gambiae melas Theobald 1901 is found breeding in brackish water along the littoral of Sierra Leone and the Gold Coast in tidal swamps and coastal streams. Adults are house haunting and take human blood freely. *Melas* is an important vector in some localities.

Anopheles hancocki Edwards 1929 is found in parts of west and central Africa, from Sierra Leone to Uganda and southward to Angola.

The adults of this species are commonly found in human habitations, particularly in Liberia and Uganda. Near Freetown, they have been taken in outdoor biting experiments, with local boys as bait. The larvae are found in clear water in grassy holes, wells, streams, and swamps in sunny places.

This species is an important malaria vector wherever prevalent. A considerable number of dissections in Uganda revealed an average monthly infection rate of 11.4 percent and an average sporozoite rate of 2.7 percent. The monthly sporozoite rate fluctuated from zero to a maximum of 7 percent. In Liberia, this species is still suspected on epidemiologic grounds, although no positive findings were obtained in a small number of dissections.

Anopheles hargreavesi Evans 1927 is found in Liberia, Sierra Leone, Gold Coast, southern Nigeria and northern Belgian Congo.

Adults are common in huts in Nigeria. Females were attracted in large numbers to human bait during night experiments at Lagos. The peak of activity is midnight or later. Larvae are found in shady places of swamps and stream margins in open jungle.

This is an important malaria vector in certain areas of west Africa where it is common. In southern Nigeria, a sporozoite rate of 5.4 percent has been found.

Anopheles moucheti moucheti Evans 1925 is found in the Belgian Congo, Uganda, and Cameroons.

In localities where this species is prevalent, females have been found indoors in considerable numbers. Larvae are found among vegetation of pools, streams, and swamps in sun to light shade.

This species, where common, has considerable importance as a vector of malaria. The total infection rate averages 8.3 percent, with the sporozoite rate fluctuating between 1.6 and 4.1 percent. Near Stanleyville, an oocyst and sporozoite rate of 4.5 percent has been found among females collected from huts.

Anopheles moucheti nigeriensis Evans 1931 is found only in southern Nigeria. Adults were found in considerable numbers in huts in villages near Lagos. Larvae are found in clear, sunny water in swamps.

This form is of importance wherever it is common. A sporozoite rate of 1.1 percent was found among females taken in huts near Lagos.

Anopheles multicolor Cambouliu 1902 is a desert species found in North Africa, Egypt, Sudan, Palestine, eastern Iran, and Baluchistan.

The adults of this species may disperse, with prevailing winds, as far as 8 miles and readily enter houses to bite humans. Larvae are found in pools, flowing or stagnant drains, and shallow wells, and tolerate desert salinity up to 5.06 percent.

This species is considered on epidemiologic grounds to be a vector of malaria.

Anopheles nili Theobald 1904 is widely distributed through west and central Africa and extends into British East Africa.

Adults are rare in houses but have been found in large numbers in huts and camps in limited areas. Larvae are found in shade among vegetation along stream edges.

Where prevalent in dwellings this species may be an important vector. Dissections have been made with negative findings in some areas, but when positive the rates were usually high. Representative findings are: In villages in Stanleyville District, oocyst rate 10 percent and sporozoite rate 5.3 percent: camps on rubber plantation, Liberia, oocyst rate 14.6 percent and sporozoite rate 0.8 percent; houses near Freetown, oocyst rate 18.2 percent and sporozoite rate 9.1 percent.

Anopheles pharoensis Theobald 1901 is widespread throughout tropical Africa and is also found in Egypt and Palestine.

In certain localities where this species is prevalent, the adults may enter houses and tents in appreciable numbers. It is described as a domestic species in Egypt. In other areas, the number of females captured indoors is relatively small in comparison with those of the other important vectors. Although *A. pharoensis* feeds readily on man, the results of precipitin tests reveal a marked preference for cattle blood. Larvae are found in swamps and rice-fields.

Much evidence has been accumulated to indicate that *A. pharoensis* is an efficient vector of malaria. Many individuals have been found naturally infected in nature, with oocysts and a few with sporozoites. The species has been infected experimentally with both *P. falciparum* and *P. vivax*. In the Nile Delta, distribution of the species correlates closely with that of malaria prevalence. It is believed to be one of the chief vectors in the Upper Nile Province. In most parts of Africa, it appears to be of less importance than *A. gambiae* and *A. funestus*. However, sporozoite rates up to 6 percent have been found. In southern Nigeria, a malaria positive rate of 1.8 percent and sporozoite rate of 0.7 percent were encountered; while in Egypt, oocysts rates of 6.7 percent to 10.8 percent and a sporozoite rate of 0.5 percent were found.

Anopheles pretoriensis Theobald 1903 is found in parts of West and Central Africa.

Adults in some areas frequent houses while in others outside resting places are preferred. Larvae are found in rock pools, hoofprints, and semistagnant pools in streams and ditches.

Although 1.7 percent of one series were found to be naturally infected, it is doubtful whether this species is of much importance as a malaria vector.

Anopheles pulcherrimus Theobald 1902 is a dominant species in regions of the lower Persian Gulf area and is also found in Pakistan and central Asia.

Some observers have found it to be a bold feeder, often taken in houses. It is a strong flier and may be carried long distances by the wind. In some areas, it has been found naturally infected, but usually it is not an important vector.

Anopheles sacharovi (*elutus*) Favre 1903 is chiefly a European and northern Asiatic species but it is of importance as a vector in portions of the Levant and Persian Gulf.

Sacharovi is an indiscriminate feeder on both man and domestic animals. Adults enter human habitations to feed. Observations in Palestine indicate that there it shows house preference. Its flight range is from 1¼ miles to more than 1½ miles. Larvae are found in open inland marshes and also in brackish waters.

This species is considered to be an important vector in the Balkans, Palestine, and Iran. An infective rate of 1.2 percent has been found in Palestine.

Anopheles sergenti Theobald 1907 is found through Northern Africa, Egypt, and Palestine. Larvae are found in ricefields, irrigation channels, borrow pits, river edges, and seepages. Adults feed indoors or outdoors but do not rest inside houses in Palestine, preferring rocky caves.

This species is a vector in Egypt and especially in Palestine.

Anopheles stephensi stephensi Listor 1901 is found in the Persian Gulf area, Iraq, Iran, Pakistan, and India. Larvae are found in wells, cisterns, flowerpots, and roof gutters. Adults are thoroughly domestic, feeding readily on man.

Stephensi stephensi is an important vector in certain urban areas and is responsible for much of the malaria in southern Iraq and Iran.

Anopheles superpictus Grassi 1899 is widely distributed in Southern Europe and Asia Minor and is found eastward to northwestern India. Larvae are found in fresh-water pools, streams, and seepages, especially in hilly areas. Adults readily enter and rest in houses, taking human blood freely.

This species is a vector in Southern Europe, Mesopotamia, Iraq, Iran, and Baluchistan.

MALARIA EXPERIENCE

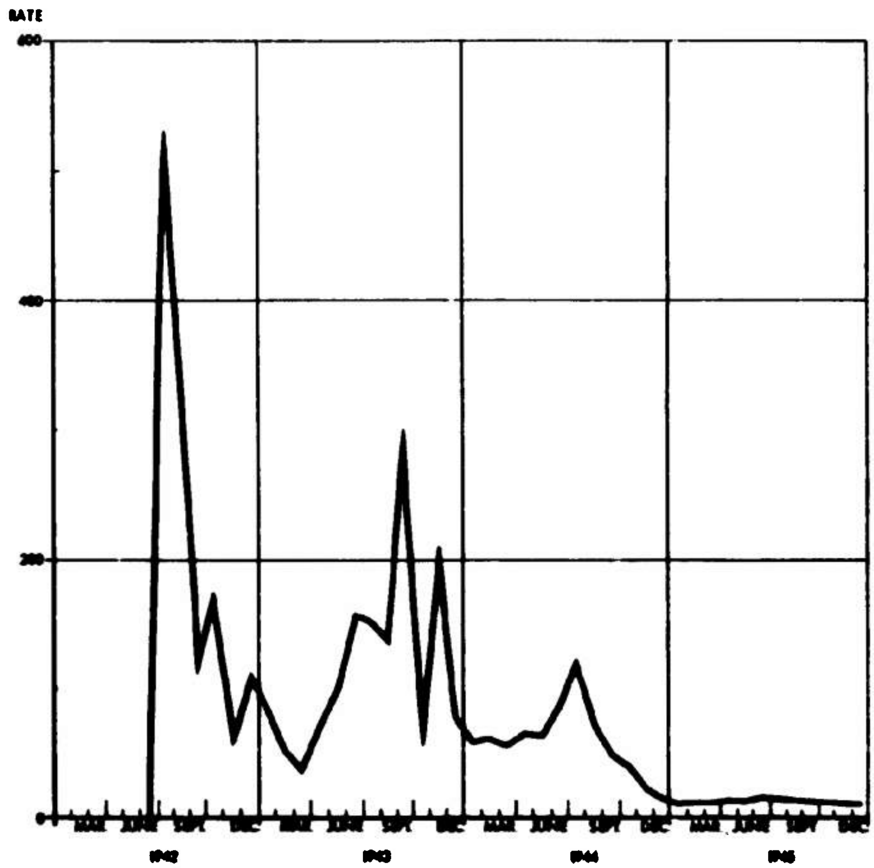
Chart 9 and table 39 show the malaria rates from 1942 through 1945 for the Africa-Middle East area. Table 39 also shows the rates for fever of undetermined origin for the same period. The overall picture shows the general effect of various methods of environmental control and suppressive medication. Moreover, it illustrates to some extent the seasonal distribution of malaria in these areas. Owing to diverse conditions, further conclusions are not warranted.

Table 40 and chart 10 show the malaria rates in forces stationed in west and central Africa during portions of 1942 and 1943. In addition, table 40 shows the rates for fever of undetermined origin among these forces for the same period. In some of this region, suppressive medication was used to supplement physical control measures.

CHART 9.—*Attack rates for malaria among U.S. Army personnel, Africa-Middle East area,[1] 1942–45*

[Preliminary data from statistical health reports]

[Rate expressed as number of cases per annum per 1,000 average strength]

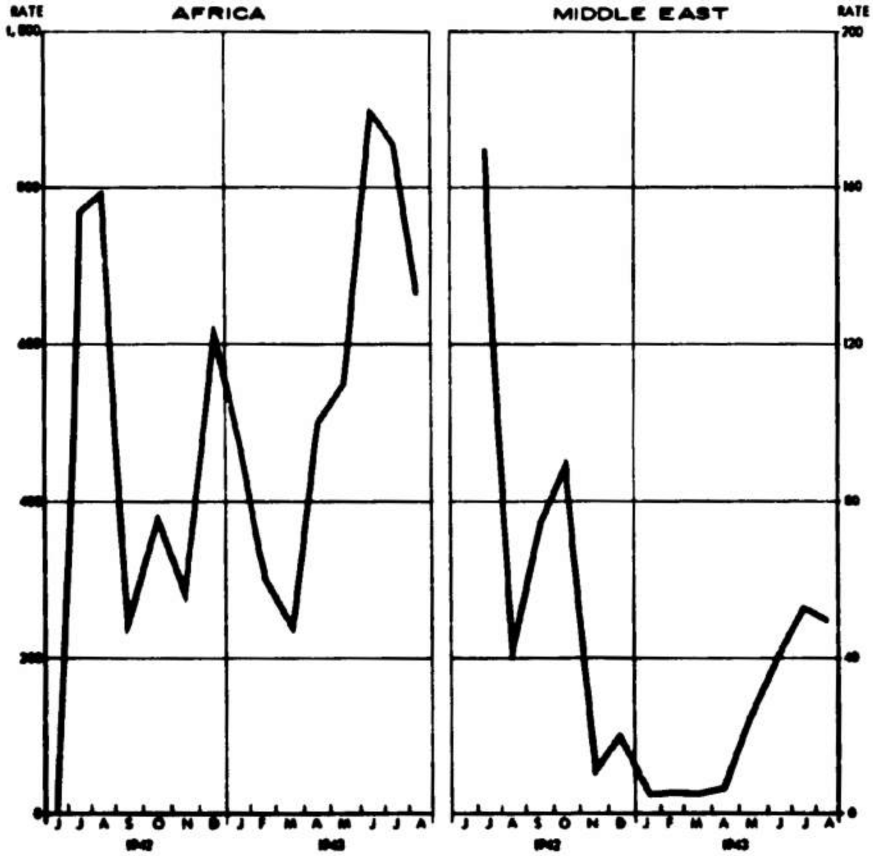


[1] Includes all of Africa and the Middle East except North African area of the Mediterranean theater, until March 1945 when this area was incorporated in the Africa-Middle East theater.

CHART 10.—*Attack rates for malaria among U.S. Army personnel in Africa*[1] *and the Middle East,*[2] *June 1942–August 1943*

[Preliminary data from statistical health reports]

[Rate expressed as number of cases per annum per 1,000 average strength]



[1] Includes British West Africa, French West Africa, Liberia, and Central Africa but not North African theater nor Delta, Levant, Eritrea, and Libyan Service Commands.

[2] Includes Delta, Levant, Eritrea, Libyan, and Persian Gulf Service Commands.

TABLE 39.—*Attack rates for malaria and fever of undetermined origin, among U.S. Army personnel, Africa-Middle East area,[1] 1942–45*

[Preliminary data from statistical health reports]

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	Malaria				Fever of undetermined origin [2]			
	1942	1943	1944	1945	1942	1943	1944	1945
January	(3)	85	61	11	(3)	15	16	12
February	(3)	52	62	9	(3)	13	9	24
March	(3)	37	58	10	(3)	11	9	31
April	(3)	77	63	11	(3)	13	21	33
May	(3)	105	61	9	(3)	21	24	35
June	0	164	84	14	0	25	21	29
July	529	156	121	14	16	44	66	50
August	205	139	71	13	43	44	52	59
September	113	301	51	12	50	16	34	49
October	176	60	40	11	29	20	30	27
November	59	205	23	8	30	11	27	25
December	118	82	15	8	11	8	21	14
Total	136	123	59	11	11	21	27	34

[1] Includes all of Africa and the Middle East except North African area of the Mediterranean theater, until March 1945 when this area was incorporated in the Africa-Middle East theater.

[2] The proportion of these figures which actually represents malaria cannot be determined.

[3] Data are not available.

TABLE 40.—*Attack rates for malaria and fever of undetermined origin, among U.S. Army personnel in Africa,[1] 1942–43*

[Preliminary data from statistical health reports]

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	Malaria		Fever of undetermined origin [2]	
	1942	1943	1942	1943
January	------	466	------	62
February	------	297	------	61
March	------	224	------	46
April	------	503	------	53
May	------	557	------	54
June	0	888	0	60
July	767	811	9	85
August	787	664	0	92
September	236	(3)	0	(3)
October	361	(3)	26	(3)
November	275	(3)	0	(3)
December	613	(3)	25	(3)
Total	452	(3)	13	(3)

[1] Includes British West Africa, French West Africa, Liberia, and Central Africa but not North African theater nor Delta, Levant, Eritrea, and Libyan Service Commands.

[2] The proportion of these figures which actually represents malaria cannot be determined.

[3] Data are not available.

The Liberian Force was given suppressive medication from before landing until October and November 1942. Then in late December, after a great increase of the disease, suppressive treatment was reinstituted and continued until late February 1943, when it was again stopped. In June, this force was again placed on suppressive medication. At least in the Accra district, suppressive medication was in force from December 1942 through March 1943. The U.S. Army Forces in central Africa were placed on suppressive medication in November 1942. It seems probable that other areas were similarly treated, but definite information other than that summarized in the section on suppressive medication is not available.

Comparable rates, for the same period, in the Middle East are shown in table 41 and chart 10. Whether suppressive medication was used to supplement other control measures is not known. The figures may represent simply the incidence as influenced by physical control measures.

TABLE 41.—*Attack rates for malaria and fever of undetermined origin, among U.S. Army personnel in Middle East,[1] 1942-43*

[Preliminary data from statistical health reports]
[Rate expressed as number of cases per annum per 1,000 average strength]

Month	Malaria		Fever of undetermined origin[2]	
	1942	1943	1942	1943
January	....	4	....	4
February	....	4	....	3
March	....	4	....	4
April	....	5	....	6
May	....	25	....	15
June	....	41	....	18
July	170	52	26	38
August	40	49	65	35
September	73	(3)	67	(3)
October	92	(3)	26	(3)
November	10	(3)	5	(3)
December	21	(3)	8	(3)
Total	30	(3)	21	(3)

[1] Includes Delta, Levant, Eritrea, Libyan, and Persian Gulf Service Commands.
[2] The proportion of these figures which actually represents malaria cannot be determined.
[3] Data are not available.

Tables 42 and 43 show malaria rates in various areas in West Africa, for varying lengths of time in the period 1942 through 1944. Whether suppressive medication was authorized in other than the Accra district of the Gold Coast and those parts administered by U.S. Army Forces in central Africa is not known. In certain of these areas, all physical control measures were the responsibility of our Allies, while in others, American forces supple-

TABLE 42.—*Attack rates for malaria among U.S. Army troops, French West Africa, January 1943–December 1944*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	Yoff-Rufisque-Dakar[1]		Eknes Field[2]	
	1943	1944	1943	1944
January	----------	192		247
February	----------	131		134
March	171	103	168	113
April	101	140	102	167
May	172	106	169	115
June	218	[3] 139	213	
July	263	41	258	
August	573	58	562	
September	1,532	57	1,554	
October	1,948	61	1,952	----------
November	1,285	30	1,302	
December	451	32	442	

[1] Annual Report, 19th Medical Composite Unit, 1944.

[2] Report, Maj. Alva J. Floyd, MC, Asst. Malariologist, USAFIME, to Commanding General, USAFIME, Cairo, Egypt, attention: The Chief Surgeon, 4 Nov. 1944, subject: Report of Malaria Control Activities at U.S. Army Installations in West Africa, 1941–1944. Part IV, French West Africa.

[3] Airbase moved from Rufisque to Yoff Peninsula, 31 May 1944.

TABLE 43.—*Attack rates for malaria among U.S. Army troops, in the Gold Coast and Nigeria, British West Africa, January 1943–December 1944*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	Gold Coast[1]		Nigeria[2]	
	1943	1944	1943	1944
January	441	539	151	110
February	235	635	162	48
March	158	355	243	90
April	164	258	150	22
May	354	260	150	22
June	636	501	163	26
July	807	683	1,501	228
August	660	236	1,314	446
September	566	31	1,712	35
October	548	34	817	45
November	548	----------	902	----------
December	495	----------	251	----------

[1] Report, Maj. Elliston Farrell, MC, to the Commanding General, USAFIME, Cairo, Egypt, attention: The Chief Surgeon, 1 Nov. 1944, subject: Report of Malaria Control at U.S. Army Installations in West Africa, 1941–1944. Part II. Gold Coast, British West Africa.

[2] Report, Maj. Elliston Farrell, MC, to Commanding General, USAFIME, Cairo, Egypt, attention: The Chief Surgeon, 1 Nov. 1944, subject: Malaria Control at U.S. Army Installations in West Africa, 1941–1944. Part I: Nigeria, British West Africa.

mented or took over these operations. These stations were in some of the classic malarious areas of the world, and a large percentage of the troops contracted the disease at some time during their stay.

Chart 11 and tables 44 and 45, respectively, show the malaria rate for 1944 and 1945 in the Middle East, excluding Persian Gulf Command, and in the Persian Gulf Command; in addition, the tables also show the fever of undetermined origin rate for the same period. These figures indicate the total effect of the various control measures used. It should be noted that rates in the Persian Gulf area at the beginning of the period were appreciably lower than in Africa. No further conclusions from these figures are warranted.

CHART 11.—*Attack rates for malaria among U.S. Army personnel in the Africa-Middle East area (excluding Persian Gulf Command) and in the Persian Gulf Command, 1944–45*

[Preliminary data from statistical health reports]

[Rate expressed as number of cases per annum per 1,000 average strength]

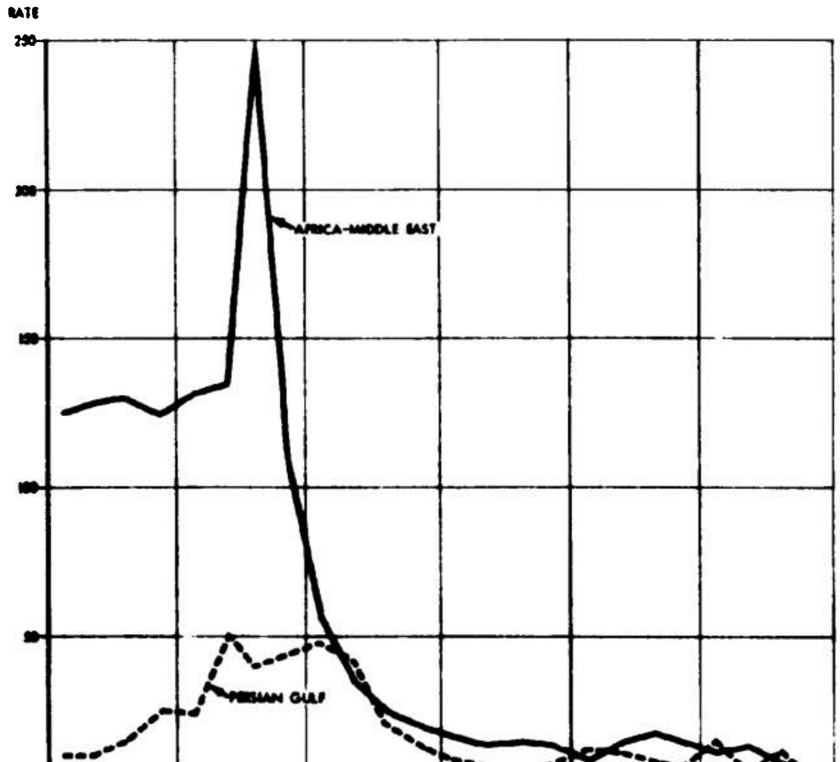
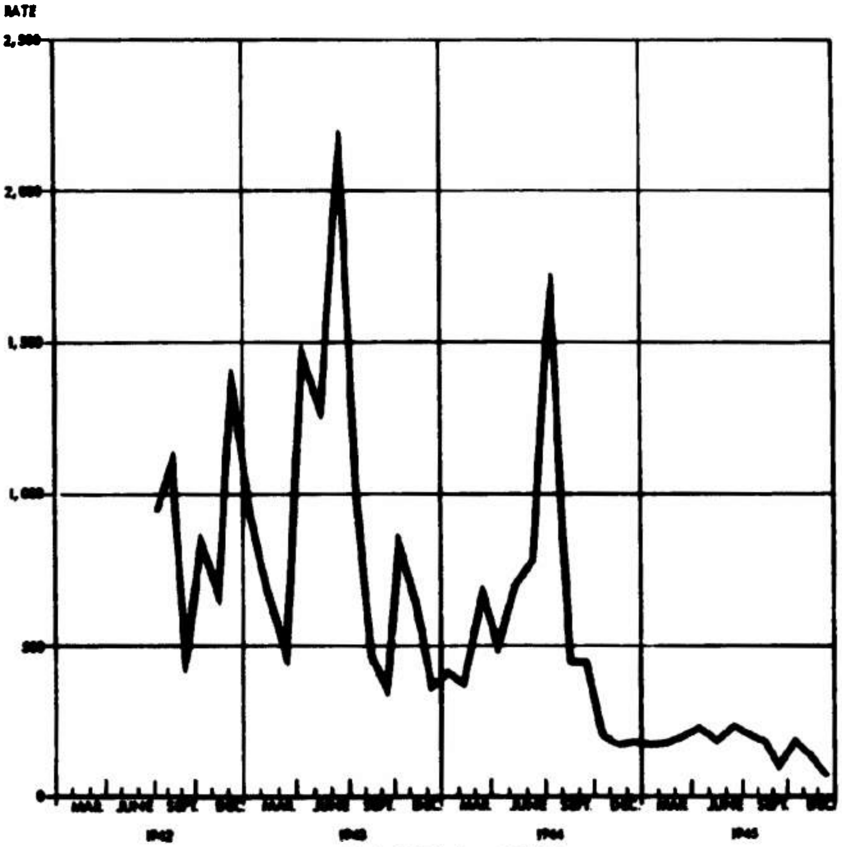


Chart 12 and table 46 show the malaria rate from 1942 through 1945, in Liberia.

For 2 weeks before the arrival of the first task force in Liberia in late June and July 1942 and until late October or early November, personnel were under quinine suppressive medication. At the time they landed, bed nets were not available for all personnel and many infections undoubtedly occurred. It is believed that the figures from October on show the result of activated latent malaria. From late December 1942 through February 1943, all troops were on Atabrine suppression. After 10 March 1943, no prophylactic treatment was administered, and at this time the second task force arrived. Rates rose rapidly, and on 21 June 1943, Atabrine suppressive medication was reintro-

CHART 12.—*Attack rates for malaria among U.S. Army personnel in Liberia, 1942–45*

[Rate expressed as number of cases per annum per 1,000 average strength]



Source: Annual Report, 27th Malaria Control Detachment, 1945.

TABLE 44.—*Attack rates for malaria and fever of undetermined origin, among U.S. Army personnel, Africa-Middle East area,*[1] *January 1944–December 1945*

[Preliminary data from statistical health reports]

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	Malaria		Fever of undetermined origin[2]	
	1944	1945	1944	1945
January	124	16	32	23
February	128	13	18	29
March	129	14	12	42
April	124	13	31	36
May	131	7	29	39
June	134	15	23	28
July	250	17	132	52
August	110	14	98	62
September	56	11	64	51
October	36	12	53	26
November	25	6	48	25
December	18	1	38	14
Total	102	13	47	39

[1] Excludes Persian Gulf Command.

[2] The proportion of these figures which actually represents malaria cannot be determined.

TABLE 45.—*Attack rates for malaria and fever of undetermined origin, among U.S. Army personnel, Persian Gulf Command, January 1944–December 1945*

[Preliminary data from statistical health reports]

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	Malaria		Fever of undetermined origin[1]	
	1944	1945	1944	1945
January	12	8	3	3
February	11	6	3	20
March	16	5	7	12
April	25	7	15	27
May	25	13	22	27
June	52	12	20	32
July	38	7	24	44
August	43	6	19	48
September	49	16	15	40
October	42	4	13	31
November	21	13	11	25
December	13	0	8	20
Total	29	8	13	24

[1] The proportion of these figures which actually represents malaria cannot be determined.

duced. This was discontinued early in 1944, but after 4 months (24 July 1944), all troops were again placed on suppressive medication. This policy continued through the remainder of that year and all of 1945. It is not known definitely, but it is believed that this treatment continued until the area was finally evacuated. In June and July 1943, over one-quarter of the force had malaria. The fluctuations in the rates apparently correlate with seasonal prevalence, exposure factors, arrival of new personnel, effectiveness of physical control measures, and the achieving of various degrees of suppression by the administration of antimalarial drugs.

TABLE 46.—*Attack rates for malaria among U.S. Army personnel, Liberia, 1942–45*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	1942	1943	1944	1945
January		920	425	167
February		694	370	170
March		475	671	187
April		1,490	485	229
May		1,255	690	166
June		2,125	775	248
July	951	1,125	1,710	202
August	1,118	470	454	174
September	429	355	454	72
October	863	865	197	166
November	650	645	162	130
December	1,340	365	163	54
Total	832	898	551	172

Source: Annual Report, 27th Malaria Control Detachment, 1945.

Statistics, making it possible to contrast experience in various areas or types of troops, other than those given are not available. Considerable detailed information on the Liberian Force is on file but other comparable records are not at hand. Some reports have given figures to illustrate malaria incidence at particular points and times but how these figures were compiled and their degree of accuracy is not known.

Although excessive prevalence of malaria was noted in several areas, the disease responded to control and preventive measures. In some areas when troops were released from suppressive medication, rates rose alarmingly, but when this medication was reintroduced reductions were quickly evident. In all cases when incidence was exceptionally high, troops had either recently arrived in hyperendemic areas or been released from suppressive medication.

The malaria rate among local population in the controlled area showed some response to control activities. Representative findings are given in the section on surveys. No information concerning prisoners of war is available.

ANTIMALARIA ORGANIZATION

From available information, it would seem that the antimalaria organization was not strongly centralized. For example, it is not easy to ascertain the degree of interrelationship between such areas as the Persian Gulf Command and the U.S. Army Forces in Liberia, both of which were at times independent commands. There was a central supervisory administration, but considerable freedom of action was allowed to the various commands.

During the first months of the war in this region it would seem that each command approached the problem without reference to other headquarters. This divided authority clearly interfered with malaria control and discipline. After a study of the problems, in November 1943, by several officers from the Surgeon General's Office and by the Medical Inspector, USAFIME, the organization was overhauled and responsibility was assumed by the theater. At the close of 1943, the Medical Section, Headquarters, USAFIME, had a Preventive Medicine Section with medical inspectors and a malariologist. The latter was given the duty of technical supervision of malaria control.

The surgeon and other special staff officers performed in a dual capacity. They were the special staff of both services of supply and the theater.

Cooperation with the British resulted in the formation of an inter-Allied malaria control group for the purpose of providing a coordinated antimalaria program in British West Africa. This resulted in control operations at numerous bases being the responsibility of the Royal Air Force or other Allied groups. In some of this area and particularly at Accra, Gold Coast, the unfortunate experience of American forces, depending on malaria control by other agencies, necessitated constant inspection and initiation of local control activities similar to those carried out routinely elsewhere among American troops. In other areas, American personnel took over full control at their own installations and also supplemented the work of other agencies. In some cases, complete responsibility for control of the area passed to American forces. Moreover, as the various civilian contractors and Pan-American Airways withdrew, the Army assumed responsibility for control operations that they had begun.

In each of the commands, various programs were developed. Antimalaria units were organized in each service command in 1942. General malaria control measures were strengthened by the designation of one man per hundred for malaria control work within units as directed by Circular No. 31, USAFIME, 2 September 1942.

In February 1943, the surgeon of the U.S. Army Forces in Liberia was given the general responsibility for malaria control and sanitation. When theater supervision was unified under USAFIME, late in 1943, all malaria control became the responsibility of the theater.

In the Gold Coast, until 1944, U.S. Army authorities failed to organize and implement an adequate malaria control program. Local commanders had not supported antimalaria measures recommended by their own medical staff and as required by Army Regulations. Furthermore, integration of British and American malaria control efforts did not promptly achieve the coordinated program which was essential to success.

Mention should be made of the Egyptian *gambiae* eradication project that began early in 1943 and continued until August 1945. *Anopheles gambiae* had invaded Egypt as far north as Asyut by November 1942 and was causing devastating epidemics along the path of the invasion down the Nile. Allied military forces, the Rockefeller Foundation, and the Egyptian Government cooperated in a campaign that made full use of therapeutic and suppressive Atabrine, paris green larvicide, and pyrethrum adulticide. The invasion was finally halted and the invader was eradicated. The last *A. gambiae* in Egypt was found on 19 February 1945.

In 1943, the Brazilian Government reported that *A. gambiae* had been brought to Brazil by aircraft from West Africa. This was strongly deplored by the Brazilian Government as they had just finished a long and costly campaign to eradicate this mosquito from their country. To investigate the problem, a committee from the Office of The Surgeon General, the malariologist for the North African Theater of Operations, U.S. Army, and the medical inspector of the USAFIME went to West Africa.

In the first place, this group noted the following:

> The large-scale malaria control program undertaken jointly by the British Army, the RAF, the American Army, and the civil authorities at Accra is considered to be sound and gives every promise of being successful if supported by all agencies concerned, and if vigorously pushed to completion and maintained. Proposed malaria organization is excellent.

The committee recommended that full American support be given to the proposed inter-Allied mosquito control program at Accra.

In the second place, the committee made numerous recommendations which resulted in several changes, described as follows:

There was formed at Accra in the inter-Allied malaria control group, a team which formulated policies and methods of control and obtained necessary supplies and equipment. All the individuals involved cooperated fully in attempting to break the man-mosquito-man cycle at as many points as possible. To this end, the following practices were put into effect: (1) Destroying *Anopheles* larvae, (2) attacking adult *Anopheles*, (3) preventing infested *Anopheles* from biting the population at risk, and (4) administering suppressive medication.

Furthermore, to combat any possible reintroduction of *A. gambiae* into Brazil, special disinsectization methods were started both at the African airbases and at the various Brazilian points of entry. In addition, it was decided that Brazilian authorities would help to supervise mosquito control procedures at the various African airports. Under this new plan, Brazilian authorities were in key positions on both sides of the Atlantic to safeguard their country from airborne African insects. This was a welcome procedure to all concerned, as it allowed the sharing of duties and responsibility with representatives of the Brazilian Government.

Throughout the theater, unit antimalaria details were formed to supplement the control programs organized by the malariologists and control detachments.

Indigenous labor was utilized a ll military establishments to install and maintain the control program. In many instances, it was necessary to use large numbers of laborers to achieve adequate drainage, larviciding, and pyrethrum spraying.

No definite information concerning dusting and spraying from airplanes is available except that such dusting with paris green was carried out in Egypt in 1943 and that of three light planes in British West Africa the first became operational on 24 August 1944.[20] The only other recorded statement concerning this phase of the work is that up until November 1944 no aircraft were available for air spray operations in Liberia.[21] A Stearman biplane (PT–17) had been allocated.

Training and Propaganda

Practically no information is available regarding training and propaganda for malaria control and prevention purposes in the Africa-Middle East Command.

Personnel of locally activated malaria detachments were trained in the field while those arriving as complete units had been trained before entering the area. The methods and time spent on these operations is not known.

One active educational program was developed in Liberia. In this, a series of lectures was given, microscopic demonstrations were prepared, and posters were displayed.

No doubt, in connection with the strengthening of malaria control and prevention measures just mentioned, some training was carried out, and some aids, such as posters, radio reminders, and bulletins, were utilized.

Other Duties of Antimalaria Organizations

Antimalaria organizations and personnel in the Africa-Middle East area were used for other duties than malaria control in a number of instances. For example, in an outbreak of bubonic plague in Dakar, malaria personnel experimented in the use of DDT against fleas. It was found in controlled experiments that DDT not only killed fleas within a matter of hours after contact but that it inhibited their host-seeking and biting activities within 10 minutes after direct spraying or within 15 minutes after a 10- to 25-second contact

[20] See footnote 14, p. 317.
[21] See footnote 13, p. 317.

with a DDT sprayed surface. It did not act as a repellent as did dimethyl phthalate.

African sleeping sickness or trypanosomiasis was present in a portion of the occupied territory. The vector *Glossina palpalis* was common at some installations and particularly along the Farmington River in Liberia. Here, antimalaria personnel found that 5 percent of the flies caught and dissected were infected. Of 200 natives examined for sleeping sickness, 20 had enlarged glands; but gland punctures gave negative results. In view of the results of inquiries and of the extensive clearing along the riverbanks for malaria control purposes, no special precautions or control measures against *Glossina* were considered necessary.

In addition to usual activities, the malaria units were on the lookout for *Wuchereria bancrofti*, the cause of filariasis. Both *A. funestus* and *A. gambiae* are efficient vectors of this organism. As these species were being controlled for antimalaria purposes, no special additional measures were needed. In Liberia, 7.95 percent of 1,182 natives examined were found to harbor *W. bancrofti*, and 4 percent of 220 *A. gambiae* dissected were found to contain larvae of *W. bancrofti*. In Nigeria, the incidence was somewhat less; in fact, *Loa loa* was found more frequently than *W. bancrofti*.

Yellow fever prevention had to be continued without relaxation. By careful disinsectization of aircraft to kill all mosquitoes, it was hoped to prevent the spread of the vector from yellow fever areas in the path of the Central African air routes to other parts of the theater, or to India. The control of *Aedes aegypti* along with other mosquitoes helped to reduce the incidence of dengue among U.S. Army personnel. The antimalaria units often in practice performed as insect control units; for the comfort and protection of the commands, they attacked many problems which were not strictly concerned with malaria prevention. The units were also used to control sandflies, bedbugs, and other insects. Disinsectization was carried out not only in the field, but also in theaters, halls, barracks, and billets. Such general insect control activities were particularly useful in Egypt where units were not faced with malaria hazards so severe as those on the west coast of Africa.

SURVEY ACTIVITIES

Entomological Investigations

In all areas, survey activities were an important part of the antimalaria program. At first, the surveys were made to find out which species of *Anopheles* were present, which were acting as vectors of malaria, and where they were breeding. When control measures were in operation, adult and larva surveys were made to assess the results. A certain amount of research was also undertaken after control had been established.

Some results of surveys are cited to illustrate their scope and importance in relation to control operations. For instance, in the Rufisque district of

French West Africa, despite what appeared to be an adequate larviciding program, large numbers of *Anopheles* mosquitoes, including malaria vectors, were present in the camp area. It became evident that the flight of such local vectors as *A. gambiae* was long enough to break through the 1-mile control zone. The zone was therefore extended to 1½ miles, and there was an immediate drop in the number of *Anopheles* mosquitoes in the protected area.

A survey of the Yoff Peninsula, near Dakar, French West Africa, was made during January and February 1944, to obtain data regarding malaria problems. Control operations were then started. In July 1944, however, an unforeseen problem was encountered. Previously, control had easily been maintained during the dry season, but now a large number of *Anopheles* mosquitoes appeared. Surveys disclosed that they were being blown into the controlled area from the north and northwest. As a result, it became necessary to extend the control zone out to 7 or 8 miles.

Extensive survey activities in Liberia were made to determine adult mosquito densities in occupied military quarters. As control measures improved, these densities became lower, allowance being made for seasonal prevalence, as indicated by checking the huts of the local population in uncontrolled areas. Such figures were used to determine the effectiveness of control. Similarly, larval searches were made. The following figures illustrate the size of this program: In 1944, over 26,000 pools were searched. In the 251 found positive for *Anopheles*, there were 894 *A. gambiae* larvae and 28 larvae of other species of *Anopheles*. Over 18,000 rooms were searched with 3,100 positives, and a total of 9,914 adult anophelines were collected. In 1945, among some 43,000 pools that were searched, 138 were positive and 1,030 larvae were found. In over 22,000 rooms searched, 792 were positive, yielding 1,920 *Anopheles*. Larvae and adults were identified and several series of *A. gambiae* were dissected for malaria parasites.[22]

On the Yoff Peninsula, special studies were made to determine the effect of desiccation on the viability of *A. gambiae* eggs, and the length of the breeding cycle in this section of Senegal. Eggs kept dry for 24 hours had a little higher than 50 percent hatching rate; those kept for 48 hours, 19.8 percent; for 72 hours, 6.1 percent; and those that were dry for 96 hours, 0.7 percent. Obviously, even if only 0.7 percent of the eggs of *A. gambiae* could hatch after 96 hours of desiccation, one could not depend on the temporary drying of pools for control of this species. Other studies of the life cycle disclosed that it took only from 7 to 12 days for the eggs of *A. gambiae* to develop into adults in this area. This information was utilized in scheduling larviciding activities.

The same organization in French West Africa performed DDT experiments in 1944, when a small quantity of this material was received. The application of 150 milligrams of DDT per square foot of surface was found to give satisfactory mosquito control under certain conditions for 2 months

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[22] (1) See footnote 13, p. 317. (2) Annual Report, 27th Malaria Control Detachment, 1945.

Tests of the length of time of exposure to DDT-treated surfaces necessary to kill mosquitoes revealed that only 5 seconds contact with a surface treated at the rate of 100 to 125 milligrams per square foot were required to permit *A. gambiae* adults to acquire a lethal dose of DDT. Further studies demonstrated that there was a marked and slowly declining residual action of DDT upon *A. gambiae* larvae.

In Liberia, also, experiments with DDT were undertaken.

Parasitological Investigations

Numerous blood surveys were made in all areas where troops were stationed. In some places, the surveys were continued long enough to give some indication of the effects of control operations. An example of this is the following, reported from Dakar:

Surveys in villages surrounding American installations, made in January 1944, revealed a parasite index of 58.7 percent and a gametocytic index of 5.2 percent. By January 1945, these indexes had dropped to 11 percent and 0.6 percent, respectively, and, by July 1945, a further drop to 5 percent and 0.5 percent was noted.

In Liberia,[23] in 1943, blood smear surveys among the local populations near camps revealed from 23 to 68 percent positive for malaria parasites. Gametocytes were found in 2.3 to 10 percent of the total. The higher percentages in the surveys included both children and women. In 90 to 98 percent of blood smears examined, the parasite was *P. falciparum*.

During the period from 16 June through 25 December 1942,[24] 538 positive examinations for malaria parasites in military personnel and white civilians in the Roberts Field area of Liberia showed the following: 95.4 percent *P. falciparum*, with 1.7 percent showing gametocytes; *P. vivax*, 0.6 percent; *P. ovale*, 0.2 percent; and undetermined, 2.1 percent.

In early 1943,[25] thick blood smears among U.S. Army troops in Liberia revealed that 1 percent of the command was positive for malaria parasites and that half of these were gametocyte carriers. No microfilariae were found. Two other blood surveys were conducted on troops: one in December 1943 and January 1944 which showed 1.9 percent with malaria infections, with 0.3 percent of the positive smears having gametocytes; and a survey in January 1945 that revealed only one man having trophozoites and one with gametocytes of *P. falciparum*.

Numerous blood surveys of the local population near camps in other areas were also made in an effort to evaluate the malaria problem.

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[23] See footnote 13, p. 317.

[24] Report, Lt. Col. Justin M. Andrews, SnC, to Chief Health Officer, Roberts Field, Liberia, 3 Jan. 1943, subject: Malaria Investigation and Control Activities in the Roberts Field Area during December 1942, with Brief Summaries for the year 1942.

[25] Annual Report, Malaria Control Activities at Roberts Field, Liberia, 1943.

ANTIMOSQUITO MEASURES

In all the occupied areas of Africa and the Middle East, various methods of physical control aimed at the elimination of breeding places and the destruction of larvae and adults were used. The establishment of adequate drainage, larviciding with oil or paris green, and spraying with pyrethrum and Aerosol bombs, and finally the use of DDT were major methods utilized. At first, many difficulties were encountered in obtaining supplies, but subsequently adequate material was available. Malaria control was established at an effective level throughout the region in 1944 and was improved in 1945. The most important factor in the 1944 control program was the arrival of sufficient quantities of DDT for large-scale use. It was used in a hand-larviciding mixture of sand and waste oil and in larvicides and kerosene as a residual spray (fig. 41). The fight against malaria was a difficult and prolonged one, but in the end it resulted in one of the quiet victories of the war.

In general, the control program consisted of permanent draining or filling of low areas in and around bases; larviciding of mosquito-breeding waters within flight range of camps; extensive systems of ditching for draining valleys; when possible, removing villages away from proximity of camps;

FIGURE 41.—DDT residual spraying with power spray.

and controlling of ocean lagoons through a combination of larviciding and intermittent flooding.

Drainage was the method favored by the British Army authorities, because, despite its drawbacks of expense and time, it had some permanency. Water was diverted to well-defined channels which could readily be controlled. Before the drainage system was completed, larvae were killed by larvicides.

Adult mosquitoes were killed in military quarters and in the houses of the indigenous population by spraying with pyrethrum and DDT. Repeated sprayings in houses and Army installations were carried out throughout 1944 and 1945.

The Yoff Peninsula, where a comprehensive program of insecticiding was carried on, will serve as an example of this type of control operation. Routine spraying of over 2,400 dwellings in villages within a mile of American installations was undertaken. Here, it was found easier to apply the DDT-kerosene solution with knapsack sprayers than with the hand or power sprays. For larval control, a power-driven unit for paris green dusting was developed (figs. 42 and 43). This consisted of a motor-driven propeller into which lime and paris green were fed from a hopper. The whole apparatus was mounted on a plank and bolted to a platform on a truck. Under favor-

FIGURE 42.—Improvised paris green duster.

FIGURE 43.—Dusting with paris green.

able conditions, this machine could dust as many as 25 acres of water surface in an hour and a half.

A campsite near the city of Rufisque [26] presented the problem of interrupting the transfer of malaria from an infected local population to the Army personnel. To do so, the mosquito vectors had to be eradicated for a distance of 2 miles or more from troop concentrations. It was not feasible to remove infected residents from the area. The eradication of breeding sites without disturbing the district's limited water supply was essential. Destroying *Anopheles* larvae within a radius of 3 miles by larviciding, and the killing of adults by insecticiding all buildings, insofar as possible, within a 2-mile radius of camp was the solution. In addition, malaria discipline was essential for the protection of troops.

Information concerning supplies used in Liberia illustrates the extent of control activities. With an average of a 5-day oiling cycle, the following quantities of oil were used as larvicide: [27] 7,550 gallons in 1942, 51,823 gallons in 1943, 106,220 gallons in 1944, and 73,852 gallons in 1945. The quantities of insecticide, Aerosol bombs, and DDT used in connection with the antimalaria program were similarly large.

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[26] See footnote 9, p. 316.
[27] See footnote 22 (2), p. 337.

At this base, local labor was excellent for unskilled work, such as digging, chopping, and channel cleaning, but it was, with rare exceptions, almost futile to employ it for operations requiring any degree of skill, judgment, or independent responsibility, such as oiling and spray killing. In 1942, spray killing in village quarters took 147 local labor man-days, drainage operations, 1,450 man-days, and village construction—resettlement for gametocyte removal—1,521 man-days.

Drainage operations in Liberia, in 1943,[28] completed the following tasks: 51,863 yards of new ditching, 80,304 yards of maintenance of old ditching, 9,294 yards of reconstruction of old ditches, 23,130 cubic yards of filling, 76,185 square yards of brush removal, and construction of 31 spillways. This work used 60,638 local labor man-days and 2,235 soldier man-days. During 1944,[29] the following was accomplished: 9,370 yards of old ditch reconstruction, 58,338 yards of old ditch maintenance, 36,745 yards of new ditching, 92,917 square yards of brush removal, 14,010 cubic yards of fill, and construction of 14 spillways. Spray killing was carried on extensively: 6,402 gallons of insecticide and 8,407 Freon dispensers were used. An average of 270 laborers per month were employed during the first 7 months of 1944, and 390 per month for the remaining 5 months.

During 1945,[30] in Liberia, larviciding alone required 15,374 man-days. Spray killing utilized 4,889 gallons of ready-mixed insecticide and 3,738 Freon bombs. A 5-percent solution of DDT in kerosene was available in sufficient quantities for application in and around the base as a residual spray. A total of 7,072 gallons of this mixture was dispersed. The drainage system was completed, and in the end there were approximately 55 miles of major ditches in the sanitated area. The following engineer operations were carried out: 1,635 yards of new ditch construction, 6,360 yards of old ditch reconstruction, 71,891 yards of old ditch maintenance, 85,874 square yards of brush removal, and 2,852 cubic yards of fill. For the first 8 months of the year, an average of 310 laborers were employed and for the last 4 months only 150. The drop was due to the reduction in personnel and to the completion of large-scale drainage projects.

A much needed powerboat for larviciding finally arrived in Liberia in 1945. Considerable difficulty was encountered in obtaining suitable equipment from engineer depots in the United States. In spite of repeated specifications supplied by the Liberian base regarding the proper type of oil sprayers for larviciding, the equipment received consisted of knapsack firefighting sprayers. These were not only unsuitable for handling oil larvicides but were not even complete for use in spraying water.

The Deversoir Air Base, between Port Said and Suez, had a high initial incidence of malaria. A problem was presented by the swamps, lakes, and

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[28] See footnote 25, p. 338.
[29] See footnote 13, p. 317.
[30] See footnote 22 (2), p. 337.

irrigation ditches with which the airdrome was surrounded. With local labor, these ditches were cleared, and the swamps and lakes were drained. Paris green and oil larvicides were employed. After the program had been completed in January 1944, very few cases of malaria developed, and many or all of these may have been contracted elsewhere.

In the Persian Gulf area, malaria control operations were delayed because of insufficient personnel and equipment. Essential malaria control equipment was lacking during most of 1943. A few knapsack sprayers were taken over from a construction company, but they were in a bad state of repair and few of them could be used. Eventually, sprinkling cans were procured from local sources to spread oil on water surfaces. These were of poor construction, did not last long, and results were not too favorable. There was some dusting equipment for application of paris green, but as local road dust was the only available diluent the equipment was soon ruined. After this, a paris green mixture was broadcast by hand. In the latter part of 1943, the first "flit guns" were available. Eventually, in the fall of 1943, two portable air compressors arrived.

Supplies of insecticide were inadequate, and during the summer of 1943 they were completely exhausted. Materials were not available for spraying nearby native villages until August 1943, when equipment was secured from British Army stocks in the Middle East. The British released 5,000 gallons of Flysol (a pyrethrum insecticide), 6,000 pounds of pyrethrum powder, 3,000 flit guns, and 5,000 pounds of paris green. At about this time, the malaria control units began to prepare their own insecticide by soaking pyrethrum powder in kerosene. Fortunately, there was plenty of fuel oil No. 2 for the malaria control needs. It was not until the 1945 season had begun that the 5 percent DDT kerosene residual spray became available for general use within the command.[31]

In 1944, in the Persian Gulf area, the following was accomplished:[32] Over 600 acres cleared; over 1,500,000 lineal yards of ditching cleared or straightened; over 40,000 yards of new ditching installed; and over 2,600 water acres, over 3,300,000 lineal yards of small ditches, and over 100,000 square feet of other water surfaces larvicided. Over 17,000 gallons of kerosene-pyrethrum spray, 167,000 gallons of oil, and 470,000 pounds of mixed paris green dust as well as 3,600 gallons of 2 percent DDT were used. Over 850,000 man-hours of labor were needed for these operations.

For the period from January to September 1945,[33] inclusive, the following was accomplished: Over 59,000 lineal yards of channel or ditch cleaning, over 1,000 lineal yards of new ditching, more than 600 cubic yards of fill, and over

[31] Report, Capt. Manning A. Price, SnC, to Commanding General, Persian Gulf Command, subject: Report of Malaria Control Activities for Month of September 1945.

[32] Letter, Capt. Manning A. Price, SnC, to Commanding General, Persian Gulf Command, 10 Jan. 1945, subject: The Malaria Problem and a Summary of Malaria Control Operations for 1944 in the Persian Gulf Command.

[33] See footnote 31.

575 water areas and over 25,000 lineal feet of small streams (less than 5 feet wide) larvicided. These operations required over 45,000 man-hours of labor for spraying and over 250,000 man-hours for other aspects of the control program.

PERSONAL PREVENTIVE MEASURES AND MALARIA DISCIPLINE

The use of personal preventive measures, such as repellents, bed nets, and proper clothing, was directed by various War Department publications and in addition was supported by directives and circulars issued by the various headquarters. Remarks to the effect that malaria discipline was enforced, or strengthened, are found in many of the documents dealing with malaria. It is not possible to obtain a clear picture of this aspect of the program for the entire area. Some typical illustrations of conditions are cited to show the general trends.

At Eknes Field and Dakar, Senegal, until about June 1943, barracks were not sprayed regularly, and there was no malaria discipline. After that time, all barracks were sprayed nightly, but none of the buildings were adequately mosquitoproofed. Protective clothing was required, suppressive Atabrine was administered, and mosquito repellent was issued to all personnel.

In Liberia, military quarters were sprayed once nightly, and bed nets were lowered and tucked in by 1600. The wearing of proper clothing at night out of doors was enforced, but the wearing of head nets was discontinued when mosquito repellent was issued to the troops in May 1943. Standing orders at Roberts Field prescribed the wearing of protective clothing after 1800 when out of doors. Military police were stationed in the theater and at other points to enforce the regulations.

At some of the Air Transport Command bases in 1943, enlisted personnel were restricted to the base from 1800 to 0600 to reduce exposure to malaria.

Although, at first, in the Gold Coast, there were unscreened quarters and theaters and malaria discipline was lax, the situation was corrected. Most of the necessary screening had been installed by the middle of September 1943. At this time, malaria discipline was strengthened.

After this time, in the Accra area the U.S. Army camp and the Royal Air Force camp were well screened and well maintained (fig. 44). The usual protective clothing was worn, mosquito nets were used, and the American outdoor movie was screened.

A report on the status of malaria control at Central African Stations in August 1943 [34] tells of the following general policies: All barracks and quarters were sprayed regularly with liquid insecticide. Nearby villages were sprayed daily with insecticide, and British Army authorities sprayed other villages three or more times a week. The majority of American soldiers were

[34] Report, Col. Arch A. Fall, A.G.D., United States Army Forces in Central Africa, to The Surgeon General, 20 Aug. 1943, subject: Present Status of Malaria Control at USAFICA Stations.

FIGURE 44.—Type of barracks housing U.S. troops at Accra Airport, showing the single mosquito trap entrance to building.

housed in mosquitoproofed barracks, and all men were supplied with mosquito bars (bed nets). The maintenance of these bars was each man's responsibility, and most of the bars were kept in good repair. Atabrine for suppressive medication was taken regularly. The usual protective clothing measures were enforced. However, mechanics working at the airport at night could not repair aircraft while their arms were covered. To obviate this difficulty, mosquito repellent was issued to each man.

In the Delta Service Command area, normal mosquito control measures were carried out, but emphasis was placed upon individual protective measures. Proper emphasis and strict supervision of individual protective measures were the rule.

Lack of malaria discipline in the Persian Gulf area was not solely a local characteristic, as American troops often slept without mosquito nets. This was particularly true of motor transport drivers. Maintenance and repair of bed nets and the supplying of them for transients was a constant problem.

Although, throughout all occupied areas of the Africa-Middle East, personal preventive measures were stressed, the degree of compliance with, and therefore the effectiveness of, the program varied considerably at the different installations.

SUPPRESSIVE MEDICATION

Quinine and, later, Atabrine were used for suppressive medication in the Africa-Middle East area. In practically all areas of high or hyperendemicity, this method of combating malaria was used for at least limited periods of time, but whether the entire region was on suppressive medication is not known.

In the various stations in French West Africa, Atabrine suppressive medication was authorized in June 1943. In March 1944, the Dakar area was relieved from this medication for the dry season.

In Liberia, suppressive medication was used at various times. Two weeks before debarkation of the original task force, all troops were placed on quinine prophylaxis. After the arrival of Circular Letter No. 135, Office of the Surgeon General, dated 21 October 1942, most of the troops were taken off suppressive treatment. About half the troops were ordered off quinine prophylaxis on 2 December and the remainder on 16 December 1942. Subsequently, the number of hospital admissions for malaria increased considerably. On 24 December, a radiogram was received from Headquarters, U.S. Army Forces in Central Africa, which read:

> * * * Your stations have been taken off antimalaria prophylaxis. Request confirmation and reason. The administration of Atabrine to all troops in prophylactic doses is directed. Request information as to cause of increase in malaria rate.

On 27 December, orders were issued for the restoration of prophylaxis, using Atabrine instead of quinine.

From the first of the year through February 1943, all troops were on Atabrine prophylaxis, but the defense force which arrived on 10 and 11 March was not placed on prophylaxis. In June, the number of malaria cases surpassed all previous records, and the institution of Atabrine suppressive medication was begun on 21 June. This prophylactic treatment was continued as far as is known, except for 4 months early in 1944, for the remainder of the occupation.

At Accra, on the Gold Coast, American troops were placed on voluntary quinine suppressive treatment until 3 November 1942, when Atabrine suppressive medication was substituted. From then on, at least through 1944, Atabrine suppression was required in compliance with several directives. All base unit personnel were issued Atabrine cards to be punched daily when the tablet was given in the mess. At the end of each week, those whose cards lacked the requisite seven punches reported to the dispensary to receive the remainder of their week's Atabrine quota. By the end of November 1944, the malaria rates in all forces were at the lowest point for the Accra area.

In Nigeria,[35] Atabrine suppressive medication was administered in accordance with the provisions of Air Transport Command Regulations No. 25–8 dated 12 July 1944.

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[35] Report, Maj. Elliston Farrell, MC, to Commanding General, USAFIME, Cairo, Egypt, attention: The Chief Surgeon, 1 Nov. 1944, subject: Malaria Control at U.S. Army Installations in West Africa, 1941–44. Part I: Nigeria, British West Africa.

CHAPTER VII

China-Burma-India Theater

John W. H. Rehn, Ph. D.

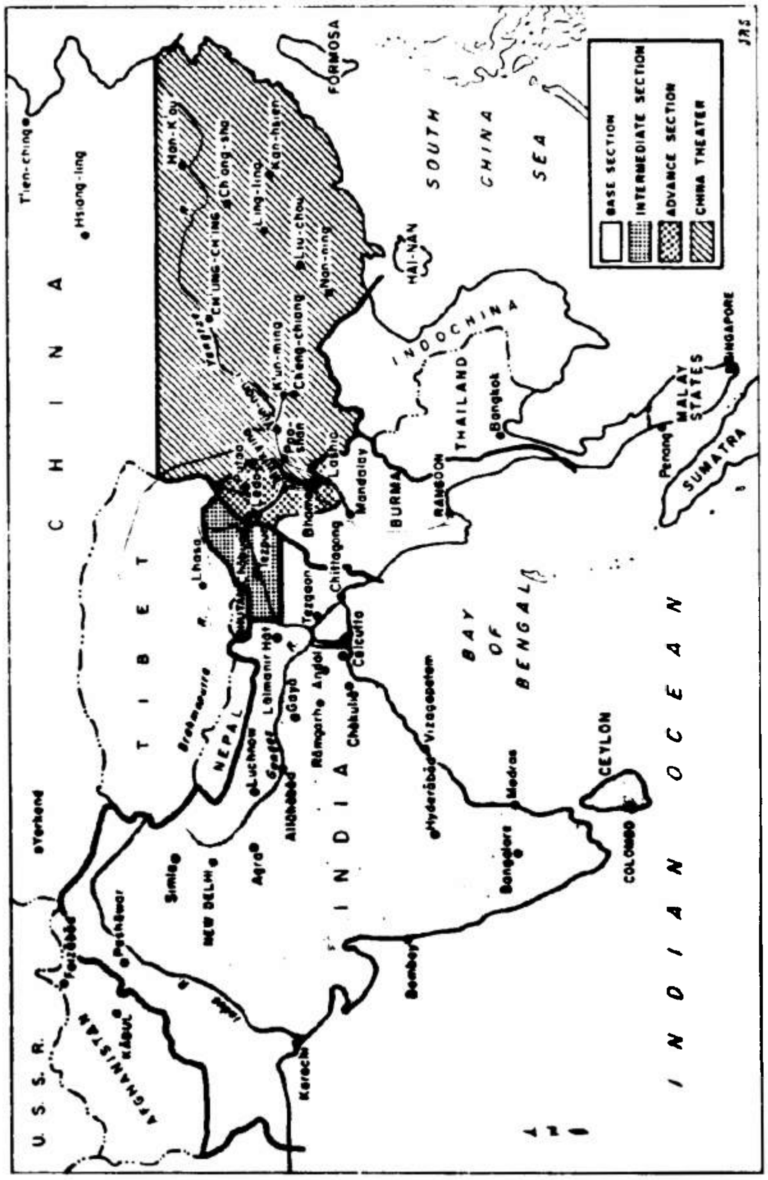
MILITARY HISTORY

The China-Burma-India theater was established on 4 March 1942 to transport supplies to the forces of the Chinese Central Government (map 19).[1] To accomplish this mission, it was necessary to augment existing air transport facilities and to build a road from India to the Burma Road leading to China on ground which it hoped to wrest from the Japanese. These major activities had to be carried on more or less simultaneously. In addition, Army Air Forces supported Chinese, British, and American operations. Other elements of the U.S. Army provided advisory, training, liaison, and other facilities to assist the Chinese Central Government.

The first major event in the theater was the inglorious retreat from Burma in the spring of 1942. For all practical purposes, this divided the theater into two distinct areas separated by the Himalayan uplift. At that time, limited flights over these mountains were being made principally by the Chinese National Aviation Corporation. The India-China Wing of Air Transport Command was directed to construct airfields and to establish regular flights in this area for the movement of military personnel and to China. This dangerous and arduous trip was the only available means of communication with China except for the century-old caravan routes crossing various parts of central Asia which were impractical for movement of essential personnel and materiel. Air service over "the Hump" was steadily built up until tonnage moved by this means increased from the initial trickle to sizable quantities.

Other means were still necessary, however, to move the enormous quantities of gasoline, expendable supplies, vehicles, and other heavy equipment. A supply route was commenced in December 1942 to extend from the Ledo area of Assam, India, across the Patkai Range through the Hukawng and Irrawaddy Valleys to the old Burma Road, subsequently renamed the Stilwell Road. This project involved construction through virgin jungles crossed only by poor foot trails or pack trails and peopled by indigenous tribes. During 1943 and 1944, when construction of the road, pipelines, and telephone lines was continuing as closely behind combat operations as supply and climatic conditions would allow, great quantities of material were moved inland from

[1] Except as otherwise indicated, data in this chapter are derived from Van Auken, H. A.: A History of Preventive Medicine in the U.S. Army Forces of the India-Burma Theater, 1942 45. [Official record.]



MAP 10.—Southeast Asia, showing India-Burma theater with major administrative divisions and China theater in 1945.

the ports for construction purposes and to build up a backlog of supplies for shipment over the road on its completion. The road was finished and opened for the first China convoy on 1 February 1945 and was officially closed on 31 October 1945.

Operations for the capture of northern Burma, across which the road was to be built, were carried on by the Chinese Army in India and by Merrill's Marauders. This polyglot organization was assembled in India and started from the Ledo area late in February 1944, conducting a jungle campaign which led to the capture of Myitkyina, Burma, in August 1944.

The Burma Road in the Salween River area was captured by the Y Force (Chinese). The second American contingent, the Mars Task Force, left Myitkyina in August 1944, to make contact with the Y Force, after which they headed south and made contact with British troops, which had been operating in central and south Burma. This completed the neutralization of the entire route over which the highway extended to K'un-ming, China.

The pipeline project was really twofold. One branch went to the Manipur Road area of Assam to supply petroleum products to the British and to the Tenth Air Force poised for their south Burma offensive. The other line went through the Brahmaputra Valley supplying airfields, after which it continued with the road and made contact, early in 1945, with the section being constructed from K'un-ming to near the China-Burma border.

The Tenth Air Force supported all operations, both the Chinese-American in northern Burma and those of the British. The Fourteenth Air Force supported Chinese operations and performed missions in conjunction with the various Pacific commands to the limit of their resources. Finally, the Twentieth Air Force was established in the theater for long-range bombing of enemy strongholds.

Many Americans were involved in advisory capacities or in training and supplying the Chinese, both in China and in India. Additional personnel served to maintain liaison with the various Chinese forces. The India-Burma theater, except the area from Ledo eastward in Assam through northern Burma and, for a time, a limited portion of eastern Assam (Manipur Road and Kohima area), was considered a rear area. In the China theater, established on 24 October 1944, supply and training functions were intimately connected with various Chinese operations.

Bases were established at ports and at intervals along water, rail, and road transportation systems, either utilized in part or operated by Americans. The actual location and disposition of forces depended upon operating conditions, transshipment points, maintenance needs, and other problems. Army Air Force installations, particularly Air Transport Command bases, formed a network linking the various parts of the theater. Installations were especially numerous through the upper Assam portion of the Brahmaputra Valley. With the exception of bases in eastern Bengal and Assam, Tenth Air Force installations were located near those of other commands. In China, Army Air

Force installations were principally combat bases. The Fourteenth Air Force worked in conjunction with the Chinese ground troops. In the Bengal area, relatively isolated bases were installed for the Twentieth Air Force and for some sections of the Tenth Air Force.

With the cessation of hostilities, all bases contracted in size and gradually closed as evacuation progressed. In China, bases were established at some of the major ports to facilitate the movement of personnel and supplies in the freed areas. At the end of 1945, only a few of the main depot areas, particularly those near ports or centrally located for a large area, were left in operation.

AREA CHARACTERISTICS [2]

Geography

The occupied portion of the theaters included areas of India, Burma, and China with a few personnel stationed in Ceylon.[3] The India-Burma area was enormous, being more than 2,400 miles from east to west and 1,800 miles from north to south, including more than 2 million square miles (map 19). In southern China, troops were scattered in portions of six provinces which had an area of about three-quarters of a million square miles.

As a whole, the India-Burma area is one of great diversity in physiographical, climatological, and biological conditions. Within its borders are areas of great elevation and large river plains practically at sea level. It also encompasses regions with very great rainfall as well as those with true deserts. In all the area, with but limited exceptions, malaria was either an actual or a potential problem. Roughly, India may be divided by landform and geology into three sections (map 20): The northern mountains or Himalayan uplift; the dissected plateau in the peninsular portion of India, at times spoken of as the Deccan; and the great Indian Plains, often called the Plains of Hindustan. This latter includes the valleys of the Indus, Ganges, and Brahmaputra Rivers. On the east, the Assam Hills are actually contiguous with the Burma mountains. These together form an effective barrier between India and Burma. Burma has, in addition, the following distinct geographic areas: Irrawaddy Valley, Shan Plateau, and Tenasserim Coast.

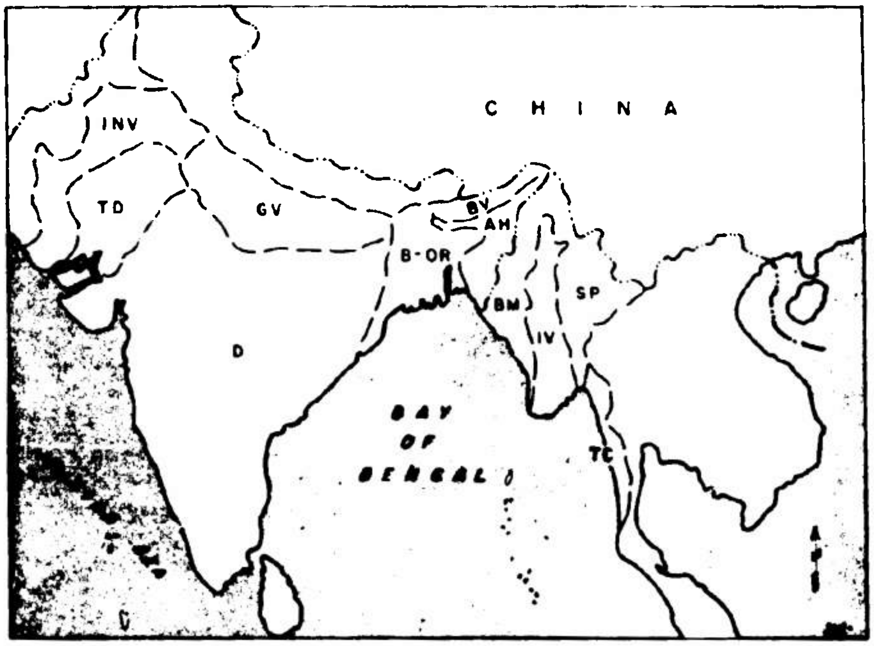
The hill rest camps, such as Darjeeling, India, were located on the south slope of the Himalayas. Usually, they were in the deciduous forest belt at 6,000 to 9,000 feet elevation. These areas were mostly natural forest with some tea gardens. In most of the area, malaria is not a major problem.

Bombay, a port utilized at times by U.S. Forces, is on the west coast. It is situated on a hilly island, sheltered at all seasons.

Bangalore, in the Mysore State, was an important Army Air Force installation. Its elevation gave it a healthy, pleasant aspect.

[2] (1) Cressey, George B.: Asia's Lands and Peoples; A Geography of One-Third the Earth and Two-Thirds Its People. New York: McGraw-Hill Book Co., Inc., 1944 (2) China Handbook, 1937–43. New York: The Macmillan Co., 1943.

[3] It will be recalled that the partition of Pakistan from India did not take place until 1947. Prepartition names are retained in this chapter.



INV-INDUS VALLEY
TD-THAR DESERT
GV-GANGES VALLEY
BV-BRAHMAPUTRA VALLEY
B-OR-BENGAL-ORISSA
AH-ASSAM HIGHLANDS
BM-BURMA MOUNTAINS
IV-IRRAWADDY VALLEY
SP-SHAN PLATEAU
TC-TENASSERIM COAST
D-DECCAN

MAP 20.—Southeast Asia showing geographic divisions in portions of India and Burma occupied by U.S. troops.

Ceylon served as a base for a limited number of U.S. troops. They were mainly stationed in the interior hills which have the remnants of forests but are largely devoted to tea gardens. It may be described as a "typical" tropical island. At times, the area has explosive malaria epidemics.

The great Hindustan Plain is the section in which most of the rear area installations and Air Force bases were established. The forward areas passed through the mountain barrier separating these plains from the essentially similar river plains of Burma.

The great Indian Plain itself is divisible into several major geographic regions (map 20): The Bengal-Orissa lowlands, Ganges Valley, Brahmaputra Valley, Indus Valley, and Thar Desert. In all these areas, malaria was prevalent. The Assam Hills and Burma mountains on the east separate these areas from the Irrawaddy Valley. In all these divisions, except the Thar

Desert and the Indus Valley, troop concentrations were of sufficient size to warrant consideration in some detail. Moving from west to east, one progressed from an area with limited concentrations of forces to the areas in which they were numerous.

Only at Karachi were troop concentrations permanently established in extreme western India. Karachi, while technically in the Indus Valley, possesses the features of the Thar Desert. It is in a low, level area with little rainfall, mostly a desolate region of shifting sands and scattered xerophytic brush.

In the Ganges Valley, fairly numerous well-isolated rear installations and airbases were established. This broad valley, with its vast deltaic area and practically featureless relief, is intensely agricultural. It has greater precipitation in the eastern portion.

The Bengal-Orissa lowlands likewise contained rear area installations and airbases as well as the main port for supplies (Calcutta) for the theater. It is essentially a flood plain area of two river systems, with a deltaic maritime district bordering the Bay of Bengal. It is an agricultural province with relatively heavy rainfall and with trying climatic conditions, ill-suited for Europeans.

The Brahmaputra Valley is best defined as the region from the river's entrance into the Assam lowlands to the Bengal-Assam boundary. The valley, which is moist to wet, has considerable agriculture but still retains large tropical forests. Through this area passed the supply lines for and the start of the Stilwell Road and in it were situated many airbases.

The Assam Hills-Burma mountains barrier was an area in which some combat occurred and through which the road was constructed. This area, with its rugged terrain covered almost entirely with dense tropical rain forests, was a little known section of the world.

The Irrawaddy Valley, the northern portion of which concerned us, is another set of river systems with flood plains but with definite elevational relief. In some portions, agriculture is important, but much of the area is either tropical forest or scrub, or has reverted to grassland. Rainfall is heavy in most of the area where Americans were stationed.

China exhibits great diversity in physiographical, climatological, and biological conditions. However, the south China area in which U.S. troops were stationed exhibited rather limited diversification. This area is composed of the following general regions: Szechwan lowlands, mainly in that province; southern uplands, including parts of Hu-nan, Kuei-chou, Yünnan, and Kuanghsi Provinces; and southwestern uplands, including portions of Kuei-chou and Yünnan. U.S. troops were scattered through all these areas in order to perform their mission of supply and liaison with Chinese forces.

The Ssu-ch'uan lowland is an isolated area near the heart of China. Elevations from 3,000 to 4,000 feet are found with valleys of one-half this height. Ch'ung-ch'ing dominates this area. There is also an alluvial fan, the Ch'eng-tu Plain, near its western margin. The natural flora has largely been replaced by cultivated crops. Pine, bamboo, and cypress are characteristic of the area, with deciduous trees mixed with pine on the higher hills.

The southern uplands include a large area of south China. Hills and mountains are always in sight. It is estimated that flatland occupies not over 15 percent of the area. Most of the area is under cultivation or is grassland, but remnants of the original tropical semideciduous (broadleaf) and subtropical forests persist.

The southwestern uplands are a subdued continuation of the Tibetan highlands. The only level area is the K'un-ming Plain. As a whole, it is a region of plateau remnants cut by deep valleys. Undisturbed areas are rare, but in places the original flora, consisting of subtropical forest and dense coniferous and deciduous upland forests, may be found.

Climate

Within India and Burma, all climatic conditions present an appreciable variation. In general, from west to east there is a progression from a very arid region through increasingly moist areas to the rainsoaked tropical forests of the Assam Hills. In the Irrawaddy Valley, conditions are similar to those of the Bengal-Orissa lowlands and the Brahmaputra Valley. Throughout much of the area, the conventional seasons—spring, summer, autumn, and winter—do not occur. The area as a whole has three seasons: The wet (monsoon), the cool, and the hot. Most of the precipitation occurs during the monsoon season. The time of arrival of the wet southwest monsoon depends largely on the latitude of the location. In late May or early June, it begins in Ceylon, south India, and the southern tip of Burma, reaching Bombay early in June and Calcutta by the middle of that month, then progressing up the Ganges and Brahmaputra Valleys. These conditions continue until mid-September in Punjab, mid-October in Bombay and in the Irrawaddy Valley, late October in Calcutta, and early November in the south. In the winter, rain is brought to Ceylon by the northeast monsoon.

It is during the summer that the greatest precipitation occurs in China. The southern area of China, with 40 to 75 inches of rain, is more moist than the northern area, which usually has less than 25 inches. The southern region shows much less diversification than is found in India and Burma.

Table 47 presents the average precipitation and seasonal variation in selected localities in the various areas.

In India and Burma, the wet (monsoon) season is one in which the temperature is fairly high and the humidity high. As the season progresses, the humidity becomes higher and the actual temperature lower, although the perceptible temperature increases. After the rains, the temperature decreases and the cool season has arrived. This continues until late in February. Early in March, the hot season begins with its high daytime temperatures but relatively cool nights. This condition prevails until the monsoon breaks.

Temperature conditions at selected localities in various areas are shown in table 48.

TABLE 47.—*Average precipitation (in inches) at selected localities in China, Burma, and India, for various time periods* [1]

Area and locality	January	February	March	April	May	June	July	August	September	October	November	December	Total	Number of years
Indus Valley:														
Karachi	0.1	0.4	0	0	0	0.4	2.8	2.4	1.7	0	0.3	0.3	8.33	54
Ganges Valley:														
Delhi	1.0	.8	.5	.4	.6	2.7	7.2	7.2	4.4	.5	0	.5	25.73	55
Patna	.9	.5	.3	.3	.6	4.9	12.0	10.8	7.3	1.8	.6	.8	40.57	10
Bengal-Orissa lowlands:														
Andāl [2]	.2	.8	.7	1.8	2.0	5.3	6.2	12.6	5.8	3.2	0	0	40.6	2
Calcutta	.6	.9	1.0	1.8	3.5	11.0	15.6	14.5	9.0	4.2	.6	.1	62.57	10
Brahmaputra Valley:														
Gauhāti	.7	.8	2.0	6.0	9.9	11.7	16.5	11.4	5.4	2.2	.8	.1	62.43	[illegible]
Dibrugarh [3]	1.5	2.6	5.0	9.9	13.1	18.9	21.2	18.7	18.8	5.5	.9	.6	116.7	------
Assam Hills:														
Cherrapunji	1.4	1.3	6.6	30.4	50.3	108.3	92.4	50.4	44.9	18.8	3.1	1.0	418.04	10
Shillong	1.0	.8	2.5	5.2	8.6	18.4	11.9	11.5	13.2	6.1	1.8	.3	81.47	10
Irrawaddy Valley:														
Myitkyina	.4	.9	.9	2.0	6.0	15.1	19.2	16.4	9.7	6.8	1.2	.4	79.0	------
Mandalay	.1	.3	.2	1.6	4.9	5.6	3.6	3.5	6.1	7.6	3.5	.3	37.24	10
South Burma:														
Rangoon	0	.1	.4	2.6	11.7	19.6	26.7	22.3	14.6	7.5	2.3	.1	107.95	10
Deccan:														
Bombay	.4	0	0	0	.3	21.4	24.0	10.6	12.8	1.7	.7	.1	71.95	10
Bangalore	.3	.4	.4	2.3	3.9	2.4	4.1	3.6	6.2	6.0	2.0	.3	75.40	10
Ssu-ch'uan lowlands:														
Ch'ung-ch'ing [4]	.7	.8	1.5	3.9	5.7	7.2	5.4	4.9	5.7	4.3	1.9	[illegible]	42.86	[illegible]
Ch'eng-tu [4]	.6	.7	1.4	2.3	3.9	6.4	10.8	17.2	6.6	2.1	.8	.5	53.25	2
Southwestern uplands:														
K'un-ming [4]	.2	.8	.9	.9	4.4	8.2	10.3	9.7	6.2	3.0	1.6	1.3	43.66	7
Southern uplands:														
Lung-ching [4]	.8	1.4	2.6	3.1	7.1	8.7	9.2	9.4	5.5	2.5	1.3	1.0	51.73	40

[1] Precipitation data were taken from World Weather records and Smithsonian Miscellaneous Collection, volume 90, May 1934.

[2] Report, Capt. Leslie K. Sherman, SnC, 73d Malaria Control Detachment, to Col. R. O. Prentiss, Army Committee for Insect and Rodent Control, subject: DDT Experiments in Vicinity of Andāl, Bengal, India, during 1945.

[3] Champion, H. G.: A Preliminary Survey of the Forest Types of India and Burma. India Forest Records 1: 43, July 1936.

[4] China Handbook, 1937-43. New York: The Macmillan Co., 1943, pp. 14-15.

TABLE 48.—*Average temperatures in degrees Fahrenheit, in selected localities, in China, Burma, and India* [1]

Area and locality	January	February	March	April	May	June	July	August	September	October	November	December	Average temperature	Number of years
Indus Valley:														
Karachi	66.0	68.7	75.8	81.1	85.2	87.5	85.6	83.0	82.3	81.1	75.5	68.7	78.4	54
Ganges Valley:														
Delhi [2]	59.0	62.0	74.0	84.0	89.0	93.0	87.0	86.0	84.0	79.0	68.0	60.0	77.0	
Patna	61.0	66.0	78.0	87.0	89.0	88.0	85.0	84.0	84.0	80.0	70.0	62.0	78.0	
Bengal-Orissa lowlands:														
Andal [3]	63.3	67.7	77.2	83.0	91.0	89.0	84.2	84.0	84.0	77.7	70.2	65.5	78.1	2
Calcutta	67.3	72.3	81.4	86.5	87.8	86.4	83.9	83.7	84.0	81.4	74.0	67.7	79.7	10
Brahmaputra Valley:														
Gauhâti	62.4	65.8	73.5	77.9	79.8	82.2	84.1	84.2	82.7	78.4	70.7	63.9	75.5	10
Dibrugarh [2]	60.0	63.0	69.0	72.0	77.0	80.0	81.0	82.0	81.0	77.0	70.0	61.0	73.0	
Assam Hills:														
Cherrapunji	53.4	55.6	62.3	65.6	67.0	68.4	69.1	69.1	68.9	65.8	60.9	55.6	63.5	10
Shillong	49.3	52.3	60.9	65.5	66.8	68.8	70.3	69.8	67.5	62.5	55.8	51.0	61.7	10
Irrawaddy Valley:														
Myitkyina	61.0	66.0	73.0	78.0	82.0	81.0	81.0	81.0	83.0	78.0	70.0	63.0	77.0	
Mandalay	71.0	74.0	83.0	91.0	90.0	86.0	84.0	82.0	83.0	81.0	75.0	72.0	81.0	
South Burma:														
Rangoon	78.8	79.9	83.8	85.9	84.4	81.4	80.3	80.3	81.5	82.5	81.8	78.5	81.6	10
Deccan:														
Bombay	75.4	75.9	80.9	84.1	86.6	84.4	81.5	81.0	81.1	83.1	80.9	78.0	81.1	10
Bangalore	71.4	74.2	78.9	82.1	81.2	77.0	74.3	74.5	74.8	74.1	71.8	70.0	75.4	10
Ssu-ch'uan lowlands:														
Ch'ung-ch'ing [4]	46.0	49.5	57.6	66.0	72.9	77.2	83.8	84.6	75.4	66.0	57.7	50.4	65.7	12
Ch'eng-tu [4]	39.6	47.8	53.8	62.6	70.9	76.6	80.1	79.2	72.3	63.0	53.6	45.7	62.1	4
Southwestern uplands:														
K'un-ming	48.6	51.6	57.6	63.5	66.7	66.9	68.0	67.8	82.6	60.4	54.9	49.8	60.1	7
Southern uplands:														
Lung-ching	57.7	59.5	66.1	73.8	82.0	83.7	84.2	84.0	82.0	75.2	69.1	62.8	73.2	12

[1] Weather data were taken from World Weather records and Smithsonian Miscellaneous Collection, volume 90, May 1934.

[2] Champion, H. G.: A Preliminary Survey of the Forest Types of India and Burma. India Forest Records 1: 42, 131, 153, 180, July 1936.

[3] Report, Capt. Leslie K. Sherman, SnC, 72d Malaria Control Detachment, to Col. R. G. Prentiss, Army Committee for Insect and Rodent Control, subject: DDT Experiments in Vicinity of Andal, Bengal, India, during 1945.

[4] China Handbook, 1937–43. New York: The Macmillan Co., 1943, pp. 11–12.

LOCAL POPULATION AND MALARIA ENDEMICITY

As is well known, the racial types, religion, languages, and cultures found in India and Burma are diverse.[4] Many races other than the true Chinese are found in China. In the southwest, especially, where most U.S. troops were stationed, there were many residents of other racial stocks. Much of the area is overpopulated, and troops were almost constantly in close association with the local inhabitants in all but a few areas. This was partly because the residents were living in proximity to the various supply lines and also because large numbers of labor troops and civilians were employed in various phases of the work. In China, the mission of liaison or supply involved continual contact with the residents and with the Chinese Armed Forces. The only areas in which these conditions did not prevail were along portions of the Stilwell Road, sections of the pipeline, and in areas in north Burma. Here for various reasons, such as general inaccessibility, limited tribal population, or evacuation due to combat activities, contact with the local population was more limited.

On the whole, throughout the area, local housing was poor, sanitation practically nonexistent, and public health work limited. In some portions of India, control measures had been established to reduce the malaria incidence, but such activities were limited by lack of sufficient funds.

Malaria is the most important disease in both India (map 21) and Burma (map 22).[5] In India, with a population of about 388 million in 1941, it has been estimated that there were between 100 and 200 million cases of malaria and between 1 and 1½ million deaths each year from this disease.[6] In Burma with a population of 16,823,798 in 1941, there were over one-half of a million (604,049) hospitalizations during the year 1939, with a death rate of 214 per 100,000 population in the towns alone.[7] Although malaria is known to be a major problem in south China, statistics concerning its frequency are not available. In some instances, U.S. troops were stationed in areas of hyperendemicity, while large numbers were in areas of moderate to high endemicity.

MALARIA VECTORS

The anopheline fauna of the India-Burma areas are very diverse, there being more than 50 known forms.[8] Over one-half of the species have at some

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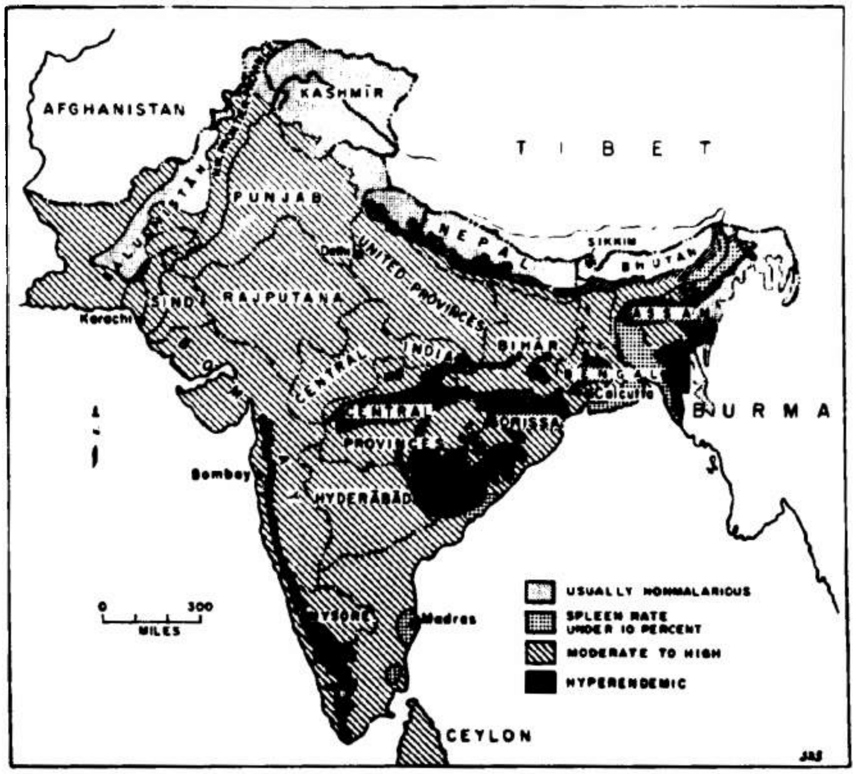
[4] (1) Gilbert, William H., Jr.: Peoples of India. Smithsonian Institution War Background Studies, No. 18, April 1944, pp. 17–19. (2) Deigman, H. G.: Burma-Gateway to China: Smithsonian Institution War Background Studies, No. 17, October 1943, pp. 7–9.

[5] Of the localities indicated by number on map 22, a selected number are presented and identified in table 50.

[6] War Department Technical Bulletin (TB MED) 174, July 1945.

[7] War Department Technical Bulletin (TB MED) 77, 2 Aug. 1944.

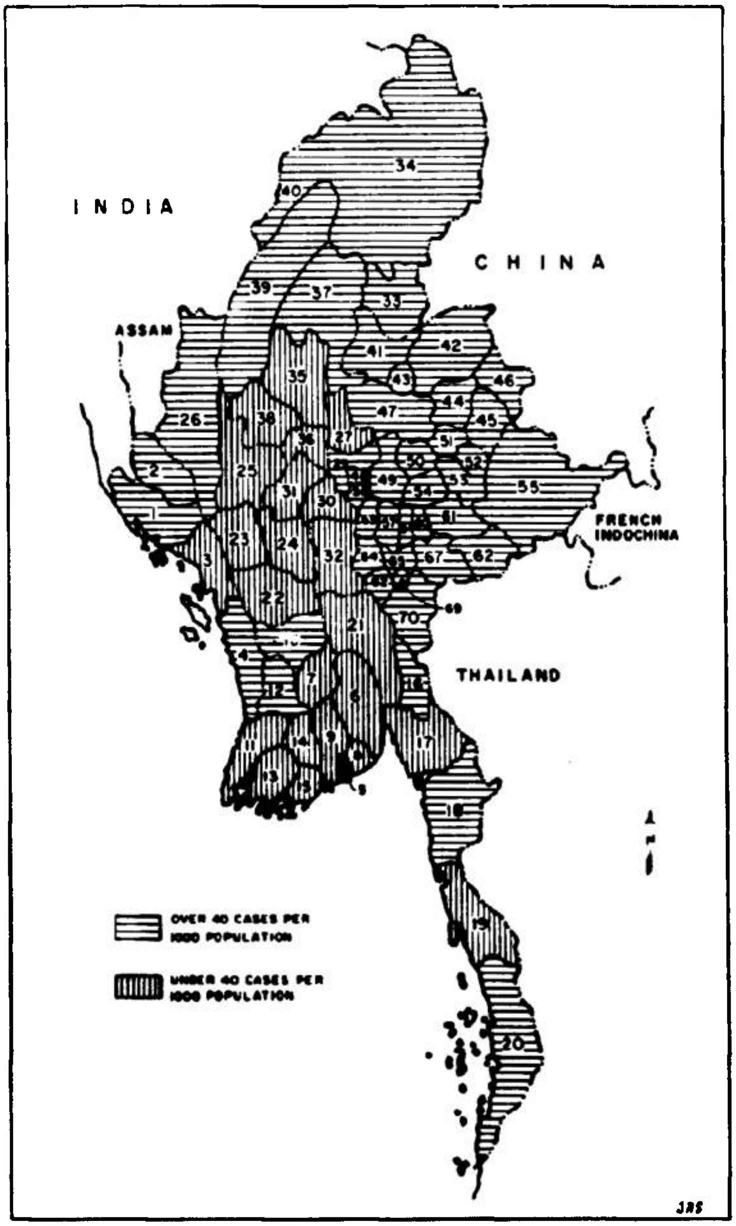
[8] The information in this section dealing with anopheline habits and their roles as vectors of malaria has been compiled from the literature listed below. The evaluation of evidence presented there has taken into consideration knowledge gained by the author while a member of the 35th Malaria Survey Detachment or as Base Section Malariologist, as well as information gained from personal contacts with or correspondence from many of these authors, U.S. Army malaria control personnel in these theaters, and from civil and allied military control personnel within the areas. (1) Christophers, Sir Rickard: Diptera, Family Culicidae, Tribe Anophelini (Fauna of British India Including Ceylon and Burma). London: Taylor and Francis, October 1933. (2) Covell, G.: Notes on the Distribution, Breeding Places, Adult Habits and Relations to Malaria of the Anopheline



MAP 21.—Malaria in India.

time or place been found infected with malaria oocysts or sporozoites, but only some 11 or 12 species are believed to be important vectors (tables 49, 50, and 51).

Mosquitoes of India and the Far East. J. Malaria Institute of India 5: 399–434, December 1944. (3) Russell, Paul F., Rozeboom, Lloyd E., and Stone, Alan: Keys to the Anopheline Mosquitoes of the World, With Notes on Their Identification, Biology, and Relation to Malaria. Philadelphia: American Entomological Society, Academy of Natural Sciences, 1943. (4) Roy, D. N.: The Potential Danger of *Anopheles leucosphyrus* in Assam. Indian M. Gaz. 77: 318, May 1942. (5) Notes on the More Important Malaria Vectors of South China. Naval Medical School, National Naval Medical Center, Bethesda, Md., 1945. (6) Clark, R. H. P., and Chowdhury, M. A.: Observations on *Anopheles leucosphyrus* in the Digboi Area, Upper Assam. J. Malaria Institute of India 4: 103–107, June 1941. (7) Ramsey, G. C., Chandra, S. N., and Lamprell, B. A.: A Record of an Investigation to Determine the Anthropophilic Indices of Certain Anopheline Mosquitoes Collected on the Tea Estates in Assam and Northern Bengal. Records of the Malaria Survey of India 6: 49–52, March 1936. (8) Knowles, Robert, and Senior-White, Ronald A.: Malaria: Its Investigation and Control, with Special Reference to Indian Conditions. Calcutta: Thacker, Spink and Co., 1927. (9) Quarterly Report, Consultant Malariologist, Allied Land Force, South East Asia Command, January-March 1945. (10) Puri, I. M.: Synoptic Table for the Identification of the Anopheline Mosquitoes of India. 3d edition. Health Bulletin, No. 10, Malaria Bureau No. 2. India: Delhi, Manager of Publications, 1945. (11) Memorandum, Surgeon, Headquarters, U.S. Forces, India-Burma Theater, to The Surgeon General, U.S. Army, 5 May 1945, subject: Publication of an Article on Malaria, inclosure No. 2, Observations on *Anopheles leucosphyrus* Don. by Capt. Louis C. Kuitert, SnC, and Staff Sgt. John D. Hitchcock.



MAP 22.—Malaria in Burma.

TABLE 49.—*Distribution of some of the important anopheline vectors of malaria in selected portions of India*

Vector	Assam	Bengal	Bihār	Bombay (Deccan)	Delhi Province	Kashmir	Orissa	Rajputana (east)	Rajputana (west)	Sikkim	Sind	United Provinces (east)	United Provinces (west)
A. culicifacies	X	X	X	X	X	X	X	X	X	X	X	X	X
A. fluviatilis	X	X	X	X	X	X	X	X	X			X	X
A. sinensis	X												
A. jeyporiensis candidiensis	X	X											X
A. leucosphyrus leucosphyrus	X	X											
A. maculatus maculatus	X	X	X	X		X	X			X			X
A. minimus minimus	X	X	X				X					X	X
A. philippinensis	X	X	X	X			X	X	X			X	X
A. stephensi stephensi	X	X	X	X	X	X		X	X		X	X	X
A. sundaicus		X											

TABLE 50.—*Distribution of important anopheline vectors of malaria in selected portions of Burma*

Vector	Mandalay (27)	Bhamo (33)	Myitkyina (34)	Shwebo (35)	Sagaing (36)	Katha (37)	Upper Chindwin (39)	North Hsenwi (Northern Shan State) (42)	Hsipaw (Northern Shan State) (47)	Yawnghwe (Southern Shan State) (57)
A. minimus minimus	X		X			X	X	X	X	X
A. philippinensis	X	X	X				X	X	X	X
A. stephensi stephensi	X		X			X	X	X		
A. culicifacies	X	X	X			X	X	X	X	X
A. fluviatilis	X							X	X	X
A. hyrcanus [1]	X	X	X			X	X	X	X	X
A. jeyporiensis [2]	X	X				X	X			X
A. leucosphyrus leucosphyrus							X			
A. maculatus maculatus	X	X	X			X	X	X	X	X

[1] *A. hyrcanus nigerrimus* and *A. hyrcanus sinensis* are not differentiated.
[2] *A. jeyporiensis jeyporiensis* and *A. jeyporiensis candidiensis* are not differentiated.
NOTE.—Numbers in parentheses refer to locations on map 23.

TABLE 51.—*Distribution of important anopheline vectors of malaria in selected provinces of south China*

Vector	An-hui	Che-chiang	Fu-chien	Hai-nan	Hu-nan	Hu-pei	Chiang-hsi	Chiang-su	Kuang-hsi	Kuang-tung	Kuei-chow	Hsi-kang	Ssu-ch'uan	Yunnan
A. fluviatilis										X				
A. sinensis	X	X	X		X	X	X	X	X	X	X		X	X
A. jeyporiensis candidiensis		X	X	X					X	X				X
A. leucosphyrus leucosphyrus				X										
A. maculatus maculatus			X	X	X		X	X	X	X	X			X
A. minimus minimus		X	X	X	X		X		X	X			X	X
A. pattoni													X	
A. philippinensis				X										

Species Characteristics

The characteristics of the species of *Anopheles* which were most important to the U.S. troops in the China-Burma-India theater are described in the paragraphs to follow.

Anopheles culicifacies Giles 1901 is a widespread species that has been found breeding in a variety of situations. Usually it is found in fresh, clean water but occasionally in brackish water and often in irrigation channels, pools, overflow water collects, slow-moving streams, and quite frequently in wells.

The culexlike adults are small to medium sized. They feed on both human and cattle blood indiscriminately. The anthropophilic index has been found to vary from 0.3 to 80 percent (the latter, exceptionally high for this species, is believed due to a relative absence of cattle). This mosquito is often found in houses or cowsheds in the daytime on the walls or secreting itself in holes; that is, among dung cakes and chaff. Effective flight is normally about one-half of a mile but may extend to a mile under favorable climatic conditions.

This species is the most important vector in the plains of India, is the only vector in Ceylon, and has been found to be of importance in Yünnan. It is particularly notorious in regional malaria epidemics. It usually has a low infection rate. In epidemics, however, it has been found to have sporozoite rates and total infection rates as high as 11.7 and 24.5 percent, respectively.

Anopheles fluviatilis James 1902 is a widely distributed species in India and Burma. It often breeds in foothill stream edges, stream pools, swamps, irrigation channels, and edges of swamps and lakes. Although it prefers sunlit breeding places, it is sometimes found in partial shade. Breeding is often in the immediate vicinity of human habitations.

Biologically, this species may comprise two races. In south India, *A. fluviatilis* is strongly anthropophilic, with indices as high as 97 percent. On the other hand, surveys in northern India show indices of 1.4 to 4.6 percent. This strong flier is commonly found resting in houses and at times in cowsheds.

The southern form is an important vector, with total infective rates of 11 to 26.3 percent. The more northern form has been found naturally infected, but it seems to be of little, if any, importance as a vector.

Anopheles sinensis Wiedemann 1828 is the commonest *Anopheles* in China. It has been found to breed in almost any collection of ground water and occasionally even in artificial containers. It has been found in ponds, ricefields, marshes, ditches, slowly flowing streams, borrow pits, and drains. It seems to favor open water, although this is by no means a rule. Usually, the breeding habitats contain aquatic vegetation. It is predominantly a clean water breeder, although in Burma it has been recorded from foul water.

The observations on biting habits, food preferences, daytime resting places, and other aspects of behavior of this subspecies vary considerably. Whether these variations are due to ecology or to physiological races within the subspecies is not known. In some areas, this species appears to be strongly zoophilic, rarely attacking man: in other areas, relatively large percentages of engorged females are found to contain human blood. Of those caught in houses, practically all have human blood, while most of those taken in cowsheds have cattle blood.

Its role in malaria transmission varies in different parts of its range. It is considered to be the chief vector in the plains of China. Wherever it occurs in appreciable numbers and has anthropophilic feeding habits, it is a potential vector.

Anopheles jeyporiensis candidiensis Koidzumi 1924 has a widespread distribution and is an important vector in some portions of its range. The typical form, *Anopheles jeyporiensis jeyporiensis* James 1902 has rarely been found naturally infected and is not considered important in the transmission of malaria. *A. jeyporiensis candidiensis* is most frequently seen breeding in grassy shallow waters, such as seepages, water from hillsides, abandoned ricefields, and among the stubble of ricefields. It often occurs in connection with rice cultivation.

The adult is markedly anthropophilic, although less so than *A. minimus*. It also attacks domestic animals. Its flight range has been recorded as exceeding one-half of a mile. Usually, it rests in houses or cattle sheds, but in Burma it is reported to leave after feeding. It has been observed biting fiercely toward evening in the open, but usually seeks its host inside habitations or closed shelters.

A. jeyporiensis candidiensis has been found naturally infected in several areas. It is a vector secondary to *A. minimus* in the foothills but has had natural infection indices as high as 10 percent during epidemic periods in China. In the Burma highway area, an infection rate of 5.55 percent was found in 1941. It should be regarded as an important vector.

Anopheles leucosphyrus leucosphyrus Dönitz 1901 is a wild species usually breeding in deep jungle and forest. Larvae have been found in heavily shaded portions of rock pools, in stagnant pools in the beds of mountain streams, in densely shaded swamps, and in borrow pits along heavy forest roads. At times, it has been found some distance from jungle.

This wild species apparently feeds on humans most commonly during the middle of the night. Its flight range is probably not over 800 meters. It has most often been found resting in such natural situations as tree trunks and overhanging banks. However, in some areas it has been found in houses or trapped in bed nets. In Assam, up to 75 percent were found to have taken human blood.

Until recently, this species was believed to be a vector only in Indonesia, but it is now known to be of importance also in some areas of Assam, with infection rates of 3.1 to 4.9 percent where *A. minimus* is less plentiful. It is probably the chief vector in at least some areas of northern Burma: for instance, a sporozoite rate of 2.7 percent was found at Shingbwiyang, Burma.

Anopheles maculatus maculatus Theobald 1901 is essentially a stream and riverbed breeder, with a preference for springs and seepages. It is also found in small pools, ricefields, lake margins, and ditches but seems to prefer partially shaded areas with sandy or rocky bottoms.

The adults enter houses and bite man readily at night, chiefly between 2100 and 0200 hours. The majority leave after feeding and rest outdoors, especially along stream ' anks. In some areas, the species appears to be more zoophilic than in othe. but it is often found to have a high anthropophilic index. An effective flight range of more than one-half of a mile has been found as a result of recent observations.

Although but few naturally infected individuals have been found in the area of the theaters, it has been considered on epidemiological grounds to be a vector. In the area of the Burma highway, it is probably a secondary vector to *A. minimus*.

Anopheles minimus minimus Theobald 1901 is found in eastern and northern India, in Burma, and in southern China. It is a most important vector in Assam and north Burma and is believed to be the most important vector in south China. It breeds in clear, unpolluted slow-running streams and springs with grassy margins and in irrigation ditches and ricefields at low to moderate altitudes. It never breeds in dense virgin jungle, but frequently in secondary jungles.

The chief resting place is on the walls inside dark houses, the majority being in the lower one-half of the room. About 90 percent of the blood feeding takes place after midnight. It is a highly anthropophilic form often with an index of 85 percent or more. Even those found in the open or in cattle sheds may have an appreciable percent of human blood. It is interesting to note that in Hu-nan, south China, *A. minimus* apparently leaves habitations after feeding.

A. minimus is one of the most dangerous malaria carriers because of its domestic habits and its preference for human blood. Large numbers of dissections have shown total infection rates varying from 3 to 18.6 percent. This species is an important vector of malaria wherever found.

Anopheles pattoni Christophers 1926 is found in China, mainly north of 30° north latitude. As a result, few U.S. troops came in contact with it. Breeding occurs chiefly in slowly running hill streams, in rainwater pools, and in riverbeds with sandy bottoms, usually where considerable algal growth is present. The larvae have been found under the ice, and the species is assumed to be able to pass the winter in this stage.

The adults are apparently zoophilic as well as anthropophilic. It is considered to be an important vector on epidemiological grounds wherever it occurs.

Anopheles philippinensis Ludlow 1902 is a widespread species and is an important vector in the Bengal area. It has been found breeding in tanks, pools, drains, ditches, swamps, borrow pits, and ricefields. It breeds only in clear water and has a definitely limited ecological association, some types of aquatic vegetation being preferred while others appear to be inhibitory.

The adult has a definite preference for resting in human habitations, usually near the floor. Preferred feeding times seem to be from 2000 to 2200 and from 0200 to 0400 hours. Although anthropophilic in Bengal, it seems to be definitely zoophilic in Assam.

Total infection rates of 1.04 to 7.2 percent have been found in Bengal where it is the most important vector. In Assam and Burma, it is not generally regarded as a vector of importance (fig. 45).

Anopheles stephensi stephensi Liston 1901 typically breeds in wells, cisterns, flowerpots, discarded tins, roof gutters, and other temporary water receptacles. It also has been found in such places as pools, rivers, streambeds, sluggish creeks, and drains. It can tolerate high salinity and organic pollution. Sunlit breeding places appear preferred. The larvae often sink to the bottom of their breeding location, remaining there for some time so that they may be difficult to discover.

A. stephensi has a range of dispersal up to 2.5 km., perhaps longer. It readily feeds on man. Adults occur in cowsheds, barracks, and houses but are secretive and difficult to find.

This species is an important vector under rural conditions in western and northwestern India and under urban conditions in peninsular and northern India.

Anopheles sundaicus Rodenwaldt 1926 is a broadly ranging species that breeds in saline water. The larvae occur most frequently in sea water lagoons, swamps, and collections of brackish water behind coastal embankments. The water in which it is found usually has a saline content of 1.2 to 1.8 percent but occasionally up to 4 percent and, in the Ganges Delta area, often with as little as 0.4 percent. It usually breeds in the presence of algae.

Adults are strong fliers and may travel up to 3 miles. They occur in large numbers in cowsheds and in huts and other human dwellings. Females generally prefer human blood and have anthropophilic indices as high as 94 percent. They are voracious, occasionally feeding in daytime but usually during the first half of the night.

Anopheles sundaicus is highly susceptible to infection, with total infectivity rates up to 23.4 percent. While it is usually an important carrier, it has been found in large numbers where the incidence of malaria was low.

Effect of Military Activity on Mosquito Breeding

It is possible that in the rear areas mosquito breeding may have been slightly enhanced because additional breeding places were formed as a result

FIGURE 45.—Tank with aquatic vegetation, vicinity of Calcutta, Bengal, showing *Anopheles philippinensis* breeding area in proximity of campsite.

of construction. It is doubtful, however, whether these breeding sites caused any actual increase in the mosquito population. In practically all areas, the establishment of some type of control around camps reduced the breeding sites. Moreover, these new breeding situations were eliminated as soon as they were noticed.

In the combat areas, very little is known as to whether or not mosquito production was increased because of military activities. Throughout these areas, malaria control had not previously been attempted, and no information regarding breeding or prevalence of the disease was available.

Indigenous labor was used throughout the theaters. In many sections, these laborers were brought from other districts. In practically all instances, however, these personnel had previously been exposed to malaria. How much this added to the problem cannot be ascertained. It is known that some of these groups suffered severely from malaria. Routine examinations of thick- and thin-blood films showed about 20 percent positive. Gametocyte rates, however, were always very low.

Prisoners of war were few, and their care and disposition was in the hands of the British authorities. Information concerning them is given later.

MALARIA EXPERIENCE

The annual rates for malaria and for fever of undetermined origin are shown in table 52, by month; the malaria rates are depicted in chart 13. The amount of the fever of undetermined origin which was actually malaria cannot be ascertained. It can readily be seen that malaria was a major problem to troops within the area. Transmission did not, however, continue throughout the year in all portions of the theaters. In examining these figures, it should be noted that suppressive treatment was started in the area forward of

TABLE 52.—*Attack rates for malaria and for fever of undetermined origin, China-Burma-India theater, 1942–45*

[Preliminary data from statistical health reports]

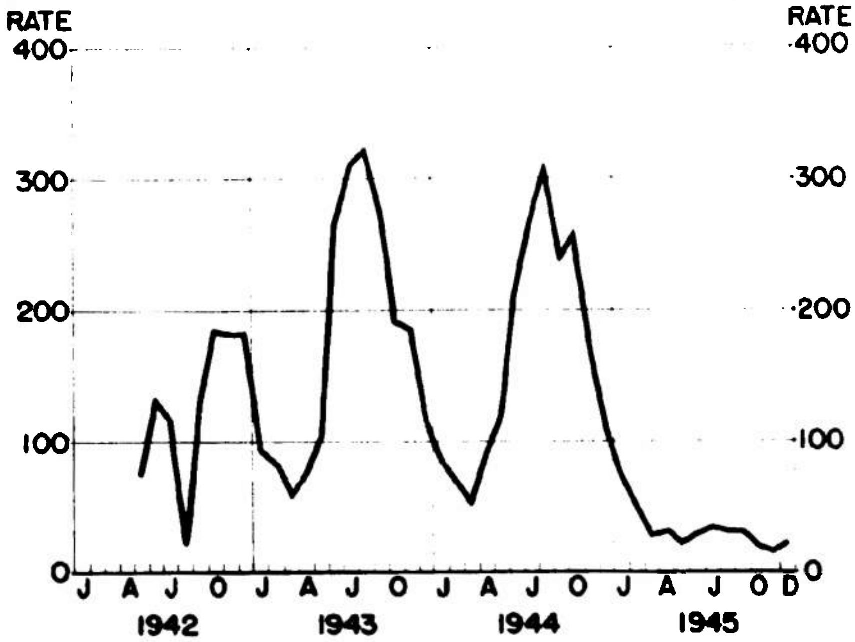
[Rate expressed as number of cases per annum per 1,000 average strength]

Month	Malaria				Fever of undetermined origin [1]			
	1942	1943	1944	1945	1942	1943	1944	1945
January		94	86	74		41	46	87
February		81	66	49		40	28	60
March		58	50	28		32	36	56
April		74	91	20		39	62	59
May	74	104	116	23	0	67	87	70
June	127	264	210	28	0	96	118	89
July	114	311	265	33	18	181	209	102
August	26	322	310	31	0	131	247	91
September	128	273	240	29	42	106	184	76
October	187	190	255	21	48	56	213	52
November	182	185	165	18	50	47	133	45
December	181	116	112	22	43	41	97	50
For year	165	181	174	32	43	71	131	72

[1] It seems certain that a portion of these undoubtedly represent malaria; however, it is impossible to determine the proportion.

CHART 13.—*Attack rates for malaria, China-Burma-India theater, 1942–45*

[Rate expressed as number of cases per annum per 1,000 average strength]



Shingbwiyang, in April 1944, and was extended to include all forces east of the Brahmaputra River by February 1945. In April 1945, Atabrine suppressive therapy was initiated in a large portion of the China theater (chart 14).[9] These were regions of high endemicity (maps 21 and 22). In certain organizations, Atabrine suppressive treatment was discontinued late in 1945.

The malaria rates in the various sections of the India-Burma theater and in the China theater varied considerably, as can be seen in tables 53, 54, 55, and 56 and in charts 15, 16, and 17.

Malaria rates for most of 1943 among troops stationed along the Stilwell Road are shown in table 57.[10] Given for comparison are the predicted rates supplied by British authorities. From table 57, it can be seen that even with the limitations of the malaria control program at that period its efficiency probably materially reduced transmission.

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[9] Circular No. 13. Chinese Combat Command Provisional, U.S. Forces, China Theater, 4 Apr. 1945.

[10] Letter, Lt. Col. Hardy A. Kemp, MC, Rear Echelon, Headquarters, U.S. Army Forces, China-Burma-India, 11 Dec. 1943, subject: Comparative Malaria Rates on the Ledo Road Project.

CHART 14.—*Attack rates for malaria, China theater, 1944–45*

[Rate expressed as number of cases per annum per 1,000 average strength]

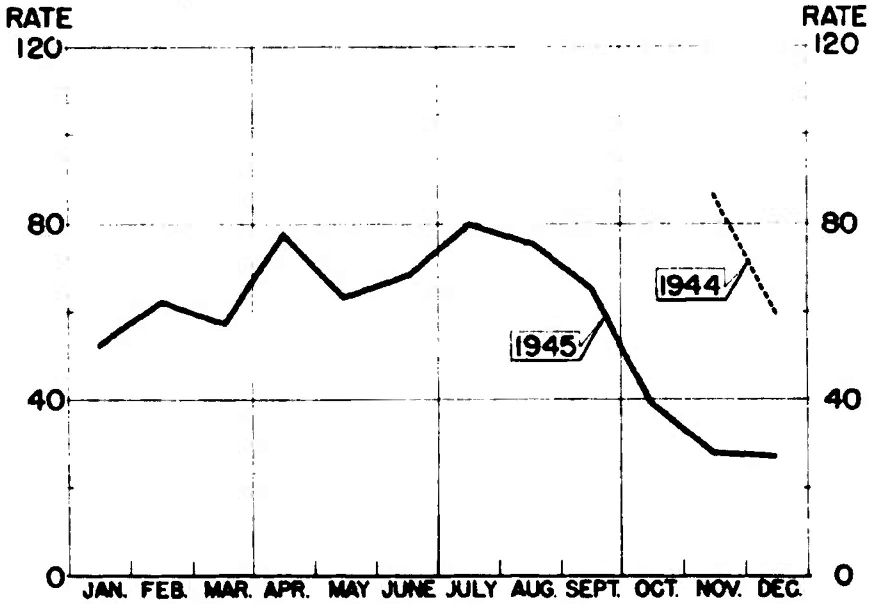


TABLE 53.—*Attack rates for malaria and for fever of undetermined origin, India-Burma theater and China theater, 1944–45*

[Preliminary data from statistical health reports]

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	India-Burma theater				China theater			
	Malaria		Fever of undetermined origin [1]		Malaria		Fever of undetermined origin [1]	
	1944	1945	1944	1945	1944	1945	1944	1945
January	------	77	------	88	------	52	------	81
February	------	47	------	58	------	63	------	75
March	------	23	------	53	------	57	------	76
April	------	19	------	54	------	78	------	85
May	------	13	------	62	------	64	------	106
June	------	17	------	81	------	69	------	116
July	------	19	------	95	------	80	------	123
August	------	15	------	91	------	76	------	92
September	------	15	------	81	------	66	------	62
October	------	16	------	51	------	39	------	55
November	176	17	141	41	88	28	79	64
December	119	21	98	46	59	27	90	79
For year	------	25	68	------	------	63	------	87

[1] It seems certain that a portion of these undoubtedly represent malaria; however, it is impossible to determine the proportion.

Owing to the changing of names and of geographic limits of the various sections, the following terms for the areas are defined (map 19): The Base Section included all of India in which there were troops, except Assam. The Intermediate Section comprised all of Assam except the portion from the

CHART 15.—*Attack rates for malaria, Base Section, India-Burma theater, 1944–45*

[Rate expressed as number of cases per annum per 1,000 average strength]

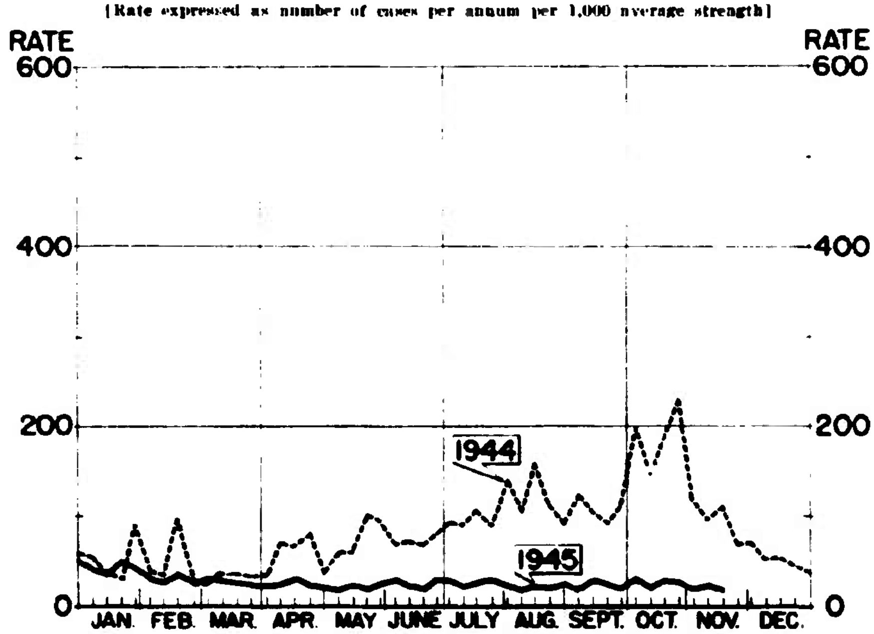


TABLE 54.—*Attack rates for malaria, Base Section, India-Burma theater, 1944–45*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	1944	1945
January	42	41
February	86	30
March	28	24
April	61	21
May	62	16
June	75	23
July	94	23
August	126	19
September	103	20
October	178	22
November	84	18
December	45	(1)

1 Information not available.

Margherita-Ledo area eastward to the Burma border. The Advance Section comprised the Margherita-Ledo area of Assam east to the Burma border and all of Burma that U.S. or Chinese troops occupied. Included in this is the territory of the Northern Combat Area Command. The term "China theater"

CHART [illegible].—*Attack rate for malaria, Intermediate Section, India-Burma theater, 1944–45*

[Rate expressed as number of cases per annum per 1,000 average strength]

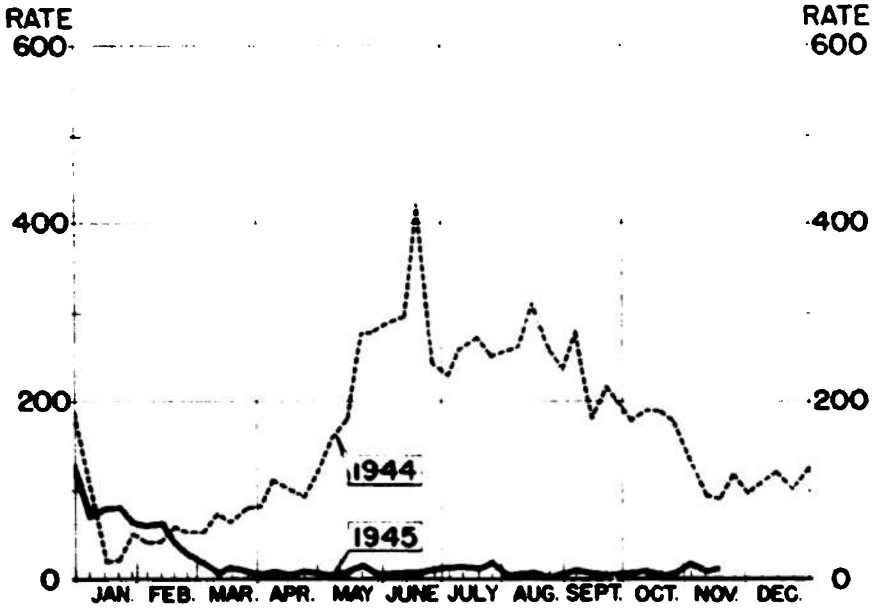


TABLE 55.—*Attack rates for malaria, Intermediate Section, India-Burma theater, 1944–45*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	1944	1945
January	85	82
February	46	55
March	63	14
April	98	5
May	183	6
June	300	5
July	251	11
August	271	2
September	220	6
October	185	5
November	103	11
December	109	(1)

[1] Information not available.

has been used for all the area of that country in which there were U.S. troops.

Because of the scattered distribution of all Army Air Force troops, information about these forces is not given separately. Their malaria incidence is included in that of the area in which they were stationed.

CHART 17.—*Attack rates for malaria, Advance Section, India-Burma theater, 1943–45*

[Rate expressed as number of cases per annum per 1,000 average strength]

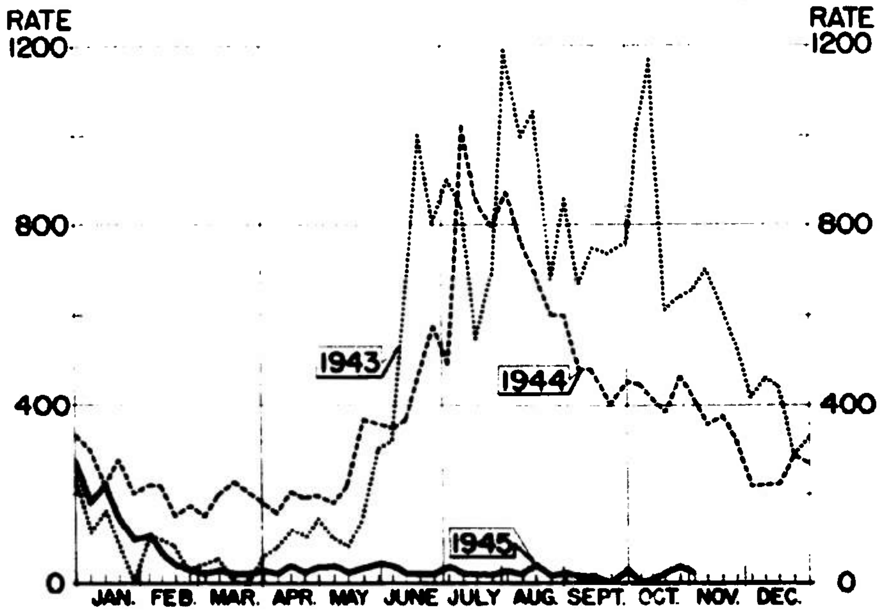


TABLE 56.—*Attack rates for malaria, Advance Section, India-Burma theater, 1943–45*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	1943	1944	1945
January	150	263	198
February	64	180	67
March	20	186	12
April	80	175	14
May	107	236	19
June	613	411	24
July	743	793	20
August	974	722	17
September	751	472	9
October	850	420	11
November	576	335	8
December	379	242	(1)

1 Information not available.

TABLE 57. *Attack rates for malaria along the Stilwell Road, 1945*

Month	U.S. troops		Chinese troops		Predicted [1] local labor	Predicted [1] imported labor	Actual Indian labor
	Predicted [1]	Actual	Predicted [1]	Actual			
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
April	10	0.2	10	0.35	2	15	3.0
May	15	.4	15	.65	5	20	4.6
June	30	1.3	30	2.2	10	35	2.4
July	25	3.4	25	13.2	10	30	8.0
August	25	3.8	25	13.7	10	30	[2] 13.8
September	25	2.8	25	9.6	10	30	19.8
October	30	3.4	30	7.5	15	25	19.6
November	15	--------	15	--------	5	20	--------
December	10	--------	10	--------	2	15	--------

[1] Monthly incidence percent predicted by British authorities.
[2] By this time, a considerable quantity of native labor had been imported.

It must be realized that malaria data have numerous sources of error. The amount of malaria that was undiagnosed, fever of undetermined origin, as well as the movement of Army Air Force personnel actually contracting the disease in one area but being hospitalized in another, seems to have been about equal in the different divisions of the theater. However, the number of cases for which records were not turned in (treated in quarters) and the amount of clinical malaria reported was probably greater in the Advance Section than in other areas. Until the middle of 1945, the Advance Section and China theater hospitalized more malaria patients who had contracted the disease outside the limits of their areas than did the others.[11] After that time, the Base Section figures show the same disproportionate share of malaria. This condition was brought about by troop movements. Moreover, the administration of Atabrine suppressive treatment to combat forces in June 1944 and to those forward of Shingbwiyang further confused the figures in the Advance Section. After February 1945, all troops in the Advance Section, the Intermediate Section, and a portion of the Base Section were receiving Atabrine suppressive treatment. Similarly, figures from the China theater are confused by the fact that first some of the combat forces and later troops in various portions of the theater were placed on suppressive treatment.

Epidemic Malaria

The only special epidemic in the China-Burma-India theater occurred in the Karachi area, Sind Province, India, in the fall of 1944 (table 58).[12] In this area, as in most others within the theater, the close proximity of a highly

[11] Letter, Surgeon, Headquarters, Tenth Air Force, U.S. Army, to Theater Malariologist, Office of the Surgeon, Rear Echelon, Headquarters, U.S. Army Forces, China-Burma-India, 27 Nov. 1943, subject: Malaria Control.

[12] Essential Technical Data, U.S. Army Forces, India-Burma theater, for 15 Oct.–15 Nov. 1944, dated 27 Dec. 1944.

infected human reservoir of parasites and of efficient vectors represents the potentiality for an epidemic.

The Sind Province is usually comparatively dry from July to September, even though this is the so-called wet season. But during 1944, heavy rains occurred in July and August, creating numerous mosquito breeding areas. Weather conditions were near the optimum for breeding and transmission. The mean minimum temperature was 80° F., or above, in the period June through August; practically 80° F., in September; and then it dropped to 73.7° F., in October. These factors produced an explosive epidemic starting early in September. The spread of the disease was undoubtedly aided by the fact that the previously low rate for malaria in this area had produced a false sense of security. As a consequence, there was a general lapse of malaria precautions and failure to take seriously the warnings issued concerning the possibilities of a malaria outbreak. Soon after control was started in the area, satisfactory results were achieved (table 58). The effect of rapid institution of malaria control under such circumstances cannot be overemphasized.

TABLE 58.—*Epidemic malaria in Karachi, India, July through December 1944*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	Rate	Rainfall [1]	Variation from normal [1]
		Inches	*Inches*
July	28	11.28	+8.08
August	62	13.19	+11.63
September	221	0	−0.52
October	1,085	0	−0.02
November	319	(2)	(2)
December	[3] 149	(2)	(2)

[1] From information supplied by the U.S. Weather Bureau.
[2] Information not available.
[3] Calculated from figures for 2 weeks.

Sources of Difficulty

In all portions of the theaters where there were troops, malaria was present, often highly endemic, and in certain areas hyperendemic (maps 21 and 22). With this situation and with the impossibility of separating troops from the local population, only the application of all feasible means of malaria control could keep the rates from being excessive. Unfortunately, at the start of operations, both antimalaria supplies and personnel were insufficient to establish control.

At first such supplies as were available to the British were shared with the U.S. forces, and, in addition, permission was given to procure mosquito netting and other supplies locally, even though all supplies were short. Thousands of laborers were made available for drainage projects and for the construction of mosquitoproof quarters. Many troops did not have sufficient instruction in malaria prevention, and malaria discipline was lax. Intimate contact with the highly infected reservoir population while working in uncontrolled areas, where most personal protective measures were all but impossible, helped to increase infection. Education was stressed, and malaria discipline improved as soon as the importance of the problem was recognized. When U.S. Public Health Service personnel became available, all the antimalaria work was greatly stimulated. As supplies and personnel became available, areas were brought under control and rates dropped. After the use of DDT was instituted, still further reductions were noted, and finally, with employment of general Atabrine suppressive treatment in the more highly endemic areas, rates showed a further decrease. When all these various means were in operation, the rates dropped to a small fraction of what they had been in the early days of the China-Burma-India theater.

As shown in maps 21 and 22, malaria is prevalent to a varying degree in practically all areas of the theater but was most prevalent in the areas with the largest numbers of troops—Upper Assam and north Burma. Surveys by malaria personnel and local civilian assistants substantially verified these findings.

Malaria in Prisoners of War

Only a few prisoners of war were ever questioned by U.S. forces regarding malaria, but some captives from northern Burma revealed that malaria was very prevalent among the Japanese forces. Working through an interpreter, the following information was obtained: "Eight out of every 10 men had it." "They all had malaria at once." "Ninety percent had it." "Three out of every 10 men were sick with malaria at all times." "Some men had it 8 to 15 times, many had it 3 to 4 times."

The British found that 6 of 19 prisoners from the 18th Division (which had been operating in Burma and China for some time) had malaria parasites in their blood (31 percent), and 3 out of 11 miscellaneous troops (27 percent).[13] No evidence of malaria was found in 22 prisoners from the 45th Division. The British also received such statements from prisoners of war as "every soldier in Burma has malaria at least once."

The number of items for prevention gathered from the battlefield, such as head nets, mosquito gloves, and repellents, indicated Japanese recognition of the problem and attempts at control.

ANTIMALARIA ORGANIZATION [14]

In early 1942, there was no specialized organization for malaria control in the theater. Control was a responsibility of individual commanders. Pre-

[13] See footnote 8 (9), p. 357.

[14] Unless otherwise indicated, data in this section are derived from: (1) Mantz, Frank A.: A History of Malaria Control Activities in the China-Burma-India Theater from July 1942 to July 1944. [Official record.] (2) Report, Maj. Mont A. Cazier, SnC, Headquarters, Services of Supply, U.S. Forces in China Theater, 10 Oct. 1945, subject: History of Malaria Control in the China Theater.

ventive measures consisted of unit malaria discipline and, in rare instances, of attempts by individual commands to carry out environmental control operations.

In May 1942, the U.S. Public Health Service Medical Commission to the Yünnan-Burma Railway was sent to K'un-ming, detailed by the War Department for duty with the military mission to China. The Commission was assigned to Headquarters, Services of Supply, theoretically, to the Office of the Surgeon. However, urgent need for engineers for the construction of airfields necessitated the assignment of most of the sanitary officers to construction duties, with sanitation as a secondary duty. Soon, the Chief of the Commission, Lt. Col. Victor H. Haas, MC, became in effect the first chief of preventive medicine and malariologist for the theater. At larger U.S. Army installations, the chief sanitary engineer undertook general sanitary surveys, while the entomologists began malaria surveys. In time, these surveys gradually developed into control programs, insofar as limited trained personnel and extremely limited supplies permitted. During this period, supplies were procured by Services of Supply, wherever they were available, on recommendation of the U.S. Public Health Service. However, control depended chiefly on the starting of such permanent measures as draining and filling.

As manpower wastage from malaria was considerable, the theater surgeon recommended the creation of a special organization for malaria control. The commanding general approved, and the position of theater malariologist was created and filled by February 1943.

In the absence of theater directives, the officers of the U.S. Public Health Service outlined standard operating procedures to be established wherever they were assigned. In place of trained personnel, they persuaded commanding officers to detail small squads to carry out environmental control measures under their supervision. This system worked, but a precedent was established which later became troublesome. This disadvantage was that the preventive medicine malaria control program appeared to be entirely a Services of Supply operation. It was not intended that major commands in the theater should relinquish their responsibilities even though only Services of Supply had the personnel and supplies available to exercise control measures.

When the War Department announced the organization of malaria control detachments, four such organizations were activated in the China-Burma-India theater. Initially, U.S. Public Health Service officers and casual Medical Department enlisted men available within the theater were to be used. This did not prove satisfactory, since these officers were attached to the U.S. Army from another service and could not assume command duties. As soon as possible, they were replaced by Sanitary Corps officers flown out from the United States.

In March 1943, when the earliest phases of the malaria control program for the year were commenced, there had been a shift in the theater organization. This removed Services of Supply from the controlling position and placed all personnel under the command of the theater surgeon. Malaria control and survey units, which began to arrive at the end of May 1943, were considered "theater" troops even though attached to and in effect operating under Services of Supply commands.[15]

The next organizational outline established for malaria control assigned final supervision to the theater rather than to Services of Supply malariologists. Services of Supply section commanders remained responsible for environmental antimalaria activities. They were required to use theater malaria control personnel, including the assistant theater malariologist, who were only attached to Services of Supply for administrative purposes and duty. This program was confusing to the personnel actually in the field. Those who were carrying out malaria control activities were not directly responsible to the commanders in the areas where they operated. These commanders could not deal with their operating personnel except through a separate and higher echelon.

This objection was partially overcome on 7 August 1943, when the Commanding General, Services of Supply, was authorized to move personnel from one Services of Supply section to another, providing concurrence was obtained from the theater malariologist or his assistant.[16] This still left a double line of administration. It did, however, give local commanders greater freedom in carrying out their responsibility for environmental control.

Because of critical shortage of supplies, all items used in the control of malaria were brought under Medical Department jurisdiction.[17] Requisitions were edited and distribution was made on the recommendation of the theater malariologist. The scale of issue was based on troop strength and relative malaria hazard in various areas. Further distribution of supplies was made by the assistant malariologist of these areas. The control of supplies was exercised far more diligently by the theater malaria control supervisors than was control over the units. This was due to the fact that the units were assigned to extremely large areas and that they could scarcely ever be in zones where the need for their services was not great. On the other hand, supplies were so scarce that strict care had to be maintained to see that they were distributed to critical points at critical times.

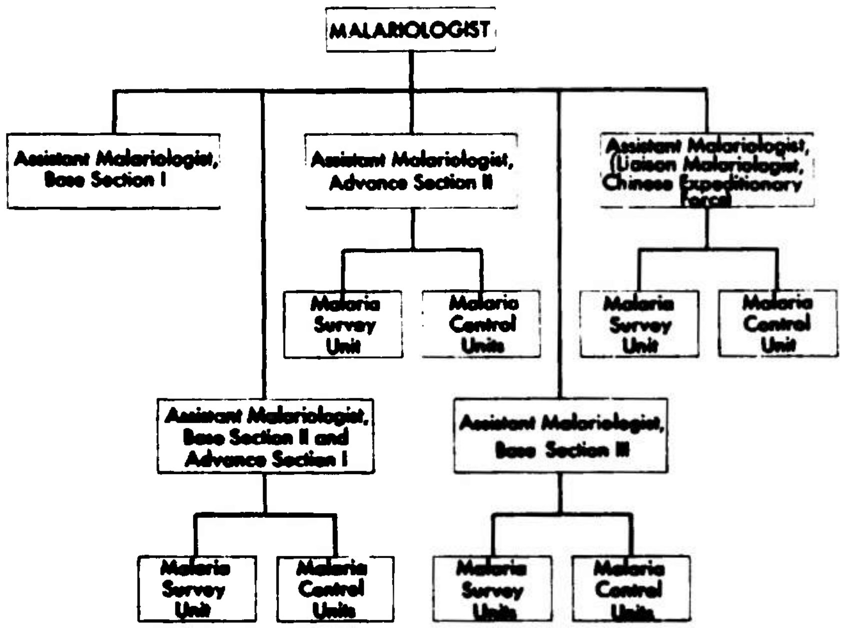
This system was not without unwieldy characteristics. The intervention of two command headquarters between supervisory and operational antimalaria personnel sent all action a long way around before it went into effect. With the thought of eliminating some of the disadvantages and the dual command of administration, the theater malariologist drew up an outline for a "Malaria Control Regiment." Although interest in this idea continued until late in

[15] Memorandum, Maj. Frank A. Mantz, MC, to Surgeon, Services of Supply, China-Burma-India Theater, 26 June 1944, subject: Critical Analysis of the Organization of Malaria Control in the China-Burma-India Theater.

[16] Circular No. 42, Rear Echelon Headquarters, U.S. Army Forces, China-Burma-India Theater, 7 Aug. 1943, subject: Theater Directive on Malaria Control.

[17] Memorandum No. 112, Headquarters, Services of Supply, U.S. Army Forces, China-Burma-India, 13 July 1943.

CHART 18.—*Malaria control organization, Headquarters, China-Burma-India theater, 1943*



1944, the more conventional forms of organization continued to be used. At the end of June 1943, the theater surgeon's staff was further increased by the designation of four assistant theater malariologists.

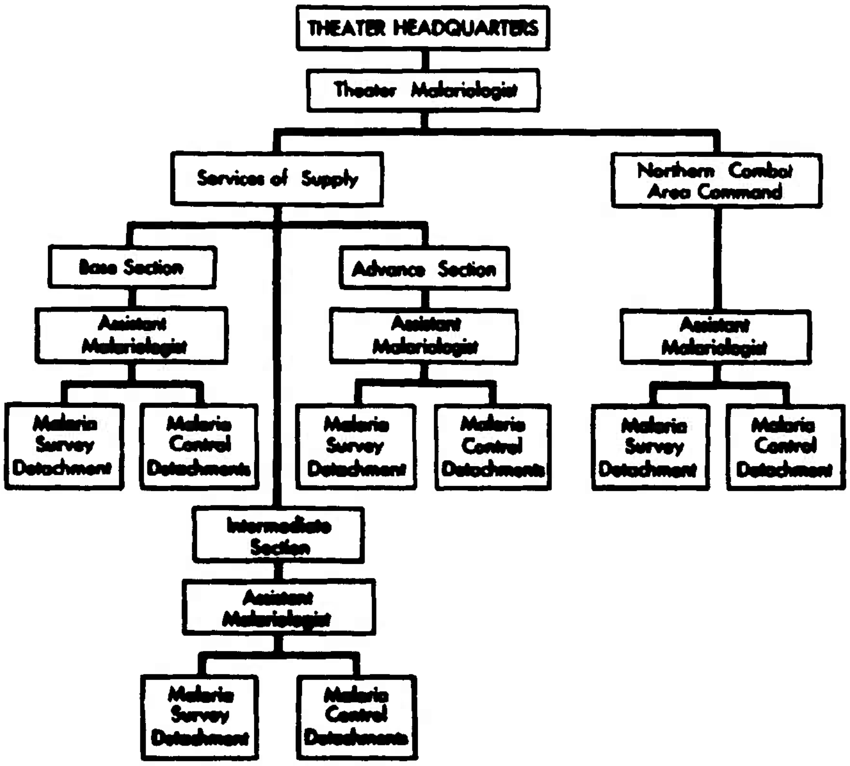
In December 1943, the title of malariologists was abolished by the theater commander and was replaced by that of medical inspector special (malariologist). The duties of this officer were as follows:

> Initiates and directs control measures to combat malaria; is consultant in matters pertaining to mosquito control; makes or initiates inspection of areas in which troops will be operating or quartered. Coordinates the work done by malaria survey teams and malaria control detachments; maintains liaison with and advises Quartermaster Corps and Corps of Engineers on supply requirements and aids in the procurement and distribution of antimalarial equipment and supplies. Maintains records and statistics on incidence and control measures relative to malaria.

By 1 January 1944, all U.S. Public Health Service officers engaged in the malaria control and preventive medicine programs had been returned to the United States, having rendered services of inestimable value to the U.S. Army.

Until March 1944, malaria control organizations were administered directly from theater headquarters by the theater malariologist (chart 18). After this time, the theater malariologist was completely divorced from the control organization (chart 19). He retained only the function of inspection, general

CHART 19.—*Malaria control organization, India-Burma theater, after October 1944*



planning, and recommendation. The remainder of the organizations took over independent operation in each of the several commands to which they were assigned. At this time an all-inclusive theater directive governing malaria control practices and policies was prepared by theater malariologists. According to the new directive, personal protective measures were to be enforced by command discipline. Services of Supply was made responsible for control of malaria and was ordered to direct its section commanders to take all necessary action. Procurement and issue of supplies remained with Services of Supply. Monthly reports of the malariologists in each Services of Supply section were to be sent to theater headquarters rather than to Services of Supply headquarters.

The new arrangement was not satisfactory. The Air Forces protested that the new directive was contrary to established regulations in that it relieved unit and area commanders of their responsibility for the initiation and enforcement of malaria control measures. The practical disadvantage to the arrangement, insofar as the Air Force was concerned, was that the deployed Army Air Force troops were likely to come under the jurisdiction of several different malaria control programs and agencies. With these objections Services of Supply agreed. While elements of malaria control and the activities of antimalaria units might conceivably be delegated to Services of Supply, it was not apparent how the Air Forces could be relieved of, or Services of Supply assume the responsibility for malaria education, discipline, and the enforcement of control measures. It was also obvious that since environmental measures were an integral part of the discipline, these activities could not be entirely divorced from other command responsibilities. Responsibility for coordination and advice was too completely removed from operations to bring the malaria control program to a high degree of effectiveness. A second defect was the lack of centralized or uniform policy.

The solution to the problem was the consolidation of the staffs of the theater and the Services of Supply surgeons (General Orders No. 104, on 22 Aug. 1944). This merger solved the majority of difficulties which had arisen out of the confusion of command in technical channels of authority. In the realm of malaria control, the fact that Services of Supply had malaria control personnel assigned to it, while the theater had the malariologists and most of the other preventive medicine personnel, made little or no difference, since all members of the staff were unified under the direction of the deputy theater and Services of Supply surgeon. Even the formality of preserving the identity of the two staff sections became unnecessary in May 1945, when the Services of Supply was absorbed into a single theater command.

The China area until October 1944, when it became a separate theater, was administered as one of the major sections of the China-Burma-India theater. After separation, a theater headquarters was established. In January 1944, a malariologist for the area was appointed. In March 1944, malaria control was made a function of Services of Supply. After October 1945, the duties of malariologist were assumed by the theater medical inspector. With limited personnel and equipment, control measures had to be confined to the larger installations.

Although for a great portion of the time the various section commanders were responsible for malaria control measures and distribution of supplies, these functions were supervised either from Services of Supply or theater headquarters. These various section headquarters issued their own malaria control directives. In most major features, the directives were essentially similar, varying in minor respects, relating mainly to physiographic and biologic differences in malaria epidemiology.

For all practical purposes, no great distinctions were made between forward areas and rear areas in regard to this program. As already stated, the Army Air Force installations had command responsibility for malaria discipline and such preventive measures, but the physical control measures were carried on by the troops assigned to Services of Supply. At this late date, it is practically impossible to follow the eccentricities of the developing plans of the sections. Throughout the theater, the program was varied to meet the immediate needs of the problem at hand. The assistant malariologists in the various sections had free reign to make such modifications in existing programs as they deemed necessary for the adequate and prompt control of the disease.

For the most part, the activities of malaria control in this theater were carried out by a self-contained organization. However, liaison with the Southeast Asia Command was permanently maintained. At times, the consultant malariologist for this command undertook special research in connection with the development of programs within the theater.

Extracantonmental Control

From the beginning of the program, it was obvious that some extracantonment sanitary control was necessary if adequate protection was to be provided. It was recognized that this could not be carried out effectively by U.S. authorities because of the unusual relationship which existed between the Central and Provisional Governments; because of language difficulties, each area having a different dialect; and most important, because of religious customs which, for example, made impossible the spraying of the Moslem homes by a squad of "GI's." By working through General Headquarters, India, the Central and Provisional Governments were contacted early in 1943, and they instituted a program of extracantonment environmental and sanitary control around many of the larger U.S. Army installations.[18]

In the Calcutta area, two other procedures were followed. In some of the outlying areas, an arbitrary division was made so that U.S. forces controlled one side and British or Indian forces took care of the other. These projects were made effective by close liaison. In the large dock and warehouse district, control was placed in the hands of the Garden Reach Anti-Malaria Association.[19] This efficient, cooperative organization was paid to control certain areas and thus could augment its existing program to include the territory occupied by U.S. forces.

Antimalaria Details

Under the authority of War Department Circular No. 223, dated 21 September 1943, and the India-Burma theater Circular No. 11, dated 31 January 1945, antimalaria details were formed in all companies and similar organizations. They carried out simple antimosquito measures such as maintaining mosquitoproofing, aerosol spraying, ditching, and larviciding. At times, they did the highly beneficial residual spraying (with 5-percent DDT) and mosquitoproofing within their own organizations. Their duties were

[18] Letter, Additional Deputy Secretary to the Government of India, to all Provincial Governments: The Agent to the Governor-General, Resident and Chief Commissioner, Baluchistan: The Chief Commissioner, Delhi, 11 July 1944, subject: Measures to Reduce the Risk of Infection to U.S. Army Forces Camps Caused by Neighboring Villages.

[19] Annual Report, Secretary, Garden Reach Anti-Malaria Association, Calcutta, 1944-45.

undertaken after preliminary training with the malaria control detachment or under the supervision of the battalion surgeon. These units were not at all times effective; for example, when the personnel were used for other duties and did not have time to attend to the malaria program. This was especially true where the medical section was made responsible for these activities.

Most of these details should be described as antimosquito details rather than antimalaria details. Their work as a rule eliminated numerous breeding areas for pest mosquitoes. Most of the anopheline vectors of malaria did not breed in situations which the details controlled. However, their effectiveness in the overall picture should not be forgotten, because some malaria was undoubtedly prevented by their efforts.

Malaria Laborers

Most of the malaria mosquito control projects required extensive labor, due to the topographical conditions and to the lack of available mechanical equipment. In order to facilitate the work, large numbers of laborers were employed. Most of them were hired by the Army and had had no previous experience with this type of work. Some were supplied by the Indian Tea Garden Association. In addition, India Pioneer Corps, Porter Corps, and Chinese Army troops were used. In many instances, they worked under the supervision of Indian Army units.

When it was possible to retain the same personnel and to give adequate supervision, results were good. However, in some cases the personnel would not be the same from day to day, or at the most would only be retained for a very short time. Under these conditions, results were by no means as satisfactory. In a few areas, sufficient laborers were not available, and, as troop strength was always low, necessary operations suffered.

Supervision of these workers was a serious problem. Even though they were for the most part employed as simple laborers, for example, to clear ditches, they had to be instructed. At first malaria control personnel were used as supervisors, but, as projects expanded, their numbers were not sufficient. At that time, personnel from other organizations, such as Quartermaster truck companies, and Quartermaster service companies, were used for this purpose. These men were not trained for the work, but members of the control organizations quickly showed them what was needed. In this way, some specially trained personnel could be released for other necessary work.

In the Ledo area, another method of supervision was employed. Stationed in this area was an Indian Army antimalaria company, and it was arranged to have them take over a considerable portion of the supervision. This worked well, as the men had not only been instructed in the fundamentals of control but also did not have to contend with the language barriers that made supervision so difficult for U.S. troops.

In the China theater, both Chinese troops and locally procured laborers were employed.

Organization for Airplane Spraying

The first DDT air-spray experiment in the China-Burma-India theater was done with an L-4 cub plane equipped with Hausman-Longcoy accessories. It demonstrated that air spraying was effective against both larvae and adults, but the plane was too small for the job in this theater.

Subsequently, in the India-Burma theater, the P-40, P-47, and B-25 planes were investigated. After experimentation, it was finally decided that the B-25 had the most desirable characteristics. It had the essential large carrying capacity, long range, and maneuverability. Some B-25 planes were therefore equipped with a 585-gallon bomb bay tank, an M-33 CWS discharge tube, with suitable outlet valve, and an operating lever. Experiments with this equipment indicated that under normal conditions the following results could be expected: (1) Each planeload of 585 gallons of 5-percent DDT solution could be spread over a swath about 200 yards wide and 9 miles long, and (2) the rate of dispersion across the swath would be reasonably uniform.

By the fall of 1944, after 6 months of experimentation, an organization was developed, consisting of three B-25 planes modified for air spraying, six L-5 cub planes modified for air spraying, and two M-4 Chemical Warfare Service decontaminating apparatus, for mixing DDT solutions. The personnel were pilots and ground maintenance crews, two malaria control units, and one malaria survey unit. This organization was completed by February 1945 and continued in operation throughout the season. It was operated by the U.S. Army Air Forces under the name "India-Burma Air Spray Flight." Over 70,000 pounds of DDT were air sprayed in the form of 5-percent kerosene solution during its 9 months of activity (fig. 46).

Experimental work led to the following conclusions: (1) When spray applications were followed within a few hours by rain, the effectiveness of the spray material was greatly reduced; (2) the continued low mosquito population in areas treated after 1 March 1945 was due to its early reduction during the premonsoon season; (3) in order to bring the mosquito population under control during the monsoon season, it was necessary to make applications more often than every 14 days or to use a higher concentration of DDT; however, no data are available on the effectiveness of a higher percentage of DDT; and (4) under the conditions of the experiments, the effective period following aerial application of 5-percent DDT was no more than 3 days.

Air spraying was established in the India-Burma theater on the premise that it would supplement groundwork and be especially useful in rapidly controlling newly captured areas.

There were certain basic organizational difficulties which were never completely overcome. The three major subdivisions of the theater were all interested and involved in this project. The U.S. Army Air Forces had the planes, pilots, and maintenance facilities. Services of Supply was responsible for malaria control; it had the antimalaria units that did the groundwork and

FIGURE 46.—DDT air spraying at Myitkyina, Burma.

determined the needs for air spraying. The Northern Combat Area Command had an area of responsibility, antimalaria units on the ground, and occupied a rapidly fluctuating front that needed air spraying. The administrative problems were numerous and complex. The overall results obtained were as good as could be expected in a theater where distinction between air and ground forces' authority was so sharply drawn. Ground-air liaison, although stressed by both sides as being one of the most important features of the program, was never effectively carried out. Even the simplest types of liaison attempted did not achieve any definite results. The inability of the air-spray flight to meet its commitments definitely hindered this phase of the program.

Starting in August 1944, L-5 cub aircraft were used for air spraying in the China theater, around hostels occupied by U.S. troops. A 5-percent DDT solution was dissolved in a mixture of Chinese gasoline, 6 parts and kerosene, 4 parts. It was found that this mixture did not have a burning effect on rice and adjacent crops. Insufficient DDT was available to obtain adequate coverage.

As the capacity and flight range of these planes was limited, efficient ground-air liaison was easily maintained.

Activities of Other Army Organizations

Except for supply activities of the Quartermaster Corps and the Corps of Engineers and limited programs by various Army Air Force installations, no other agencies were engaged in special antimalaria activities. The Air Force bases usually followed policies agreed upon between their surgeon and either the theater malariologist or assistant malariologist of the various sections. In these activities they were often helped by the malaria control personnel assigned to Services of Supply.

At times, the Quartermaster Corps and the Engineer Corps were responsible for the requisitioning and issuing of the various malaria control supplies and equipment. As already discussed, for a time this responsibility was taken from them and given to the theater malariologist in order that more adequate and equitable distribution could be made.

ANTIMALARIA ACTIVITIES

Malaria Education

Training.—No special technical and professional schools were maintained for antimalaria training. A few officers were assigned to take the general course at the Malaria Institute of India in Delhi. Some medical officers informally attended other established centers, such as the Calcutta School of Tropical Medicine. The opportunity for such instruction was unfortunately restricted by the capacity of the schools and by the limited personnel available for actual control work in the theater. Instruction of some of the enlisted men in malaria detachments was more easily accomplished at the various hospital and medical laboratories in which they worked. Training of this type, while greatly needed, was of necessity somewhat informal and erratic owing to the constant shortage of personnel.

Formal education of the troops in malaria prevention was initiated following the publication, in September 1943, of War Department Circular No. 223, which required that all personnel in the Army undergo an intensive 4-hour course in malaria and its prevention. This course was to be given before oversea assignment. For those troops who were in the theater before the issuance of the directive, instruction was given in the field.

Education of incoming troops started on the transport at the port of debarkation. Personnel were given a lecture on antimalaria procedure and reminded that they were entering one of the most malarious areas in the world. They were told how to protect themselves, and special emphasis was placed on the immediate problem of protecting themselves while traveling across India.

At various times antimalaria personnel, either singly or in small groups, circulated through the theater contacting organizations. In lectures they explained the antimalaria program, answered questions concerning it, and checked the antimalaria campaign.

Maj. Gen. (later Sir) Gordon Covell, Malaria Institute of India, lectured on the problem and its control at various locations within the theater. Attendance of at least one officer from each U.S. Army organization in the areas was required at these lectures. This program was well received and was of definite help to all concerned.

Organizations that reported a high malaria rate were visited by various antimalaria personnel. Inspections were made and problems discussed. When necessary, instructions were given to the malaria control officer, antimalaria detail, or at times, to as many of the command as could be gathered together. This was particularly important in relation to the DDT residual spray program. The result of these activities was better cooperation in the existing programs.

Propaganda.—The bulletins of the various headquarters published all necessary information about malaria control. They were used to inform all personnel when changes were made or to emphasize some aspects of the program which were not receiving sufficient attention. These publications were used to prepare for the DDT residual spray program and air-spray operations. Various news sheets stressed the program with frequent short notices, warnings, and notes about changes in the program.

Attractive posters were supplied for exhibition in dayrooms, on bulletin boards, in messhalls, and in orderly rooms. These stressed personal preventive measures, Atabrine (quinacrine hydrochloride) suppressive treatment, and other aspects of the program. Attempts were made to have the posters changed at frequent intervals in order to maintain their effectiveness.

Radio reminders were used in the various GI radio stations. These varied from simple warning statements (several times daily) to short skits. At GI movies, antimalaria trailers were used with almost all shows. In addition, the various short films on malaria were shown at intervals throughout the theater. In connection with this, it might be noted that to enter a motion picture theater one was usually required to apply a repellent liberally. Road signs were used extensively from the port of debarkation to the gates of K'un-ming.

In 1944 and 1945, the troops in this theater had a working knowledge of malaria and they were never allowed to forget it. Some propaganda methods were used so frequently, however, that their effectiveness was impaired.

Survey Activities

Both entomological and parasitological surveys were conducted to obtain the necessary information concerning species of *Anopheles*, their distribution and habits, and their importance as vectors, and to determine the prevalence and types of *Plasmodium*. However, most malaria survey detachments within the area were actually engaged chiefly in control work. On the other hand, certain control detachments supplemented their work by survey activities.

In areas where limited or no information was available, these surveys obtained sufficient data on which to base specific control measures. Unfortunatley, records are not available to give a comprehensive summary of this work. The following record of the 35th Malaria Survey Detachment that was able to devote its time to survey activities will give some idea of the extent of information compiled. In one year, more than 5,000 thick- and thin-blood film examinations (34.8 percent positive for *Plasmodium*), representing over 120 groups of individuals, were examined. More than 30,000 *Anopheles* larvae from over 1,300 positive collections and 5,500 adults from more than 350 groups of collections were identified by species. Over 2,500 mosquito dissections were made.

Mosquito Control Measures

Larviciding.—Larviciding was one of the most important methods of malaria control and was utilized throughout the China-Burma-India theater. The availability of Malariol or other larviciding material and the ease of application by untrained labor added to the desirability of stressing this method. It was used extensively where other methods were not feasible, for example, in ricefields which could not be drained because of their essential food crops, in low flat areas which could not be drained satisfactorily, in water tanks (that is, reservoirs) essential to the life of villagers, and in breeding places requiring only temporary treatment or control only until more permanent measures could be put into effect.

Although Malariol was used more extensively than any other larvicide in the India-Burma theater, paris green was used in China in many of the ricefields, and white gasoline was sprayed in wells and in some tanks. When DDT became available, small amounts of it were dissolved in oil and this acted as a more effective larvicide. Smaller amounts of the DDT solution could be spread effectively over larger areas than could be controlled by simple oil sprays. In the China theater, waste motor oil and tung oil kerosene were mixed and extensively used as a larvicide. DDT dusting powder was found to be superior to paris green and was widely used to control mosquito breeding in ricefields. In addition to the ground larviciding, the air-spray program was established. It was found that this method was useful in large, flat, inaccessible swamp areas and also in quickly controlling the mosquitoes in newly captured areas. Effectiveness was definitely limited by rough mountainous terrain, which kept planes high, by dense jungle canopy, and by monsoon rains which frequently prevented routine operations or washed away the DDT immediately after spraying.

Filling and clearing.—Filling for malaria control purposes was little used largely because of inability to obtain vehicles to transport fill and also because of lack of machinery to obtain material for filling.

Clearing was done extensively in connection with drainage. In many cases this was the only method of revealing detailed topography so that drainage could be established. In addition, continued clearance of secondary growth in established drainage canals and other waterways was necessary so that larviciding and inspection crews could have access to mosquito breeding areas. For all these operations, simple handtools were all that were available in the majority of cases; in some sections, however, powersaws were used effectively in clearing logjams and a right-of-way.

In tanks (that is, earth-bunded reservoirs) for ground shortage of water, the situation amounted to a constant struggle to keep ahead of the abundant aquatic growth. Various methods were tried, but only two were at all effective, the first being hand cutting and pulling, and the second a method of dragging. In the latter, a drag was attached to the winch cable of a truck and this was pulled across the tank. Both of these methods were slow and, due to the very rapid growth, were only partially effective.

Drainage.—Adequate drainage wherever possible and larviciding of other areas constituted the main antilarval operations. Literally hundreds of miles of drainage canals were dug and maintained by the malaria control detachments. In all but a very few areas, this work was done by laborers under the supervision of the control detachments or other personnel working for them.

In some of the northern Burma areas, dynamite was used to establish drainage. This was an effective method and required much less manpower in an area where manpower was limited. Of course, labor was needed to maintain this drainage once it was established. No machines were available for ditching within the theater.

Naturalistic control.—No attempts were made at regular flushing of waterways within the theaters. During the wet season, flash floods occurred frequently. For this reason, every effort was made to keep all drainage ways free from vegetation so that these torrents would be given full opportunity to flush breeding areas.

In portions of the Calcutta area that were being controlled by the Garden Reach Anti-Malaria Association, tidal flushing was utilized.

The U.S. Army did not attempt any naturalistic methods of control. In some villages surrounding various installations, however, the tanks, wells, and other waters had been stocked with larvivorous fish which helped to control mosquito breeding. It might be noted that in many areas tanks were used as commercial fish hatcheries. The fish undoubtedly helped reduce the mosquito population.

Due to the enormity of the problem and to the lack of special equipment or time for much experimentation, few special methods were utilized in the theater. One special method used was assault boats fitted with power sprays to disperse larvicide in some of the rivers and larger lagoons.

Adulticidal sprays.—Space spraying was carried out in buildings throughout the theaters whenever the necessary materials were available. Aerosol bombs, hand sprayers, and, at times, knapsack sprayers were used. Particular attention was given to barracks, messhalls, and latrines. The effectiveness of this method against flies led to its use in buildings where mosquitoes were not the primary problem. These activities were carried on by the organization's antimalaria details or by individuals within their own quarters. The frequency and thoroughness of such spraying depended upon efficiency of the

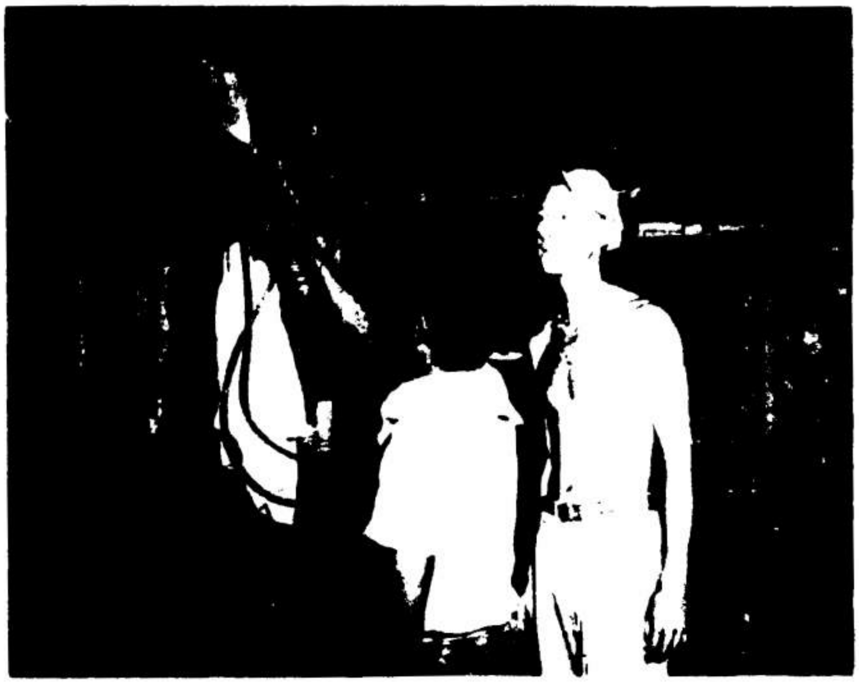


FIGURE 47.—DDT residual spraying in native quarters, using spray gun with power spray, vicinity of Ledo, Assam.

spraying crews. The proper method was outlined by the various malaria control directives.

Limited space spraying outside of buildings was attempted. For a time, spraying of open-air movie areas was undertaken. However, before this had been fully organized, the DDT residual spraying program was established, and many of these areas were treated by the latter method. Space spraying was also accomplished by the air-spray program as the DDT in oil acted as a space spray as well as a larvicide.

When quantities of DDT became available, an intensive residual spraying program was started. The details of application varied within the various sections of the theater. Village buildings within the supposed mosquito flight range were sprayed by the malaria control detachments, while in some areas they also sprayed troop quarters and other buildings. When the spraying of the very numerous local villages constituted a major problem, the spraying of military quarters was left to the organizational antimalaria details. These men were trained whenever possible by members of the malaria control detachments (figs. 47, 48, 49, and 50).

FIGURE 48.—DDT residual spraying in native quarters, using backpack spray with extension nozzle, vicinity of Ledo, Assam.

The frequency of the spraying depended upon climatic conditions (as they influenced breeding and transmission), the scope of the program, and the amount of spray necessary for complete coverage. This program was stressed until it became the most efficient and probably the most effective portion of the antimalaria campaign. The relative ease of application, the duration of the spray deposit, and the readily visible effect on most insects won for it almost wholehearted cooperation.

Mosquitoproofing.—Throughout the theater, the necessity for screening and mosquitoproofing was stressed. Due to a limited supply of materials, more were distributed, by order of the theater malariologist, to the areas of higher endemicity than elsewhere. Hessian cloth (burlap) and mosquito netting were used. During the early days of the theater, the entire supply was of British manufacture and was very scarce. During 1944 and 1945, large amounts of American-made netting and nylon and wire screening arrived to supplement the British stocks. However, it was not until midsummer of 1945 that sufficient quantities could be moved to the forward areas in Burma to meet the demand. Mosquitoproofing in the China theater was never adequate. The malaria control units distributed the mosquitoproofing supplies, supervised installation, and checked maintenance. Without this skilled assistance in the India-Burma theater, mosquitoproofing would have been much less effective.

FIGURE 50.—DDT residual spraying in native quarters, using hand spray, vicinity of Ledo, Assam.

The standard materials were burlap (hessian cloth) for walls and ceilings and mosquito netting for doors and windows. The materials deteriorated rather rapidly in the jungle but were usually effective as long as the organization was stationary. Both the American pyramidal and the British EPIP (European Privates, Indian Pattern) tents provided comfortable living quarters when placed over a wooden framework, elevated to give 6-foot sidewalls, and then mosquitoproofed. Nylon and wire screening was used in relatively permanent buildings, such as hospitals and messhalls (fig. 51).

Basha-type buildings (grass and bamboo construction) were often mosquitoproofed by native contractors under the supervision of malaria control personnel. This method was very effective, and as the men became trained in its use, efficiency was increased and waste decreased. In these more or less per-

FIGURE 59.—DDT residual spraying in latrine, using continuous hand spray and showing mosquitoproofing with mosquito netting and hessian cloth, vicinity of Ledo, Assam.

manent buildings, mosquitoproofing lasted for a considerable length of time (fig. 58).

Maintenance of mosquitoproofing was the responsibility of the individual organization but was checked by malaria control personnel. In the areas where frequent movement of the organization occurred, there was considerable but unavoidable wastage.

Bed nets and jungle hammocks were used throughout the theater. Early models of bed nets were of poor quality; they restricted air movement, and became rapidly mildewed. They were hot and smelly. Later models were made

FIGURE 51.—Mosquitoproofed tents, vicinity of Ledo, Assam.

of a tightly woven netting and were less objectionable. Little trouble was experienced in enforcing the bed net regulations. Jungle hammocks were used in forward areas until permanent quarters could be erected.

Mosquito repellents.—Ample quantities of insect repellent began arriving in the China-Burma-India theater in the summer of 1943, and it became one of the few items of which the supply exceeded the demand. As the relative effectiveness of the various formulations became known, all but dimethyl phthalate were discarded and returned to Quartermaster stock.

Repellents were universally objectionable to the troops, as they added to the general discomfort. They often smarted when applied to wind- or sunburned skin, they were sticky and oily, they made the user feel hot, they soiled clothes, and dissolved plastic. They were not used by the average soldier except under pressure from his commanding officer or when there were overwhelming numbers of mosquitoes. Various methods of using the repellent were tried with but fair success. In some sections of the theater, it was impossible to go to GI movies unless one submitted to a liberal application of repellent. While all individuals had repellent available and most believed in its effectiveness, its use was not as general as it should have been.

Protective clothing.—Head nets and mosquito gloves were seldom if ever worn. They were extremely uncomfortable and restricted the efficiency of the

FIGURE 52.—Mosquitoproofing basha-type building, vicinity of Ledo, Assam.

wearer. In a few instances guards wore them but their use was soon discontinued entirely.

Atabrine Suppressive Treatment

The history of Atabrine in the theater is a recapitulation of the general experience of the Army with this drug. Its use was characterized by the hesitation and vacillation common to all theaters during 1942 and early 1943. The therapeutic value of Atabrine was established and accepted by medical officers long before its suppressive properties were fully appreciated. Atabrine was used successfully in the hospitals in accordance with the suggestions and directives published by the Office of The Surgeon General, but no effort was made to employ the drug on a large scale for its prophylactic effects during the campaigns of 1943.

Circular No. 5, published on 8 April 1943, contained this phrase: "* * * use of drugs for suppression of malaria symptoms, an emergency measure, to be employed only where other methods are impractical or inadequate, and dependent on military necessity when ordered by the commander concerned on the advice of the chief surgeon concerned." Again, on 7 August 1943, theater directive on malaria control (Circular No. 42) stated: "* * * prophylactic administration of drugs against malaria is to be carried on only when directed by the theater commander."

In the spring of 1944, when the Japanese hold in northern Burma was challenged, mass atabrinization of troops exposed to the malaria hazards of this hyperendemic area was started. The administration of one tablet of Atabrine daily was prescribed for "all American and Chinese troops operating in upper Burma forward of Shingbwiyang and west of Paoshan, Yünnan Province, China." [20] Some months later, the Atabrine zone was extended northward to include the extreme northern tip of Burma forward of the Tirāp River (some miles east of Ledo). In September 1944, it was decided to continue this suppressive program indefinitely. At the same time, units and individuals leaving these areas were directed to continue taking Atabrine for at least 4 weeks after departure.

The early program of suppressive treatment was not successful. In July 1944, malaria reports from the Northern Combat Area Command recorded 5.8 percent of U.S. troops as malaria casualties (696 per 1,000 per annum). The causes were manifold—lack of understanding of the suppressive action of Atabrine, poor discipline and indifference, poor morale, and hostility to suppression caused by the belief that it lessened the soldier's practice of individual protection against mosquitoes.

The belief that Atabrine suppressive treatment was detrimental to malaria discipline and to personal efforts to evade the mosquito persisted among many thoughtful and experienced malariologists throughout the remainder of the theater's existence. Once the idea was brought home to the soldier that faithful taking of one tablet of Atabrine a day would keep him from getting clinical attacks of fever, he became somewhat indifferent to the occasional mosquito bite that otherwise might have caused him real concern.

Atabrine propaganda, to be effective, had to be dogmatic and forceful, emphasizing good features of the drug and minimizing its shortcomings and occasional undesirable side effects. This caused a certain amount of dissatisfaction among medical officers, especially those who questioned the intellectual honesty and scientific accuracy of such propaganda. The theater surgeon's office was at times hard pressed to maintain its policy as laid down in official publications, when presented by evidence as to the occasional toxic effects of Atabrine.

In December 1944, the theater surgeon, knowing that Atabrine discipline in the forward areas was not producing the desired suppression of clinical malaria, personally visited a large number of combat units and supporting elements then operating in the Bhamo-Lashio-Myitkyina area. The interest in Atabrine as a suppressive drug at that time is further demonstrated by an-

[20] Circular No. 33, Rear Echelon Headquarters, U.S. Army Forces, China-Burma-India, 23 Mar. 1944.

other tour conducted independently by representatives of the Advance Section. It was inevitable, therefore, that the conference called by the theater surgeon in late December 1944 to revise malaria control policies should have been dominated by a desire to emulate the extraordinary success of the 1944 malaria control programs of the Australian and American forces in the Southwest Pacific Area. As a result of this meeting, India-Burma theater Circular No. 11 was published on 31 January 1945. This directive provided for the extension of the compulsory Atabrine suppression treatment to include most of the hyperendemic malaria areas in Assam, East Bengal, and all of Burma (comprising about 60 percent of the India-Burma theater strength during the period January through August 1945). This was a compromise between those who believed that suppressive treatment should be restricted to troops living continuously outside the protected areas and those who believed that there should be a blanket suppressive treatment covering the entire theater.

On 28 January 1945, India-Burma theater Circular No. 4 was published. It was educational in form and purpose, containing a summary of the new work in the Southwest Pacific Area. It emphasized the absolute necessity of 100 percent daily Atabrine administration.

By the middle of March 1945, the Atabrine program was fully established in the designated area. Its success, even beyond expectation, was due to a remarkable degree of command acceptance of responsibility for its execution. The low winter malaria rate continued on into the spring and summer and stabilized between 15 and 20 per 1,000 per annum. There was no appreciable summer or fall increase in malaria morbidity. The highest incidence of malaria in 1945 occurred in the Base Section outside the Atabrine zone, where the rates differed little from those of previous years.

On 4 April 1945, China theater Circular No. 13 directed the use of Atabrine suppressive treatment in the more malarious areas of the command. Results similar to those in the India-Burma theater were achieved.

The relative importance of the blanket Atabrine suppressive treatment compared with that of the efficient environmental mosquito control program carried out by China, Burma, and India malaria control detachments in bringing malaria under control will never be determined. That mosquito control was brought to an extremely high level of effectiveness during 1945 cannot be denied. Irrespective of relative effects of these factors, there remains one other factor that undoubtedly had a major influence on sick rates during the last 9 months of 1945. Except for traffic operations along the Stilwell Road and air support of British forces in central Burma, most of the U.S. troops, soon after the capture of Lashio in March 1945, quickly returned to a tranquil and orderly garrison life in well-policed and relatively mosquito-free areas.

After an exchange of correspondence late in 1945 between theater headquarters and the new Intermediate Section, the Atabrine suppressive treatment program was considerably modified. The main change was to put suppressive treatment on an optional basis in the large well-controlled troop concentration areas. This was because of the excellent state of mosquito control in these areas and because of the growing concern over the rising incidence of atypical lichen planus. The change was agreeable to all and appeared to be working reasonably well up to 4 December except for a mild increase of recurrent malaria in troops en route to ports of embarkation. Attempts to determine the total incidence of suppressed malaria in the troops living in the advanced sections were not particularly successful.

On the debit side of the ledger must be recorded the occasional toxic reaction to Atabrine. Of the various conditions held to be due to Atabrine intolerance, the syndrome known as atypical lichen planus was the most important. The transient gastrointestinal upsets sometimes seen in the first week or two of suppressive treatment caused no serious concern. Likewise, Atabrine psychosis was of relatively little importance. Precise data on the occurrence of atypical lichen planus in the India-Burma theater are not available. It is believed that the total number of cases was about 260.

In August 1944, a malaria commission for instituting research in malaria was established. It was to deal chiefly with the chemical problems connected with Atabrine therapy. Unfortunately through lack of cooperation, the commission was broken up on arrival. Early in January 1945, it was established at the 20th General Hospital in Ledo, Assam. One of the chief aims was to develop a simple urinary chemical test that would indicate the concentration of plasma Atabrine by using a technique developed by the British and described in Interim Report No. 27 of the Malaria Research Unit, November 1944. A paper describing this research was forwarded to The Surgeon General on 16 August 1945. This work was well received and proved to be of value to commanding officers in enforcing the Atabrine program.

Field Research

Various malaria control detachments carried out field research on the methods of applying DDT residual spray. Considerable time was spent trying to develop more effective and efficient sprayers for this work. In most cases, this involved modifying existing equipment.

In connection with the DDT air spray, much field study was done, primarily to obtain information regarding distribution of material, droplet size, and results of various meteorologic conditions upon both the spray and the effects of the spray. Other experiments in conjunction with this work were made to try to determine the effectiveness, penetration, exposure, and time before maximum kill.

The various survey detachments, whenever they were able, did considerable research work concerning the biology of the various anopheline mosquitoes within their areas. With the finding of infected *A. leucosphyrus* within the area, a great deal of time was spent in trying to determine the importance of this species as a vector.

Other Activities of Malaria Control Personnel

Early in the theater history there was a tendency to use malaria control organizations for duties other than their primary mission. This was stopped by a letter to the commanding generals of all major commands in August 1944. From that time on, malaria control organizations officially devoted all of their time to their immediate mission.

At times, their advice or cooperation was secured in other problems as, for example, fly control. Some of their equipment and supplies were expended for this purpose; personnel, however, were not diverted for this use. For a certain time, personnel were withdrawn for entomological investigations of a reported epidemic of sandfly fever at Gayā, Bihar Province, India.[21] This was because malaria control personnel were the only qualified individuals to conduct such an investigation. In a number of instances, also, malaria control personnel gave advice or checked on water supply installations. They also handled the supplies for the prevention of scrub typhus. As the supplies were the same as those used for malaria control, it seemed advisable that their distribution be centralized. This worked efficiently. In making routine surveys, other features of sanitation were often checked. In these cases information was usually passed orally to the organization involved or to the sanitary inspector for the section in which the violations occurred. In addition, personnel in these organizations with special qualifications were consulted, when it was thought their advise would be helpful, concerning other problems within the theater.

SUMMARY

Most of the areas in China, Burma, and India occupied by the U.S. Army were malarious; the intensities of infection varied from slight endemicity to hyperendemicity on a scale as high as any in the world. Living conditions were often primitive, and local populations were largely uneducated, so that, except in limited areas, little or nothing had been done to prevent the disease. Efficient malaria control, therefore, had to be established by the Army in order to maintain its effectiveness.

Malaria control activities were undertaken throughout the occupied sections. Practically all known means of control were utilized, the actual type

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[21] Letter, Capt. John W. H. Rehn, SnC, 9th Malaria Survey Detachment, to Commanding General, Headquarters, U.S. Forces, India-Burma Theater, 4 Sept. 1945, subject: Sandfly Investigation in the Gayā Area.

and scope depending upon the immediate needs of the area and the supplies available. These included standard and modified antilarval and antiadult mosquito control methods, supported by personal preventive measures and, in certain areas, by suppressive medication.

Because of the great variety of conditions encountered, a highly centralized malaria control organization was not practicable. Organization eventually developed along distinctly sectionalized lines, with ample authority being delegated to sectional malaria control groups for dealing with local situations by the best available means.

CHAPTER VIII

New Hebrides, Solomon Islands, Saint Matthias Group, and Ryukyu Islands

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A review of the experiences with malaria control of the USAFISPA (U.S. Army Forces in the South Pacific Area) may logically be divided into two parts: The first, dealing with the problem of malaria and other insect-borne diseases on those South Sea Islands which lay within the jurisdiction of the wartime command known as the South Pacific Area; the second, dealing with similar problems on Okinawa and other islands which were the responsibility of the Ryukyu Islands Command.[1]

The military campaigns in both these areas were a series of amphibious operations which called for the closest cooperation between land, sea, and air forces. The antimalaria organization in both areas was also a joint Army, Navy, and Allied operation under centralized control. This report is concerned primarily with the malaria control activities of Army personnel, but it is emphasized that much of the success of the organization was due to its joint service nature which was the concept of the first theater malaria and epidemic disease control officer in the South Pacific, Comdr. (later Capt.) James J. Sapero, MC, USN,[2] and of his successor, Comd. F. A. Butler, MC, USN.[3]

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[1] Unless otherwise indicated, Part I of this chapter is based on the material from a series of papers published in a supplement to the *American Journal of Tropical Medicine*, May 1947, on "Malaria and Other Insect-Borne Diseases in the South Pacific Campaign, 1942–1945." Appreciation is expressed to the editor and publisher of this journal for permission to utilize this material.

Appreciation is also expressed to Brig. Gen. Earl Maxwell, U.S. Army, Surgeon, U.S. Army Forces in South Pacific Areas, and subsequently Surgeon, Ryukyu Islands Command; to Capt. Arthur H. Dearing, MC, USN, Force Medical Officer, South Pacific Area; to his successor, Capt. Frederick R. Hook, USN; and to Brig. J. W. Twhigg, Director of Medical Services, New Zealand Expeditionary Forces, Pacific. These officers gave their constant support to the Malaria and Epidemic Control Organization and its work as described in this chapter.

[2] (1) Sapero, J. J., and Butler, F. A.: Highlights on Epidemic Diseases Occurring in Military Forces in the Early Phases of the War in the South Pacific. J.A.M.A. 127: 502–506, March 1945. (2) Sapero, J. J.: The Malaria Problem Today; Influence of Wartime Experience and Research. J.A.M.A. 132: 623–627, November 1946. (3) Sapero, J. J.: Tropical Diseases in Veterans of World War II. New England J. Med. 235: 843–846, December 1946. (4) Sapero, J. J.: Tropical Diseases as a Cause of Manpower Loss in Military Operations. Mil. Surgeon 106: 111–114, February 1950. (5) Sapero, J. J.: Prevention of Malaria Infections by Drug Prophylaxis. *In* Malariology, edited by Mark F. Boyd. Vol. II, pp. 1114–1132. Philadelphia: W. B. Saunders Co., 1949.

[3] (1) Butler, F. A.: Malaria Control Program on a South Pacific Base. U.S. Nav. M. Bull. 41: 1603–1612, November 1943. (2) Butler, F. A., and Sapero, J. J.: Postwar Tropical Disease Problems in the United States. South. Med. J. 38: 459–465, July 1945. (3) Butler, F. A., and Sapero, J. J.: Pacific Vivax Malaria in the American Negro. Am. J. Trop. Med. 27: 111–115, March 1947.

Subsequently, Captain Sapero occupied a similar position on the staff of Commander in Chief, Pacific, during the campaign for the Ryukyu Islands.

The reason for having one group of authors report about malaria control in such widely separated places is that members of this group, together with their Navy colleagues, participated in the planning and execution of insect control programs in both areas, first in the South Pacific and later on in the Ryukyu Islands, which was the scene of the last severe land fighting of the war.

Part I. New Hebrides, Solomon Islands, and Saint Matthias Group

GENERAL CONSIDERATIONS

Malaria problem, 1942–45.—Malaria was the single most serious health hazard to Allied troops in the South Pacific Area during World War II; it caused more than five times as many casualties as did combat. It is estimated that more than 100,000 individuals among Allied military personnel contracted malaria in the South Pacific, most of whom had several attacks. At least, on Guadalcanal, Solomon Islands, this disease threatened the success of the military campaign.

The first outbreak of malaria occurred on the small island of Efate in the New Hebrides, where it reached epidemic proportions with a rate of nearly 2,700 cases per 1,000 troops per annum in April 1942. The most serious epidemic of this disease began on Guadalcanal within 3 months of the initial landings. Lesser outbreaks occurred on Espíritu Santo, Tulagi-Florida Islands, the Russell Islands, and Munda, New Georgia. No serious outbreaks occurred on Treasury, Bougainville, Green, or Emirau Islands, which were the last four bases to be occupied and which were the scene of intense antimalaria measures from the time of the initial landings.

In the early days of the South Pacific campaign, it was considered good medical practice to give therapeutic doses of Atabrine (quinacrine hydrochloride) or quinine to heavily seeded troops after removal from malarious areas and then to stop suppressive medication and treat the remaining malaria as it occurred. This process was called demalarialization and was based on the thesis that if troops were first treated with therapeutic doses and then allowed to have their malaria relapses they would develop an immunity and so overcome the disease. This regimen was undertaken by the 2d Marine Division, the Americal Division, the 147th Infantry, and other troops who had been on Guadalcanal during the malaria epidemic. It resulted in an enormous amount of malaria before it was abandoned in favor of continuous suppressive therapy for heavily seeded troops. The rehabilitation period of units who were subject to this procedure was approximately double the time estimated for this purpose and meant a serious decrease in the number of available combat troops.

Malaria was serious enough for the Allies, but it was far worse for the Japanese; the few prisoners taken were almost invariably malarious. For example, 9,000 Japanese died of disease—malaria, malnutrition, beriberi, and dysentery—on Guadalcanal;[4] this was nearly one-half of all their dead on this island.

Other insect-borne diseases which occupied the attention of the antimalaria organization were dengue fever, filariasis, and tsutsugamushi disease. The importance of dengue tended to be obscured by the deluge of malaria; actually, dengue could and did cripple a military force for short periods more rapidly and more effectively than did malaria. Filariasis also led to the medical evacuation of many thousands of troops. Rodent control was undertaken to prevent the spread of epidemic diseases which were harbored by rats or their ectoparasites as well as to prevent the economic loss by large rat populations. The control of all these arthropodborne diseases became the responsibility of the South Pacific Malaria and Insect Control Organization.

Antimalaria organization.—The South Pacific Malaria and Insect Control Organization[5] was developed to meet the peculiar needs of a mixed Army-Navy-Marine-New Zealand combat force engaged in a series of amphibious operations on 11 malarious islands scattered over many thousands of square miles of ocean (maps 23 and 24). This organization had several unusual features which were important to its success and which are briefly noted, as follows:

1. The mixed service character greatly facilitated the best utilization of scarce technical personnel and aided the supply problem by making it easier to draw available supplies from all services and to distribute them as needed.

2. The chain of command was unusual for a medical organization in that the senior malariologist (Navy) was on the staff of ComSoPac (Commander, South Pacific) and in that on each base the reports and recommendations of the senior base malariologist were submitted directly to the island commanders with copies to subordinate service commands.

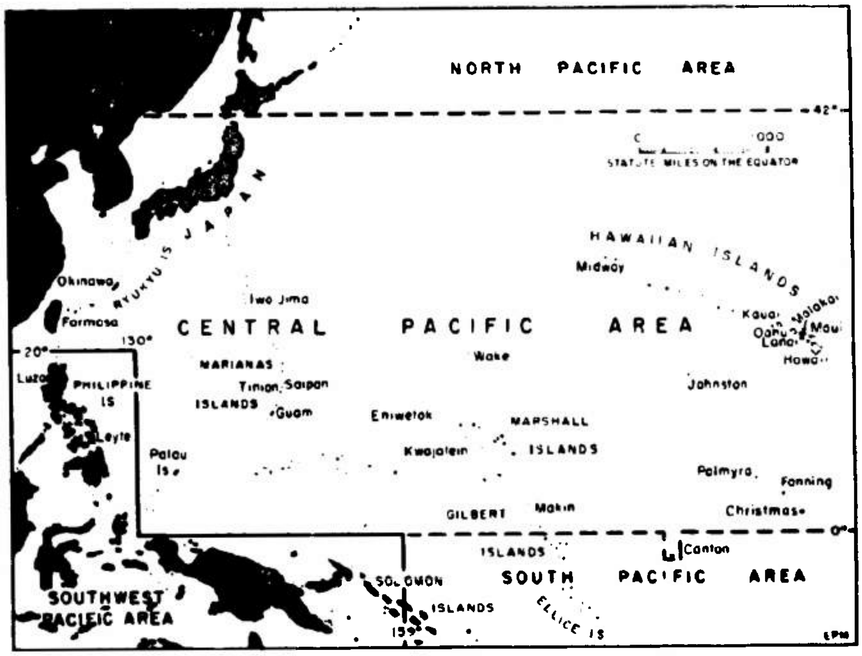
3. Malaria control headquarters were established at the theater level and on each large base, although there was no table of organization and equipment for such groups. The theater malariologist and his staff were responsible for recommending assignment of scarce personnel and for establishing uniform policies regarding control measures and supplies.

4. The last unusual feature was the amount of autonomy and initiative allowed to the local malaria control groups on each island base.

Malaria control activities.—From the very beginning of planned malaria control in the South Pacific Area, the approach was primarily one of control of the mosquitoes responsible for transmission, with suppressive medication

[4] Miller, John: Guadalcanal: The First Offensive. United States Army in World War II. The War in the Pacific. Washington: U.S. Government Printing Office, 1949.

[5] This organization was first known as "South Pacific Malaria Control," and later as "South Pacific Malaria and Epidemic Control."

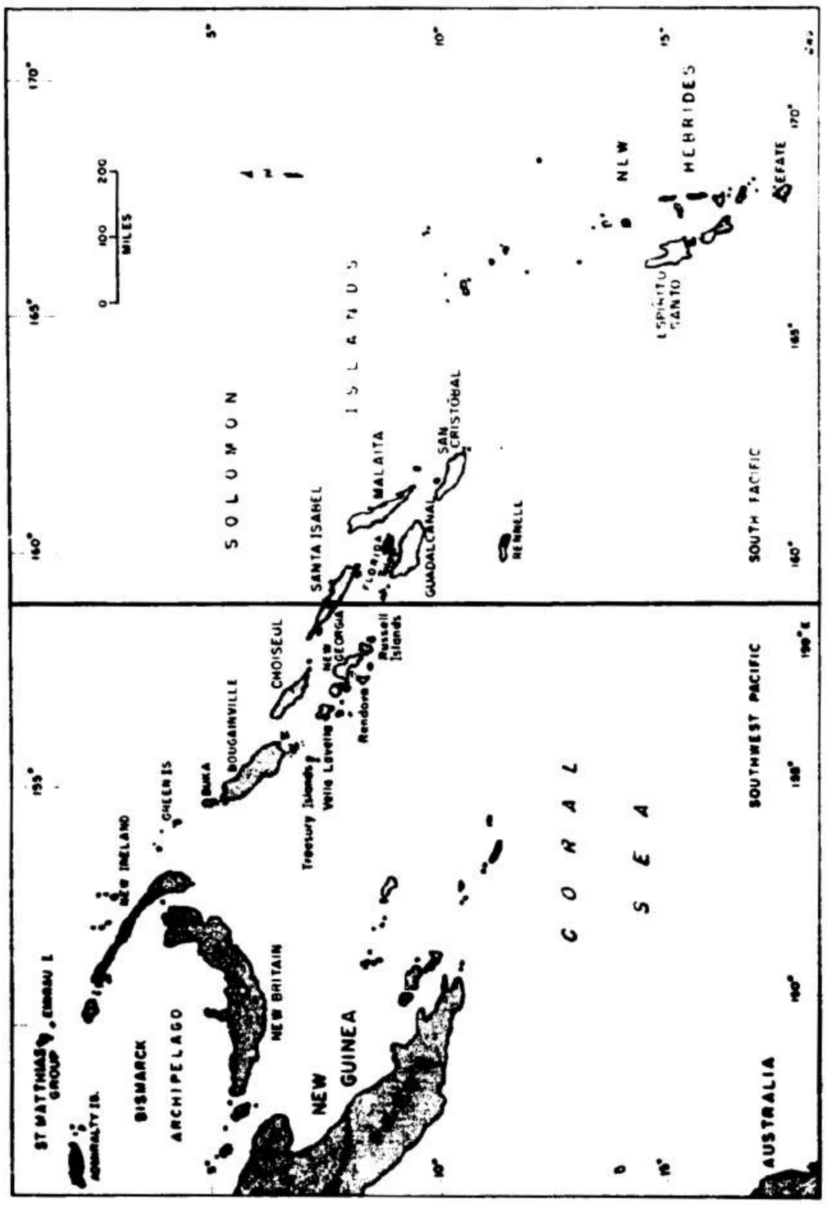


MAP 23.—Pacific Ocean Area.

as a secondary insurance factor. The exact sequence in which measures directed against mosquitoes could be applied depended upon such factors as supplies, manpower, and authority to undertake the work; once these problems were solved, the mosquito was attacked with all these weapons in combined offensive.

The basic control measure, and that usually first initiated, was larval control by larvicides. Until mid-1944, the chief larvicide was diesel oil, applied by knapsack-type sprayers and vehicle-mounted power sprayers. After the advent of DDT, which became generally available about July 1944, airplane spraying was utilized effectively for elimination of larval populations. Coupled with the larvicidal program was a systematic program of reduction of water surfaces through drainage, road-rut elimination, stream cleaning, and installation of flumes to permit fluctuation of water level in lagoons along the beaches. Through these two general methods, the control of anopheline breeding became highly effective.

The control of adult populations of *Anopheles* was at first limited to spraying with petroleum base insecticides by hand-operated "flit guns," by the use of Aerosol bombs, and by barriers, such as bed nets and screens. Head nets were never widely used, nor were repellents, and the degree of



MAP 24.—Malarious islands of the South Pacific Area.

malaria control attained by these means is considered negligible. During the latter half of the war in the South Pacific, DDT was widely used as a residual spray in living quarters, messhalls, latrines, and native quarters.

The systematic indoctrination of troops in the principles and practices of malaria control was, in the final analysis, probably as important an undertaking as any phase of malaria control. This training not only made possible a great extension of mosquito control activities but also paid dividends in the observance of personal protective measures, which at first were completely ignored. The success of the malaria control activities resulted from the multiple-faceted approach to the problem by many individuals.

MILITARY DEVELOPMENT

Mission

The Allied Armed Forces in the Pacific area were ordered on 2 July 1942 by the U.S. Joint Chiefs of Staff[6] to mount a limited offensive to stop the southward advance of the Japanese toward the sealanes between the United States, New Zealand, and Australia. The immediate objective was to obtain control of the Guadalcanal-Tulagi area where the Japanese were beginning the construction of an airfield (Guadalcanal) and had established a seaplane base (Tulagi). The ultimate objective of Allied war effort in this area for the next 2 years was to be the capture or neutralization of Rabaul as a Japanese stronghold.

It is to be recalled that the Allies had agreed to make their first major effort in Europe against Germany; meanwhile, the operation against Japan had to take a secondary place and was limited by the ships, troops, and supplies which could be spared. Furthermore, the initial surprise achieved by the Japanese gave them an extraordinary advantage which in less than 12 months of war enabled them to overrun and control a huge area of land and ocean. This area, with Japan as the hub, swung in a great southwestward arc from the western Aleutians through Guadalcanal to the southern tip of New Guinea and thence through the East Indies to the mainland of Asia. The Allies and particularly the United States were unready in many ways for this onslaught. Our lack of preparedness to handle the malaria problem and our failure even to realize how important malaria would become were symptomatic of the more general unreadiness.

The division of responsibility for operations in the Pacific is shown in map 22. The South Pacific Area was commanded first by Vice Adm. Robert L. Ghormley and, subsequently, by Adm. William F. Halsey, Jr.; they were responsible to Adm. Chester W. Nimitz, the Commander of the Pacific Ocean Areas. The Southwest Pacific Area was under the command of Gen. Douglas MacArthur.

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[6] See footnote 3, p. 401.

The South Pacific Area and Force was eventually given responsibility for land operations throughout the Solomon Islands and the Saint Matthias Group. Its area of authority was extended by successive orders and attained its maximum extent as shown in map 24.

Chronological Table of Operations

Early in the War, Allied naval, land, and air forces were gathered as rapidly as possible in the major nonmalarious bases—Samoa Islands, New Zealand, Fiji Islands, and New Caledonia. Theater headquarters were first established in New Zealand and later were moved to New Caledonia. Subsequent land operations were on malarious islands in the New Hebrides, Solomon Islands, and Saint Matthias groups. The chronological table for occupation of malarious bases was as follows:

- Unopposed landings in New Hebrides:
  - Efate—advance group landed, 18 march 1942.
  - Espíritu Santo—4 May 1942.
- Assault landings in Solomon Islands and Saint Matthias Group:
  - Guadalcanal—7 August 1942. Island secured, 9 February 1943.
  - Tulagi and adjacent island—7 August 1942. Secured, 9 August 1942.
  - Russell Islands—21 February 1943 (no land opposition).
  - New Georgia (Rendova landings)—30 June 1943. Secured, 26 August 1943.
  - Vella Lavella—15 August 1943. Secured, 9 October 1943.
  - Treasury Islands—7 October 1943. Secured, 10 October 1943.
  - Bougainville (Empress Augusta Bay area)—1 November 1943. Perimeter defense until V–J Day.
  - Green Island—15 February 1944. Secured, 20 February 1944.
  - Emirau Island, Saint Matthias Group—20 March 1944. No land opposition.

"Secured" was the official term to denote the end of effective enemy opposition. The length of time between the initial attack and the date when each island was declared secured approximates the period during which malaria control activities were carried out under combat conditions.

Rear Area and Air Force Installations

The rear area installations of greatest importance were on New Caledonia, which was the headquarters of the South Pacific Area Command. This island was 1,000 miles south of Guadalcanal. During the early part of the campaign, it was an important transshipping and supply base. But, after Guadalcanal was secured, many supply activities were gradually moved to that island which became the staging area for successive attacks on Japanese-held islands to the northwest.

There were excellent harbors at Nouméa in New Caledonia, at Havannah Harbour in Efate, and at Segond Channel in Espíritu Santo. Major naval supply and repair depots were developed at Nouméa and at Espíritu Santo, and an advance naval base was established at Tulagi in the Florida group. All these were malarious areas except New Caledonia, and even there mosquito control activities were required to prevent dengue fever which caused sharp epidemics before it was brought under control.

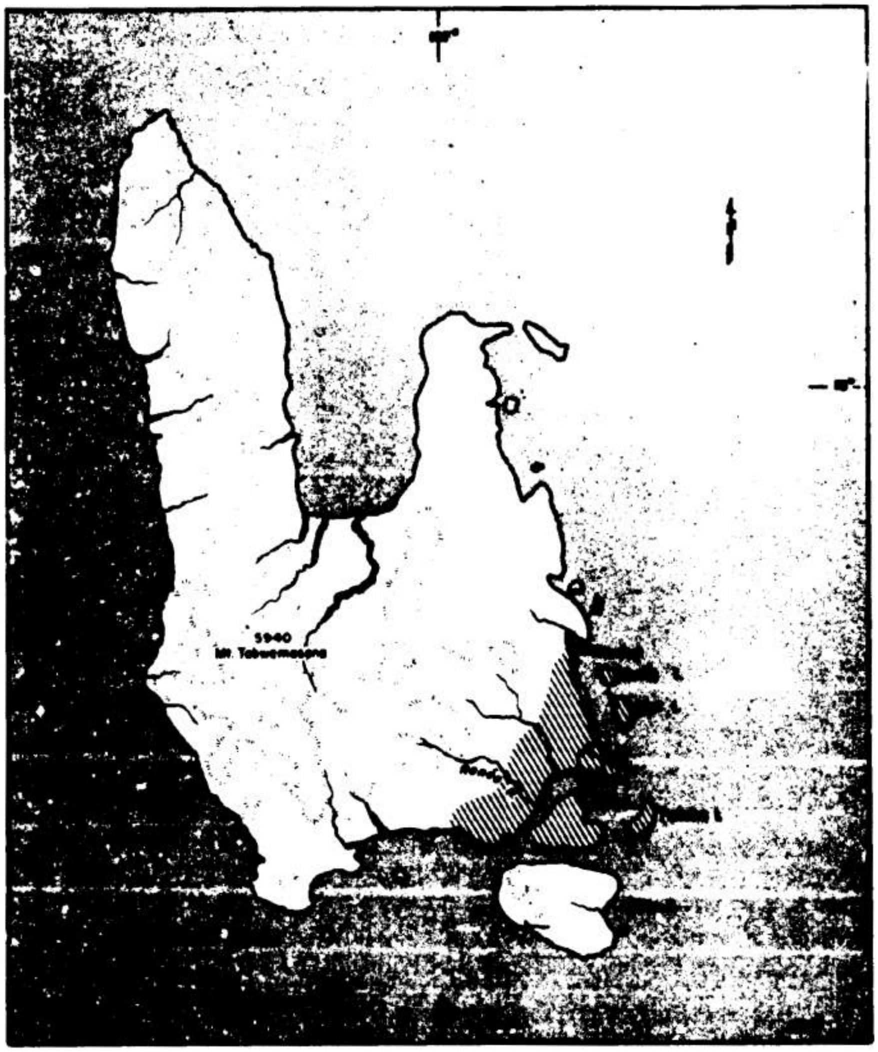
AREA CHARACTERISTICS AS THEY PERTAIN TO MALARIA AND ITS CONTROL

Physiography

Extent and area.—The malarious areas here discussed comprised 11 bases in the South Pacific Area. Although the total occupied area on these bases consisted of only approximately 350 square miles of territory, they were scattered over vast reaches of the Pacific Ocean (map 24). These islands, from Efate, in the New Hebrides to Emirau in the Saint Matthias Group, extend in a long chain from 17°30′ south longitude and 168°30′ east longitude to 1°8′ south longitude and 150° east longitude. The total distance from Efate to Emirau is approximately 1,550 nautical miles. The total area of the New Hebrides is 5,700 square miles; that of the Solomon Islands is 18,000 square miles. Espíritu Santo, the largest island in the New Hebrides, is 76 miles long and 40 miles wide. Efate, at the southernmost tip of the New Hebrides, is 26 miles long and 14 miles wide. Bougainville, largest of the Solomon Islands, is 120 miles long and averages 40 miles in width; while Guadalcanal, the second largest of the Solomons, is 90 miles long and has an average width of approximately 30 miles.

The military occupied area of Efate and Espíritu Santo included approximately 40 square miles on each base. On Guadalcanal, approximately 110 square miles of territory on the northwest coast were occupied, although combat operations had extended well beyond the area of occupation. On Bougainville, the area originally occupied totaled about 30 square miles but was later expanded to 50 square miles. Approximately 30 square miles were occupied on Empirau. The military occupation of other South Pacific bases involved relatively small areas, usually less than 20 square miles each.

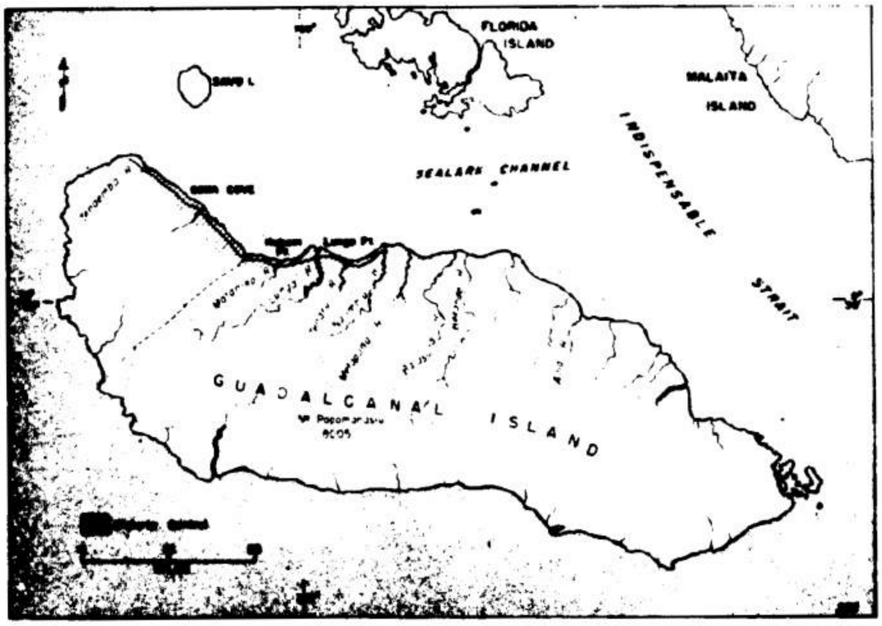
Types of terrain and watered areas.—With the exception of Emirau, Green, and Treasury Islands, which are coral, all the malarious bases occupied during the South Pacific campaign are of volcanic origin and are mountainous. On Bougainville, Mount Balbi reaches to 10,171 feet; on Guadalcanal, Mount Popomanasiu reaches 8,005 feet; and on Espíritu Santo, Mount Tabwemasana reaches 5,940 feet. Occupied portions of the bases were usually limited to relatively narrow coastal strips, which consisted, for the most part, of coral uplifts or alluvial plains. In the occupied portions of some of the bases, the hills extended nearly to the sea; on others, such as Guadalcanal, the major portion



MAP 25.—Espíritu Santo, New Hebrides.

of the occupied area was on an alluvial plain from 1 to 10 miles in width. There are no large rivers and only a few permanent streams on the smaller islands, but the three largest bases represented different and varying types of terrain and deserve more detailed discussion.

The occupied area on Espíritu Santo (map 25) consisted of a long, narrow coastal strip on the southeastern portion of the island, extending from Turtle



Map 26.—Guadalcanal, Solomon Islands.

Bay on the north to the Renée River on the south. This area is underlaid with coral, and the hills extend nearly to the sea. There are numerous large streams, some of which emerge near the coast from huge coral craters. The longer streams, arising in the mountains, are swift flowing and subject to considerable variation during times of heavy rainfall. The short streams, emerging from the coral craters, have a fairly uniform flow but are subject to considerable tidal influence, their level often fluctuating as much as 3 feet each day for a mile or more inland and sometimes to the crater source. A considerable part of the occupied area of Espíritu Santo consisted of coconut, coffee, and cacoa groves.

The occupied area on Guadalcanal (map 26) extended from the Balasuna River, near the north central portion of the island, to beyond Doma Cove toward the northwestern tip and included about 45 miles of coastline. The broad alluvial plain on the north central coast of Guadalcanal becomes progressively narrower from a width of about 10 miles between the Balasuna and Metapona Rivers to less than a mile at the Lunga River, the largest of the rivers in this area. West of the Lunga, the plain narrows rapidly and beyond Kukum Point consists largely of a narrow fringing strip. The broad portion of the plain is transected at intervals of about 3 miles by major drainage courses arising in the mountains to the south. Between these rivers (Balasuna, Metapona, Nalimbiu, Tenaru, and Lunga) are numerous sluggish meandering streams.

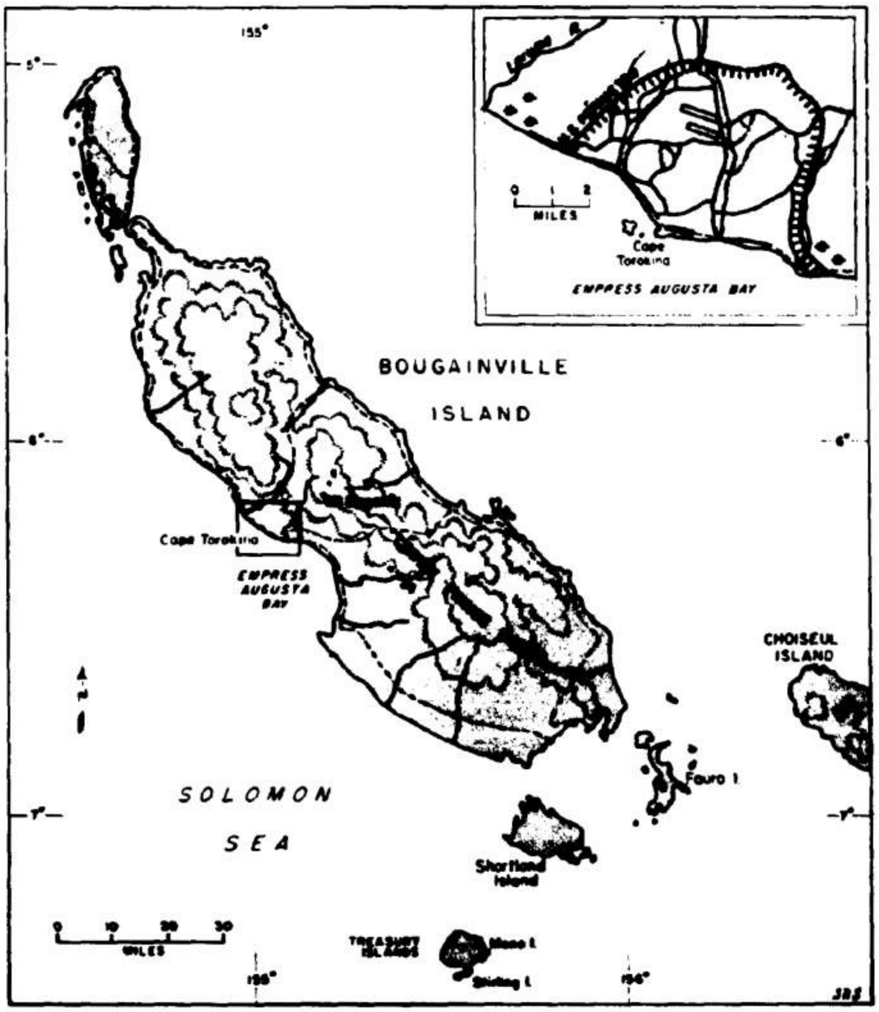
The beaches east of the Mataniko River, the first river west of the Lunga, are of dark volcanic sand and slope rather gently to the ocean floor. West of the Mataniko River, the beaches are of relatively coarse gravel and are more precipitous. The soil of the alluvial plain is a fine, black silt, underlaid by a yellow clay subsoil. The topsoil, when undisturbed, is capable of absorbing and holding an enormous amount of water but once packed by vehicular traffic becomes highly impervious. All the small streams between the Balusuna and the Lunga, and many of those to the westward, were periodically blocked at the mouth by sandbars built up by surf action. The coastal lagoons and swamps thus formed often remained blocked for long periods of time, permitting the development of aquatic vegetation and making ideal breeding places for *Anopheles farauti*. West of the Mataniko River, streams are generally smaller than in the north central part of the island but are less likely to become blocked by sandbars at the coast because of the more precipitous beach and the oblique ocean currents striking the coast in this area. Many of the small drainage courses west of the Mataniko are dry during a part of each year.

The occupied portion of Bougainville (map 27), near Empress Augusta Bay on the southwest coast, is a recently uplifted area. The soil is volcanic sand for some miles inland, and the terrain consists of a series of sandy terraces, representing old beach lines. The eastern portion of the area contains some steep foothills. The sand terraces are transected by a few rivers and small streams, some of which were clogged by the accumulated debris of centuries with the result that each terrace contained a series of fresh-water swamps. A high water table, which quickly filled foxholes and shell and bomb craters, characterized much of the area before cleaning of drainage courses, but subsoil drainage was generally good. As on Guadalcanal, streams were often blocked at the mouth by sandbars to form coastal lagoons.

Prevailing vegetation covers.—The occupied malarious bases of the South Pacific lie within the true tropic belt, and the vegetation of these islands is accordingly influenced greatly by the climate of the tropics. For purposes of discussion, it is convenient to distinguish between the low coral formations, such as Emirau, Green, and Treasury Islands, and the larger volcanic islands that constituted the remaining bases.

Because of the very porous condition of the soil, the coral islands are without tropical rain forests and have relatively little dense growth that approximates true jungle. The vegetation consists primarily of cocoanut palms, low-growing brush, grass, and weeds. More luxuriant, junglelike growth occurs in the marshy areas of the islands. Vegetative cover was not an important factor in malaria control operations on these islands.

The larger volcanic islands of the South Pacific are typically covered with heavy rain forests except along the coast where narrow strand formations occur. The coastal areas, and sometimes the inland areas as well, are often occupied by extensive plantings of cocoanut palm, coffee, and cacao. There



MAP 27.—Bougainville Island.

are occasional rubber plantations and other cultivated tropical plants. Since plantation areas are usually level and open, they were widely used for bivouac areas and supply dumps. As such, they became an important part of the malaria control problem.

The coastal strand formation consists of two general types. Around the tidal mudflats at the mouths of the numerous permanent streams, mangrove swamps are common. These mangrove swamps were of little importance except in the innermost portions where tidal action was minimal and relatively fresh water permitted the growth of aquatic vegetation. On the beaches, between streams, the strand formation consists of coconut palms intermixed with scattered large forest trees growing to a height of 60 feet or more. Occasionally, there are huge banyan trees. In most places, a dense undergrowth extends to within a few feet of the high tide line, and, except on the more barren shores, the undergrowth within the strand formation is almost impenetrable. The secondary plants making up the strand formation contain such forms as *Hibiscus*, *Pandanus*, and a herbaceous ground cover of tangled vines, grasses, sedges, and other low plants. The entire formation is narrow, often no more than a few yards in width.

Wherever they occurred and had been maintained, plantations were relatively open at ground level. Before military occupation on most bases, and throughout the occupation on some, cattle were widely grazed in coconut groves. Grazing together with periodic removal of secondary undergrowth maintained such groves as open, parklike areas offering easy passage for traffic of all kinds. Coconut groves that were not grazed or otherwise maintained quickly developed into a thick tangle of young coconut palms, brush, and tall grass. Coffee and cacao plantations, being heavily shaded by towering jungle trees, had somewhat sparse ground cover. The orderly arrangement of the plantings and their excellent camouflage qualities made them ideal for supply dumps. When used for that purpose, however, roads were but rarely constructed until after long use. This resulted in mile after mile of water-filled ruts caused by the movement of heavy vehicles between the rows of trees. Plantations in general, and coconut plantations in particular, became one of the big problems from a malaria control standpoint.

The true rain forest formation consists of a towering canopy of trees reaching to 150 feet in height, with successively lower layers of trees which supply a very dense shade at ground level. Various climbing plants, some of which extend to the uppermost canopy, form an undergrowth that is difficult to penetrate except along established trails. Off the trails in the jungle, where it is necessary to hack a way through the undergrowth with machetes, a half-mile per hour is considered a rapid march speed. Even along trails, rapid movement is impossible because of the slippery footing, obstructing roots, and the long, whiplike extensions of the rattan palm that hang across the trails and grasp at clothing or flesh with sharp, stout, recurved spines. Because of high humidity, lack of aeration, and difficulty of clearing these areas, the true rain forest was little used for bivouac purposes and only to a limited extent was it necessary to extend malaria control activities into this type of growth.

The plant formations of Guadalcanal,[7] and to a limited extent those of Tulagi, differ considerably from those encountered on others of the major

[7] Pendleton, R. C.: The Rain Shadow on the Plant Formations of Guadalcanal. Ecological Monographs 19: 75–93, 1949.

South Pacific islands. Guadalcanal lies athwart the prevailing trade winds in the area, and the high mountains in the central part of the island, forcing the air upward, cause heavy rainfall on the south side of the island and diminished rainfall on the northwest coast. Within this area of rain shadow effect, which extends to Tulagi, there is a greater seasonal variation in rainfall than is characteristic of parts of the island not influenced by high elevations in the path of the trade winds, and a total rainfall somewhat less than is required to support tropical rain forests. This results in the absence, from the northwest coast of Guadalcanal, of true rain forest formations and accounts for the extensive grasslands of the coastal plain and lower hills. Because these extended grasslands and associated vegetative features had a profound influence on the malaria control problem on Guadalcanal, they are discussed in some detail.

On the eastern part of Guadalcanal, where seasonal variation and total rainfall is not influenced by high elevations in the path of prevailing winds, there is dense rain forest. From the Berande River, some 4 miles east of the limits of the occupied area, to the northwestern tip of the island, the vegetation of the north coast is influenced by the rain shadow caused by mountains. This portion of the island is characterized by extensive grasslands, while the high central part of the island and the south side are covered by rain forests. The northwest coastal area is transected by numerous rivers and smaller streams, and along most of these there is a strip of forest connecting the forests of the hills with the narrow coastal-strand formation.

Although these forest strips along stream courses are narrow, being in some places only a few hundred feet in width, they consist of much the same type of vegetation as is encountered in typical rain forests. These jungle strips rise abruptly from the grasslands to a height of 100 feet or more, often with scattered taller trees reaching many feet higher. The height and uniformity of the vegetation increases with the width of the jungle zone bordering the stream, and forest belts along the larger permanent streams present a relatively uniform canopy. The vegetation bordering temporary streams usually consists of a narrow belt of trees of various heights, so that from a distance the canopy presents a ragged appearance. Because these forest belts admit a considerable amount of sunlight, the undergrowth is frequently more dense than that of true rain forest, particularly at the forest edge. From the standpoint of mosquito control operations, these jungle strips were comparable to true rain forest. On Guadalcanal, they were widely used for bivouac and supply areas when cocoanut palm groves were not available.

The extensive grasslands are the dominant vegetative feature of the northwest coast of Guadalcanal. Between the Berande and Lunga Rivers, they occupy the major portion of the flat coastal plain and extend inland for several miles, well into the foothills. West of the Lunga, where the coastal plain becomes progressively narrower toward Cape Esperance, the grasslands are largely on the rugged foothills. The dominant grass in these areas grows to a height of 4 to 6 feet, forming a tangled mass of vegetation that is often more difficult to penetrate on foot than is the jungle. On the flat alluvial plain between the Balasuna and Lunga Rivers, these open grasslands offered an inviting area to drivers of vehicles, either on legitimate business or aimless exploring. Soon the entire area was crisscrossed with innumerable trails, most of which became badly rutted and held water either periodically or constantly. Once a trail became impassable because of rutting, a new trail parallel to the old one would be started, adding to the miles of ruts. The elimination of these road ruts, and the closure of the grasslands to indiscriminate driving, became a major malaria control problem on Guadalcanal.

Climatic Features

In general, it may be said that the climatic features of the South Pacific islands favor malaria. The absence of the vector of malaria, and hence the absence of the disease from many of the smaller islands in the malarious zone, appears to be correlated with physiographic rather than climatic features. Although rainfall is abundant throughout the area and the temperatures are high and fairly uniform, many of the smaller coral islands have no permanent fresh water suitable for anopheline breeding.

Rainfall.—On all bases, the total yearly rainfall was high, usually exceeding 100 inches. This factor, coupled with a constantly high humidity, served to keep the soil well saturated during the greater part of the year. The terms "dry season" and "wet season" are relative; during most months of the year, there was sufficient rainfall to maintain numerous small surface pools of water. During the period from June to August, the intertropical front is north of the Equator and the prevailing winds are from the southeast. This is the so-called dry season. From December to February, when the intertropical front is south of the Equator, the prevailing winds are from the northeast. The periods from March to May and from September to November are characterized by unsettled weather when the doldrums and their intertropical fronts are moving across the Equator. Marked seasonal variation in rainfall, such as occurs on the northwest coast of Guadalcanal, may have been due to local topographic features. During the so-called wet season, heavy rains may be expected daily for as much as a week at a time. As much as 36 inches of rainfall in 1 month has been recorded for Bougainville (Kieta); the total rainfall for March 1944 on Espiritu Santo was 28 inches, of which 10.5 inches fell during one 24-hour period on 27 March.

The influence of rainfall on the problems of malaria control is difficult to evaluate, but it was undoubtedly the most important single factor in causing seasonal variations in the problems. Periods of heavy rainfall, causing flushing of drainage courses and opening of some lagoons, resulted in the temporary elimination of anopheline breeding from most streams. The great increase in surface water that resulted from heavy rains served to disperse current larval populations and gave the impression that there was some cessation of breeding. On most bases, peak anopheline populations usually occurred soon after the cessation of heavy rains. A number of factors apparently contributed to this situation. The stabilization of abundant water surfaces combined with increased sunlight and its resultant effect on the development of plant life to make conditions ideal for larval development. Larvicidal crews were frequently unable to obtain complete coverage for several days or weeks following heavy rains.

Temperature.—There is little variation in temperature at sea level in the Solomon Islands, and the daily temperature range is remarkably uniform throughout the year. The maximum daily temperature rarely exceeds 94° F., and the minimum is seldom below 67° F. The usual daily temperature variation was about 20° F. from a high of about 90° to a low of about 70° F. These temperatures, together with a high relative humidity of approximately 80 percent, provided almost optimal conditions for mosquito development. At no time were temperatures in the Solomon Islands bases so low as to be considered unfavorable to anopheline breeding.

Temperatures in the New Hebrides exhibited a greater range of daily variation, as well as less uniform daily change throughout the year. Temperatures as low as 53° F. were recorded at Segond Channel on Espíritu Santo, and as low as 58° F. on Efate. Maximum temperatures of 96° and 95° F., respectively, were recorded for these two bases. Because the periods of both low and high temperatures were relatively brief, it is doubtful if these extremes had any appreciable effect on mosquito development.

Local Population

New Hebrides.—The population of the New Hebrides in 1939 was given as 218 British, 687 French, 2,282 Asiatics (Tonkinese, Chinese, and Japanese), and about 40,000 native Melanesians. Of the Melanesians, about 4,000 lived on Espíritu Santo and 1,700 on Efate, mostly in small, independent villages scattered through the islands.

During the first part of the occupation of Efate and Espíritu Santo, the troops were bivouacked near labor camps of natives who were heavily seeded with malaria and in areas where anophelines were numerous. Later on, troop concentrations were kept away from local communities as much as possible, but this could not be done in outlying areas.

In the New Hebrides, yaws, hookworm infestation, malaria, dysentery, and tuberculosis are endemic. *Wuchereria bancrofti* is also present. The results of surveys by the malaria control organization follow.

Solomon Islands and Saint Matthias Group.—The natives of the main Solomon Islands and the Saint Matthias Group are Melanesians. In 1939, the population of the Solomons, including Bougainville, was given as 500 Caucasians, 140,000 Melanesians, and 200 Chinese. At the time of Allied occupation, most of the Caucasians had fled. The population of Guadalcanal was about 20,000 and that of Bougainville about 45,000. The natives lived rather primitively in small villages, family groups, or families.

When the fighting began in the Solomons, the local inhabitants left the combat areas. After the islands had been secured, they were usually prevented from reentering the troop area. Native labor camps, however, were at first often located in the troop area. Later, some were moved away. Local traders also visited the troop areas during the daytime to trade, but were not permitted to sleep there.

Solomon islanders are heavily infected with tuberculosis, yaws, and hookworms. In surveys of 2,500 Guadalcanal residents carried out by military malaria control personnel, 22 percent were found to have *W. bancrofti* microfilariae in their blood. Malaria is hyperendemic among the natives.

Incidence of malaria.—Data on the incidence of malaria in the New Hebrides, Solomon Islands, and Saint Matthias Group have been given by Levine and Harper.[8] In addition, the report of Sayers[9] on malaria in the New Georgia Group, Solomon Islands, became available during the war. Sayers, who had conducted a hospital at Munda and later at Vella Lavella, Solomon Islands, from 1927 to 1934, had treated 741 parasite-positive natives from a population of about 6,000. In these clinical cases, *Plasmodium falciparum* was present in 44 percent, *Plasmodium vivax* in 32 percent, *Plasmodium malariae* in 18 percent, and undetermined species in 6 percent. The splenomegaly rate among 365 children was 73 percent. Clinical malaria was not common in New Georgia natives over 30 years of age.

The malaria rates reported by the military malaria control personnel were based on single-smear surveys made on thick smears stained with Giemsa stain. They are not comparable with Sayers' figures, since his were based on clinical cases.

The prevalence of malaria observed in these surveys is given in table 59. The surveys on natives of Malaita and San Cristobal, Solomon Islands, and one of those on Guadalcanal were made on adult male laborers who were living in labor camps on Guadalcanal at the time of examination. The parasite rate was relatively low in these three surveys, ranging from 7 to 11 percent. Since the parasite rate among the Guadalcanal villagers was 52 percent and the rate among the Guadalcanal laborers was 10 percent, it is clear that the prevalence of *Plasmodium* in healthy, adult laborers cannot be taken as indicative of the rate among the people as a whole.

***Plasmodium* species distribution.**—The species of *Plasmodium* encountered in the surveys are given in table 60. *P. vivax* was the most common on all islands except Emirau, being found in 41 to 88 percent of the positive

[8] Levine, N. D., and Harper, P. A.: Malaria and Other Insect-Borne Diseases in the South Pacific Campaign, 1942–1945: IV. Parasitological Observations on Malaria in Natives and Troops, and on Filariasis in Natives. Am. J. Trop. Med. 27 (suppl.): 119–128, May 1947.

[9] Sayers, E. G.: Malaria in the South Pacific With Special Reference to the Solomon Islands. New Zealand Government Printing Office, 1943.

smears from these islands. The most common species on Emirau was *P. falciparum*, which was present in 45 percent of the smears. On the other islands, this species was found in 6 to 37 percent of the positive smears. *P. malariae* was not found on Efate, Treasury, Malaita, or San Cristobal Islands. However, surveys on the last two islands were made on adult laborers. *P. malariae* comprised 25 percent of the positive smears on Emirau and 20 percent of those on Savo. Its prevalence on the other islands ranged from 0.5 to 12 percent.

TABLE 59.—*Prevalence of malaria parasitemia on South Pacific islands*

Islands	Surveys	Examined	Parasitic index	
			Average	Range
	Number	*Number*	*Percent*	*Percent*
New Hebrides:				
Efate	12	4,000	10	5–50
Espíritu Santo	6	4,000	13	7–57
Solomons:				
Guadalcanal:				
Villagers	15	451	52	6–74
Laborers	1	106	10	......
Savo	4	427	26	11–39
Florida	1	37	65	......
Malaita (laborers)	6	286	11	4–19
Russells	3	193	64	57–73
Bougainville	1	500	10	......
San Cristobal (laborers)	1	57	7	......
Treasury	1	37	16	......
Bismarck Archipelago:				
Green [1]	2	350	45	43–48
Emirau	2	313	16	12–21

[1] Smears were made 1 month after evacuation to Guadalcanal.

Relation of age to prevalence of malaria and species of *Plasmodium*.—In surveys made on Guadalcanal, 91 percent of 44 children from birth to 5 years of age, 72 percent of 51 children from 6 to 15 years of age, and 38 percent of 96 persons over 15 years of age carried plasmodia in their blood. Similar decreases in prevalence with age were found on Savo, Green, and the Russell Islands. On Guadalcanal, the most common species in all age groups was *P. vivax*. In the youngest age group, *P. falciparum* was the least common species, but its prevalence was higher in the two older groups, while that of *P. malariae* decreased with age. The prevalence of *P. falciparum* also increased with age on the other islands but that of *P. malariae* was variable.

Splenomegaly rates.—Splenomegaly was observed in 61 percent of 110 residents on Efate, 57 percent of 101 on Espíritu Santo, 73 percent of 258 on Guadalcanal, 70 percent of 37 natives on Florida, 57 percent of 219 laborers

TABLE 60.—Plasmodium *species in South Pacific surveys*

Island	Surveys	Positive smears	Species: *P. vivax*	*P. falciparum*	*P. malariae*	Mixed	Undetermined
	Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
New Hebrides:							
Efate	5	205	67	25	------	4	4
Espiritu Santo	5	486	57	37	1	------	5
Solomons:							
Guadalcanal	14	200	60	18	12	6	4
Savo	3	103	56	13	20	11	------
Florida	1	24	80	12	8	------	------
Malaita	5	29	67	21	------	------	12
Russells	3	123	41	30	4	------	25
San Cristobal	1	16	88	6	------	------	6
Treasury	1	6	84	16	------	------	------
Bismarck Archipelago:							
Green [1]	1	132	46	14	1	8	31
Emirau	1	25	29	46	25	------	------

[1] Smears were made 1 month after evacuation to Guadalcanal.

from Malaita, 66 percent of 193 residents on the Russells, 75 percent of 500 natives on Bougainville, 57 percent of 219 laborers from San Cristobal Island, 34 percent of 37 villagers on Treasury, 65 percent of 542 natives from Green, and 85 percent of 263 on Emirau.

Mosquito Vectors of Malaria

Six species of *Anopheles* are known to occur in the islands of the South Pacific Area. These species and their recorded distribution are as follows:

	Area
Anopheles farauti Laveran 1902	All malarious bases.
Anopheles koliensis Owen 1945	Guadalcanal, north coast.
Anopheles lungae Belkin and Schlosser 1944	Guadalcanal, north and northwest coast; Empress Augusta Bay, Bougainville; Munda, New Georgia.
Anopheles nataliae Belkin 1945	Guadalcanal, north coast.
Anopheles punctulatus Dönitz 1901	Guadalcanal, north and southwest coasts; Empress Augusta Bay, Bougainville.
Anopheles solomonis Belkin, Knight, and Rozeboom 1945	Guadalcanal, northwest coast; Munda, New Georgia.

Characteristics of malaria vectors

In the South Pacific Area, the principal vector of human malaria, and probably the only one of military importance, was *A. farauti* Laveran (fig.

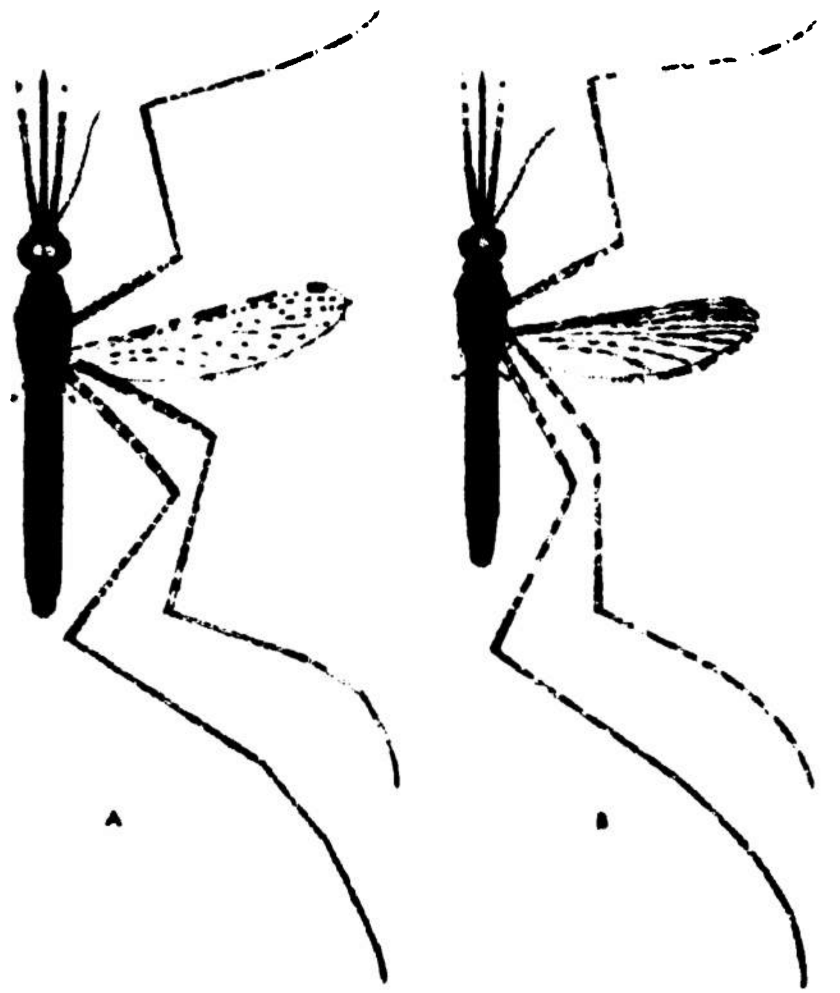


FIGURE 53.—Principal vectors of malaria in the South Pacific Area. A. *Anopheles farauti* Laveran. B. *Anopheles koliensis* Owen.

53A). *Anopheles koliensis* Owen (fig. 53B) was known to be strongly anthropophilic and thus potentially an important vector but of limited geographic distribution. In the limited area on Guadalcanal, in which it is known to occur, it may have been of some consequence during the period of combat and early occupation. Available information indicates that other species of *Anopheles* were not involved in the transmission of malaria to troops.

Breeding habits.—*Anopheles farauti* larvae usually occurred in greatest numbers and highest concentrations in sunny, slightly brackish lagoons in association with emergent aquatic vegetation and surface debris. The species also utilized almost every conceivable type of aquatic habitat with the exception of artificial containers, tree holes, open moving water, and highly saline water. On occasions *A. farauti* larvae were even found in artificial catchments when these were of sufficient size to approximate ground pools. The ability of the species to utilize these many types of habitats greatly influenced its importance as a malaria vector. It occurred abundantly in permanent or temporary surface water catchments of all kinds, in tidal and fresh-water swamps and lagoons, and to a lesser extent in streams, seepage areas, and open wells. Although it preferred sunlit water, it also occurred in rather heavily shaded areas. The larval developmental period was short, especially during the so-called dry season when prolonged periods of sunlight considerably increased the water temperature of typical breeding habitats.

Observations on Guadalcanal showed that under favorable circumstances *A. farauti* could complete development from egg to pupa in 5 days, and from egg to adult in 8 days. The normal developmental cycle from egg to adult was usually considered to be between 7 and 10 days, and larvicidal schedules were arranged accordingly. The ability of *A. farauti* to initiate an epidemic of malaria is clearly illustrated by the experiences of combat troops during the early phases of the Guadalcanal Campaign.

Insofar as they are known, the larval habitats of *A. koliensis* are similar to those of *A. farauti*, although information is not available to indicate whether or not *A. koliensis* adapts itself to the wide range of habitats that are utilized by *A. farauti*. During periods of prolonged rainfall, *A. punctulatus* larvae are found in typical *A. farauti* habitats, but during the dry season this species disappears from the coastal section of Guadalcanal. *Anopheles lungae* occurs in coastal swamps and seepage areas and shows a decided preference for shaded habitats. Both *A. solomonis* and *A. nataliae* occur in the low foothill section along the northwest coast of Guadalcanal, the former having been collected from potholes in a coral streambed and from seepage areas. Both species were usually found in clear water, densely shaded.

Habits of adult Anopheles.—All the species of *Anopheles* encountered in the South Pacific Area were nocturnal in their biting habits, although under favorable conditions of low light intensity daytime biting by *A. farauti* was not uncommon. This species was observed to bite as early as 1500 hours in jungle area on a cloudy day and as late as 0730 hours in thatched huts on a relatively bright day. Normally, the biting activities of *A. farauti* were limited to the period from dusk to shortly after dawn. Practically all *Anopheles* caught in routine night-biting catches on Guadalcanal were *A. farauti*, except for the relatively limited area in which *A. koliensis* was known to occur.

Man is generally considered to be the normal host of *A. farauti* perhaps in part because there are usually few other large mammals available in the

South Pacific islands. However, host preference tests conducted on Efate showed that the species fed readily on cattle, horses, goats, pigs, dogs, and chickens. Available evidence also indicates the probable existence of host-adapted strains of *A. farauti* on Guadalcanal. In 1944, numerous attempts were made to attract adult *A. farauti* to humans at night in the vicinity of an abandoned plantation near the mouth of the Balasuna River. Although weather conditions were favorable for mosquito activity, and high larval and pupal populations were known to exist in nearby lagoons, no adults were seen. Similar observations were made in other areas remote from existing human habitations. It was also repeatedly observed that adults reared from larvae collected outside the zone of normal human activity fed rarely or not at all on humans under laboratory conditions. On the other hand, specimens in captivity reared from the eggs of gravid females captured in native villages usually fed readily on humans. The successful colonization of *A. farauti* for laboratory study was usually accomplished by starting the colony with such material. Inadequate facilities and lack of time prevented detailed study of this interesting and probably important phenomenon.

As previously indicated, *A. koliensis* was strongly anthropophilic and frequently taken in night catches with humans as bait, and in the tents and thatched huts of native laborers. *Anopheles punctulatus* and *A. lungae* were but rarely attracted to humans, even when existing populations were high.

The daytime resting places for both *A. farauti* and *A. koliensis*, except for recently engorged females, apparently consisted of any cool, moist, shaded place. Because adult population sampling is generally thought to be the most accurate measure of an existing mosquito population, many efforts were made to seek out the daytime resting places of *A. farauti* in the South Pacific. Although almost every conceivable type of habitat was explored, at no time were adults encountered with sufficient consistency or in sufficient numbers for this method to be used as a basis for measuring the effectiveness of a control program. On the day following a nocturnal blood meal, *A. farauti* and *A. koliensis* females frequently remained in the dark parts of native huts or tightly closed tents but would leave by dusk or shortly thereafter. There was little evidence to indicate that blooded females lingered after obtaining a meal in open tents such as were usually used by troops, in thatched shelters without walls, or in the more open type of native huts. Observations conducted during 1944 on Guadalcanal, involving daily counts of the *Anopheles* resting in pyramidal tents used to house Melanesian laborers, showed that the population remained fairly constant but consisted almost entirely of freshly blooded females.

Anopheles punctulatus and *A. lungae* were observed to rest during the daytime on the moist, lichen-covered surface of the buttressed bases of huge forest trees in deep jungle shade. Only rarely were specimens of *A. farauti* observed in such places.

Results of Combat and Occupation on Malaria Potentialities of the Area

The full significance of the changes which led to increased mosquito breeding under conditions of combat and occupation in the South Pacific Area are appreciated only when viewed in contrast to the conditions prevailing in jungle or tropical areas occupied only by local populations. Before invasion or occupation, extensive breeding of *A. farauti* was limited largely to coastal lagoons and native clearings along inland streams, if one may correctly judge by the situation pertaining in those areas not disturbed by occupation forces. Although mosquitoes were almost invariably present in isolated native villages, the numbers were small.

With the advent of combat and occupation, and its associated myriad activities of supply and movement, there were soon created innumerable water catchments such as shell and bomb craters, abandoned gun positions and bomb shelters, foxholes, and ruts made by vehicular traffic. Airfield construction and roadbuilding, often hastily done, created further impoundment of water. Once created, these water catchments could never be quickly eliminated because of the limited amount of personnel and equipment that could be assigned to malaria control activities. *Anopheles farauti* soon utilized these many water surfaces for larval development, with the result that there was a rapid and enormous increase in the anopheline population of the area. Because personal protection from the bites of mosquitoes during combat and early occupation was difficult to attain, a high percentage of the female *Anopheles* were able to obtain blood meals, further enhancing the mosquito breeding and malaria transmitting potential.

MALARIA EXPERIENCE

Admission rates for malaria in Army personnel in the South Pacific theater are given in tables 61, 62, 63, and 64. Since these rates include both malarious and nonmalarious bases, they do not give a true picture of the situation in the command. Since Army, Navy, Marine, and Allied troops lived in close proximity and since different islands differed markedly, a much better picture of the situation is given if the rates of all troops are considered on each island. Rates in these tables refer to clinical malaria cases and do not indicate the actual malaria infection rate. Many troops on suppressive Atabrine therapy did not develop clinical malaria until after they had stopped taking the drug. An indication of the true infection rate was obtained in units which were taken off suppressive Atabrine therapy after having become more or less heavily seeded with malaria.

Efate.—Efate was the first malarious island to be occupied in the South Pacific. Troops landed, in March 1942, to build an airfield. They were bivouacked near a native labor camp in an area where anophelines were numerous. They lacked sufficient bed nets and were required to work at night.

TABLE 61.—*Admission rates for malaria in combined Army, Navy, Marine, and Allied troops in selected areas of the South Pacific, by month and year, April–December 1942*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month and year	Efate		Espiritu Santo		Guadalcanal	
	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions
1942						
April	2,632	2,678				
May	838	982				
June	667	915				
July	354	518				
August	113	209				14
September	84	144	36	36		177
October	135	289	55	59		1,664
November	304	520	30	82		1,781
December	177	377	137	142		972

Furthermore, they did not realize how serious malaria could be. The malaria rate reached 2,678 per 1,000 per annum in April (table 61). Quinine was the only antimalarial drug available, and in May about one-half the troops were ordered to take 0.33 gm. quinine daily; this amount was later increased to 0.66 gm. daily. These amounts failed to suppress the disease satisfactorily, and in July, 0.4 gm. Atabrine weekly was begun. The first malaria control personnel, one Navy officer and three enlisted men, arrived on 28 July 1942. Malaria rates decreased to 982 per 1,000 per annum in May and continued to decline until they reached a low of 144 per 1,000 per annum in September. This decline was due to the initiation of insect control measures, to suppressive therapy, and to the onset of the dry season. Atabrine was given to the villagers, and their huts near the troop areas were sprayed daily with a pyrethrum spray. The largest native labor camp was not moved to a safe distance from troops until nearly a year after the original epidemic. Antimosquito work was well organized by early 1943, but heavy equipment for semipermanent mosquito control work did not become available until 16 months after the first landing.

Suppressive Atabrine therapy was discontinued in September 1942 because of the low malaria rate. The rate promptly increased, reaching 520 per 1,000 per annum in November. Suppressive Atabrine therapy was resumed in November except for lightly seeded personnel living in screened quarters, and the malaria rate again decreased. In 1943, many of the heavily seeded troops left Efate, and the remaining troops were withdrawn from poorly controlled areas. By July 1943, the malaria rate was 128 per 1,000 per annum, of which only 66 were original admissions (table 62). At this time suppressive Atabrine therapy was discontinued on the island. The subsequent rates remained low, with a high percentage of relapses.

TABLE 62.—*Admission rates for malaria in combined Army, Navy, Marine, and Allied troops in selected areas of the South Pacific, by month and year, January–December 1943*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month and year	Efate		Espiritu Santo		Guadalcanal		Tulagi		Russells		Munda		Vella Lavella		Bougainville	
	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions
1943																
January	123	290	219	255		1,169	229	311								
February	207	342	208	253		878	281	409								
March	163	217	150	181		1,052	305	389	281	281						
April	130	179	160	191		1,182	352	516	194	204						
May	118	176	109	130		900	396	593	239	271						
June	72	145	62	85	396	636	249	486	283	324						
July	66	128	58	98	342	608	230	417	328	395		416				
August	37	76	35	68	142	263	240	373	261	346		329				
September	58	165	20	51	181	287	214	363	146	258		629		96		
October	20	92	40	83	124	230	215	366	80	137		625		94		
November	10	83	16	53	91	206	98	211	46	95		504	42	83	54	58
December	18	84	17	41	71	149	97	163	57	99	123	258	43	104	94	95

TABLE 63.—*Admission rates for malaria in combined Army, Navy, Marine, and Allied troops in selected areas of the South Pacific, by month and year, January–December 1944*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month and year	Efate		Espiritu Santo		Guadalcanal		Tulagi		Russells		Munda		Vella Lavella		Bougainville		Treasury		Green		Emirau	
	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions
1944																						
January	25	122	20	53	130	200	93	167	69	105	107	200	67	166	35	119	11	12				
February	14	100	7	32	74	126	91	194	129	158	57	114	78	160	37	104	6	21				
March	20	79	7	28	59	124	85	177	110	189	30	65	129	282	37	83	6	15	24	37		
April	11	69	4	16	50	99	34	115	66	142	22	52	133	329	61	103	5	26	29	41	58	111
May	10	45	3	16	48	95	27	99	71	170	20	51	15	54	66	104	15	34	42	62	23	46
June	6	37	8	19	30	75	32	107	41	104	(1)		(1)		(1)		(1)		(1)		(1)	
July	2	20	2	15	33	66	29	86	30	88												
August	4	32	1	8	20	58	9	51	12	57												
September	8	30	1	5	28	63	16	58	11	45												
October	0	27	1	4	22	51	11	37	6	30												
November	0	0	0	2	18	43	14	53	10	31												
December	0	0	0	3	11	29	12	26	12	29												

[1] Base transferred to Southwest Pacific Area.

TABLE 64.—*Admission rates for malaria in combined Army, Navy, Marine, and Allied troops in selected areas of the South Pacific, by month and year, January–June 1945*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month and year	Efate		Espiritu Santo		Guadalcanal		Tulagi		Russells	
	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions	Original admissions	All admissions
1945										
January	0	0	2	4	18	35	38	59	16	37
February	128	128	4	5	14	25	15	28	18	40
March	0	0	3	4	6	14	73	99	6	15
April	0	0	3	3	8	19	27	40	9	21
May	0	0	7	8	13	19	54	66	5	10
June	0	0	2	4	6	9	13	26	5	8

Espiritu Santo.—This island was occupied without opposition in May 1942. The dry season had begun, and there was very little mosquito breeding near the campsites. Even though drug suppression was not practiced, no cases of malaria were reported until September. In September, October, and November, fresh troops were camped near heavily seeded natives in anopheline breeding areas. The more exposed personnel were placed on suppressive Atabrine therapy, and the malaria rate did not rise beyond 255 per 1,000 per annum.[19] It reached this level in January 1943, and thereafter declined slowly (table 62). After the original admission rate had reached 109 per 1,000 per annum in May 1943, suppressive Atabrine therapy was discontinued. The rate continued to drop, the original admission rate being 16 per 1,000 per annum in November 1943 and declining still further later on.

A base malaria control group consisting of two Navy officers and eight Navy enlisted men was set up in September 1942. Troop areas were kept as far from local settlements as possible. The inhabitants were given suppressive Atabrine therapy, and their huts were sprayed regularly with pyrethrum beginning early in 1943. Residual spraying of the huts with DDT was begun in mid-1944. An extensive larviciding and semipermanent control program was in operation by mid-1943. It was so effective that after this time it was unusual to find adult anophelines in the main troop areas. Outlying areas, however, continued to be highly malarious, and troops on outpost duty became heavily infected.

Guadalcanal.—The first landing on Guadalcanal was made by Marine units in August 1942. The first Army units arrived in October. At first antimalaria supplies were either unavailable or inadequate, and no significant amount

[19] Malaria rates on Espiritu Santo are not comparable with those on the other islands. Only cases contracted on Espiritu Santo are included, while on the other islands all cases wherever contracted (except cases among hospital patients admitted on an in-transit basis) are included.

of mosquito control was done. The fact that there were few cases of malaria in August and September led to the feeling that the disease would be unimportant. No malaria control measures were undertaken during the early months, partly because of the desperate military situation and partly because responsible officers did not understand how serious a hazard malaria could be. The prevailing attitude was expressed by one high ranking officer who said: "We are here to kill Japs and to hell with mosquitoes."

However, the terrain and the results of combat combined to produce ideal conditions for the breeding of enormous numbers of mosquitoes. The combination of abundant anopheline breeding, a highly malarious source of infection (the native Melanesians and the Japanese troops), and almost complete absence of antimalaria precautions caused the malaria rate to rise precipitously to 1,664 per 1,000 per annum in October 1942 and to 1,781 in November (table 61). Malaria remained epidemic for at least 9 months. Of the estimated 100,000 cases of malaria contracted in the South Pacific, more than three-fifths were probably contracted on Guadalcanal, and most of these during the period October 1942 to August 1943. In July 1943, the malaria rate was 608 per 1,000 per annum, of which 342 per 1,000 per annum were original admissions (table 62). The rate dropped to 263 per 1,000 per annum (of which 142 were original admissions) in August 1943 and continued to decline steadily thereafter. In February 1944, when the original malaria admission rate was 74 per 1,000 per annum, suppressive Atabrine therapy was discontinued in lightly seeded units. The rate continued to decrease. By October 1944, about 26 percent of the troops had been taken off Atabrine, the total malaria rate was 51, and the original admission rate was 22 per 1,000 per annum (table 63). By June 1945, over 75 percent of the troops had been released from suppressive Atabrine, the total malaria rate was 9, and the original admission rate, 6 per 1,000 per annum (table 64).

A base malaria control group consisting of two Navy officers and eight Navy enlisted men was established in November 1942. This organization was later expanded greatly, and Army personnel eventually predominated. By far the largest amount of antimalaria work on any island was done on Guadalcanal. By the latter part of 1943, control work was well advanced. After that time, adult anophelines were difficult to find in the occupied area except during sporadic infestations.

The most important measure responsible for the great decline in the malaria rate was the extensive mosquito control work, both larvicidal and drainage, which was carried out. Atabrine suppressive therapy lowered the rates in heavily seeded troops. Administration of suppressive Atabrine and mass therapy to natives, spraying of their huts, and removal of native labor camps from troop areas (not accomplished completely until August 1944) were also helpful. Other factors were the improvement in living conditions for the troops, particularly the provision of screened quarters, and extensive education in personal malaria preventive measures.

During the early period, troops which had staged in uncontrolled areas on Guadalcanal for only a few days and then moved on to other islands often had severe malaria outbreaks traceable to their exposure on Guadalcanal. To prevent this, a troop bivouac area of about 90 square miles was established in November 1943. Mosquito control was carried out here continually. No organization was allowed to bivouac outside this area without special permission.

Tulagi-Florida Islands.—The initial landing in the Florida group of islands was made in August 1942. Combat did not last long, but small groups of troops were widely scattered and had inadequate antimalaria supplies. A Navy malaria control group began its activities late in 1942. Before this time, no malaria rates for all troops were available, although in one organization of 237 men the malaria rate was 2,004 per 1,000 per annum in December 1942, when the men were supposedly taking 0.4 gm. Atabrine a week.

The highest total rate for this small group of bases was 593 per 1,000 per annum in May 1943 (table 62). Most of the cases were in a few units in poorly controlled areas. Atabrine suppression therapy was discontinued in about one-half the troops in August 1943; it was discontinued in all troops in September 1944. At this time, the total malaria rate was 58, and the original admission rate, 16 per 1,000 per annum (table 63). Effective mosquito control work played the major part in reducing the malaria rate on these small bases. It was made difficult and complex by their scattered situation.

Russell Islands.—Unopposed landings were made on the Russell Islands in late February 1943, and a base malaria control unit arrived on March 3. There were neither natives nor Japanese on Banika or Pavuvu, the two main islands occupied. Mosquito breeding sites were numerous; hundreds of ponds about 30 feet in diameter were present in the cocoanut plantations.

The 43d Division, which made the initial landings, had been seeded with malaria on Guadalcanal, as had many of the troops which arrived later. Antimalaria details were established in all units of the 43d Division and in the Navy and Marine units within a month of occupation. A small staff of malaria control personnel was able to effect a very considerable degree of control under conditions which were favorable to the development of epidemic malaria. The malaria rate for March was 281 per 1,000 per annum, most cases being caused by *P. falciparum*. Suppressive Atabrine therapy was given at the rate of 0.4 gm. per week, a dosage later found to be inadequate; supervision was unsatisfactory. As a consequence, malaria rates of 200 to 400 per 1,000 per annum continued through September. However, unseeded units which came to these islands did not develop these high rates.

New Georgia Group.—The 43d Division attacked Rendova Island in the New Georgia Group on 1 July 1943 and assaulted Munda in mid-July; the 37th and 25th Divisions joined it later. During the first 2 months, heavy combat caused the formation of many shellholes, bomb craters, foxholes, ruts, and other sources of mosquito breeding. The seedbed consisted of Japanese and already infected Allied troops. The Allied troops were presumably taking

0.4 gm. suppressive Atabrine weekly, but its administration was poorly supervised. Anopheline breeding rapidly became a serious problem both on Rendova and New Georgia.

A malaria control team consisting of an Army malariologist, a Navy parasitologist, and several corpsmen landed on Rendova on 11 July and moved to Munda in August. This group early initiated a control program on Rendova which kept mosquito breeding at low levels and then vigorously attacked anopheline breeding areas in the main occupied areas of New Georgia. This was the first attempt to control malaria under combat conditions in the South Pacific Area and demonstrated that a small group of trained personnel with simple equipment could accomplish much valuable work. It was a new concept in malaria control and was the basis for the subsequent assignment of survey and control personnel to all large combat units.

The malaria rate reached a peak of 629 per 1,000 per annum in September 1943; much of this was due to relapses in the heavily seeded 25th Division which had a rate above 1,000 per 1,000 per annum at this time. By December, most of the heavily seeded units had left the base, and the rate was 258 per 1,000 per annum. By May 1944, it had dropped to 51 per 1,000 per annum.

Vella Lavella.—Vella Lavella was invaded on 15 August 1943 by the 3d New Zealand Division and a small American force. It was secured on 9 October. A malaria control unit consisting of 4 officers and 33 enlisted men arrived with the division, and a Navy control group was also present. Most of the malaria cases occurred in a Marine defense battalion which had been heavily seeded on Efate in 1942. The rate in this battalion was 964 per 1,000 per annum in April 1944; at the same time, the island rate was 329 per 1,000 per annum (table 63). The method of administration of suppressive Atabrine in this battalion was improved; in May its malaria rate had fallen to 114, while the island rate was 54 per 1,000 per annum. The continuing low rates in the previously unseeded New Zealand division are a tribute to its malaria discipline and effective larviciding program.

Bougainville.—The landing was made at Empress Augusta Bay, an almost uninhabited area, in November 1943. Malaria control groups accompanied the 3d Marine, Americal, and 37th Divisions. A base malaria control group was established in January 1944. Because there were extensive swamps near the beach, the troop area was established at some distance from the beach, where the underlying sandy soil proved easy to drain. Control work was started early, and the malaria rate never became high. A peak rate of 119 per 1,000 per annum was recorded in January 1944 (table 63). Even though many of the troops were already seeded, 0.6 gm. weekly of suppressive Atabrine helped keep the rate low. Aerosol bombs were available and were widely used.

Minor outbreaks of malaria occurred in troops on perimeter defense and in those making sorties into enemy territory. Most of these cases were due to *P. falciparum*, while most of those in the controlled area were relapses due to *P. vivax*.

Emirau Island.—An unopposed landing was made on this small island in March 1944. A malaria control group accompanied the troops and began a very effective mosquito control program immediately. Even heavy equipment drainage of all swamps was completed in 3 months. The 220 natives who lived in Emirau were moved to another island.

The malaria experience of some of the Army units is of particular interest, since their personnel did not change so much as did those on the various islands.

Americal Division.—This division moved to Gaudalcanal by echelons in October, November, and December 1942. The troops lived and fought in highly epidemic areas. There was very little malaria discipline, no repellents or Aerosol bombs, and, although 0.4 gm. Atabrine weekly was prescribed, it is doubtful if it was taken very carefully. The monthly malaria rate ran as high as 1,358 per 1,000 per annum, while the division was on Guadalcanal.

In March 1943, the division was moved to Fiji, a nonmalarious island, for rehabilitation. The entire division was treated with Atabrine and Plasmochin between April and June. Thereafter, no antimalarial drugs were administered except to persons with clinical malaria. The malaria rate rose promptly to a high of 3,760 per 1,000 per annum in August; it was still 2,880 per 1,000 per annum in October. The division was alerted for combat in November, and suppressive Atabrine therapy was given at the rate of 0.4 gm. per week. This was increased in December to 0.6 gm. per week. By January, the malaria rate had fallen to 43 per 1,000 per annum. After 5 months of combat on Bougainville, the total rate for May 1944 was only 112 per 1,000 per annum. More details on malaria in this division are given by Tumulty and coworkers.[11] The malaria experience of this division is shown in chart 20.

Plasmodium falciparum caused more than one-half of all malaria cases reported on Guadalcanal during January, February, and March 1943, and *P. vivax* caused about 25 percent of the cases. *Plasmodium falciparum* continued to predominate for a few weeks after the division arrived on Fiji, but *P. vivax* rapidly came to the fore and caused practically all the subsequent cases.

Suppressive Atabrine therapy was discontinued on Fiji in the hope of demalarializing the division. The theory was that if the troops were allowed to have their malaria, they would get it out of their systems and become free of it. The experience with this and other units showed that this would not take place within a reasonable length of time but that repeated relapses would occur.

147th Infantry.—This regiment landed on Guadalcanal in November 1942 and February 1943, and took part in combat. The regiment was on 0.4 gm. weekly suppressive Atabrine, but its administration was not closely supervised. While most of the diagnoses were not confirmed by blood smear examination,

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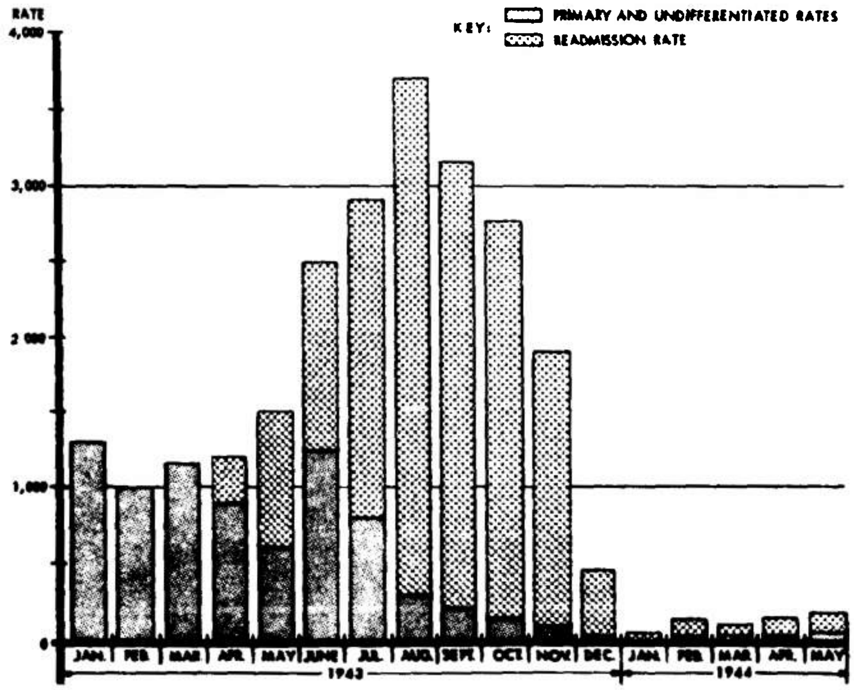
[11] Tumulty, P. A., Nichols, E., Singewald, M. L., and Lidz, T.: An Investigation of the Effects of Recurrent Malaria; an Organic and Psychological Analysis of 50 Soldiers. Medicine 25: 17–25, February 1946.

CHART 21.—*Incidence of malaria in the 147th Infantry, December 1942 to October 1944, inclusive*

[Rate expressed as number of cases per annum per 1,000 average strength]



the regiment's sick reports showed malaria in 48 percent of the men, and the malaria rate reached a peak of 1,558 per 1,000 per annum in April 1943.

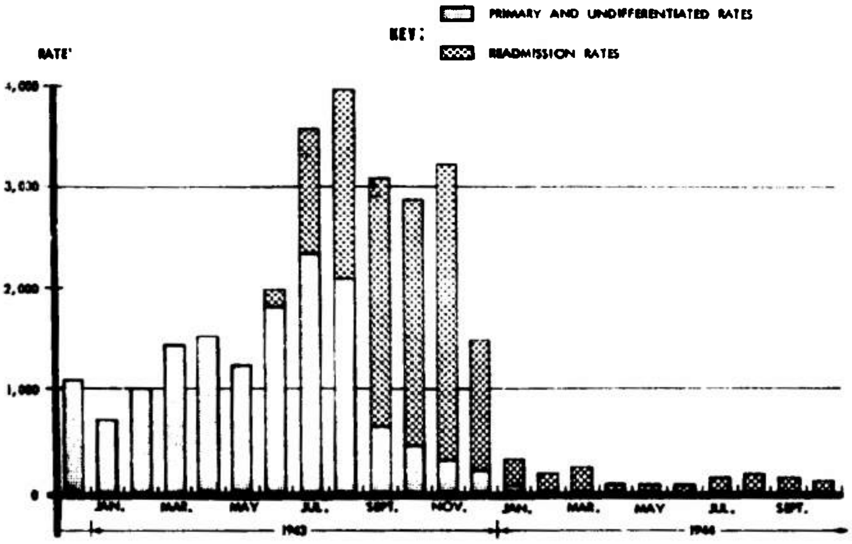
In May 1943, the regiment was sent to British Samoa, a nonmalarious island, and demalarialization was begun. Downs [12] described the malaria history of this regiment in detail. The regiment was divided into four groups. One received Atabrine mass therapy at once; the second received Atabrine mass therapy after a 10-day period without medication; the third received mass therapy with Atabrine and Plasmochin; and the fourth received no mass therapy. Suppressive treatment was then discontinued, although clinical cases were treated as they occurred.

There was no relationship between the treatments and the incidence of malaria in the four groups. Because the termination of mass therapy was staggered, the peak malaria rate of the regiment did not exceed 4,090 per 1,000 per annum, although peak rates in different groups exceeded 14,000 per

[12] Downs, W. G.: Results in an Infantry Regiment of Several Plans of Treatment for Vivax Malaria. Am. J. Trop. Med. 26: 67–86, January 1946.

CHART 21.—*Incidence of malaria in the 147th Infantry, December 1942 to October 1944, inclusive*

[Rate expressed as number of cases per annum per 1,000 average strength]



1,000 per annum. The rate continued high until suppressive Atabrine therapy was begun again in December 1943. In January 1944, the rate had dropped to 334 per 1,000 per annum, and it continued to decline thereafter (chart 21).

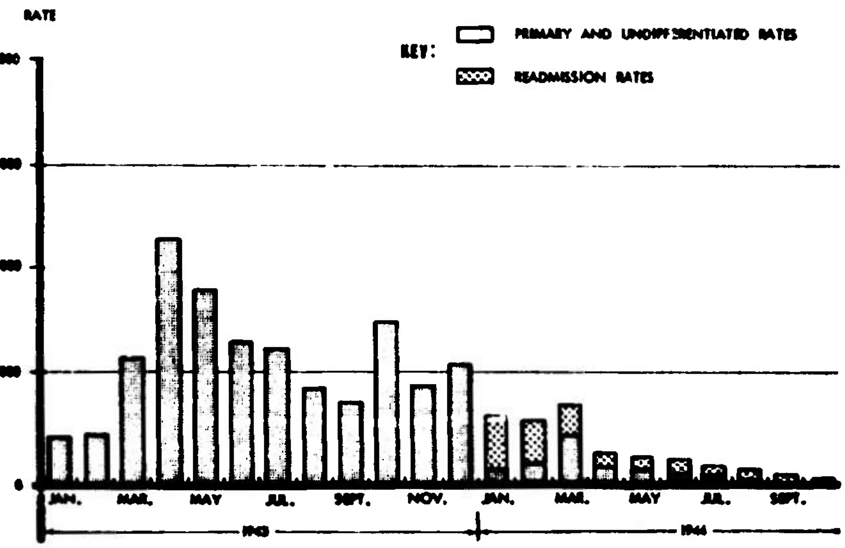
An even more marked reversal than in the Americal Division of species predominance from *P. falciparum* to *P. vivax* occurred in this regiment after it left Guadalcanal.

25th Division.—This division landed on Guadalcanal in late December 1942 and fought through the latter part of the campaign. It soon became heavily infected; in April 1943, the malaria rate reached a peak of 2,335 per 1,000 per annum, although the division was presumably receiving 0.4 gm. per week suppressive Atabrine. The division took part in the New Georgia and Vella Lavella campaigns from July to October. In October 1943, its malaria rate was 1,550 per 1,000 per annum. In December, the division was sent to New Zealand and later to New Caledonia, both nonmalarious islands. Suppressive Atabrine therapy was discontinued in a small group to learn how heavily the division was seeded. In 4 weeks, the rate in this group was 2,091 per 1,000 per annum. Because of the experience already described, no attempt was made to demalarialize this division. Atabrine administration was improved, and the malaria rate declined progressively to 44 per 1,000 per annum in October 1944 (chart 22).

37th Division.—The division arrived on Guadalcanal in March 1943 and was bivouacked in a relatively well controlled area. It at once instituted an

CHART 22.—*Incidence of malaria in the 25th Division, January 1943 to October 1944, inclusive*

[Rate expressed as number of cases per annum per 1,000 average strength]



effective larviciding program and enforced the use of individual malaria discipline. Suppressive Atabrine therapy was administered by roster, 0.4 gm. per week being given until October 1943, and 0.6 gm. per week thereafter. The division took part in the New Georgia campaign, from July to September 1943, and then returned to Guadalcanal. It was sent to Bougainville in November 1943, where it took part in limited combat for nearly a year.

The malaria rate remained low in this division, never exceeding 250 per 1,000 per annum, and usually being much below this figure. This was partly because the division was bivouacked in a relatively well controlled area when it first came to Guadalcanal, partly because of its early recognition of the malaria hazard, and finally to the energetic and thorough control program that it carried out.

43d Division.—This division bivouacked on Guadalcanal in February 1943 while en route to the Russell Islands and New Georgia. It remained on the latter islands until December 1943, when it was transferred to nonmalarious New Zealand. Throughout its service on the malarious islands, the division had been kept on suppressive Atabrine therapy. During February and March 1944, a small group was taken off Atabrine to learn how heavily the division was seeded. The malaria rate in one company rose to 2,025 per 1,000 per annum, approximately one-half the peak rate of the Americal Division. The monthly malaria rate of the remainder of the division did not exceed 235 per 1,000 per annum and by July 1944 had dropped to 64 per 1,000 per annum. During all this time, the division was receiving 0.6 gm. Atabrine per week.

***Plasmodium* species in troops.**—*P. malariae* was rare among troops in the South Pacific, almost all the cases being due to *P. falciparum* or *P. vivax*. The predominant species changed with the progress of each campaign. Early in the campaign, *falciparum* malaria predominated, but, as control measures progressed and the general malaria rate declined, *vivax* malaria became increasingly common, until at length it far outweighed *falciparum* malaria.

This sequence of events is well illustrated by the experience on Guadalcanal. In January 1943, there were twice as many cases of *falciparum* as of *vivax* malaria; the two species were about equally common in July, while in January 1944 there were 20 times as many *vivax* as *falciparum* cases. The total malaria rates per 1,000 per annum for the island decreased coincidently from 1,169 in January 1943 to 608 in July 1943 (table 62) and to 200 in January 1944 (table 63). Several factors were responsible for this change. In January 1943, a condition of hyperendemicity existed, with a high transmission rate. Many of the cases recorded as *falciparum* were probably mixed *vivax-falciparum* infections in which the *vivax* had been temporarily suppressed. During this period, too, almost all malaria cases were primary ones, while later on an increasing percentage of them were relapses. Since relapses occur more frequently in infections of *vivax* malaria, than in *falciparum*, the proportion of *vivax* cases increased steadily. The infected troops formed the seedbed for new infections, and as the species distribution of the seedbed shifted, so did the species distribution of new infections. As a result, the percentage of *vivax* cases increased progressively. In addition, as the overall incidence of malaria decreased, double infections became less common, so that *falciparum* malaria no longer masked the *vivax* form. Improvement in Atabrine discipline also decreased the incidence of *falciparum* malaria.

Prevalence and Decline of Malaria

High malaria rates occurred in the early landings because the importance of malaria was not properly assessed by the troop commanders until it had incapacitated many men and had interfered seriously with the efficiency of their activities. No attempt was made at first to carry out individual protective measures, to enforce suppressive medication, or to combat mosquitoes. In addition, the proximity of infected natives or Japanese provided a seedbed of the disease, and the combat-produced shellholes, foxholes, and ruts greatly increased the mosquito breeding areas. When the importance of malaria was once recognized, elimination of mosquito breeding places, larviciding, enforced use of suppressive Atabrine and of individual protective measures, elimination of infected Japanese, and removal of infected natives all helped to control the disease. The most important of these measures was the elimination of anopheline mosquitoes. While Atabrine undoubtedly prevented the clinical appearance of *falciparum* malaria in many thousands of troops, it merely postponed the inevitable clinical attack of *vivax* malaria.

Malaria in Enemy Troops

Data on the prevalence of malaria in South Pacific natives have already been given (table 59).

The Japanese suffered more severely from malaria than did the Allied troops. They apparently carried out little mosquito control in the Solomons, although a few knapsack sprayers and small quantities of larvicidal oils were captured. They also had bed nets, a repellent cream whose active ingredient was oil of citronella, a mosquito-repelling punk, quinine, and Atabrine.

Captured medical reports quoted by Harper, Lisansky, and Sasse [10] stated that among the Japanese forces in the Solomon Islands and Bismarck Archipelago the primary malaria rates per 1,000 per annum were 450 in December 1942, 1,098 in January, and 1,637 in February 1943. At Rabaul, New Britain, 32.4 percent of one unit and 22.09 percent of another were malaria patients during February 1943. The total malaria rate for Rabaul and vicinity was 2,593 per 1,000 per annum in April 1943.

The few prisoners captured in the South Pacific were usually emaciated and almost invariably malarious.

ANTIMALARIA POLICY AND ORGANIZATION

At Theater Level

The South Pacific Force under Navy command was a joint U.S. Army, Navy, Marine, and New Zealand group. Commander, South Pacific, was the senior Navy command. The senior Army command within the area was U.S. Army Forces in the South Pacific Area. Island commanders were responsible to ComSoPac and to Commanding General, USAFISPA. On each base, there was an army service command and a naval headquarters, each responsible to the island commander. Commanding generals of divisions, if on established bases, were responsible to island commanders on matters pertinent to that base.

Development of area organization

The initial malaria epidemic among Allied troops occurred on Efate which was occupied in March 1942. During the following month, the military forces on this island experienced a malaria rate of 2,678 per 1,000 per annum (table 61). This explosive outbreak of malaria caused great concern, and an experienced Navy medical officer, Commander Sapero, was sent to Efate in July 1942 to take charge of malaria control measures. An organization had to be created

[10] Harper, P. A., Lisansky, E. T., and Sasse, B. E.: Malaria and Other Insect-Borne Diseases in the South Pacific Campaign, 1942–1945; I. General Aspects and Control Measures. Am. J. Trop. Med. 27 (suppl.): 1–67, May 1947.

from the ground up: personnel had to be secured, trained, and assigned, directives issued, and supplies obtained.

This organization developed slowly. It required time to procure and train personnel in the problems of entomology, engineering, and malariology peculiar to this area. Only after field trial was it possible to develop a staff for area headquarters and to make those transfers which were essential to build a strong organization. The directives which formed the legal basis of this organization and which established malaria control policy were written and rewritten as new problems were encountered over a period of more than 2 years. The first directive, ComSoPac Serial 301e, was issued on 2 September 1942 and called attention to the existence of a "malaria control unit" available for use on the three bases then occupied, Efate, Espíritu Santo, and Guadalcanal. A group of 10 persons was sent to Espíritu Santo in September 1942 to set up the base malaria control unit there.

Despite the fact that anopheline populations on Guadalcanal were increasing and that malaria was beginning to appear, no malaria control personnel was allowed to start work on that island until mid-November, when the malaria epidemic was in full swing and the anopheline breeding had reached a high level. Such an attitude toward malaria control measures was typical of the prevailing opinion that malaria and malaria control were of minor importance during combat operations. This attitude was largely due to ignorance of the damage that uncontrolled malaria could do to military personnel. The difficulties in establishing malaria control on Guadalcanal despite the obvious need made it increasingly evident that a stronger area directive was necessary. Such a directive, ComSoPac Serial 0094b, was issued on 13 November 1942 and is quoted in part:

Malaria control units, with headquarters at Base Roses (Efate), have been and are being established at various bases in the South Pacific Area. Each unit consists of a medical officer in charge, an entomologist, and laboratory and field technicians who are specialists in problems of malaria control. These units will advise and render service in connection with malaria control to U.S. Army, Navy, and Marine Corps Units and Allied Forces occupying malaria infected islands.

It is the responsibility of the Malaria Control Units to: (1) make epidemiological studies pertaining to malaria, (2) operate laboratories for diagnosis, (3) train personnel from other organizations in laboratory procedures pertaining to malaria control, (4) advise in regard to mosquito control measures, (5) advise in regard to disinsectization of aircraft, (6) make such recommendations to the proper authorities in regard to malaria control as the circumstances require, (7) procure, store and distribute antimalarial drugs for chemoprophylaxis as may be required by the forces at each base.

A laboratory section of a Malaria Control Unit will be established at certain nonmalarious bases. The officers in charge of these units will carry on studies of malaria infected personnel evacuated from malarious bases and will make recommendations with respect to treatment of and malaria control measures pertaining to evacuated personnel. They will also undertake training of laboratory and medical field technicians attached to organizations preparing to enter malarious bases in the special procedures applicable to malaria control.

Personnel of Malaria Control Units will be attached to the major medical department activity of the base to which the unit is assigned for administrative purposes, berthing and subsistence. The major medical department activity will also provide laboratory facilities for these units.

The Commanders of all bases in which Malaria Control Units are established are enjoined to cooperate to the fullest extent with the officer in charge of Malaria Control Units in order that these units may accomplish their extremely important mission. It is directed that officers in charge of malaria control units be consulted in connection with the selection of sites for camps and airfields and that their recommendations in such matters be given due consideration.

The last sentence of this quotation gave the malaria control personnel on each base a voice in and a responsibility for the location of campsites and other facilities. The malariologists, entomologists, and sanitary engineers made surveys and gave valuable advice concerning the selection of sites which were or could be made relatively malaria free and to the avoidance of highly malarious areas.

A year later this and other orders governing malaria control operations were consolidated greatly strengthening control efforts. Responsibility for the control of insect-borne diseases in all forces was now clearly fixed on one officer with a headquarters unit of mixed Army and Navy personnel. The provision that this officer should recommend "the establishment of Malaria Control Units at bases, and the administration and coordination of malaria and epidemic control" was translated in practice into responsibility to recommend the assignment and reassignment of all malaria control personnel in the area. Similar centralization of responsibility for antimalaria activities on each base was provided by the provision that the senior malariologist at each base should make recommendations and report directly to island commanders. This centralization of responsibility followed a year after the height of the epidemic of malaria on Guadalcanal and at a time when repeated malaria relapses were seriously delaying the return to combat of such combat troops as the Americal Division and the 147th Infantry (charts 20 and 21). Excerpts from ComSoPac Serial 002263, dated 24 September 1943, are as follows:

Organization and Responsibilities

a. Pertaining to the area program of control. A Malaria and Epidemic Control Officer on the Staff of Commander South Pacific has cognizance of all matters pertaining to the control of malaria in all forces in the area. He makes recommendations to the Commander South Pacific for the overall area program of control and recommendations for the establishment of Malaria Control Units at bases, and the administration and coordination of malaria and epidemic control.

An Area Entomologist and an Area Engineer serve to coordinate efforts in their special fields. A Training and Education Officer is responsible for an educational program of practical measures of malaria prevention for all shore-based forces in the Area. He prepares such educational material as malaria training manuals for line and medical officers, and for enlisted men. Posters, films, and other useful training aids are distributed.

b. Pertaining to the control program at malarious bases. The senior Malaria and Epidemic Control Officer of base units is directly responsible to the Island Command for an effective program of control, applicable to all forces at the base. He formulates the control program for the base and makes recommendations to the Island Commanders who in turn will require subordinate units to carry out prescribed control measures within their respective commands.

Reports of the senior base Malaria and Epidemic Control Officer are submitted directly to the Island Commander. Copies of such of these as are pertinent are forwarded directly to the senior subordinate commands of the various services at each base, to the Force Medical Officer, Commander South Pacific, the Surgeon, USAFISPA, and Headquarters, Malaria and Epidemic Control.

Base Malaria Control Units are permanently established and serve all forces without service distinction. The units are jointly constituted, being composed of specially trained Army and Navy personnel—malariologists, entomologists, engineers, parasitologists, and laboratory and field enlisted technicians.

The Malaria Control Unit described in this directive, or Malaria Control Group as it was subsequently called, consisted of a malariologist, one or more Army malaria survey detachments, and one or more Army malaria control detachments, or equivalent Navy personnel. The command channels of this group are discussed later (p. 442).

The area organization developed as the area expanded to 11 malarious bases, as the legal basis was broadened, and as the personnel increased from 4 persons in July 1942 to over 750 technically trained personnel and nearly 4,000 laborers in June 1944. This growth made clear the need for an area staff which was developed in the following order of appointment: An area malaria and insect control officer; an area entomologist; an Army liaison officer, an area training and education officer; an area administrative assistant; an assistant malaria and insect control officer; an area engineer and two filaria survey officers.

Responsibilities and duties

The duties and responsibilities of the area organization were as follows:

1. It served all Allied Forces in the area.

2. It formulated area directives which were issued by ComSoPac and Commanding General, USAFISPA, and which defined and gave authority to insect and rodent control policy, organization and function.

3. It made recommendations for the procurement, assignment, and transfer of all personnel assigned to insect control activities.

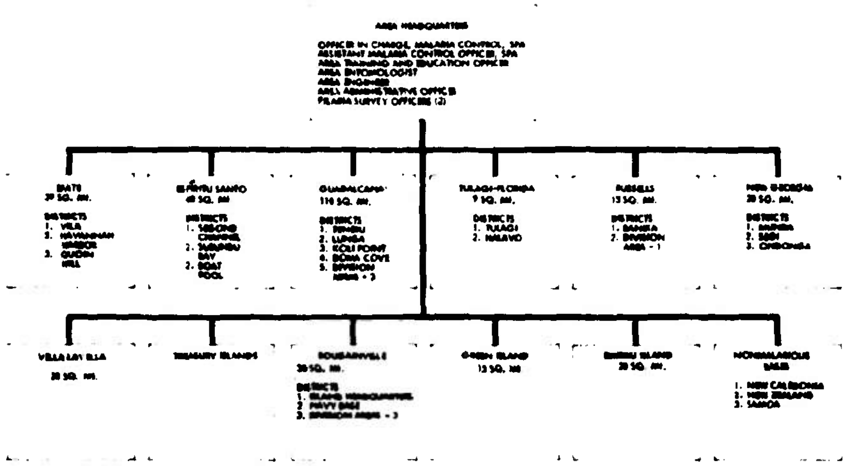
4. It provided technical and supervisory assistance to the various base and division malaria and insect control groups.

5. It was responsible for the control work of the base groups and established a uniform system of reports and inspections.

6. It recommended allowances and provided for procurement and distribution of malaria control equipment and supplies.

7. It provided an areawide educational and publicity program of malaria and insect control for all personnel, and special information for line officers, medical officers, and for personnel assigned to malaria and control work.

CHART 23.—*Malaria and Insect Control Organization, South Pacific Area, 1 June 1944*



8. It made personnel and equipment available for special problems of malaria control such as airplane application of DDT solutions and spraying of bed nets with DDT, and for problems concerned with filariasis, mite-borne typhus, dengue, and rodent control.

Chart 23 shows the personnel of the area organization and the distribution of base and division groups. Letter orders authorizing all necessary travel to malarious bases were given to the area staff. Some member of the headquarters staff made a complete circuit of the malarious bases every 4 to 8 weeks to keep in touch with local work and needs. The area entomologist and engineer offered technical assistance and advice to the corresponding officers in each base unit. Distribution of technical information was also accomplished through a newsletter and through special publications such as synoptic keys to mosquitoes. Uniform methods of reporting information were adopted for all base reports as well as for area reports.

Procurement and assignment of technically trained personnel.—Table 65 describes the personnel engaged in insect control work as of 15 May 1944. The technically trained personnel comprised medical officers, entomologists, parasitologists, sanitary engineers, and enlisted personnel of the control and survey detachments. They formed the Base and Division Malaria and Insect Control Groups. As of 15 May 1944, this personnel comprised 128 officers and 643 enlisted men, divided as follows: Army, 452; Navy and Marine, 282; New Zealand, 37.

Technically trained Army malaria control personnel was provided by the War Department in three categories: Malariologists (medical officers), malaria survey detachments, and malaria control detachments.

TABLE 65.—*Malaria and insect control personnel, South Pacific Area, 15 May 1944*

Type of personnel	Source of personnel	Number
Technically trained personnel:		
Malariologists, entomologists, parasitologists, sanitary engineers, rodent control officers, and trained enlisted personnel.	War Department and Navy Department Base and Division malaria and insect control groups, comprised of medical officer personnel and personnel from special survey and control detachments for tropical diseases.	771
Skilled labor:		
Operators of heavy equipment, dynamite crews, and flume and culvert crews.	Navy construction battalions and Army Engineer Corps.	[1] 634
Unskilled labor:		
Medical sanitary companies	War Department	936
Troop antimalaria details	Troop units	1,479
Natives	Local Government agency	587
Total		4,407

[1] Average figure for 6 months, December 1943 to June 1944.

Army malariologists arrived as casual officers. Almost all of these officers had taken the course in tropical medicine at the Army Medical School, and the majority had had field work at the Army school in Florida or Panama. They were attached to Headquarters, Services of Supply, South Pacific Area, and then ordered on detached service to the various bases and divisions. There were 21 Army malariologists in the area: 2 lieutenant colonels, 8 majors, and 11 captains. One Army malariologist was on the area malaria control staff, 6 were senior base malariologists, 6 were division malariologists, 1 was assigned to the Office of the Chief Surgeon, USAFISPA, 1 to Headquarters, XIV Corps, and the remainder acted as assistant base malariologists.

There were 17 malaria survey detachments and 20 malaria control detachments within the area, as of 1 June 1944. The officers of these detachments all met the basic technical requirements for their specialty. The enlisted men were untrained at time of assignment but were usually of high caliber and rapidly became competent technicians under the guidance of their officers. There would be great advantages if in the future these enlisted men could have a period of formal training at Army medical centers or at one of the Army malaria control schools.

Navy malaria control personnel was procured through the Navy Department either from the Malariology School of the Naval Medical School, Bethesda, Md., or from Navy replacement pools or other organizations within the South Pacific. The usual Navy malaria control team consisted of one officer, an entomologist, and from three to five enlisted men. Each Marine division was provided with a larger team (called an epidemiology unit) of 3 officers (malariologist, entomologist, parasitologist) and 12 enlisted men. An engineer for this team was provided from the sanitary section of the naval construction battalion which was attached to each Marine division. Enlisted men from Bethesda were well trained in laboratory diagnosis and in elementary field procedure. Several Navy officers experienced in rodent control were obtained from organizations in the South Pacific. Navy warrant and Hospital Corps officers were also secured locally to administer malaria control personnel and supplies on larger bases.

The Navy malariology teams were often broken up and assigned to Army-Navy or all Navy groups to meet the needs of a local or island situation. This was in contrast to the policy of assigning Army units intact and resulted in a valuable flexibility.

Procurement of labor and equipment.—Skilled and semiskilled labor was needed for semipermanent mosquito control work which required the operation of heavy equipment such as bulldozers and draglines and special skills such as those of a dynamite expert. Almost all such skilled labor and heavy equipment were obtained from naval construction battalions or from the Army Corps of Engineers.

An entire naval construction battalion was assigned to malaria control work on Guadalcanal in May 1943 on recommendation of the theater malariologist. Subsequently, sanitary sections for malaria control work were organized in all naval construction battalions.

Unskilled labor was recruited from three sources: Army medical sanitary companies, natives, and troop unit antimalaria details. The first Army medical sanitary company arrived about mid-1943 and was assigned to Guadalcanal. Subsequently, nine such companies arrived of which eight were assigned to malarious islands on recommendation of the theater malaria and insect control headquarters. It should be emphasized that every medical sanitary company on a malarious island in the South Pacific worked full time at malaria control. Credit for withstanding the pressure to assign these units to other work must be given to the Surgeon, USAFISPA.

Native labor was scarce and was strenuously competed for by both combat and service units. Usually a certain proportion were assigned by the Island Command headquarters to malaria control work.

The work of skilled and unskilled labor is described on pages 445 and 467.

Supplies and equipment.—There were acute shortages of all antimalaria supplies and equipment in 1942, of which the most important were Atabrine, mosquito repellent, insecticide and knapsack sprayers. In this early period, the area malaria control organization advised on allowances and was responsible for the establishment of quotas and distribution of those items in which shortages were acute. Excerpts from the pertinent directive[14] follow:

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[14] Circular Letter No. 15, Headquarters, Services of Supply, South Pacific Area, 13 May 1943.

1. Central procurement, distribution and issue of insecticides, pest control supplies and equipment for all Armed Forces located in the South Pacific Area (less those located in the Samoan Group) has been assigned to the Army Services of Supply by ComSoPac.

2. Service Command Quartermasters, * * * in cooperation with the Base Malaria Control Officers, will receive, store, and distribute the above supplies to all Armed Forces at each base. Navy Supply Officers, Marine Quartermasters and New Zealand Supply Officers may obtain their stocks in bulk from Base or Service Command Quartermasters at each Base. by requisition.

* * * * * * *

5. The use of insecticides and insect repellents within the South Pacific Area will be governed by instructions issued by each base malaria control officer.

Transportation was often a serious problem. Each malaria control group was responsible for a territorial coverage which averaged about 20 square miles, often in the shape of a long narrow beachhead. In addition to distributing their own survey and control crews to all parts of this territory, most groups transported 50 to 100 native laborers to and from work each day and hauled labor details. They also did power spraying, hauled gravel, and did other work requiring vehicles. The increased number of vehicles which were finally authorized for malaria detachments and for medical sanitary companies were adequate. A special theater directive provided transportation for malariologists.

Liaison

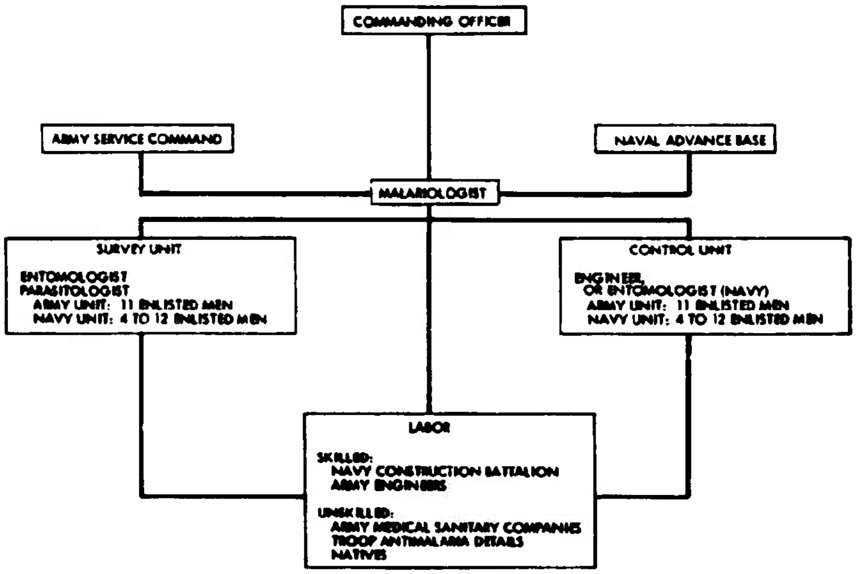
Since this was a joint service organization, no liaison was needed between branches of military service or with Allied Forces. There were contacts with the civil population on New Caledonia and on Efate chiefly in connection with antimosquito operations. These were ordinarily easily handled through official channels. The assistance of the parish priest was sought, and generously given, when dengue carrying mosquitoes were found breeding in flowerpots and other receptacles used for decorating graves in the cemetery.

Local or Island Organization and Procedure

The work of the malariologist

The command basis for the work of the island malariologist has been described (pp. 435, 436). By these directives, the senior malariologist at each base eventually was made directly responsible to the island commander for formulation of a program of control applicable to all forces—Army, Navy, Marine, and Allied—and for recommendations to make this program effective. The commanding officer of each subordinate organization on the island was responsible for all malaria control activities within and adjacent to this bivouac site. Reports and recommendations of the senior base malariologist were submitted directly to the island commander, who, in turn, required the subordinate commanders to carry out prescribed control measures. This chain of command was unusual in that it did not conform with the ordinary channels through the

CHART 24.—*Island organization and command channels, Joint Army-Navy malaria and insect control*



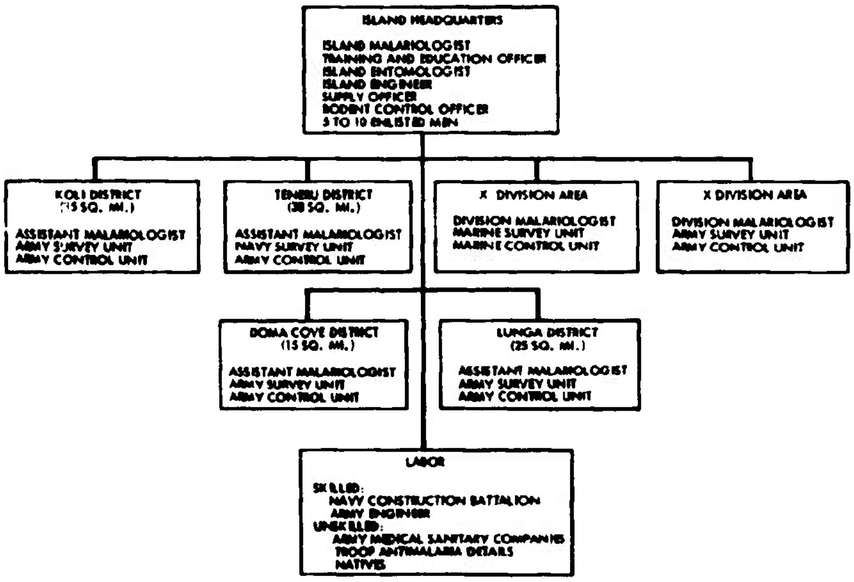
commanding officer of service command or through the Commander, Naval Advanced Base.

This latter point may be expanded by citing the problem of Guadalcanal where the malaria control organization was a mixed one of Army and Navy personnel and where the first island malariologist was a Navy officer, subsequent ones being Army officers. The question arose: Should command channels through Commander, Naval Advanced Base, be utilized when the senior malariologist was a Navy officer and should these channels be changed to go through Commanding Officer, Service Command, when the senior malariologist was an Army officer, or should both command channels be utilized since this was a mixed service group? The solution was direct reporting to the Island Command with copies to subordinate commands.

The organization of the Army-Navy malaria control personnel on a typical island base is shown in chart 24. A mixed Army-Navy group was developed on most islands. The variable size of the Navy units was particularly advantageous for small bases where only one or two officers and a few enlisted men were needed and where the Army units of fixed size were too large.

Chart 25, Guadalcanal Malaria and Insect Control Organization, is presented as an example of organizational development on islands large enough to require two or more malaria control groups. (The term "Malaria Control Group" is used to designate a working organization comprising a malariologist,

CHART 25.—*Guadalcanal Malaria and Insect Control Organization*



a malaria survey detachment, and a malaria control detachment.) The Island headquarters was not provided for by any table of organization but developed to fill a need for overall supervision on larger bases. Modifications of the headquarters section, diagrammed in chart 25, were established on Efate, Espíritu Santo, New Georgia, and Bougainville.

The malaria control personnel on most bases formed a joint Army-Navy group who lived under one roof and worked together in one area. Two-thirds of the groups were attached to Army or Navy hospitals for quarters and rations, one-third to Navy advanced bases or Army service commands. Three groups set up independent housekeeping with a medical sanitary company assigned to malaria control work. This had distinct advantages, among which was a time for meals favorable for field work.

The position of the malariologist in this organization was an ambiguous one which can be explained best by saying that he was a staff officer whose duties often required the assumption of command responsibility. This was evident in his relations with assistant malariologists and with personnel of survey detachments, control detachments, and sanitary companies. He selected their locations, directed their work, and initiated or approved recommendations for promotion. This assumption of command responsibility functioned well because of a general willingness to cooperate and because the high command fostered such a situation by directives quoted previously which made the malariologist responsible for all insect control activities on a base. However, the malariologist had no legal command authority over the malaria detachments and medical sanitary companies which were small, independent commands. In a long-range program, this officer should have command authority corresponding to his responsibility.

The duties of the malariologist included:

1. Formulation of an effective program of mosquito control, utilizing the advice and assistance of specialists, the entomologist, the parasitologists, and the engineer.

2. Integration of the work of the survey detachment, the control detachment, and labor.

3. Estimation of need for and requisition of personnel and supplies to execute the program.

4. Development of an effective malaria training and educational program.

5. Preparation of directives pertaining to malaria discipline and the making of spot inspections for violations of malaria discipline.

6. Consultation and recommendation in regard to the selection of sites, for camps, airfields, bivouac and maneuver areas.

7. Segregation of natives.

8. Recommendations concerned with the institution and discontinuance of suppressive medication.

9. Supervision of disinsectization of airplanes and ships and other measures to prevent the dissemination of disease.

10. Preparation of reports of the malaria situation on his base or in his division area, including especially statistics regarding malaria incidence, status of malaria discipline, entomological and climatological data, work of control units, activities of the training program, status of antimalaria supplies and of personnel engaged in control work, and recommendations.

The first work was done where troops were concentrated. Speed in instituting control measures was most important in occupying a new base. Initial surveys were done rapidly and more thorough work came later. Larviciding and other temporary work, such as clearing of paths to facilitate oiling, were usually initiated coincidentally with the first survey.

The initiation of semipermanent work depended on the size of the troop population to be protected, the period the area was to be occupied, and the available labor and equipment. As soon as surveys were completed, a list was prepared of semipermanent control projects with detailed estimates of labor and equipment. These projects were listed in order of priority and were initiated directly if they were within the scope of the malaria control personnel under the jurisdiction of the malariologist. Larger projects requiring special equipment and labor were submitted through proper channels to the commanding general for approval and for assignment of the needed equipment and personnel. These projects competed with other high priority work, such as roadbuilding, airfield construction, and erection of hospitals. Presentation had to be clear and concise and had to include an adequate justification for priority.

The need for continuous integration of the work of the survey and of the control units was recognized rapidly. In wartime practice, survey and control work were initiated simultaneously and continued to be interdependent.

The malaria survey and the malaria control detachments

The Army malaria survey detachment consisted of 2 officers and 11 enlisted men, all technically skilled, and charged with entomologic and parasitologic work to aid the control of malaria and all other insect-borne disease.

The entomologist and his enlisted men furnished information about the breeding of mosquitoes and other insects, their biology, and relations to disease. This information was always accompanied by recommendations as to specific control measures. The work was continuous and was recorded on maps and other forms so as to give a clear and continuous check on the effectiveness of control.

The parasitologic section of the survey unit furnished information about the incidence of malaria and other parasites in natives, in U.S. troops, and in Japanese prisoners and recorded this knowledge so as to aid both the planning and the evaluation of control work.

The Army control detachment comprised an engineer and 11 enlisted men and was responsible for planning, executing, and maintaining all insect control measures based on the findings of the survey detachment; for supervision and correlation of all labor and equipment for this work; and for maintenance of suitable records to give a continuous and clear picture of control activities.

The enlisted personnel performed a variety of duties, according to the local situation. These men were most economically and efficiently employed as supervisors. Occasionally, on large bases, an entire control team was made responsible for a special project such as work on flume and culvert maintenance. Additional enlisted personnel were assigned to work with dynamite or bangalore torpedo ditching crews. Men were trained to operate bulldozers, draglines, and other heavy equipment. On islands where airplane spraying of DDT solutions became an important control measure, crews of one to six men were assigned to mix DDT solutions and to service the spray apparatus installed in the planes.

Table 66 shows the average number of personnel available for the work of the malaria control units during the 6-month period from December 1943 to June 1944. The engineer was responsible for the work of these laborers except that of the troop antimalaria details. Thus, on the larger bases, each engineer had from 100 to 250 men, exclusive of troop units, working under his general supervision.

TABLE 66.—*Personnel available for work of malaria control units, South Pacific Area* [1]

Base	Area to be controlled (sq. miles)	Number of laborers					
		Base control unit	Seabee or Army Engineer unit	Medical sanitary company	Natives	Troop antimalaria details	Total
Efate	39	15	12	0	95	40	162
Espiritu Santo	40	33	10	0	0	350	393
Guadalcanal [2]	110	55	355	292	250	350	1,302
Tulagi-Florida	9	18	35	0	37	70	160
Russells	15	15	42	117	40	150	364
Munda	20	18	35	117	75	80	325
Bougainville [2]	[3] 50	22	10	117	80	150	379
Green Island	15	5	12	65	0	125	207
Emirau	30	15	60	50	0	60	185
Vella Lavella	20	10	33	0	10	(4)	53
Treasury [2]	7	4	30	0	0	104	138
Total		210	634	758	587	1,479	3,668

[1] Average figures for 6 months, December 1943 to June 1944 (except Emirau which was occupied in March 1944).
[2] Omits divisional units.
[3] Controlled area increased from about 20 to 50 square miles during above period.
[4] Information not available.

Troop Unit Antimalaria Organization

From the first, antimalaria details were expected to do the larvicidal work in their own areas. The assignment of men to oiling details in 1942 and the early half of 1943 was irregular and depended on personal arrangements between the island malariologist and each commander. In September 1943, an areawide directive, ComSoPac Serial 01619, dated 13 September 1943, ordered the formation of a mosquito control squad in every batallion. A subsequent directive, ComSoPac Serial 02158, dated 19 October 1944, ordered the formation of an antimalaria detail in each company, battery or similar unit. This detail consisted of one noncommissioned officer and two enlisted men per infantry company or a proportionate number for other units. In nonmedical units, these details were made up of nonmedical personnel. These details were responsible for all insect control work within the region occupied by their units, and their work was checked by technicians from the base or division malaria survey detachment described previously.

These antimalaria details worked effectively in all situations except those of frontline combat. It was not only impossible for most antimalaria details to do antimosquito work under combat conditions, but these personnel were as fatigued as their comrades at the end of the combat period and so further postponed this work. To remedy this situation, temporary spray teams were formed in combat regiments and are described in the next section.

Division Malaria and Insect Control Organization

The Division Malaria and Insect Control Group comprised the division malariologist, a malaria survey detachment, and a malaria control detachment totaling 4 officers and 22 technically trained enlisted men. This group was attached to the division over and above its established allowance for Medical Department personnel. They performed the same functions for the division as did the base malaria and insect control group for each island base, with the additional duty of providing antimalaria protection during the periods of active combat. This resulted in less emphasis on specialization and more emphasis on flexibility, with every man trained to aid in all phases of a simple antimosquito program.

It was the duty of the division malariologist to provide plans for the control of malaria, dengue, mite-borne typhus, and other insect-borne diseases during a period of active operation. The final plan, selected from several prepared in advance, was determined by the particular military situation.

An important feature of all such plans was the provision for a pool of trained men to do temporary insect control work behind the lines during combat periods. This pool of personnel was obtained by drawing one man from each antimalaria detail and adding a technically trained nucleus from the attached survey and control detachments. In most plans, this personnel was split into four temporary spray teams, of which one was attached to division headquarters and one to each of the three regimental headquarters. The temporary spray team went ashore with the division or regimental headquarters to which it was attached and began work. Fly control was done by spraying unburied bodies with 5-percent DDT solution or 1-percent sodium arsenite solution. Straddle trenches, pit latrines, and other sources of fly breeding were treated similarly. Mosquito control measures were carried out around headquarters, medical facilities, supply dumps, and along communication lines. (See appendix A, p. 592.)

Malaria Control Labor

Unskilled labor was obtained from Army medical sanitary companies and natives. Each Army medical sanitary company consisted of 3 officers and 100 enlisted personnel. These companies provided their own messing facilities and were authorized [16] to operate nine vehicles and other suitable equipment. They were assigned to island commands and were employed as directed by the malariologist in conjunction with antimalaria work. There were eight medical sanitary companies used only for malaria control within the South Pacific Area as of 1 June 1944, located as follows: Four companies on Guadalcanal; one each on Russell Islands, Munda, and Bougainville; and one divided company

[16] T/O&E 8-117, Medical Sanitary Company, 13 May 1944.

with a platoon on Green Island and a platoon on Emirau Island. They rapidly developed an understanding of the problems of malaria control and facility in necessary procedures. Enlisted men who showed aptitude were trained in the operation and maintenance of heavy equipment, in dynamite work, and in mosquito survey work. These troops were of great value as a constant source of experienced labor. Their activities included larviciding, application of residual spray, hand ditching, and similar work.

Natives were employed on nearly all bases. The decision to utilize this source of labor was made early in the campaign with the knowledge that these local inhabitants constituted a potential seedbed of malaria and filariasis. The malaria control organization attempted to minimize this health hazard by segregation and by other means described in the section on malaria control measures. Laborers worked in sections of 25, each with its own native sergeant. The total number of imported Melanesian laborers on all bases was over 6,000 in 1944. About 600, or 10 percent, worked daily on malaria control during the period of maximum activity in the theater.

Airplane Spraying Arrangements

Arrangements made by the malaria and epidemic disease control organization for the accomplishment of airplane spraying varied on different bases. In one respect, however, they were uniform; that is, all spraying was done on a scheduled basis and because of known need for larvicidal work, with the exception of spraying done on a purely experimental basis for evaluation of equipment. Only small aircraft were routinely used. Frequently, the equipment used and operating arrangements resulted from informal arrangements, and much of the spray equipment was fabricated at airplane maintenance shops. On most bases, pilots were assigned to the malaria control organization for operational control, a most important factor in the accomplishment of efficient airplane spraying. The arrangements eventually worked out for airplane spraying on Guadalcanal may be considered representative of this work in the South Pacific.

All regularly scheduled and special flights were under the control of the Island Command entomologist who briefed the pilot on the area to be covered and arranged for loading the airplane with insecticide. The pilot arranged for operational clearance from the field where the plane was based and from the field from which operations were to be carried out. Usually, the field nearest the site to be sprayed was selected for use, in order to minimize the time required for return to the field for reloading. Frequently, abandoned airstrips were used until this practice was forbidden because of the lack of emergency equipment. Aircraft were serviced by means of a mobile service truck developed and equipped for the specific purpose. In practice, the use of aircraft without radio equipment proved an advantage because of priority in landings and takeoffs from busy fields. Experienced pilots, properly briefed, needed no ground guides other than terrain or vegetative features in order to accomplish thorough coverage.

Other Military Agencies Engaged in Antimalaria Work

Skilled labor for malaria control work included dragline and bulldozer operators, dynamite experts, carpenters, and welders to make flumes and culverts. Such skilled personnel and heavy equipment were obtained chiefly from naval construction battalion personnel, and in small part from the Army Corps of Engineers.

In May 1943, the need for large-scale mosquito control work on Guadalcanal became so urgent that the entire 63d Naval Construction Battalion was ordered by ComSoPac to malaria control work at that base. The personnel of this battalion rapidly became acquainted with malaria control problems and techniques and accomplished an extraordinary amount of semipermanent control work over the entire base.

The formation of sanitary sections in all naval construction battalions for use on malaria control work was authorized by a series of directives issued in July and August. These directives ordered each naval construction battalion to form a sanitary section of 110 enlisted men and to provide specified equipment for work on malaria and epidemic control projects under the direction of base and division (Marine) malariologists. Equipment assigned to each sanitary section included one dragline crane, one tractor with bulldozer blade, and seven trucks. Since there were about 20 naval construction battalions on malarious bases in the year subsequent to this order, these directives made available to malaria control a potential total force of over 2,000 men and more than 20 bulldozers, 20 dragline cranes, and 140 vehicles. Actual compliance with these directives furnished about 500 men, 10 to 15 bulldozers, and 8 to 12 dragline cranes daily for work on malaria control projects during the 8-month period, November 1943 to June 1944.

Despite outstanding work by many of these battalions, compliance with these directives was usually delayed and incomplete. Work often was done too late to forestall an initial outbreak of malaria and seeding of troops. This was due to high priorities for airfields, roads, harbor, and storage facilities. Requests for diversion to malaria control of 10 percent of men and equipment often seemed unreasonable to the officers responsible for major construction projects.

Certain faults were inherent in the sanitary section of the construction battalion as originally conceived. Construction battalion personnel comprised for the most part highly skilled labor with technical ratings and with only few unskilled workers. It was wasteful and damaging to morale to use skilled labor for unskilled manual work. Wherever possible, the use of skilled construction battalion labor was limited to the use of heavy equipment and to other skilled jobs while unskilled manual work was done by native labor.

The use of Army engineers for malaria control was authorized [16] as follows:

"The Corps of Engineers is charged with the responsibility for the execution of mosquito control work on real property. This includes such measures as drainage, filling, larvicidal programs, and screening."

The number of troops in the Army Corps of Engineers in the South Pacific Area was small, as compared with the number in the naval construction battalions. The use of such troops for malaria control projects was subject to the same delays encountered with naval construction battalion sanitary sections with the added handicap that no set percentage of troops in the Army Corps of Engineers was directed to do malaria control work. A few of these troops did excellent work on insect control projects, but the total was small.

The practice was begun during 1944 of submitting consolidated estimates for all base malaria control projects to the commanding general, with the request that these projects be assigned to heavy equipment units. This resulted in the division of these projects between Army engineer units and naval construction battalions. Such projects were well prosecuted.

A large share of semipermanent work was done with borrowed equipment which was maintained and operated by personnel of malaria control detachments and medical sanitary companies. Such equipment which was in great demand was obtained by a process of barter and exchange, the details of which were best known to Army supply sergeants and Navy warrant officers.

Thus, malaria control personnel on Guadalcanal operated an average of 10 bulldozers, 2 draglines, and several disk harrows throughout 1944, and similar personnel on Espíritu Santo and Bougainville operated about one-half of this amount of equipment. A few experienced operators of such equipment were found in the various malaria control detachments and others were trained. The great majority of all semipermanent drainage work done in the early months of occupation on several island bases was accomplished in this extralegal manner. These experiences led to a recommendation to the War Department, which was approved by Headquarters, Services of Supply, South Pacific Area, to add a limited amount of heavy earth-moving equipment to the table of organization and equipment of medical sanitary companies. This recommendation was rejected on the ground that medical sanitary companies did not have the necessary maintenance crews and facilities to service such heavy machinery. This objection was theoretically valid; in practice, however, such equipment in the hands of malaria control units had an excellent record for days worked per machine per month and for rapid repairs when needed.[17]

[16] War Department Circular No. 223, 21 Sept. 1943.

[17] It is still our opinion that some plan of assigning such equipment to a malaria control organization is essential if semipermanent control work is to be accomplished during the early months on a new base.—Authors' Note.

ANTIMALARIA ACTIVITIES

Training, Information, and Propaganda

The training and education program was planned to reach every officer and man in the area on a level consistent with his responsibility. This program fell into two parts: (1) The work of the area headquarters staff which developed the necessary directives, provided manuals, posters and other educational aids and conducted a small area training center; and (2) the work of base and division malaria control groups which directed the mass education program.

The area staff prepared six pocket-sized manuals, three on malaria and one each on dengue, filariasis, and rodent control. The three manuals on malaria were written respectively for medical officers, for line officers, and for enlisted personnel. About 500,000 copies were printed locally to provide one for every officer and man in the area. The area staff included an artist, who, over a 2-year period, produced 15 posters, a monthly pinup calendar, and a weekly cartoon for the Sunday edition of the local mimeographed paper. "Malaria Moe" and the Frank Mack versions of a pinup girl and of an anopheline mosquito were found in nearly every tent and quonset hut in the area. Posters were reproduced in numbers to supply one large and one small size for every 200 men. One calendar was printed monthly for every five men.

A library of malaria control films was obtained and circulated to all base and division groups which arranged for command showing of the more important ones. Only two films were considered adequate, a "Snafu" film on malaria and a film produced by the Army Air Corps, TF1-3343. Such excellent results were obtained from the few satisfactory films that were available that it is to be hoped that more and better training films will be prepared for these subjects.

A monthly newsletter was found to be a most successful method of disseminating current information to malaria control officers, hospitals, and base and division surgeons.

An area training center in malariology and other insect-borne diseases was established first on Efate and later on Espíritu Santo. It began late in 1942 with small classes of three to five officers for 2-week periods. The students at this school included all newly arrived malariologists and such troop unit malaria control officers as could be spared from their organizations. The school was located on the grounds of a large hospital which had a high census of patients ill with malaria and other tropical diseases and who were available for clinical and parasitologic study. The medical staff of the hospital aided the area malaria control staff in the teaching program. Adequate parasitologic and entomologic collections were built up and a small but good library was obtained. Thirty malariologists, or more than two-thirds of those who worked in the area, attended these schools as did a larger number of troop unit malaria control officers.

The training program on each island or base was divided into three parts: An apprenticeship system for newly arriving personnel of malaria control and survey detachments; a short school for troop unit antimalaria details; and a simple educational program for every man in the area.

The apprenticeship system was devised to meet the needs of incoming malariologists, entomologists, parasitologists, engineers, and the men of their detachments, a few of whom were experienced in the problems peculiar to the South Pacific Area. This apprenticeship period lasted from 1 to 3 months. The teaching staff consisted of the entire personnel of a veteran group, and the curriculum was the daily work of this established group. After a short time, the newly arrived personnel were assigned a small area and were made responsible for all phases of antimalaria work therein, before being given a completely independent assignment.

It was often possible to place six or eight men of a control unit with a naval construction battalion or Army engineer company, where they rotated through a program of work with dragline crew, transit crew, dynamite gangs, and heavy maintenance section.

The training of enlisted personnel as technicians qualified to read blood smears for malaria was one of the urgent problems in the early period. The first school for technicians was started at Efate, using as instructors corpsmen who had been trained at the Naval Medical School. From 50 to 100 routine thick-blood smears were examined each day by these corpsmen and were available for teaching purposes (fig. 54). Similar schools were established on Espíritu Santo, Guadalcanal, and other bases as soon as malaria control groups arrived. Students were trained either singly or in small groups. Over 450 technicians were trained in the first 2 years of this work with an improvement in malaria diagnosis throughout the area to the point where over 95 percent of all cases were confirmed by the laboratory.

The School for Troop Unit Anti-Malaria Details was designed to teach the elements of larviciding and other control measures to the men who comprised these details in each company. This activity was initiated by ComSoPac Serial 01619, issued on 13 September 1943 and revised on 19 October 1944 by ComSoPac Serial 02158.

An effort was made not only to show how to control malaria but also to explain the rationale of this work, thus creating a nucleus of informed officers and men in each battalion and company. An average class consisted of 10 to 15 students. The officers and selected enlisted men from base and division malaria control groups comprised the faculty. The period of instruction was usually 2 to 3 days. The presentation of subject matter was elementary. The unit medical officer was required to attend because he was expected to use this type of presentation in his talks with the men of his

U.S. Army Photo

FIGURE 54.—Recording results of microscopic examinations of blood smears.

organization. Emphasis was placed on practical fieldwork. Between 4,000 and 5,000 officers and men attended these schools during the first 2 years of their activity.

Educational Program for All Personnel

All of these programs were concerned with personnel engaged in full- or part-time insect and rodent control work. The basic educational program, to be described, aimed to impress every man with the importance of malaria and with how he might protect himself from mosquitoborne disease. Few troops had had any education in malaria before arrival in the area. The need for this educational work was so apparent that programs were initiated almost simultaneously on several staging bases including the Fiji Islands, New Zealand, and New Caledonia. The value of these early uncoordinated efforts was immediately evident. At the same time, there was apparent need for a uniform area training and education program, for approved training manuals, and for a publicity program employing the radio and other educational aids. A theater directive was first issued in mid-1943 and was revised by ComSoPac Serial 02158, 19 October 1944. An extract follows:

Training Program in Malaria Control

1. Unit Commanders will allot in the training schedules sufficient time for the proper instruction of their troops in the principles of malaria prevention.

2. Lectures will be given to small groups of men by their respective medical officers. These lectures will cover the following:

a. Military Importance of Malaria.

b. Nature of Malaria, How Transmitted and Effects.

c. Individual Protective Measures, Conditions in Which Each Is Applicable, Especially in Combat.

Repellents.

Use of Ordinary Clothes for Protection.

Spray-killing of Adult Mosquitoes.

Bed Nets.

Atabrine Suppressive Therapy.

Avoidance of Unnecessary Exposure.

d. Control of Mosquito Breeding.

e. Man-made Malaria—How to Avoid It.

3. All personnel will be given initial instruction in prevention of malaria by lectures and motion pictures as soon as practicable. Subsequently, a review of the subject will be carried out at least once a month.

4. Additional instruction will be given to officers and non-commissioned officers, or petty officers, covering especially the selection of campsites, the hazard of natives as a source of malaria, and the enforcement of precautions under varying field conditions. Emphasis will be put on the responsibility of officers and non-commissioned officers for good "Malaria Discipline" and its importance to military success. Arrangements may be made to have members of Base Malaria Control Units assist in this program.

5. To aid in this program permanently based Malaria Control Units (or Island Surgeons) will issue the following malaria training manuals:

All Medical Officers:	MTM No. 1.	Prevention of Malaria in Military and Naval Forces, SPA.
All Officers:	MTM No. 2.	Military Malaria Control, in the Field.
Enlisted Men:	MTM No. 3.	Malaria, Mosquitoes, and Men.

Movies, additional literature, posters, and other material will also be made available by Malaria Control Units.

6. Every unit will periodically conduct field exercises in the practical application of antimalarial measures. On maneuvers, these measures will be standard procedures.

Arrangements were made for brief radio announcements on each base every evening which reminded listeners to roll down sleeves, to use repellent, and to take other precautions. The radio stations were known as the Mosquito Network, and on Guadalcanal a program of recorded music known as the Atabrine Cocktail Hour began each evening with a plug for malaria or dengue control.

Parasitological Survey Activities

The parasitology sections of the malaria survey units participated in the educational and inspection activities of the malaria control groups. In addition, they were charged with the responsibility of seeing that all blood smears were read correctly. Upon request, they trained technicians for the hospitals, sickbays, and other installations where blood smears were examined. They also made periodic checks on the accuracy of the diagnoses made by these installations. They provided a microscopic diagnostic service for dispensaries, sickbays and other installations which were unable to examine slides themselves. In 1943 alone, over 75,000 slides were read on Guadalcanal. The parasitology sections carried out surveys of malaria and filariasis among natives and others. The parasitologists also collected and compiled statistical data on malaria incidence in the troops.

Entomologic Survey Activities

The personnel and organizational structure utilized for entomologic survey activities in the South Pacific Area were discussed previously (chart 25). In actual practice, this organization was an exceedingly flexible one, adaptable to peculiar circumstances and problems as the need arose, and Army malaria survey detachments were seldom used as distinct and independent units. Responsibility for survey work was assigned on an area basis, with an entomologist, either Army or Navy, in charge, and personnel from either or both of the services detailed as needed or available. An area entomologist was on the staff of the area malariologist to provide overall coordination of the work. Island entomologists were designated to coordinate the survey work on the larger bases; namely, Bougainville, Espíritu Santo, and Guadalcanal.

In general, within a designated area, the entomologist and his crew were responsible for surveys to determine the incidence, distribution, and biology of arthropods of medical importance; for recommendations as to the areas requiring control operations, their proper treatment, and relative importance; for routine inspection surveys to evaluate the effectiveness of control operations; and for maintenance of appropriate records of insect populations and their fluctuations in response to control activities or other factors. Special investigational projects were undertaken as time permitted or the need arose.

The duties of the area entomologist were to advise the area malariologist concerning the broad aspects of the entomologic work, to aid in the procurement of entomologic supplies, and to assist base entomologists in the establishment of survey procedures. A similar relationship existed between the island entomologists and the malariologists of the respective bases. In no instance were these command positions, and the personnel assigned to them acted merely as technical advisers and coordinators. The value of this type of coordination was recognized, particularly since it facilitated the dissemination of ideas and information of value to the general program. The area entomologist prepared and distributed a monthly newsletter which included pertinent entomologic and engineering data. Monthly meetings of the entomologists on Guadalcanal were held, and these were occasionally attended by entomologists from Tulagi. These meetings were conducted in the best entomologic traditions and greatly facilitated the problem of coordinating survey work on the base.

Field survey work within an assigned area was usually conducted by from 7 to 10 enlisted technicians in addition to the officer in charge. The senior noncommissioned officer was in direct charge of both field and laboratory work,

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2 or 3 men were usually detailed to insectary and laboratory activities, and the remainder to field surveys. Area assignments varied in size, depending upon the complexity of the problems encountered and the terrain involved. They usually consisted of from 10 to 45 square miles of territory. The entomologist and the senior noncommissioned officer were necessarily familiar with the entire territory in a general way, and field scouts were expected to become acquainted with their assigned subareas in a detailed fashion.

In actual practice, no sharp distinction could be made between initial exploratory surveys and routine inspection surveys, since the one gradually evolved into the other. Under ideal conditions, initial surveys of a territory followed critical inspection of maps and aerial photographs of the area. Unfortunately, during the early phases of the South Pacific campaign, this was seldom possible. The lack of adequate maps for malaria control activities reflected the situation from the tactical standpoint. There were no good maps of Guadalcanal before the invasion, nor was that deficiency corrected throughout the combat period. Initial surveys were often sketchy and incomplete, either because of combat conditions, inadequate personnel, or other factors. The objective of the initial surveys was to determine as quickly as possible the location, extent, and description of actual or potential mosquito-breeding places; the records of current adult and larval populations; and the locations of native villages or other possible reservoirs of tropical diseases. As survey work progressed, the accumulated information was used to draw up detailed recommendations for a control program. As the control program developed, the survey activities became progressively more routine, but field survey personnel were at all times enjoined to report on the necessity for new projects to correct potentially dangerous situations, as well as the need for maintenance work of any kind. Because of the ever-changing situations on most bases, initial survey activities were never really terminated.

Routine survey activities were primarily aimed at improving the larvicidal program. Various attempts were made to evaluate the control program through sampling the adult mosquito population, but these were not generally successful. As indicated previously in the discussion of the habits of *A. farauti*, all attempts to estimate the population of this species through counts of adults in daytime resting places failed, or were of very limited practical value. The routine operation of mosquito light traps seldom produced *Anopheles* in sufficient numbers to be of significance and in areas of relatively low populations seldom produced any specimens. Night catches of mosquitoes were fairly reliable as a measure of the population but were time consuming if properly carried out. For these reasons, sampling of the larval population was usually the method of evaluating the control program. In addition to supplying a more sensitive measure of population fluctuation, larval sampling permitted immediate application of control measures.

It was recognized early in the work in the South Pacific that close coordination of survey and control activities was necessary to attain the highest degree of efficiency in the approach to malaria and epidemic disease control. This was particularly true with respect to the larvicidal program. In order to facilitate coverage of all available water surfaces, survey crews routinely maintained maps showing the location of water catchments and the results of larval population sampling. Since primary emphasis was placed on malaria control, the location of *A. farauti* breeding foci was indicated on the map in red, the density of the population being shown in terms of a fraction, the number of larvae over the number of dips taken. Thus 150/60 meant that a total of 150 larvae was taken in 60 dips. Populations of culicine larvae were similarly recorded in blue. These data were recorded daily on large-scale wall maps covered with a transparent overlay.

At the end of each checking period, usually 1 week, the data were transferred to record-size maps, and the overlay was cleaned off before the results of the next survey were added. Control crews consulted the map daily and guided their efforts accordingly. This system permitted personnel concerned to note at a glance the situation throughout the area and enabled the entomologist and engineer to follow, week by week, the progress being made in the elimination of "hot spots." These data gave an accurate picture of the potential malariousness of an area long before that information could be derived from reports of incidence of the disease.

Antimosquito Operations

The story of mosquito control operations in the South Pacific is a story of improvisation and salesmanship. Under the stress of wartime conditions, it was necessary to work under the handicap of critical shortages of personnel and equipment. Much of the equipment available during the early phases of the work was ill adapted to the job and had to be discarded or constantly repaired. Attempts to obtain heavy earthmoving equipment always met with competition from high priority projects such as airfield and road construction. Control work other than hand larviciding was delayed for many months after occupation on all of the bases occupied during the first 1½ years of the campaign. Larviciding was not started on Efate and Guadalcanal until a malaria epidemic was well underway.

DDT, with its immense laborsaving potentialities, did not become available for general use until after the middle of 1944, by which time the major task of malaria control—that on Guadalcanal—had already been accomplished. The urgency of the situation in late 1942 and early 1943 made it necessary to undertake the work with all possible speed. A studied and strictly scientific approach was not possible. Although primary emphasis was placed on malaria control from the outset, it was not known how many vectors of this disease were present, or what other mosquitoborne diseases might be encountered. It was felt that quick control of mosquitoes in general would ultimately be the cheapest control of malaria and other epidemic diseases transmitted by mosquitoes.

Antilarval activities

Larviciding.—The initial approach to mosquito control was largely through elimination of the immature stages of development. In part, at least, this decision was dictated by the limited materials at hand, mostly diesel oil and a small number of hand-operated sprayers. Only limited drainage could be accomplished with the few troops assigned to malaria control activities, and line and service organizations were slow to cooperate in reducing the extensive water surfaces unless compelled to do so for personal comfort. Many months were to pass before an adequate number of vehicles and power sprayers was available, and airplanes were not used until after DDT became available late in 1944.

Of the several makes of hand-operated sprayers that were ultimately used, the 3-gallon chemical warfare sprayer, M1, was generally the most satisfactory. When modified with a suitable nozzle and oil-resistant hose and gasket, it made a fairly light and serviceable item. It had the added advantage of having interchangeable parts, a feature that did not apply to some other types of sprayers furnished as equipment to Army malaria control units. Until power sprayers became available, most larviciding was done with this item, carried by men on foot. In order to improve the efficiency of the operation, it was the general practice to distribute drums of oil to the field by truck, spotting them at strategic places so that walking could be cut to a minimum.

Once power sprayers became available, they were mounted on jeeps or weapons carriers and used to patrol the miles of water-filled roadside ditches and ruts that existed on nearly every base. Complete coverage of all static water surfaces was attempted each week on most bases, although this frequently could not be accomplished until the program was well underway. Eventually, it became the general practice for organizations to larvicide within their own cantonment areas, while the base malaria control organization assumed responsibility for all other larvicidal work. Larviciding crews were usually assigned definite areas of responsibility and were expected to become familiar with all details of the area that required attention. Crews usually contained 5 to 15 men each, depending upon the extent of the area to be covered. A noncommissioned officer was in charge of each crew. The members of the crew might work singly, in pairs, or as a group, again depending upon the problem at hand. Under conditions of normal rainfall, the crew was expected to be able to cover its assigned territory once in 4 or 5 days. This schedule left a safety factor of 2 or 3 days for repair of equipment, rainy days, and recreation.

Larviciding was not customarily carried out during periods of excessive rainfall because of the quick runoff of water and larvicide. On some bases, it was found expedient to organize "shock" oiling crews, usually of two or three men, whose duty it was to cover breeding areas missed by the regular crews. When unoiled breeding areas containing either fourth stage larvae or pupae of *Anopheles* were reported, it was customary for the shock crew to cover the area on the same day, regardless of the time of day at which the report was received. To expedite this work, survey crews resorted to the use of "flag" in the field to mark the breeding site, or, if necessary, a survey man would accompany the oiling crew into the field to point out the site. Although this system occasionally caused some hardship through disruption of planned after-hour activities, it served to emphasize the importance of thorough coverage. The comments of the shock crew called upon to take care of such special assignments were usually sufficient to improve the work of the regular crew.

The routine use of DDT, when it became available, resulted in a great economy of both labor and diesel oil. Usually, the spray schedule was not altered. Some larvicidal crews were equipped with 2-quart continuous-spray dispensers, and it was found that where scattered small pools were involved this item of equipment would hold enough solution to last a man for one-half day of work. Crews that continued to use knapsack-type sprayers adjusted the nozzles to the finest spray and could work all day without refilling. Spray crews were taught to apply only a minimal amount of the solution and to take advantage of wind drift in applying the larvicide to extensive water surfaces.

Dusting for the control of mosquito larvae was little practiced in the South Pacific Area. Before the use of DDT, some attempts were made to use paris green for the control of *Anopheles*, with varying success. This arsenical was used as a temporary control measure along grassy stream margins and around the edges of swamps until cleaning could be accomplished. Condemned flour was the most commonly used diluent but was unsatisfactory because in the humid climate bacteria and mold contamination tended to make it lumpy. Lime, pyrophyelite, and talc were not available for use as diluents. DDT dust, 10 percent, gave excellent control but was little used because of lack of suitable dusting equipment. Survey men often carried a 2-ounce can of DDT dust for treatment of rain barrels and small road-rut areas.

Airplanes were first used in the South Pacific for the dispersal of insecticides in May 1944. This type of work was initiated on an experimental basis by members of NAMRU (Naval Medical Research Unit) No. 2 with the cooperation of base malaria control personnel. The Husman-Longcoy spray apparatus was installed on a Piper Cub plane. It was first used for evaluating the effectiveness of aerial spraying in heavy jungle areas of the tropics, the equipment having already been thoroughly tested for performance at the laboratory of the U.S. Department of Agriculture, Orlando, Fla. The success of the first tests, and the increasing availability of DDT, made it apparent that this method of application of insecticides would greatly increase the efficiency of the entire program and would, in addition, obviate the necessity of many extensive drainage projects then under consideration.[19] It offered, for the first time, a practical method of controlling mosquitoes in areas that

[19] Report, Capt. Bruce E. Sasse, SnC, to Officer in Charge, Malaria and Epidemic Control, South Pacific Area, 19 June 1944, subject: Airplane Spraying.

could not be entered because of the presence of uncharted landmines or other explosives. Steps were immediately taken to utilize aerial dispersal of DDT solutions and to explore the practicability of other types of airplanes for this work.

Several types of equipment for use on airplanes were developed in the South Pacific Area,[19] some of which were thought to be superior to the Husman-Longcoy spray apparatus because they could be readily constructed from material available at most airbases. Exhaustive tests, involving swath width, optimum flight speeds, droplet size, and biologic evaluations were conducted with various airplanes and items of spray equipment. No large multiengine airplanes were used routinely in the South Pacific since the terrain and the problems existing at that time were thought not to justify use of large aircraft. Aircraft used on both a routine and experimental basis included 65- and 85-hp. Piper Cubs and TBF and TBM planes. Tests were also conducted with F-4U airplanes, but the limited carrying capacity and high speed of this plane made it impractical for use in rear areas.

In order to increase the efficiency of aerial spray operations, and to take full advantage of the short period during the day when atmospheric conditions were suitable for spraying, a special ground crew was developed to load and service aircraft. This unit consisted of two or three men with a ¾-ton truck and tank trailer. Accessory equipment included such items as a motor-driven fuel pump, a hand-operated fuel pump, water-stop filter, fire extinguishers, sundry tools and replacement parts, DDT solution, and gasoline for the airplane. Thus equipped, the unit could move to the airfield nearest the site of operations for the day and service two Cub-type planes for one-half day of operations.

The effectiveness of aerial dispersal of larvicides in the control of mosquitoes exceeded the fondest hopes of the personnel in the South Pacific Area. Even in areas covered by a dense jungle, the fine spray penetrated to small ground pools, and the results were conclusive. In retrospect, it appears that the use of DDT and airplanes could have prevented the disastrous epidemics of malaria that delayed and threatened the success of the early phases of the South Pacific campaign.

During the latter part of 1944, the increasing use of DDT solution in diesel oil for both aerial and ground dispersal brought out a new operational problem. Hand mixing of this material was slow and tedious, and when the consumption on larger bases rose to several hundred gallons daily it was necessary to devise some means of mechanical mixing. The most practical of the methods devised for turning out large quantities of solution involved conversion of a 400-gallon capacity orchard sprayer to a mixing vat. A satisfactory

[19] (1) Report, Lt. S. R. Fallender, USNR, February 1945, subject: Analysis of Aircraft Spraying and Equipment for Routine Use in Malaria Control. (2) Report, Lt. Comdr. H. S. Hurlbut, USNR, Guadalcanal, dated 10 and 12 Feb. 1945, subject: Droplet Size, Distribution and Swath Width for Husman-Longcoy and Fallender Type Airplane Spray Equipment.

solution could be obtained in a short time by means of mechanical agitation, and this means was used to supply DDT mixtures to all base control units and sanitary companies on Guadalcanal. The solution was returned to the empty diesel oil drums, which were used to transport the material from the central mixing station to substations. By continued re-use of the same drums, any residues of precipitated or undissolved DDT were not wasted but were retained in subsequent lots of the solution. An improved method for the preparation of DDT-diesel oil solution on a large scale was subsequently developed and is described in the section on Okinawa.

Filling.—If DDT had been available from the beginning of malaria control activities in the South Pacific, it is possible that much less work aimed at reducing the existing water surfaces would have been required. However, although diesel oil was an effective insecticide when properly distributed, its spreading qualities on water were not sufficient to give good control in pools and swamps containing abundant vegetation or debris. Under such circumstances, it became imperative to bring the total water surfaces requiring larvicidal treatment within the capacity of the crews available. Accordingly, a systematic attempt was made to eliminate all possible surface water. Among the first of the projects of this type was the filling of shell and bomb craters, abandoned bomb shelters, pits along roads, and foxholes. When bulldozers were available, they were used for the larger water catchments. Smaller catchments, such as foxholes, usually in somewhat inaccessible places, were best sought out and filled by crews of Melanesians. Since Melanesians customarily wore no footwear, one important modification had to be made in equipment to assure its proper use. Shovels were provided with a broad plate on the blade next to the handle so that foot pressure could be applied.

One of the most important of all filling operations was the elimination of road ruts by the use of a disk harrow. Especially on Guadalcanal, where innumerable miles of ruts were cut through the extensive grasslands, this was a most important contribution to malaria control. Once disked and closed to vehicular traffic, these areas were quickly revegetated and gave no further trouble.

Clearing and stream cleaning.—The clearing of undergrowth during the process of establishing bivouac areas automatically reduced the existing mosquito population to a considerable extent through the elimination of harborage. Although this was an important contribution to mosquito control, it was not considered sufficiently important to warrant clearing outside the cantonment area. The major portion of the clearing that was done for mosquito control consisted of cutting away the marginal growth along streams to expedite the passage of oiling crews and of removing emergent aquatic vegetation and debris from swamps and slow streams. Cleaning of streams hastened the runoff of water and greatly improved the drainage of an area. Since slow, sluggish streams and swamps were important sources of anopheline breeding during periods of little rainfall, reduction of the mosquito population in such places delayed the spread of breeding to temporary surface pools that developed following heavy rains.

The job of stream cleaning and clearing of underbrush was accomplished by native laborers whenever they were available. Troops were very reluctant to do this type of work because it was dirty, tiresome, and frequently resulted in fungus infection of the skin. Moreover, Melanesians were infinitely more skilled in the use of machetes, the preferred tool for this type of work, and could accomplish a great deal more than a similar number of troops working under the same conditions; moreover, the cost was relatively low.

Stream cleaning in the Solomon Islands was not entirely a dull routine. Many of the sluggish streams were inhabited by crocodiles, some of which reached a length of 10 or 12 feet. When one of these ill-tempered reptiles was encountered by a native crew, a scene of wild confusion ensued, which might be compared with the spectacle of a pack of dogs around a raccoon at bay. The Melanesians were anxious to kill or capture the quarry but were still respectful of the damage that could be inflicted by it. The chase nearly always ended in a feast of crocodile meat. The tail was much prized as food, the meat being white and shrimplike in taste when properly prepared.

Drainage.—Drainage projects planned and carried out by the malaria control organization in the South Pacific were customarily accomplished either by hand ditching, dragline ditching, or the use of explosives. By July 1944, on all bases combined, there were 157 miles of dragline ditches, 153 miles of hand-dug ditches, and 26 miles of ditches made with explosives. These figures involve only operations done primarily for the purpose of mosquito control. They do not include ditching accomplished by organizations engaged in establishing or improving bivouac areas, ditching in connection with new road construction, or shallow ditches cut with a pull grader.

Draglines, either ⅜- or ¾-yard capacity, were used primarily on major drainage projects such as draining swamps, channeling sluggish streams, deepening existing roadside ditches, or connecting oxbows with stream channels. In swampy areas, the use of mats was necessary, especially during the rainy season. Ditching machines were of little value and were little used. When such equipment was used, it was necessary to follow up with a hand crew to cut the ditch sides back to a 45-degree angle to prevent cave-ins and ditch blockage. Underground title or tile inverts were not used.

Many of the roads constructed during the early phases of the campaign were completely unsatisfactory from a drainage standpoint. This was also true of some airfields, although Koli Field and Koli bomber strip, constructed in the flat alluvial plain on Guadalcanal, were notable exceptions. The most common fault in road construction was failure to cut ditches to grade and failure to install sufficient or properly placed culverts and connecting drainage with stream courses. For example, the main highway on Guadalcanal, between the little Tenaru and Nalimbiu Rivers, was so constructed that during the rainy season of 1943–44 it blocked the drainage of approximately 500 acres of grassland to the south which was flooded with water to a depth of several inches. In order to eliminate this hazard, it was necessary to cut several miles of shallow ditches with a pull grader and to connect the entire network of ditches into a main ditch leading to the Nalimbiu River.

Hand ditching was customarily limited to the construction of shallow ditches. Most medical sanitary companies had ditching platoons organized to carry out such projects. Melanesians were not skilled at ditch digging and were little used for this purpose. Feeder ditches from bivouac areas were ordinarily dug by details from the organization concerned.

In very swampy areas, explosives proved the most practical method of ditching. Some work was accomplished with dynamite, but this item was difficult to obtain and, being inferior to bangalore torpedoes for use in swamps, was not widely used. Bangalore torpedoes, metal pipes packed with high explosive, condemned for combat use and hence readily available to malaria control organizations on some bases, proved ideal for use in soft, mucky soil. By laying these bangalores in a series and pressing them slightly into muck or soft mud, several yards of ditch could be dug with one explosion. Bangalores had the added advantage in that upon fragmentation the hundreds of pieces of sharp steel cut away the undergrowth and small roots, leaving a well-trimmed ditch. If greater depth was desired, a second series of bangalores, laid in the first ditch, would complete the job. In the same way, small shallow streams could be rapidly cleared of muck and debris.

On those islands having a thin topsoil and coral substratum, vertical drainage could be accomplished with relatively little effort. On Green Island, for example, vertical drainage of small catchments required only a few holes punched through the soil into the porous coral beneath. A single blow with an iron rod would often sink the rod to a depth of several feet. Limestone sinkholes were present on some of the islands, and although they often silted in and became closed they could usually be opened with a single charge of dynamite. On Munda, Ondongo, and Bougainville, large bomb craters in some instances gave excellent vertical drainage.

Flushing.—Flushing dams were constructed in suitable streams in a few instances, and where accompanied by stream cleaning they were very effective in controlling mosquito breeding of all kinds. Without stream cleaning, they were ineffective. In all, a total of nine dams were constructed, seven on Guadalcanal and two on Efate. In view of the difficulty of construction, and lack of suitable materials, it is doubtful if wide use of flushing dams under most conditions of military occupation is justified.

Natural control.—*Gambusia*, the surface feeding fish often used in tropical areas for the control of anopheline mosquitoes, was used on several bases in the South Pacific. Stocks were placed in swamps and permanent ponds on Espíritu Santo and Munda, and in wells and cisterns of Efate. They had been stocked on the Russell Islands many years previously. Their chief value was in reducing breeding in marginal areas not readily accessible for larviciding.

They were of little or no value in the presence of vegetation. Except for use in wells and cisterns, they were not routinely stocked within the established control areas. Even after establishment, constant maintenance and restocking was necessary.

Flumes.—Coastal lagoons on Bougainville, Green, Emirau, and Guadalcanal Islands constituted one of the most difficult control problems encountered. There were more than 60 lagoons along the coast within the occupied area on Guadalcanal. These served as permanent breeding foci for *A. farauti* during the dry season, and even though breeding in other areas was minimal at that time the populations developing in the lagoons served to repopulate adjacent areas whenever surface water became available. Control of breeding in lagoons was therefore given high priority in the control program.

These coastal lagoons ordinarily remained closed for long periods of time, although they were occasionally opened by flash floods during periods of heavy rainfall. Water within the lagoons rose to a level of 3 or 4 feet above sea level and provided ideal breeding sites for malaria mosquitoes. Cutting ditches through the enclosing sandbar offered only a temporary solution since wave action would quickly close the mouth of the stream, usually within 24 hours. The problem was finally solved by the use of flumes made from a series of oil drums with the ends removed and welded together end to end. The lagoon end of the flume was set approximately 6 inches below sea level at mean low tide, and the flume extended out through the sandbar until the opposite end was approximately 12 inches above the floor of the sea beyond the area of normal surf action. The length of the flume depended upon the pitch of the beach. The first flumes installed were placed at the narrowest point in the sandbar, but experience showed that there was more likelihood of the structure being washed out during storms if placed at this point. Subsequently, it was the general practice to place flumes well to one side of the narrow point in the sandbar.

Flumes were held in place by pilings placed on each side at intervals of 5 feet. These pilings were set with the aid of a water jet from a 500-gallon-per-minute fire pump. An experienced crew of 14 men with dragline, bulldozer, and fire pump could set double flumes some 200 feet long in from 4 to 6 days. Flumes were prepared in sections of from 15 to 20 feet in length at a welding shop and transported to the job in sections. Multiple flumes were required in some instances for large lagoons, six being the maximum installed at any one lagoon. When multiple flumes were set, they were usually laid in pairs, each pair being somewhat removed from the adjacent pair.

Flumes properly installed not only permitted the water in the lagoon to be drained, but permitted entry of some sea water and at least a slight change in the salt content of the water in the lower end of the lagoon. There was also daily fluctuation of water level in the lagoon. Under these conditions, the flora of these coastal swamps either disappeared, or was considerably altered. Once flumes were installed, there was usually little necessity for other control measures.

Agriculture.—Cultivation of extensive areas of former grassland on Guadalcanal proved to be an effective mosquito control measure. Eventually, some 2,500 acres between the little Tenaru and Nalimbiu Rivers were under cultivation for the purpose of supplying troops with fresh vegetables. Much of this grassland area had at one time been badly rutted by vehicular traffic, and although this situation was largely corrected by the time the farm was established the cultivation of the area assured freedom from mosquito breeding. Even during periods of heavy rainfall, the surface water in the cultivated areas did not persist long enough to permit breeding.

Antiadult activities

Space spraying.—During the early phases of the South Pacific campaign, the only space sprays available were the petroleum base sprays dispensed with old-fashioned "flit guns." These were more often used against flies than mosquitoes. They were relatively effective in screened messhalls and similar places but were totally ineffective in open quarters. Pyrethrum Aerosol dispensers, the well-known "mosquito bombs," became available in limited supply in forward areas, during the first half of 1943, and were first used during a combat operation in July 1943 in the New Georgia campaign. By the time of the landing on Bougainville in November 1943, an adequate supply of Aerosol bombs was available and they were widely used. As new supplies arrived, there was a gradual replacement of pyrethrum Aerosols with bombs containing a small percentage of DDT. Five-pound refillable dispensers were used to some extent in messhalls, recreation areas, theaters, and similar places where large amounts of spray were needed.

Aerosols were little used in combat areas but were extremely valuable in rear areas. Proper use of an Aerosol bomb in shelters occupied during night air raids would give protection to a number of men, and their use in this manner was encouraged. In unscreened quarters and open foxholes, the effect was extremely transitory, especially during periods of even slight air movement. For killing mosquitoes in screened quarters or in mosquito bed nets, Aerosol bombs were unexcelled. Aerosol preparations were also widely used to spray huts occupied by native laborers, in order to kill any malaria infected mosquitoes that lingered following a nocturnal blood meal. A daily schedule was established for this work, with a native dresser trained to do the spraying.

Thermal Aerosols were used on a few bases in the South Pacific, largely on an experimental basis.[29] Although they were of value under certain circumstances in reducing existing adult mosquito populations, their general use was not possible because of limited road nets. Nighttime operation was most effective, since the atmospheric conditions prevailing at that time usually held the Aerosol fog close to the ground. Daytime applications along the beach

[29] Brescia, F., and Wilson, I. B.: Treatment of Native Villages With the Aerosol Generator. J. Econ. Ent. 40: 313-316, 1947.

area, for reduction of sand fly populations, were successful in some instances but the effect could seldom be noted for more than 2 or 3 days.

Residual spray applications of 5-percent DDT in kerosene were by far the most effective insecticide applications for reduction of adult mosquito populations in the South Pacific. Eventually, nearly all buildings and enclosed tents were so treated. Most of the work was done with a power-driven paint sprayer operating at low pressure; the solution was applied to screens with a paintbrush. Other types of spray equipment were also used for treatment of the interior of structures. Regardless of the equipment used, the recommended rate of application was 1 quart per 250 square feet of surface. The general "rule of thumb" was to spray wooden surfaces until wet, but just short of runoff. This treatment was not only effective against mosquitoes and flies but was remarkably effective in eliminating ants from quarters where they had been extremely annoying before the use of DDT.

DDT residual-type spray was also used to impregnate bed nets. This practice was begun during the latter part of 1944, and the methods developed at that time were later used for treating bed nets and jungle hammocks for the use of two divisions. The solution was applied with either a power-driven paint sprayer or the standard chemical warfare decontamination sprayer such as was widely used for larviciding. Application was at the rate of 1 gallon per 6 to 8 nets. The method of application was to arrange the nets in a pile, spray the top net, turn it to start a new pile, and then spray the opposite side. Operating in this fashion, 6 men with 4 hand-operated sprayers were able to spray from 60 to 100 nets per hour; a similar crew working with power-operated sprayers could treat twice as many in the same period of time. This included preparation of the nets, spraying, and hanging the nets to dry.

Nets tested immediately after treatment and after being stored for 1 month were lethal to *A. farauti* and other species of insects used for biologic tests of the material. No further information as to the duration of effectiveness was obtained.

Screening.—Screening of any kind was practically nonexistent during the early phases of the campaign, but by early 1944, it was available in adequate amounts in all except forward and combat areas. Table 67 shows the relationship between length of occupation of each base and the percentage of screened quarters as of June 1944. Cloth bobbinet was preferred to wire for field use and for use on installations near the shore where it was exposed to windblown salt spray. During the time that the amount of screening was limited, the following priorities were established: Hospitals, kitchens, and messhalls; showers, particularly for organizations with men on night details; latrines; and offices, tents, and all other living quarters. Judicious use of the available screening materials undoubtedly contributed greatly to the reduction of malaria, as well as to the general comfort.

Bed nets were probably the most valuable single mechanical barrier against mosquitoborne diseases. There were instances on Guadalcanal and elsewhere

TABLE 67.—*Estimated percent of quarters screened,*[1] *South Pacific Area, June 1944*

Base	Date of occupation	Kitchens and messhalls		Showers		Tents	
		Army	Navy [2]	Army	Navy [2]	Army	Navy [2]
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Efate	March 1942	100	95	90	90	100	100
Espiritu Santo	May 1942	100	100	90	95	90	90
Guadalcanal	August 1942	90	90	65	70	90	90
Tulagi-Florida	August 1942	100	100	100	100	100	90
Russells	March 1943	40	40	5	5	10	10
Munda	July 1943	100	100	10	20	40	30
Bougainville	November 1943	100	100	50	15	5	5
Green Island	February 1944	100	100	40	25	15	10
Emirau	March 1944	100	95	75	25	20	2

[1] Hospitals occupied by Army and Navy were 100 percent screened.
[2] Navy data include that of Marines.

during the height of malaria epidemics where less than a week of bivouacking without bed nets resulted in a high infection rate among the troops concerned. A single night of exposure often resulted in considerable malaria in an organization. Because of such costly experiences, orders were issued making it the responsibility of each officer and man that bed nets should be available on the first night ashore except among troops actually in combat. Jungle hammocks were issued to many troops, including entire divisions beginning late in 1943. Where proper use of this item was possible, it gave excellent protection. However, the issue of jungle hammocks to all personnel of a combat force was probably not justified because these relatively bulky pieces of equipment were among the first to be discarded during combat operations. Further, it was seldom possible for all the men of a division to find suitable places for suspension of the hammocks. Head nets were practically never used for protection from mosquitoes, and their routine issue in the South Pacific Area was not considered justified.

Repellents.—Repellents were potentially one of the more valuable means of personal protection from mosquitoes and mosquitoborne diseases but were relatively little used for their intended purpose. They were more often used for protection from pest mosquitoes rather than *Anopheles*, and it is doubtful if repellents contributed materially to the prevention of malaria. Dimethyl phthalate, the most effective repellent for *Anopheles* in the southeastern United States, was comparatively ineffective against *A. farauti*. It was effective against chiggers and was used for that purpose on Bougainville where scrub typhus threatened to become a serious military disease. Rutgers 612 was superior to dimethyl phthalate for protection from *A. farauti*. The standardized repellent, consisting of 6 parts dimethyl phthalate, 2 parts Rutgers 612, and 2 parts Indalone, was not available until 1945.

In spite of the ineffectiveness of the repellents against *A. farauti*, their failure as a means of preventing malaria must be attributed more to antipathy toward their use than the fault of the item itself. Combat personnel often claimed that the enemy could smell the repellent if the wind was in the right direction. Service troops objected to the general messiness of the solutions and to the fact that dimethyl phthalate is a solvent for plastics. On Guadalcanal, nurses quartered in a beach area where sand flies were annoying refused to use repellents for protection but at the same time used copious quantities of an equally messy suntan oil. Supplies of repellent were adequate after the middle of 1943, and a surplus of over 12 million bottles by the end of 1944 attested to the failure to use this item.

Suppressive Medication

Administration policy and procedure

Atabrine was the only drug used in large quantities for the suppression of malaria in the South Pacific Area. Its value was established slowly and with difficulty. At the beginning of the campaign, little was known about its absorption, blood concentration, excretion, or toxicity. Throughout 1942 and 1943, there was disagreement and uncertainty regarding its use and dosage. Standard treatises upon malaria warned that Atabrine had a small margin of safety and that individuals receiving the drug should be under close observation.

Administration of the drug was frequently begun on shipboard as troops approached malarious islands, and seasickness, diarrhea, and emotional states were sometimes attributed to this drug. The yellow discoloration which it gave to the skin, although harmless, gave rise to the suspicion that Atabrine was injurious to the liver, and this rumor was intensified when epidemics of jaundice occurred among troops taking the drug. The rumor that Atabrine caused sterility was common and was fostered by the enemy through the broadcasts of "Tokyo Rose." The fact that this was effectively disproved by men of units sent for rehabilitation to populated areas did little to improve Atabrine discipline in forward areas. Added distrust of the drug arose when troops who supposedly were taking the recommended suppressive dose developed malaria. There was wide divergence of opinion among the medical officers of the Marines, who assaulted Guadalcanal in August 1942, regarding the value and the dangers of Atabrine as a suppressive drug. Some units took quinine, others took Atabrine, and many took nothing. There was no method such as was subsequently developed to supervise the administration of suppressive therapy.

The directives from the theater surgeon's office on the subject of suppressive Atabrine therapy illustrate the growth in knowledge of and confidence in this drug as the campaign progressed. The first such directive appeared in August 1942 and is quoted in part as follows:

Malaria Prophylaxis

> It is recommended that malaria prophylaxis be given as follows: Atabrine is the drug of choice. It should be given in doses of 0.2 grams twice weekly (0.4 grams per week). When it is used, it is to be considered advisable, after 3 months, because of slight cumulative effect of the drug, to substitute quinine for a period of 1 month. Quinine is given prophylactically in doses of 15 grains daily. This should be continued for one month and then Atabrine * * * resumed.

In October 1943, a new directive maintained the suppressive dose of Atabrine at 0.4 gm. per week, but the schedule was changed so that the drug was taken in one-half tablet (0.05 gm.) amounts per day on each day of the week except Sunday, when one tablet (0.1 gm.) was taken. In January 1944, the weekly suppressive dose was increased to 0.6 gm. per week, given in amounts of 0.1 gm. each day except Sunday. In November 1944, the final theater directive [21] on this subject increased suppressive doses of Atabrine to 0.7 gm. per week, 0.1 gm. to be taken daily.

Results

The value of Atabrine as a suppressive drug was gradually established by clinical observations made within the theater at a time when the studies on absorption, blood levels, and excretion were not yet available. It became apparent that a few heavily seeded units which had good Atabrine discipline were suppressing a large share of their malaria as long as they continued to take the drug. Thus, the 6th Marines reported less than 250 cases of malaria while on suppressive medication during January and February 1943 on Guadalcanal, as compared with over 2,500 cases in May and June after they had moved to New Zealand and had discontinued the drug. This organization of approximately 4,500 men was on Guadalcanal during the height of the malaria epidemic, was in severe combat, and had fewer cases of malaria than any other organization of equivalent size exposed in this area at the same time. Every man in this organization was given Atabrine under supervision and with the use of a checklist roster. Loading doses of the drug were given before arrival on Guadalcanal and 0.6 gm. per week while there. This dosage was given at a time when the theater directive called for 0.4 gm. per week. The regimental surgeon reported no evidence of toxicity due to the drug.

The 147th Infantry Regiment took suppressive medication in dosage of 0.4 gm. with poor to fair supervision from December 1942 through April 1943 on Guadalcanal and had a malaria rate during these 5 months which ranged around 1,000 per 1,000 per annum. This rate promptly rose after discontinuation of Atabrine in nonmalarious Samoa to an average of over 3,000 per 1,000 per annum for 5 months with peaks as high as 14,000 per 1,000 per annum in selected groups. Atabrine was then resumed with excellent supervision, and the rate dropped abruptly to well under 100 per 1,000 per annum.

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[21] Memorandum 183, Headquarters, South Pacific Base Command, 1 Nov. 1944, subject: Suppressive Treatment of Malaria.

Toxicity.—Temporary and minor gastrointestinal symptoms were not uncommon when Atabrine was first taken. Information regarding this possibility was publicized in directives and in educational material. It was recommended that medication for such individuals be continued in lower dosages for a brief period and that the full dosage be resumed as soon as possible. Less than 1 person in 1,000 developed toxic symptoms from the prescribed dosages. A few cases of skin lesions which simulated lichen planus pigmentation of the palate and subungual tissues[22] in those who took suppressive Atabrine for long periods was noted. Severe toxic manifestations including exfoliative dermatitis, hepatitis, and nervous symptoms such as confusion states were quite rare among those who took only the prescribed dose of 0.7 gm. weekly.

Research, education, and discipline

The careful studies and blood Atabrine determinations of Schaffer and Lewis[23] showed that the development of clinical malaria in troops who were supposedly taking Atabrine in suppressive doses was associated almost invariably with extremely low blood levels. These workers came to the opinion that a low Atabrine blood level was almost always due to laxity in taking the prescribed medication. They were able to confirm this by careful supervision of Atabrine administration with resultant rise in serum concentration and concurrent decrease in malaria relapse rate. Most important of all, they developed a technique which was capable of convincing the most skeptical line officer of the fact that a tightening up of Atabrine discipline would quickly reduce the malaria rates among his men.

Administration of Atabrine for suppressive purposes was ordered to be by roster for both officers and men. An officer or a noncommissioned officer was detailed to watch the actual swallowing of the drug by each individual. Precautions were taken to see that individuals who were not present were required to report and to take their medication under supervision. As already noted, the final directive on suppressive medication ordered a dosage of 0.7 gm. weekly given as 0.1 gm. daily. An alternative procedure was undertaken by the 25th Division during the latter part of 1944; the drug was given on 2 days a week in doses of 0.4 and 0.3 gm. The administrative problem was lessened and suppression appeared to be adequate.

Many men became adept in circumventing these directives by palming the drug or tucking the tablets between teeth and cheek. Administration by roster did eliminate much of this, but the only adequate solution was an educational program to impress each man with the value of the drug and with its harmlessness.

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[22] Lippard, V. W., and Kauer, G. L., Jr.: Pigmentation of the Palate and Subungual Tissues Associated With Suppressive Quinacrine Hydrochloride Therapy. Am. J. Trop. Med. 25: 469–471, November 1945.

[23] Schaffer, A. J., and Lewis, R. A.: Atabrine Studies in the Field; I. The Relation of Serum Atabrine Level to Breakthrough of Previously Contracted Vivax Malaria. Bull. Johns Hopkins Hosp. 78: 265–281, May 1946.

Discontinuance of Atabrine suppressive therapy

Atabrine suppressive therapy was discontinued in lightly seeded troops throughout the South Pacific Area as control measures became adequate to permit doing so without danger of significantly increasing malaria rates. This policy was initiated on Efate in September 1942 at a time when the malaria rate had fallen to 144 per 1,000 per annum from a peak of nearly 2,700 per 1,000 per annum during the previous April (table 61). Malaria rates in these heavily seeded troops rose rapidly during October and November, and suppression was resumed in all except a few uninfected organizations. This evidence against the blanket discontinuation of suppression in heavily seeded troops was strengthened during the next few months by such experiences as noted previously with the 6th Marines and the 147th Infantry.

These experiences resulted in the following prerequisites for the discontinuation of suppressive medication in malarious territory:

1. Anopheline breeding must be adequately controlled on the occupied portion of the island and also in any areas which the particular organization might enter for training or other activities.

2. Troops must be unseeded or lightly seeded with malaria. This was determined by the history of previous exposure and by a study of the malaria rates of each organization. Those units with a history of a high malaria rate were rarely recommended for discontinuation of suppression even if their rates fell to low levels under suppressive therapy. Occasionally, medication would be discontinued in a small pilot group in order to determine the degree of seeding in a large organization.

3. Troops were not removed from Atabrine suppression therapy while ground combat was in progress or was threatened or when they were scheduled for early movement to a combat or malarious area.

The final theater directive on this subject is quoted in part:

> 4. Island commanders are authorized to discontinue Atabrine suppressive treatment in selected "lightly seeded" units upon the recommendation of the Island malariologist as control measures become sufficiently advanced to permit doing so without interfering with the military effort.
>
> 5. Suppressive treatment may conceal the actual amount of infection or the gradual seeding of a unit. Apparent freedom from malaria may lead to a false sense of security and carelessness in regard to truly preventive measures such as mosquito control and individual protective measures. Therefore, the eradication of the *Anopheles* mosquito and protective measures against it must be continued with unabated energy.

The medical officer of an organization in which Atabrine was discontinued was advised to make an exception of those men known to have had *vivax* malaria and to continue them on suppressive medication.

Field Research

It is difficult to make any clear distinction between the routine daily operations and the investigational work that was necessary to initiate a malaria control program in the South Pacific. Before occupation of the various malarious bases, there was little concrete information about the problems to be encountered. From the beginning of the work, and almost throughout the period of occupation, there was need for continuing investigation of problems that had a direct bearing on the control program. These were usually done piecemeal, either in conjunction with or as adjuncts to the operational routine that became established. Occasionally, late in the South Pacific campaign, it was possible to assign personnel or units to investigational work for brief periods of time. On numerous occasions, from early 1944 on, it was possible to engage in research work in cooperation with special teams sent out by NAMRU No. 2.

Before occupation by the Armed Forces, only 30 species of mosquitoes were known from the entire Solomon Islands; by the end of the war, 70 species of this group were known from Guadalcanal alone. Practically all detailed information about the mosquito fauna of the South Pacific islands was either acquired or confirmed by entomologists working on insect-borne diseases during World War II. Initially, it was necessary to determine what vector or vectors of malaria were present on each base. The fact that *A. farauti* proved to be the only important species from this standpoint did not lessen the investigational work necessary to establish this fact. The bionomics of *A. farauti* were studied in detail.[24] Similar critical studies were made with other species to clarify their role in the transmission of filariasis.[25] Other field investigations in entomology were concerned with the hosts of trombiculid mites, the incidence and species involved in human myiasis, and the distribution and biologic features of various species of flies.

In the field of control operations, investigations were concerned with the determination of flight requirements of airplanes for use in aerial distribution of insecticides, droplet size analysis of airplane dispensed DDT, suitability of various types of hand sprayers, minimum lethal dosages of insecticides under tropical conditions, methods of applying residual type DDT spray to tentage and mosquito bed nets, and use of DDT in area treatment against adult mosquitoes.[26] The work accomplished was almost invariably the contribution of a number of individuals working together for the benefit of the program as a whole.

Parasitologic field research activities consisted almost entirely of surveys of malaria and filariasis in natives and troops. The results of the malaria surveys have been given previously.

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[24] Daggy, R. H.: The Biology and Seasonal Cycle of *Anopheles farauti* on Espiritu Santo, New Hebrides. Ann. Ent. Soc. Amer. 38: 1–12, 1945.

[25] (1) Byrd, E. E., and St. Amant, L. S.: Studies on Filariasis. Newsletters No. 14 and No. 16, August and October 1944. Headquarters, Malaria and Epidemic Control, South Pacific Area. (2) Bieber, R. J.: Studies on Filariasis Transmitted by *Anopheles koliensis* Owen in a Native Labor Camp on Guadalcanal. Newsletter No. 26, July 1945, Headquarters, Malaria and Epidemic Control, South Pacific Area.

[26] Special Report, Lt. John D. Maple, USNR, and Maj. Paul W. Oman, MC, dated 27 Nov. 1944, subject: Use of DDT in Area Treatment Against Adult Mosquitoes.

OTHER ACTIVITIES OF THE ANTIMALARIA ORGANIZATION

The Malaria and Insect Control Organization eventually engaged in a wide series of activities which grew out of the technical abilities of its personnel, especially those of the parasitologists, engineers, and entomologists. Most of these additional activities were concerned with the control of arthropodborne diseases, although there were occasional ramifications such as the campaign to exterminate rats, not only to destroy rats as hosts of the mite of scrub typhus but also because of the rats' economic depredations. The activities to be described briefly were usually carried on concurrently with malaria control work. Malaria was a year-round problem on the malarious islands of the South Pacific.

Dengue fever reached epidemic proportions on the Fiji Islands, New Caledonia, Efate, Espíritu Santo, and Tulagi-Florida Islands, in 1942–43. On Espíritu Santo alone, it caused illness in over 25 percent of the military population and resulted in over 80,000 sick days between January and June 1943.[27] Malaria tended to obscure the importance of this disease; actually, dengue occurred in sharper outbreaks and with a greater temporary disability to a military force than any other arthropodborne disease. Although the seriousness of malaria transmission was usually obscured by the use of suppressive medication, there was no such drug to blunt the immediate effect of a severe outbreak of dengue. Local malaria control groups had given repeated warnings of the potential hazard of tin can dumps and of other breeding places of the dengue-transmitting mosquito, *Aedes aegypti*. With the outbreak of these epidemics, the malaria control organization was given adequate authority, personnel, and equipment to cope with the problem. As a result, there was no dengue outbreak in 1944 on any base except in New Caledonia where it was held to very small proportions.

A severe outbreak of filariasis in the Samoan defense area led to the medical evacuation of many thousands of troops engaged in garrison and training activities. Studies made during this epidemic demonstrated that the disease syndrome called "mumu" by the natives was an early manifestation of infection by *W. bancrofti*. This syndrome was characterized by localized swellings, retrograde lymphangitis, lymphadenitis, and genital manifestations.[28]

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[27] Stewart, F. H.: Dengue Analysis of the Clinical Syndrome at a South Pacific Advance Base. U.S. Navy M. Bull. 43: 1233–1240, June 1944.

[28] (1) Dickson, J. G., Huntington, R. W., Jr., and Eichold, S.: Filariasis in Defense Force, Samoan Group; Preliminary Report. U.S. Navy M. Bull. 41: 1240–1251, September 1943. (2) Fogel, R. H., and Huntington, R. W.: Genital Manifestations of Early Filariasis. U.S. Navy M. Bull. 43: 263–270, August 1944. (3) Englehorn, T. D., and Wellman, W. E.: Filariasis in Soldiers on an Island in the South Pacific. Am. J. Med. Sc. 209: 141–152, February 1945. (4) Huntington, R. W., Jr., Fogel, R. H., Eichold, S., and Dickson, J. G.: Filariasis Among American Troops in a South Pacific Island Group. Yale J. Biol. & Med. 16: 529–537, May 1944. (5) Thompson, K. J., Rifkin, H., and Zarrow, M.: Early Filariasis in Young Soldiers; Clinical and Pathologic Analysis. J.A.M.A. 129: 1074–1079, December 1945. (6) Byrd, E. E., St. Amant, L. S., and Bromberg, L.: Studies on Filariasis in the Samoan Area. U.S. Navy M. Bull. 44: 1–20, January 1945.

It was discovered that *A. farauti*, the chief vector of malaria in the Solomons and New Hebrides, was also the most important vector of filariasis in these islands.[29] *Anopheles koliensis* was also found to be a vector of filariasis on Guadalcanal. Thus, the exercise of malaria control on these islands had fortunately furthered the control of filariasis.

The outbreak of tsutsugamushi disease (mite-borne typhus) on Bougainville in 1944 resulted in making the local malaria control organization responsible for preventive measures, including rodent control and the impregnation of clothing with dimethyl phthalate. Study of this disease and its control was aided by the arrival of an advance group from NAMRU No. 2. Over 75 cases of tsutsugamushi disease occurred on Bougainville, 49 of which were reported by Anderson and Wing.[30]

Rodent control was undertaken both to prevent economic loss from rats and to prevent spread of epidemic diseases which were harbored or transmitted by rats or their ectoparasites. An officer qualified as a mammalogist or with civil experience in rodent extermination was appointed as rodent control officer and attached to the Malaria and Insect Control Group at each large base. An adequate number of enlisted men, equipment, and transportation were provided. A manual was prepared, men from each military unit on the island were trained in the technique of rodent extermination, and their work was then supervised. Fumigation of ships for rat extermination was done on request.

Part II. Okinawa and Other Islands of the Ryukyus

GENERAL CONSIDERATIONS

This report is concerned with the history of malaria and other insect-borne diseases on Okinawa and adjacent islands in the Ryukyu Islands Command from the initial landings on 1 April 1945 until late in the fall of that year, after the end of the war.

Malaria was a potential threat which was prevented from developing during the combat phase and was subsequently held to a minor outbreak among natives in military government camps and to a small number of cases among adjacent troop units. This was accomplished by careful planning and prompt initiation of antimosquito measures. Airplane spraying of ricefield areas, even under combat conditions, was brought to the highest peak of efficiency obtained during the war in the Pacific and was carefully coordinated with ground control activities. An essential feature was the development of a plant for large-scale mixing of DDT with diesel oil.

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[29] See footnotes 24 and 25, p. 472.

[30] Anderson, W. L., and Wing, W. M.: Tsutsugamushi Disease (Scrub Typhus); a Clinical Study of Forty-nine Cases. War. Med. 8: 163–166, September 1945.

It was evident within 30 days after the initial landings that personnel, equipment, and supplies would be more than adequate to control malaria. A considerable amount of effort was then diverted to control breeding of flies, especially during the combat phase. It is believed that these efforts were a factor in the absence of diarrhea and dysentery which had plagued all previous combat operations in the tropics and subtropics. It should be noted, however, that fly control would have availed little had it not been for the outstanding work of the sanitary engineers in providing a safe water supply.

A localized but sharp outbreak of Japanese B encephalitis occurred among natives concurrently with the epidemic of malaria already noted, and 38 cases of encephalitis developed in troops bivouacked near these natives. Intense antimosquito activities were immediately initiated in the epidemic area, and the outbreak was rapidly brought under control.

The antimalaria organization and the control activities were similar to those already described (p. 401) with certain notable exceptions which are to be discussed in detail.

MILITARY DEVELOPMENT

The military invasion and the occupation of the Ryukyus was the first step in the plan of the United States to penetrate the inner ring of Japanese defense. In addition to cutting the enemy's air communications through the Ryukyus and flanking his sea communications to the south, Okinawa furnished airbases within medium bomber range of Japan and an advanced naval base. The plan was to use it as a supporting position for the invasion of Kyūshū and Honshu. The calendar of operations was as follows:

Assault landing, Kerama Islands, 26 March, secured 29 March 1945.

Assault landing, Okinawa Island, 1 April, secured 30 June 1945.

Assault landing, Ii-shima Island, 16 April, secured 21 April 1945.

This campaign, as is well known, was marked by some of the bitterest fighting and by the heaviest Allied casualties of the war in the Pacific. Severe combat on Okinawa was concentrated in the southern half and especially in the southern one-third of the island.

Before the military occupation of Okinawa, it was known, through Japanese reports, that malaria was endemic in the Ryukyu Islands. The extent of the problem and degree of endemicity was unknown.

Some of the troops, ground and air force and Navy, taking part in the invasion and occupation, had been seeded earlier with malaria in the Philippines, New Guinea, and the Solomon Islands, although there were no heavily seeded units in the operation. Most of the units participating had had minimal or no exposure to malaria earlier. Table 68 indicates the strength of the Tenth U.S. Army.

By 18 April, the entire northern peninsula of Okinawa had been captured (although guerrilla forces still operated), and the battle lines in the south had settled down along a line across the island from Naha and Shuri to south of Yonabaru. The entire central part of the island and the north, freed of all except occasional guerrilla actions, was available for rear-area installations. Military government installations and native camps were located in the north of the island, and airfields, dumps, hospitals, and camps were set up in the flatter central region.[31]

TABLE 68.—*Strength of Tenth U.S. Army and marine and naval forces, in the Ryukyus campaign, 30 April–30 June 1945*

Month	Army	Marines	Navy
1945			
April	102, 250	88, 500	18, 000
May	167, 971	58, 894	21, 793
June	190, 301	[1] 2, 489	[1] 1, 225

[1] The marked decline for Marine and Navy strengths in June is the result of reassignment of units rather than of large-scale evacuation of personnel.

AREA CHARACTERISTICS

Physiogeography

The Ryukyu Islands lie southwest of Japan proper, northeast of Formosa and the Philippines, and west of the Bonins. The islands, peaks of submerged mountains, stretch in an arc about 790 miles long between Kyūshū and Formosa, and form a boundary between the East China Sea and the Pacific Ocean. The archipelago consists of about 140 islands, only about 30 of which are large enough to support substantial populations.

Okinawa is the largest of the islands in the Ryukyus. Extending generally north and south, it is 60 miles long and from 2 to 18 miles wide, with an area of 485 square miles. The terrain in northern Okinawa, the two-thirds of the island above the Ishikawa Isthmus, is extremely rugged and mountainous. A central ridge, with elevations of 1,000 feet or more, runs through the length of the region; the ridge is bordered on the east and west by terraces which are dissected by ravines and watercourses, and it ends at the coast in steep cliffs. About 80 percent of the area is covered by pine forests interspersed with dense undergrowth. Narrow coastal roads go up the east and the west coast, with several narrow mountainous cross-communicating roads. The Motobu Peninsula, which is nearly square in shape and juts to the west, also has a mountainous and difficult terrain. Two mountain tracts separated by a central valley run east and west the length of the peninsula. About 3½ miles off the northwest end of the Motobu Peninsula is the small

[31] Appleman, Roy E., Burns, James M., Gugeler, Russell A., and Stevens, John: Okinawa: The Last Battle. United States Army in World War II. The War in the Pacific. Washington: U.S. Government Printing Office, 1948.

flat-topped island of Ii-shima, with a sharp pinnacle about 500 feet high at the eastern end.

The southern third of Okinawa, south of Ishikawa, is rolling hilly country, lower than the north, but broken by terraces, steep natural escarpments, and ravines. The section is almost entirely under cultivation and contains three-fourths of the population of the island and the large towns of Naha, Shuri, Itoman, and Yonabaru. Rice paddies fill the lowlands near the coasts. The roads are more numerous than in the north but usually little more than country lanes. Drainage is generally poor, and heavy rains turn the area into a quagmire of deep claylike mud.

Shortly after the occupation, the Yontan and Katena airfields were taken over, the naval base established in Nakagusuka (Buckner) Bay, and that portion of the island between Ishikawa to the north and Adaniya to the south became the center of the base military activities of the island. Most of the unloading was done on the western beaches, and most of the quartermaster areas were there. Unloading of naval supplies proceeded on the beaches on the east coast.

Climatic Features

Although located within the Temperate Zone, the Ryukyu Islands have a subtropical marine climate with a relatively high and equable temperature throughout the year. This is due in large part to the influence of the Kuroshio which arises in the equatorial ocean currents north of the Philippines and flows northeastward among the islands of the Ryukyu Archipelago. Ranging from 5° to 15° F. warmer than the other ocean waters about it, the Kuroshio serves to intensify the heat and humidity of the sultry monsoon winds from the south in the summer and to warm and moisten the cold monsoon winds from the north in the winter. The result is both an increase in year-round temperature and humidity and a modification of the climate extremes that would otherwise prevail. At Naha, which is located approximately midway in the Ryukyu chain, the mean annual temperature is 75° F. January and February are the coldest months, averaging 61° F. in Naha. Between March and May, the temperature rises rapidly, culminating in the very warm season from June to September, when the temperature hovers about 81° F. In the last quarter of the year, it drops swiftly, and December averages only two to three degrees warmer than the two coldest months which follow. Extreme temperature variations are seldom experienced (table 60).

The mean annual moisture content of the air around the Ryukyu Islands is excessive, averaging 76 percent or more. Humidity is highest during the April-September period, when it averages about 80 percent. Even during the winter, the minimum mean compiled for any month at any station was 73 percent. Diurnal humidity variation is never very great; in summer, it amounts to only about 20 percent and in winter to about 14 percent. The diurnal maximums occur between 5 a.m. and 6 a.m. and the minimums between 1 p.m. and 3 p.m.

TABLE 69.—*Air temperatures (in degrees Fahrenheit), Naha, Okinawa, during a 30-year observation period*

Month	Temperature				
	Average	Mean maximum	Mean minimum	Highest recorded	Lowest recorded
January	61	67	56	80	43
February	61	67	55	81	41
March	64	70	60	82	43
April	70	76	64	87	48
May	74	80	68	91	52
June	79	85	75	94	59
July	82	89	77	96	69
August	82	88	77	95	71
September	80	87	75	93	63
October	75	81	69	91	59
November	69	75	64	89	47
December	64	70	58	82	44
Annual	72	78	66	96	41

Rainfall is heavy at Naha, the mean annual precipitation being 82.8 inches, with at least 4 inches falling in every month of the year. There is considerable variation in the amount of rainfall from year to year. The wettest year ever recorded at Naha had 113 inches; the driest only 42 inches.

The summer months receive the greatest amount of precipitation, and the winter months, from November through February, the least. The amount of rainfall in any single month, however, varies considerably from year to year. At Naha, the least precipitation ever recorded for a single month was 0.6 inch, the greatest 28.0 inches. The maximum recorded fall for 1 day at Naha was 16.8 inches. Such extremes of precipitation, however, are usually associated with typhoons. In contrast to the seasonal and monthly variation in amount of rainfall, the number of rainy days is fairly uniform throughout the year. Table 70 presents data on rainfall (in inches) and on the number of rainy days (with at least 0.04 inch of rain) for Naha, observations ranging from 30 to 40 years, as indicated in parentheses. Observations made at 13 minor weather stations on Okinawa indicated that the average annual precipitation varied from about 65 to 90 inches at different locations. The prevailing winds are easterly with a mean annual velocity of 8 miles per hour (range from 6 to 10).

The islands lie within the typhoon belt of the East China Sea. From 12 to 45 typhoons affect the Okinawa region each year, and from 3 to 6 can be expected to cross directly over the area. The months of greatest typhoon frequency are from May to October.[32]

TABLE 70.—*Rainfall (measurement in inches) and rainy days, Naha, Okinawa*

Month	Rainfall				
	Mean (30)	Maximum, in 24 hours (30)	Maximum for month (40)	Minimum, for month (40)	Rainy days (30)
January	5.3	5.9	16.4	1.2	19
February	5.4	3.5	12.1	.7	17
March	6.1	7.8	13.4	1.7	18
April	6.1	13.9	20.3	1.4	16
May	8.9	8.1	18.6	1.3	17
June	10.0	7.2	28.0	1.3	16
July	7.1	9.1	15.3	1.2	16
August	10.0	9.7	22.6	1.4	19
September	7.1	7.3	15.7	.9	17
October	6.6	9.8	24.9	.9	16
November	5.9	16.8	20.9	.6	16
December	4.3	4.2	9.9	1.7	17
Annual	82.8	16.8	28.0	0.6	204

NOTE.—Numbers in parentheses refer to years of observation.

Native Population

Okinawa, previously semi-independent and paying tribute to China, was annexed by Japan in 1879, and the people were integrated into the Japanese governmental, economic, and cultural structure. The racial origins of the Okinawans are similar to, but not identical with, those of the Japanese, and the Okinawan stock and culture has been subject to considerable Chinese influence. While the Okinawans generally resemble the Japanese in physique, they differ appreciably in their language, the native Luchuan tongue.

The standard of living of the Okinawan people is low; the Japanese made no attempt to raise it, regarding the Okinawans as inferior rustics. Most of the inhabitants subsist on small-scale agriculture. Every foot of usable land, even extending far up the narrow valleys, dissecting the northern peninsula, is planted, and terracing is extensive. Crops are sugarcane, sweet potatoes, rice, and soybeans. Livestock (cattle, horses, goats) were apparently abundant before military occupation. In 1940, the human population of the island was 435,000.

At the beginning of the military operations, the natives took refuge in caves and in the mountains; as soon as possible they were concentrated in AMG

[32] Further geographic and climatologic details can be secured from the Civil Affairs Handbook, Ryukyu Islands, Office of the Chief of Naval Operations, U.S. Navy Department, 15 Nov. 1944.

(American military government) camps in central and northern Okinawa. Some few natives were employed in the established military areas as laborers during the latter part of the campaign, but on the whole there was little association with troops, with the exception of the personnel of the AMG units and hospitals stationed directly in the native camps. The largest concentrations of natives after occupation was the northeast coast, with a series of camps from Kin to Sedake, and another large concentration on the northwest coast in the Gaira-Hentona region at the beginning of the Motobu Peninsula. The bulk of troops was far separated from these areas, in the central and southern part of the island.

According to reports of several native doctors interviewed during the early part of the campaign, malaria was unknown among the people in the southern part of the island, but occasional cases were seen each year in the north. Extensive examinations of natives carried out by malaria survey teams confirmed this impression—only 9 blood smears were positive in more than 2,000 examinations. A different situation was found during the subsequent malaria epidemic in northern Okinawa (table 71).

TABLE 71.—*Results of blood examinations of natives during malaria outbreak in northern Okinawa, August–September 1945*

Region	Number examined	Percent positive
Ginuza	750	1.3
Sedake	75	8.0
Taira	512	10.9

Source: Downs, W. G.: Malaria on Okinawa. Bull. U.S. Army M. Dept. 9: 654, August 1949.

Mosquito Vectors

The anopheline species present on Okinawa are limited to *Anopheles* (*Anopheles*) *sinensis* Wiedeman 1828, and *Anopheles* (*Anopheles*) *saperoi* Bohart and Ingram 1946.

Anopheles sinensis (fig. 55) was found to be widely distributed and abundant in the ricefield areas—in the south, center, and north of the island. *A. saperoi* [13] was found only in limited numbers in northern Okinawa, and, although captured biting man, was apparently so rare that it could be dropped from consideration as an effective malaria vector. The sole vector, by exclusion, was therefore *A. sinensis*.

Anopheles sinensis was commonly encountered breeding in flooded rice paddies, before the rice was high, and there can be no doubt that this con-

[13] (1) Bohart, R. M., and Ingram, R. L.: Four New Species of Mosquitoes from Okinawa. J. Wash. Acad. Sc. 36: 46–52, 1946. (2) Bohart, R. M., and Ingram, R. L.: Mosquitoes of Okinawa and Islands in the Central Pacific. Washington, D.C.: Bureau of Medicine and Surgery, U.S. Navy Department, 1946.

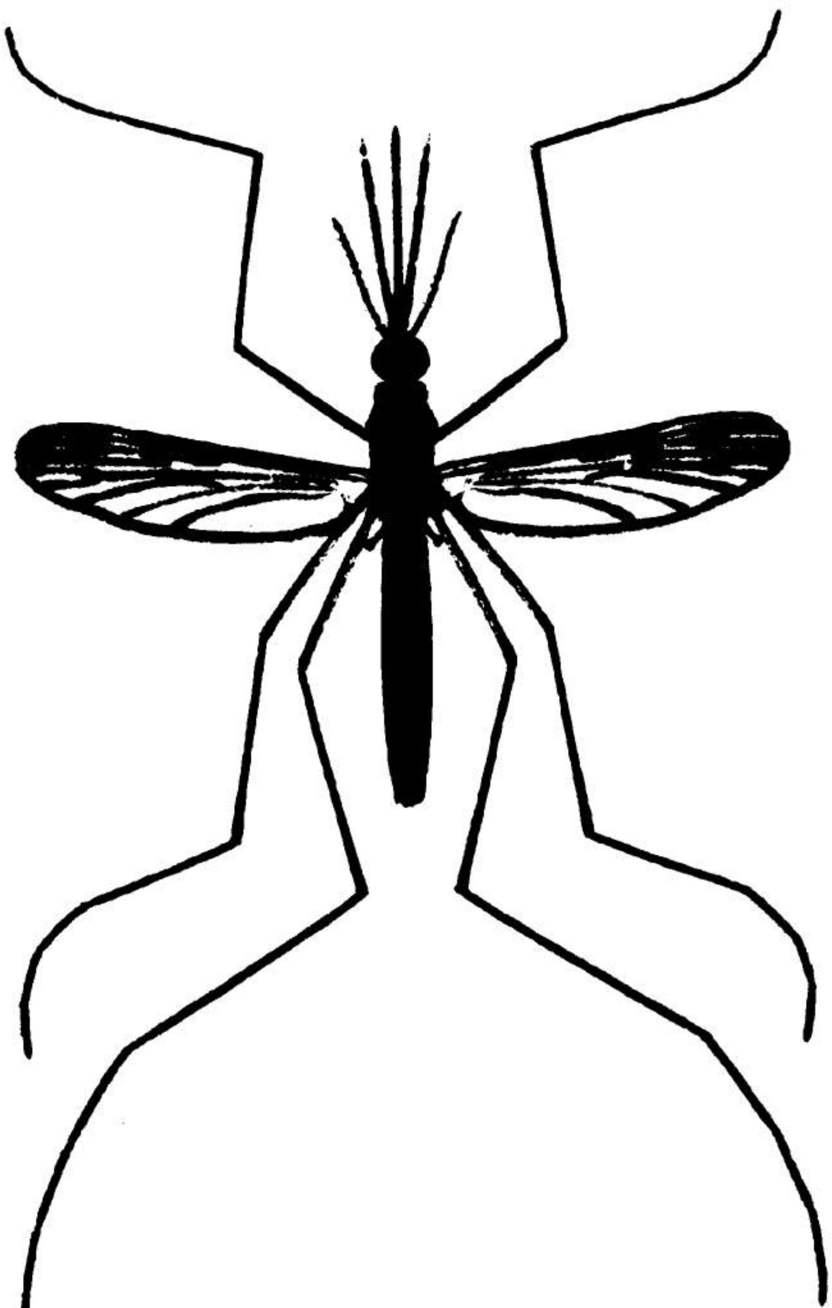

FIGURE 33.—*Anopheles sinensis.*

stituted the most favored breeding area. Widespread antilarval operations were begun promptly so that it was not possible to follow the aquatic phase closely.

Numerous observations were made on the habits of the adults of this species. Despite careful search of hundreds of dwellings, and of caves which would appear to be ideal refuges, adults were rarely encountered in such localities during the daylight hours, and there can exist no doubt that this species does not seek human habitation for refuge. Outdoor refuges were never encountered, although in some areas, mosquito densities, as determined by night captures, were high.

These mosquitoes became very active at dusk. If one stood outdoors, or in the doorway of a house, dozens of mosquitoes would land and attempt to bite within a short period of time. Even indoors, mosquitoes would be found to have entered freely and to be attempting to feed. This peak of activity lasted for less than an hour, and no observations are available as to whether activity was sustained through the night. Searching of houses shortly after the peak of evening activity revealed few or no mosquitoes resting within, suggesting that the mosquitoes leave after feeding.

Mosquitoes fed readily on man but were also observed and captured feeding on horses. No comparative studies of host preferences were made. In September, during the malaria outbreak in northern Okinawa, 72 *A. sinensis* were dissected but none contained *Plasmodium*.

Effects of Combat and Occupation on Malaria Potentialities of Area

Antimosquito operations were sufficiently effective that an outbreak of malaria was possible only under unusual circumstances. The required conditions developed around AMG camps in the areas shown on map 27 and resulted in a sharp epidemic of malaria among natives quartered in and near these camps, described as follows:

Good mosquito breeding places were adjacent to several of these camps. Although all of the AMG camps maintained antilarval crews to apply larvicidal oil to their immediate camp areas, this work was not extended far afield, or up to the narrow terraced valleys inland from the camps, because of the ever-present danger of sniper action, long after the island was declared secure. Airplane spraying was largely limited to the areas of troop concentration in the southern half of the island during May and June and was infrequent over the northern half. Moreover, the mountainous terrain in the north forced the planes to fly high and so decreased efficiency. Consequently, in many regions of northern Okinawa, anopheline populations had the opportunity to and did maintain themselves in considerable numbers. Moreover, the native livestock, probably the most important source of blood meals for the mosquitoes under normal conditions, was virtually eliminated. After several days' search in the Sedake area in the month of September, it was finally possible to find one horse to be used as mosquito "bait." Several horses were found and utilized in Japanese B encephalitis studies. Cows and goats were rarely seen.

It appears that the imbalance in the malaria transmission picture, occurring as the result of military occupation, was caused by the destruction of the usual animal blood sources, deviating the mosquitoes to humans, and, at the same time, the placing of humans in much more intimate contact with the mosquitoes, in the AMG camps, than would ordinarily be the case.

It is important to note, in connection with the habits of *A. sinensis* (entering houses to bite when necessary but feeding by preference outdoors and practically never remaining in houses as refuges), that all the native dwellings and structures in AMG camps and outside had been sprayed with a residual deposit of DDT in diesel oil before the epidemic began and one or more times during the course of the epidemic. The interior house walls were usually of unpainted wood paneling. No tests were made to determine how long the DDT residual deposits retained activity against mosquitoes.

MALARIA EXPERIENCE

There was no malaria in troops on Okinawa during the combat phase, 1 April–30 June 1945. In mid-July, an extensive outbreak of malaria began among the natives on northern Okinawa, and a few cases occurred among troops who were stationed nearby (map 28).[24] Only a few troop units were involved, and reports were fragmentary. The 27th Infantry Division reported 94 cases of malaria in August, most of them new infections. Company I, 5th Regiment, 1st Marine Division, spent 10 days at Kayō (near Sedake) in August and reported 48 new cases of malaria in 205 men. The 3d Battalion of the 147th Infantry stationed at Nago reported 24 cases of primary *P. vivax* malaria soon after its arrival early in September. None of these units was taking suppressive Atabrine. By mid-September, the epidemic had waned.

This outbreak was limited to troops in the northern part of the island; there was no malaria among the bulk of the troops who were stationed in the southern half of the island, although they were in proximity to many square miles of rice paddies and other potential breeding areas. The successful prevention of malaria among troops except for these minor outbreaks was due to early and intensive antimalaria work, especially airplane spraying. The cool weather during April, when the night temperature frequently fell to about 60° F., slowed down larval development at a time when control personnel were scarce. By the first of May, a regular schedule of air and ground application of DDT was in operation and practically eliminated mosquito production in the occupied portion of the southern half of the island.

The outbreak among the natives in the AMG camps on northern Okinawa was due to the unusual circumstances already described (p. 483). Malaria ap-

[24] Downs, W. G.: Malaria on Okinawa. Bull. U.S. Army M. Dept. 9: 652–655, August 1949.

MAP 28.—Okinawa Islands, showing localization of malaria outbreak of 1945.

peared in July and rapidly assumed epidemic proportions until brought to an end in September. It is estimated that from 2,000 to 3,000 cases occurred among the 20,000 to 30,000 natives who were crowded in the areas shown on map 28. All the cases observed were of *P. vivax*. In 600 slides examined from sick natives at Sedake, 90 percent were positive for malaria.

This epidemic of malaria was concurrent with an outbreak of about 160 cases of Japanese B encephalitis which occurred among natives and troops on northern Okinawa and on a small offshore island (p. 494).

It was soon apparent that airplane application of DDT and a small amount of antimalaria work by ground personnel would be sufficient to control malaria transmission in the areas of heavy troop concentration. Therefore, a large amount of work was devoted to the elimination of fly populations, especially during the combat phases and until bodies were buried. These activities have already been described in this chapter, but it is pertinent to note here that this was the first campaign in the experience of these authors in which there was virtually no dysentery or diarrhea among troops during the combat phase.

ANTIMALARIA POLICY AND ORGANIZATION

At Theater Level

Preinvasion planning was carried out at Navy and Army headquarters in Hawaii. Theater directives were prepared which were similar in essential respects to those already quoted for the South Pacific Area.

The staff officers who were responsible for developing the theater directives at headquarters in Hawaii were then assigned on temporary duty to fill the positions in preventive medicine in the Surgeon's Office of the Ryukyu Islands Command.

Arrangements were made for airplane spraying of the occupied area from D+2 to D+5 from a carrier based plane under the direction of Lt. John D. Maple. This activity was then transferred to Yontan airfield from which a C–47 was used for spraying; about D+7 this plane crashed and several aboard were killed, including Lieutenant Maple. The malaria control and survey personnel attached to the Army and Marine divisions taking part in this operation were shipped to arrive with their respective headquarters units. The majority of the Army malaria survey and control detachments and the medical sanitary companies were assigned to the Ryukyu Islands Command and were shipped to arrive in echelons from D+15 to D+180. Antimalaria supplies, especially DDT and equipment for its application, were also shipped in echelons.

At Local or Island Level

A team of five Army and two Navy officers, all of whom had worked together for long periods in the South Pacific Malaria Control Organization formed the nucleus of the Preventive Medicine Section of the Surgeon's Office of the Ryukyu Islands Command and coordinated malaria control activities for the Army, Navy, Marines, and military government units. These individuals went ashore with the Ryukyu Islands Command headquarters on D+4.

The following directives provide authority for and information about the insect and rodent program, of which malaria control was an integral part:

Operational Directive No. 4A, Headquarters, Tenth Army, dated 6 May 1945.

Operational Directive No. 7, Headquarters, Ryukyu Islands Command, dated 16 May 1945.

Memorandum No. 26, Headquarters, Ryukyu Islands Command, dated 1 June 1945.

The details of this program were explained in Medical Bulletin No. 6, Headquarters, Ryukyu Islands Command, dated 14 July 1945. The Preventive Medicine Section of the Ryukyu Islands Command was made responsible for the coordination of all antimalaria and other insect control activities. All malaria control personnel were ordered to communicate with the Preventive Medicine Section as soon after arrival on the island as feasible.

The Preventive Medicine Section of the Island Command Surgeon's Office was responsible for the allocation of antimalaria supplies. Knapsack sprayers and dusters were in limited supply but were obtainable at engineer dumps when requisitions were approved by Preventive Medicine Section. Other supplies were obtainable from the Quartermaster dumps, with the following allowances:

5 percent DDT in kerosene.—60 gallons per 1,000 men per month.

Aerosol, 1 pound dispenser.—225 per 1,000 men per month.

DDT dusting powder (larvicide).—50 pounds per 1,000 men per month.

Insect repellent (2-ounce bottle).—2,000 bottles per 1,000 men per month as authorized by Circular No. 91, Headquarters, U.S. Army Forces, Pacific Ocean Areas, 12 June 1945. The Preventive Medicine Section established a mixing station for DDT and diesel oil at Yontan airfield and assumed responsibility for the allocation of all of this material on quota basis.

At the time of termination of hostilities, 30 June 1945, three Army malaria control detachments, seven Army malaria survey detachments, three Army medical sanitary companies, and eight Navy units (including two rodent control units) had arrived and were at work on Okinawa or adjacent islands.

The Preventive Medicine Section of the Island Command Surgeon's Office, Tenth U.S. Army, maintained direct control over the malaria survey and control units attached to the Army divisions; the surgeon of the naval base maintained direct control over the Navy epidemic disease control units attached to the naval base and to AMG; the Air Force surgeon maintained direct control over the malaria survey and control personnel attached to the Air Force; and the Surgeon, III Amphibious Corps, Fleet Marine Force, maintained control over the two Navy epidemic disease control units attached to the two Marine divisions.

The activities of all were coordinated into the overall control program directed from the Island Command Surgeon's Office. Survey and control groups were assigned as teams and lived and worked together. Each team was assigned an area of the island as its responsibility. Maps were prepared and kept up to date showing the areas of responsibility of each team. Following cessation of hostilities, Army and Navy activities were sharply separated. A line of demarcation was drawn roughly down the center of the island; all activities to the east of the line were placed under Navy supervision and all activities to the west, under Army supervision. In spite of this geographic separation, cooperation continued to be close and effective.

One of the factors in maintaining coordinated efforts among the various malaria control detachments was a series of monthly meetings, begun in April 1945, of officers from all preventive medicine units on the island. Attendance was voluntary and excellent. A résumé of the disease picture as known, pertinent data on change in assignment of areas for control, on control methods, availability of supplies, and similar subjects were presented, followed by the presentation of results of investigations and operations conducted by the various units.

Unit antimalaria details or sanitary squads were organized and worked in the same manner as previously described (p. 446).

Malaria Control Labor

Skilled labor and supervisory personnel were provided by the malaria survey and control detachments and similar units noted previously. Medical sanitary companies and troop unit antimalaria details (sanitary squads) provided the bulk of unskilled labor. Natives were little used for control operations except around AMG camps. The wide use of airplane spraying greatly reduced the need for unskilled labor.

Airplane Spraying Arrangements

Preinvasion plans for airplane spraying called for daily operations beginning with the initial flights by carrier based TBF's and continued by land based C-47's as soon as the tactical situation permitted. This schedule was interrupted by the crash of the only C-47 available at the time after 2 days spraying from Yontan airfield. Airplane spraying was not resumed until May 1945, when one C-47 from the 9th Troop Carrier Squadron became available. Subsequently, two C-47's from the 316th Troop Carrier Squadron became available in June 1945.

During the combat operations on Okinawa, airplane spraying was under the operational control of the Island Command entomologist, Capt. Paul W. Oman, and the Command sanitary engineer, Capt. Eugene O. Harrison, SnC. The entomologist was responsible for selecting the area to be sprayed on the basis of survey information obtained from various malaria survey units, scheduling the flights, briefing the pilot and navigator as to the limits of the area to be covered, and coordinating with the Island Command Artillery control officer. The last precaution was necessary to assure that gun batteries would post a lookout for the low-flying plane during the hours when flights were scheduled. The engineer was responsible for mixing the necessary quantity of DDT solution and for loading the plane at Yontan airfield, where a hardstand had been constructed for that purpose. The efficient operation of the airplane spraying program during the early part of the campaign was largely due to the efforts of Captain Harrison and his crew, who were able to reduce the loading time to a few minutes, thus saving valuable flying time during daylight hours.

Malaria Control Battalion

Early in the Okinawa campaign, the personnel concerned with the survey and control aspects of the preventive medicine program established a headquarters near Katena airfield, some 3 miles removed from Island Command Headquarters. As the number of malaria survey and control detachments engaged in work on the island grew, it became apparent that there was needed some adequately organized and staffed headquarters that could coordinate the work of the various units, handle supply matters pertaining to their activities, and centralize the administrative functions. As a result, shortly after the island was declared secure, a malaria control battalion was activated.

Other Military Agencies Engaged in Preventive Medicine

A highly significant undertaking in connection with the development of the preventive medicine program on Okinawa was the inclusion of a team of medical specialists, including both officers and enlisted personnel, of NAMRU No. 2, each man competent in a special field of disease investigation. The objectives of this team were to find out early and conclusively the potential danger to troops of scrub typhus, schistosomiasis, malaria, filariasis, and enteric diseases. Within a few weeks, it was shown that scrub typhus and schistosomiasis constituted no hazard and that no troop protective measures would be needed. Here it may be noted that enthusiastic but unqualified workers had claimed the presence on the island of a mite vector of scrub typhus and a snail host of schistosomiasis; both claims had been made as a result of incorrect diagnosis of the specimens and were refuted by NAMRU No. 2 investigators. The same group, cooperating with other personnel, particularly of Army and Navy survey units, helped to delineate the status of the malaria and filariasis problems and their potential hazard.

When the Japanese B encephalitis outbreak occurred, NAMRU No. 2 specialists were on hand with laboratory personnel and equipment to aid in study of epidemiology, etiology, and transmission. Within 3 weeks of the initial landings, NAMRU No. 2 personnel, with the assistance of the Island Command entomologist, had prepared and reproduced an illustrated synoptic key to the common mosquitoes found on the island. The great value to the preventive medicine program of having fully competent experts available during the early stages of occupation of unknown territory cannot be too strongly stressed. The savings effected through discontinuance of protective measures against scrub typhus and schistosomiasis were enormous.

Engineering work specifically aimed at malaria control was of minor significance during active operations against the enemy. Two naval construction battalions assigned groups of 50 persons to each of the two Marine divisions, to provide labor for sanitary work, and the Army Corps of Engineers assigned details to bulldoze over and clean up large areas devastated by combat. These details rendered valuable service in general sanitation and reduction of fly breeding by establishing sanitary garbage-disposal facilities and cleaning up fly-breeding areas in destroyed towns.

ANTIMALARIA ACTIVITIES

Training, Information, and Propaganda

These activities were similar to those previously described (p. 451), but they adapted to the problems peculiar to the Ryukyu Islands. Training directives were written (in advance of occupation) which included information about schistosomiasis, Japanese B encephalitis, and scrub typhus in addition to the usual sections about malaria, dengue, and filariasis.

The monthly meetings of officers from all preventive medicine units on the island have already been noted. In addition, a monthly medical bulletin, entitled "Malaria and Epidemic Disease Situation, Okinawa," was mimeographed and distributed to all preventive medicine units, Army, Navy, and Marine. This bulletin was made as complete as possible and presented details of the work conducted by all units, observations on new disease problems as these arose, and explanatory notes on new technical developments.

Survey Activities

Initial surveys in the south central portion of the island made early in April established the fact that, while there was a high larval population of *A. sinensis*, most of the population consisted of early instars. Cool weather during much of April prevented any considerable emergence of adults before airplane spraying was initiated, and once this control measure was in operation the intensive surveys so necessary for satisfactory control in the islands of the South Pacific proved unnecessary for the control of *Anopheles* in most areas. As a result, primary survey attention was then directed toward elimination of mosquito breeding in artificial containers, determination of the incidence of different species of fleas, and detection of fly breeding. The survey program was organized on an area basis, each survey unit, both Army and Navy, having a definitely delimited area of responsibility. Since mosquito development during the early part of the season was slow, survey coverage and reports were initially established on a biweekly schedule. Special surveys of port areas were made for the detection of possible dengue fever vectors. The overall operation of the survey program was essentially the same as that reported for the South Pacific Area.

Antimosquito Operations

Antimosquito operations were begun with the opening of the campaign and continued until the advent of cold weather in the fall.

Antilarval operations

Antilarval work was the most important of the mosquito control activities. Every unit of company size had its antilarval detail, equipped with knapsack sprayers and supplied with 5 percent DDT in diesel oil from the central mixing station at Yontan airfield, to be described later. The mixing station prepared larvicidal solution for all Army, Navy, and Marine units on the island.

Personnel from the malaria survey detachments made periodic surveys of the areas under their jurisdiction and when necessary indicated to unit spraying details the areas which were not being covered properly.

Airplane spraying was done with C–47 planes equipped with two 600-gallon tanks in the cargo compartment. These tanks discharged through a 1-inch pipe which projected a short distance below the belly of the plane. The oil flowed out of the tanks by gravity and was broken up into droplets by the air current.

Airplane spraying began on the first day of invasion (table 72). As the occupied area of the island expanded, the area covered by airplane spraying followed closely. So closely did it follow, in fact, that on more than one occasion it was discovered that the spraying was being done over enemy-held territory. Airplane spraying undoubtedly was instrumental in practically eradicating anopheline breeding from the southern part of Okinawa, where the terrain was in general low, and application of larvicide could be efficiently carried out. It is doubtful whether ground control measures would have been necessary at all in this part of the island. However, on northern Okinawa, the situation was different. The region was mountainous, with narrow deep valleys, terraced from bottom to top, with ricefields along the entire length. The planes had to fly high of necessity, and, with a work schedule necessitating flying spraying missions all day long, it was not possible to select hours of correct atmospheric conditions for spraying. Consequently, plane spraying was not adequate to cope with this situation. Ground control would have been possible, although difficult, since snipers infesting the valleys greatly hindered such work. The result was considerable production of anophelines and culicines throughout the season, and epidemics of malaria and Japanese B encephalitis occurred in northern Okinawa.

The rate of use of DDT, dissolving, for airplane spraying and ground spraying was nearly 1 ton per day, and it was often necessary to mix from 7,000 to 8,000 gallons of 5 percent DDT in diesel oil daily.

The mixing of such large amounts of DDT in diesel oil presented problems from the beginning, and, in the earlier days, it was a constant struggle to transport drums of diesel oil to the mixing station, keep adequate stocks of DDT on hand, and mix the solution in the individual drums. Mixing was simplified by the use of a compressed air pump. A pipe with a series of holes drilled in it was inserted in the drum, and the airblast turned on, giving more rapid and better mixing than if done by hand; however, expanding operations required a much larger installation. Captain Harrison designed a large-scale mixing plant, obtained materials from many sources, and then set up and maintained a most successful operation. Two 1,100-gallon pontoon tanks were installed on a platform 8 feet high. Two 750-gallon tank trucks and a 2½-ton truck, fitted with a 1,100-gallon pontoon tank were used to transport oil to the mixing station. This oil was pumped up to the pontoon tanks, where the DDT was mixed in, and stirred by an airblast from a compressed air pump. The mixed material was dispensed by gravity flow. One line went directly to the hardstand area, where the plane tanks could be filled directly.

TABLE 72.—*Airplane spraying activities, Okinawa, May–July 1945*

Month	Plane days C-47	Spraying TBF	Gallons diesel used	Pounds DDT, dissolving, used
May	13	4	33,850	13,440
June	48	2	134,500	38,300
July	54	----------	140,350	50,885

A novel procedure was used to help dissolve the DDT in diesel oil. Large quantities of DMP had been brought to Okinawa in gallon cans, in anticipation of a scrub typhus problem which did not materialize. It was found that DDT dissolved readily in dimethyl phthalate. Enough dimethyl phthalate was added to the charge of DDT for mixing with 1,000 gallons of oil to convert it to a sludgy liquid. This was then poured into the diesel oil, the airblast was turned on, and complete mixing took place within a few minutes.

Extensive filling and hand ditching were carried out as circumstances dictated, and with little use of heavy machinery. Apart from malaria control, extensive operations, including the use of heavy machinery, particularly bulldozers, were carried out to clean up the debris of combat from areas to be used for campsites.

Antiadult operations

Antiadult measures were employed initially and continuously. Space spraying with a kerosene-pyrethrum spray was carried out routinely in hospitals, messhalls, and similar structures. Aerosol bombs were also used. Experimental trials were made of the Hochberg-LaMer smoke generators and of generators developed from chemical warfare smoke generators.

Special squads from the malaria survey detachments attached to the combat divisions carried out the hazardous work of spraying all caves and shelters immediately after occupation of enemy territory by U.S. troops. Some extensive caves were sealed off by dynamiting the entrances to close them.

Residual spraying of native dwellings with DDT and diesel oil was planned before the campaign began. No data are available on the number of native dwellings treated with residual spray in April 1945. Approximately 5,700 such dwellings were sprayed in May; 23,300 in June; and 15,100 in July. No data are available for August or September, but it is known that more native dwellings were sprayed during these months than during the month of June. It is important to note that the repeated spraying of all the dwellings in the areas of native concentration in northern Okinawa did not prevent the malaria epidemic which has been described. This epidemic progressed despite airplane and ground application of larvicides and residual spraying of houses. Two conclusions are inescapable: (1) The antilarval measures used on northern Okinawa were insufficient to handle the mosquito breeding problem, and (2) the habits of *A. sinensis* adults are not such as to make malaria transmission by the species easily controllable by DDT residual applications inside dwellings.

Additional measures of malaria control included the use of mosquito nets as soon as the tactical situation permitted. The unit malaria control officers were responsible for the enforcement of this measure. As more permanent camp areas developed, quarters were screened and mosquitoproofed.

Insect repellents were provided in large quantities. The mosquito concentrations were low in the areas of largest troop concentrations, and demand for repellents was correspondingly small. One of the minor problems of the Quartermaster was what to do with the huge piles of cases of repellents on hand and those continually arriving.

Drug Suppression

At the time of the invasion, all the units coming to Okinawa had been on suppressive Atabrine regimen, for at least 10 days before arrival. The regimen was the established one of 0.1 gm. daily. The responsibility for maintaining malaria discipline within the units rested with the unit malaria control officer, who was advised and supervised in turn by the personnel of the preventive medicine unit in his area.

It was soon evident that malaria was not going to constitute a serious problem in the areas of heavy troop concentration, and it was therefore felt that suppressive Atabrine administration was unnecessary. By the end of June 1945, not a single new case of malaria had been seen in unseeded units. The outbreak in northern Okinawa had not yet begun. In June, it was recommended that all troops, with the possible exception of some heavily seeded air force units, be taken off suppressive Atabrine therapy, and this was accomplished by the end of August. There was no increase in reported malaria, either relapses or new cases, as a result of this, except for the troop cases which occurred in units stationed near natives in northern Okinawa, as noted previously (p. 483).

OTHER ACTIVITIES OF THE ANTIMALARIA ORGANIZATION

Because there was no significant malaria hazard in the southern part of Okinawa, the efforts of the preventive medicine personnel attached to the troops were diverted to other aspects of sanitation, including fly control, the delousing of natives and prisoners of war, and the investigation of other parasitic disease problems among the natives.

Fly Control

It soon became evident that flyborne diseases constituted a more serious hazard to the health of troops than did mosquitoborne diseases. By late April, most pit latrines showed considerable fly breeding, and this was supplemented by the inevitable unauthorized garbage dumps and improperly disposed fecal matter of the civil population. DDT in oil proved unsatisfactory for control of flies in latrines or in bodies. Experiments with xylene emulsion DDT showed that it would satisfactorily control flies in pit latrines, but the supply was limited. Furthermore, the use of xylene emulsion constituted a distinct hazard because of the volatility of the xylene, and, after one tightly constructed pit latrine was blown up by a flash explosion initiated by a discarded cigarette, no further consideration was given to the routine use of DDT emulsion for fly control. The problem was solved by the use of sodium arsenite, both for latrines and fly-infested bodies.[26] Because of the danger involved in the use of this poison, it was deemed advisable to control its issue and use. Accordingly, all sodium arsenite was mixed at the malaria control headquarters and issued to units, along with precautions as to its use.

Large fly populations developed on a few occasions in small areas, especially where combat had been severe and where large numbers of larvae were developing in unburied bodies. Airplane application of DDT destroyed the adult flies rapidly, and concurrent larvicidal work of ground crews prevented further breeding.

Epidemiologic Investigations

Filariasis.—Filariasis (*W. bancrofti*) is an endemic disease of great prevalence among the Okinawans. Although elephantiasis was rarely seen, the per-

[26] Stilson, A. E.: Okinawa, DDT and Water Treatment. J. Am. Water Works Assoc. 38: 625–636, 1946.

centage of natives harboring filaria on night counts was high. Blood examinations made at night during April and May on about 1,000 Okinawans showed 20 percent positive smears.

Dissections of mosquitoes were made in order to determine the vector or vectors of filariasis. Of 211 *Culex quinquefasciatus* mosquitoes captured in a hospital ward for native Okinawans, where every patient had circulating microfilariae, an infection rate of 5.4 percent was found. Of 57 captured at a distance (unspecified) from native camps, none was infected.

Simpson [36] found 4 of 49 female *A. sinensis* and 14 of 180 female *C. quinquefasciatus* infected with filarial larvae and suggested that *A. sinensis* may be a possible vector of filariasis on Okinawa and neighboring islands.

The danger of transmission of filariasis to troops was localized to the areas in northern Okinawa where natives were concentrated and where troop strength was relatively low and well separated from natives, except for the AMG units working directly in the native camps.

Denguelike disease.—In late April and May, there were several thousand cases of illness, particularly among combat troops, characterized by an initial high temperature, often preceded by a chill, and leukopenia. Fever usually lasted 3 or 4 days, only occasionally with a secondary rise. Aching of back, joints, muscles, and eyeballs was a prominent feature of the illness. Symptomatology and course was not unlike that seen in atypical dengue, but, in hundreds of cases, no rashes were observed. *Aedes aegypti* and *Aedes albopictus* were encountered rarely. Lacking characteristic features of dengue, and lacking the known insect vectors of dengue in numbers sufficient to maintain an epidemic of this size, it was concluded that the illness observed was not dengue. It was officially recorded as "denguelike disease" on the medical records.

Japanese B encephalitis.—Japanese B encephalitis appeared on northern Okinawa and the small offshore islands of Heanza Shima and Hamahika in early July. A total of 38 cases with two deaths was reported among U.S. troops. At the same time, there were in all 127 cases reported among natives, with a fatality rate of 28.6 percent among the 91 cases on Okinawa, and 30.6 percent among the 36 cases on the two islands. Only a few cases were confirmed by laboratory diagnosis. The outbreak ended in late September. The efforts of preventive medicine personnel were at once directed toward limiting the extent of this epidemic as much as possible. Nothing was known of its transmission, except that a mosquito vector was suspected. Mosquito control activities on northern Okinawa, including "saturation" plane spraying of all native camps, respraying of native dwellings with residual DDT, and ground control work, were greatly intensified, malaria control personnel being moved north from southern parts of the island, and plane spraying schedules being modified

[36] Simpson, T. W.: A Note on Filariasis Among the Natives of Okinawa, With Particular Reference to Possible Transmission of *Wuchereria bancrofti* by *Anopheles hyrcanus sinensis*. Am. J. Trop. Med. 31: 614–616, September 1951.

to give more attention to the north. Vaccination of all military personnel on northern Okinawa was carried out, using a mouse brain vaccine previously untried on humans. There was no evidence to indicate that the outbreak was affected in any way by the preventive activities carried out, nor on the other hand was there any evidence to contradict the viewpoint that it might have been much worse had such measures not been taken. Sabin [57] reported a detailed account of the outbreak of Japanese B encephalitis on Okinawa.

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[57] Sabin, A. B.: Epidemic Encephalitis in Military Personnel; Isolation of Japanese B Virus on Okinawa in 1945, Serologic Diagnosis, Clinical Manifestations, Epidemic Aspects and Use of Mouse Brain Vaccine. J.A.M.A. 133: 281–293, February 1947.

CHAPTER IX

Malaria and the Defense of Bataan

Maj. Gen. James O. Gillespie, MC, USA (Ret.)

The surrender of the Filipino-American Forces at Bataan occurred, after 4 months of defensive operations, on 9 April 1942. Defeat was inevitable because of the limited resources in men and materiel and inability to replenish them, but malaria and lack of food also played a significant role in the tragedy.[1] The will to fight was weakened and this hastened defeat. Complications of disease led to appalling death rates in prison camps.

A brief review of the epidemiology of malaria, problems of malaria control, medical war planning, and military operations may enable one to appreciate the devastating effects of disease and malnutrition on U.S. Forces, the enemy, civilian refugees, and Japanese-held prisoners of war during the long years of captivity.

EPIDEMIOLOGY OF MALARIA

The mountainous terrain and climate of Bataan provide ideal conditions for the propagation of the vector of malaria.[2] From the two chief mountain masses on Bataan, numerous streams course in all directions toward Manila Bay and the China Sea. The transition from the higher altitudes to the flat and narrow coastal plain through the foothills insures a rapid flow of water in the streams. The rainfall is sufficiently adequate to maintain a large number of permanent streams through the dry season, which extends from November through May. These provide adequate breeding grounds and support protective vegetation in which adult mosquitoes survive throughout the dry season.

The chief vector of malaria in the Philippines is *Anopheles minimus flavirostris*.[3] This mosquito breeds most readily in the protected areas of rapidly flowing rivers, streams, and irrigation ditches, preferring shady places and clear, fresh water. Breeding does not normally occur in salt water, rice paddies, or in water above 2,000 feet altitude. Thus, malaria in Bataan, as throughout the Philippines, is a disease contracted in the foothills, especially between the flat coastal plain and the higher ground below 2,000 feet altitude. Seasonal variations in the incidence of malaria are related to the effects of the

[1] Hewlett, F.: Troops on Bataan Routed by Malaria. New York Times, 18 Apr. 1942, p. 5.

[2] Russell, P. F.: Epidemiology of Malaria in the Philippines. Am. J. Pub. Health 26: 1–7, January 1936.

[3] Russell, P. F.: Malaria in the Philippine Islands. Am. J. Trop. Med. 13: 167–178, March 1933.

drying of the small tributaries of streams and irrigation canals and to the flushing of the breeding grounds during the heaviest rainfall. Thus, Bataan constituted a potent hazard for malarial infection during the season when military operations were feasible.

PRE-WORLD WAR II MALARIA CONTROL MEASURES

Before World War II, malaria control measures in Bataan had not been impressive, although surveys had identified the vector and determined the incidence of malaria in the native population.

In 1930, Headquarters, U.S. Army, Philippines, authorized malaria reconnaissance throughout the Islands to determine the location of maneuver areas of relative safety from malarial infection. Holt and Russell carried out a rather complete survey of Bataan during 1930 and 1931 and included Corregidor in their observations.[4] They collected mosquito larvae, made blood film examinations for malaria plasmodia, and determined splenic indices. Corregidor was found to be relatively free of malaria, but Bataan was found to harbor a large reservoir of disease. Splenic indices varied from 3 percent in the villages of the flat east coastal plain of Bataan to over 50 percent in the populated areas of the foothills in the vicinity of Limay, Lamao, Cabcaben, Mariveles, Sisiman, and Bagac.

After 1926, the Malaria Control Division, Philippine Health Service, had carried on demonstrations and local control programs throughout the Philippines including Bataan Province.[5] The excessive cost of this program had imposed an insoluble problem, and only moderate progress had been made in the eradication of breeding areas. Military maneuvers involving small forces had been carried out in Bataan during the dry season for many years. The contracting of malaria had been an annually recurring phenomenon of varying magnitude. In 1940, the surgeon of the Philippine Division reported an appreciable lessening of the incidence of malaria in troops engaged in maneuvers in Bataan.[6] He attributed this to proper use of mosquito bars and to a more careful selection of campsites. He emphasized the importance of locating sites, preferably on the beaches, in the coastal swamplands, or in rice paddies, and of avoiding the higher ground in the vicinity of rapidly flowing streams. Quinine prophylaxis was continued for 14 days after termination of the maneuver. The Philippine Division surgeon believed that it was impracticable to eradicate all of the potential breeding areas. Virtually no antimosquito control measures were carried out by the Army in Bataan at any time.

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[4] Holt, R. L., and Russell, P. F.: Malaria and Anopheles Reconnaissance in the Philippines. Philippine J. Science 49: 305–371, November 1932.

[5] See footnote 3, p. 497.

[6] McMurdo, H. B.: Malaria, 1940 Maneuvers, Luzon, Philippine Islands. Mil. Surgeon 87: 232–233, September 1940.

MEDICAL WAR PLANNING

The developers of War Plan Orange–3 for the defense of Luzon envisioned an attack on the Philippines by a superior enemy force, withdrawal of U.S. Forces from central Luzon, fall of Manila, and delaying defensive action in Bataan to protect the key defenses of Corregidor until the arrival of naval reinforcements from the United States. The plan called for a force of 40,000 men for the defense of Bataan and the removal of the civilian population upon outbreak of war.

Prewar implementation of this plan in Bataan was meager indeed. This was due in part to the provisions of the National Defense Act passed by the Philippine National Assembly in 1935, which authorized the formation of a 400,000-man Filipino Army to assume the responsibility for defense in 1946 when Philippine independence was to be achieved. Prewar preparation on Bataan included the storage of ammunition, fuel oils, and a limited quantity of canned food.[7] Potential defense lines had been agreed upon, but no fortifications had been built. Reliance for the control of malaria was vested in quinine prophylaxis rather than on an antimosquito control program. This was considered the only feasible procedure in view of the size of the peninsula, which measured 25 miles by 18 miles, most of which was favorable to the breeding of malarial mosquitoes.

In May 1941, the Philippine Department surgeon appointed a board of officers at Sternberg General Hospital, Manila, to prepare estimates of the quantities of antimalarial drugs needed, based upon the April revision of War Plan Orange–3. Col. Rufus L. Holt, MC, the president of the board, had had extensive experience studying the incidence of malaria throughout the Philippine Islands. Guided by his advice, estimates were prepared and submitted at a level 100 percent above anticipated requirements.

Gen. Douglas MacArthur, in July 1941, expounded a more aggressive concept for the defense of the Philippines. One aspect of this concept was to defeat the enemy at the beaches rather than merely delay them to permit the withdrawal of troops to Bataan. Revision of medical plans during 1941 included requirements for the expansion of all Regular Army hospitals and plans for the construction of 10 station hospitals for the 10 Philippine Army divisions, the relocation of the Philippine Department Medical Supply Depot from the port area in Manila to a less vulnerable spot at Quezon City, and the construction of medical subdepots at Tarlac, Los Baños, and Cebu. On the basis of these considerations, requisitions were made to The Surgeon General for drugs, medical supplies, and aid station and hospital equipment. During the fall of 1941, moderate quantities of medical supplies and the equipment of two general hospitals and five station hospitals were received. One general hospital was stored at a battalion post which had been constructed at Limay

[7] United States Army in World War II. The War in the Pacific. The Fall of the Philippines. Washington: U.S. Government Printing Office, 1953.

to house the troops guarding military stores on Bataan. This construction was planned so that the utilities would be suitable for operating rooms, laboratories, wards, and storage areas. Before the outbreak of war, a tentative site was selected in the Real River Valley at kilometer point 162.5, near Cabcaben, for the location of an additional general hospital. Plans were also formulated for the development of a medical center in Manila of approximately 3,000 beds as stabilized warfare was anticipated.[8]

MILITARY OPERATIONS

There were 78,000 military and 6,000 civilian employees available in Luzon for defense when war began on 8 December 1941; a force more than twice as large as provided for by War Plan Orange–3. Also, there were approximately 25,000 civilians in Bataan whose feeding and medical care became the responsibility of the military.

The defense forces in Luzon consisted of the Philippine Division (composed chiefly of Philippine Scouts), a U.S. Army unit, nine partially mobilized Philippine Army Divisions, and miscellaneous U.S. Army troops. The Philippine Army Divisions varied from 4,000 to 6,000 men each and were organized into the North Luzon Force and the South Luzon Force with the mission of defeating the enemy at the beaches. The Philippine Division was immediately ordered into reserve in Bataan, and the Luzon Forces were moved forward to previously chosen sectors. The Japaneses Forces, supported by an overwhelming air force, succeeded in driving the Filipino-American Forces back from the beaches and prevented them from establishing any successful defense positions in central Luzon. By late December 1941, both of the Luzon Forces had been forced to withdraw from southern and central Luzon and were entering Bataan preceded by several thousand civilians.[9] During this phase of military operations, the effects of malaria on the troops were negligible.

On 8 December 1941, the Philippine Department surgeon instructed the medical supply officer of the Philippine Department to purchase all available antimalarial drugs, hospital supplies, and equipment which could be procured in Manila, and a similar program was begun at Cebu. The amounts procured proved to be a valuable supplement to the limited stocks on hand. Remarkable progress was made in the establishment of a hospital center in Manila, but, in view of the rapid withdrawal of the Filipino-American Forces, War Plan Orange–3 was placed in effect on 22 December 1941, and it became an urgent necessity to transfer all available medical resources to Bataan. On 22 December, a medical cadre was transferred to Limay to establish General Hospital Number 1. On 25 December, a similar cadre was transferred to kilometer point 162.5, near Cabcaben, to establish General Hospital Number 2. The

[8] Cooper, Wibb E.: Medical Department Activities in the Philippines From 1941 to 6 May 1942, and Including Medical Activities in Japanese Prisoner of War Camps. [Official record.]

[9] See footnote 7, p. 499.

movement of medical supplies and equipment to Bataan was accomplished during the period 23 December to 31 December, inclusive. Approximately 100 truckloads of medical supplies were moved by road, and many barges were sent both to Corregidor and Bataan.

Unfortunately, much equipment and some drugs and medical supplies were abandoned in Manila because of limited time, extreme congestion of the single road into Bataan, and limited shipping facilities. The Philippine Army medical units lost much of their medical equipment and supplies during the early contact with the enemy and in their precipitate withdrawal to Bataan.[10] The Philippine Army soldier was not provided with a mosquito bar. Many of the U.S. soldiers who were provided with this item discarded it as they considered it to be a useless inconvenience.

When the withdrawing Filipino-American Forces arrived in Bataan, they assumed a defense line across the northern part of the peninsula from Abucay on the east coast to Moron on the west coast (map 29). The central and western sectors of the defense line were mountainous, and the jungle was extremely dense on the lower slopes. An all weather highway, located 15–20 kilometers to the rear, connected the east and west roads at Pilar and Bagac and provided an excellent route for the evacuation of casualties.

Elements of the Japanese *14th Army* carried on a sustained frontal attack beginning early in January 1942, on the east side of the main line of resistance combined with penetration of the mountainous center and infiltration to the rear of units on the west coast (map 29). This caused the U.S. Forces to withdraw on 24–25 January 1942 to a new line through the waist of the peninsula, parallel to and slightly below the east-west Pilar-Bagac road. Use of this road was then precluded, and the development of trails and roads became mandatory to provide egress to the main east and west roads. The transportation of casualties from forward units to the general hospitals in the rear then posed an almost insoluble problem. General Hospital Number 1 at Limay was abandoned, having come within range of Japanese artillery, and personnel and equipment were moved to Little Baguio, kilometer 167, in the general vicinity of Mariveles.

The Japanese made repeated attacks during February with several penetrations of the Filipino-American line and also attempted coastal landings to the south and rear. All of these efforts were defeated, and, by the latter part of February, the Japanese *14th Army* had become ineffective from casualties and disease and was withdrawn. Similarly, the Filipino-American Forces were now in dire straits from disease and malnutrition. During March, the Japanese *14th Army* was reinforced with fresh troops and resupplied while the Filipino-American Forces remained in position awaiting the final blow. This came early in April and resulted in total collapse of the Bataan defense forces with surrender on 9 April 1942.

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[10] See footnote 8, p. 500.

MAP 29.—Situation on Bataan, 8 January 1942, approximate U.S. battle positions.

THE MALARIA PROBLEM

One estimate, which was probably conservative, judged the number of cases of malaria in Filipino-American Forces at the time of surrender, on 9 April 1942, to be 24,000.[11] No estimate is available of the number of cases in civilian refugees or in the Japanese Forces on that date. In a survey of 1,252 U.S. patients at General Hospital Number 2, made 3 weeks after the surrender of Bataan, 817 (65 percent) gave a history of having been treated for malaria during the preceding 4 months.[12] Early in March, the commanding officer of General Hospital Number 2, had reported an estimated 60 percent incidence of malaria in personnel assigned to the hospital. The appalling death rate in Japanese-held prisoners of war during the first 6 months of captivity is further evidence of the catastrophic effects of infection contracted in Bataan. A substantial number of these deaths is attributable to malaria.

Malaria reconnaissance of Bataan before World War II had clearly demonstrated that it was a formidable reservoir of malaria. The military situation required the placement of some 80,000 troops and several thousand displaced civilians in areas of high malarial endemicity. Some of the military units were located on the flat coastal plain, immediately adjacent to Manila Bay, which is relatively free of malaria, but the majority were located on higher ground within flight range of *A. minimus flavirostris* which preyed upon a heavily infected native population.

The civilian health authorities before 1941 had not been able to carry out an effective control program in Bataan. The military personnel did not have the authority nor the resources to carry out an antimosquito campaign throughout the entire extent of Bataan and had planned to rely chiefly on prophylaxis and careful campsite selection for peacetime needs. Aside from a limited program of prophylaxis, no antimalaria control measures of any significance were carried out during the campaign.

Quinine prophylaxis consisting of .650 gm. once daily was instituted for the Philippine Scouts of the Philippine Department upon their arrival in Bataan early in December 1941 and for service units working in the rear areas. The application of quinine prophylaxis to the Philippine Army divisions was not authorized because of an insufficient supply of quinine. Approximately 4,500,000 five-grain (.325 gm.) tablets of quinine sulfate were available in the Philippine Department Medical Supply Depot at the outbreak of war. This was only sufficient for 30 days' prophylaxis on the basis of 10 grains (.650 gm.) of quinine per man per day. In spite of the lack of a formal program of prophylaxis for the Philippine Army, many of the officers and men procured sufficient quinine for their personal use. The limited program of prophylaxis was hampered by inaccessibility of units, difficulty in medical supervision, and sus-

[11] See footnote 8, p. 500.

[12] Memorandum, Chief, Medical Service, to the Commanding Officer, Bataan General Hospital Number 2, Bataan, P.I., 7 May 1942.

tained combat. Many breaks in quinine discipline occurred. After 15 February 1942, quinine prophylaxis had virtually ceased except for personnel of the general hospitals, certain rear service units, and division, corps, and force headquarters.[13]

The diagnosis of malaria in the general hospitals in Bataan was made by the demonstration of the plasmodia in stained blood films. Positive film diagnosis was based on the presence of standard, well-documented, identification characteristics of the individual species. Approximately 60 percent of the blood films were positive for *Plasmodium vivax*, 35 percent for *Plasmodium falciparum*, and 5 percent for both types of *Plasmodia*. An occasional case of quartan malaria was diagnosed. It is likely that blood films taken earlier in the course of malaria and at frequently repeated intervals would have resulted in the finding of a higher incidence of mixed infections. Limited facilities precluded more comprehensive studies but were sufficient for fairly adequate screening until the final chaotic days preceding surrender. The degree of parasitemia in the *falciparum* cases was strikingly more evident when contrasted with the number of plasmodial forms seen in positive *vivax* blood films.[14] Microscopes were not available in the forward medical units initially, but, for a limited period, a few were provided as the military operations stabilized. On the whole, in the forward areas, reliance had to be placed on clinical acumen for diagnosis.

The treatment of malaria in vogue in 1941 consisted of 2 gm. of quinine sulfate daily by mouth for 5 days followed by .030 gm. of Plasmochin naphthoate (pamaquine naphthoate) daily in three divided doses for 5 to 7 days. Atabrine was an acceptable substitute for quinine. The long quinine treatment calling for .650 gm. of quinine daily for 8 weeks, after the initial 5-day treatment of the acute phase, was considered effective but difficult to supervise. The short quinine treatment consisting of 1 gm. to 1.3 gm. of quinine daily for 4 to 7 days, repeating for relapses, was considered to be acceptable in that it avoided the disadvantages of prolonged quinine therapy and was fairly successful. As Plasmochin and Atabrine were available only in limited amounts, a short quinine treatment was most commonly prescribed.

IMPACT ON DEFENSE FORCES

The deleterious effects of malaria on the troops in Bataan became strikingly evident in February 1942 and were aggravated by the universal state of malnutrition. Within less than 1 month after the outbreak of war, 8 December 1941, the defense forces were confronted with an acute food shortage. On 5 January 1942, the entire force was placed on half rations. The basic ingredient, of necessity, was rice, mostly of a poor quality. This was supple-

[13] Memorandum, Lt. Col. James O. Gillespie, MC, to Gen. George C. Marshall, 26 Jan. 1942, subject: Medical Supplies.

[14] Personal communication, Maj. Harold W. Keschner, MC, AUS, formerly Chief, Laboratory Service, General Hospital No. 2, Bataan, P.I., to Col. James O. Gillespie, MC.

mented by small amounts of white flour, canned goods (salmon, meat, tomatoes), evaporated milk, and irregular issues of fresh carabao. Tea, coffee, sugar, and butter were unavailable after 1 month. The ration was grossly deficient in protein, fat, and vitamins. It provided a maximum of 2,000 calories in January, gradually diminishing to 1,000 calories by early March and almost to the vanishing point by 1 April 1942.

The ill effects of semistarvation on the troops had become critical by late February 1942. The Surgeon of the Advance Echelon of USAFFE (U.S. Army Forces in the Far East), Bataan, advised the Surgeon, USAFFE, on Corregidor, in a memorandum dated 27 February 1942, that the diet of troops on Bataan was grossly deficient and urged increased allowances of beef, vegetables, milk and the procurement, if possible, of native fruits and vegetables, and in their absence the procurement of vitamin supplements.

By the third month of operations, weight loss in the range of 20 to 30 pounds was commonplace. Men complained of weakness, lassitude, lack of endurance, and shortness of breath. Moderate exertion caused tachycardia and palpitation. Those nominally listed as effective for combat could not engage in sustained exertion, so it became increasingly difficult to accomplish necessary work on airstrips, maintenance of roads, clearing of trails, hand carrying of supplies over mountainous terrain, and patrol activities. Gradually, the high morale and confidence of January was replaced by a loss of spirit and apathy. Dire predictions for the future could be heard. To lessen the morale further, the men began to note swelling of the ankles with pitting on pressure which was particularly evident toward evening. The pangs of hunger became more insistent.

Beginning about mid-February 1942, the sickness rate began to rise abruptly. The majority of patients were medical cases suffering from malaria or dysentery and showing evidences of malnutrition and avitaminosis. Some showed loss of subcutaneous fat and muscle wasting. Others appeared with a considerable degree of edema of the lower extremities. A few patients from isolated units who had undergone more severe deprivations showed marked peripheral neuritis with footdrop and wristdrop. Patients with wounds and fractures began to show a slower rate of healing.[15]

Up to the first week in March 1942, the evacuation of the sick and wounded had been accomplished in an orderly fashion. Certain patients who ordinarily would have been transferred to the general hospitals had been treated by medical units because of inaccessibility to motor vehicles. The general hospitals had expanded to meet the continually increasing demand for beds through the device of manufacturing bamboo cots and clearing larger areas of the jungle to provide space for them. Then, beginning approximately 7 March 1942, patients by the hundreds began to arrive daily at the rear hospitals. Most of them appeared to be suffering from malaria. Shortage of quinine

[15] History of General Hospital No. 2, Bataan, P.I., 28 Dec. 1941 to 9 Apr. 1942, from personal papers of Maj. Gen. James O. Gillespie.

then required the adoption of a modified short quinine therapy utilizing 15 gm. or less of quinine rather than the standard treatment of 35 or 40 gm.

Admissions for cerebral malaria became evident early in March 1942. These were chiefly men from isolated units who were in unusually poor physical condition from stress and malnutrition and for whom medical attention was not available. The number of these cases reaching the general hospitals was not large; in all they did not exceed 100 cases. Cerebral manifestations of malaria were usually associated with *P. falciparum*. The symptomatology was variable but frequently appeared with coma and a shocklike state or with delirium, convulsions, and maniacal reactions. Responses to intravenous quinine was dramatic. More often the lack of that item required the administration of 3 or 4 gm. of quinine sulfate by stomach tube. Usually the mental component of the disease was relieved in 3 or 4 days.

Malarial patients who were severely depleted from diarrhea and malnutrition did not respond well to massive antimalaria therapy. Occasional patients receiving 2 gm. of quinine sulfate daily by mouth continued to have fever and positive blood films. Other individuals on suppressive therapy of .650 gm. of quinine daily developed chills and fever and positive blood films. The same phenomena were noted frequently at prison camps during the summer of 1942. One case of blackwater fever was seen at General Hospital Number 2 in a civilian who lived in Bataan. Two cases in Japanese-held prisoners of war (one British and one Dutch) were seen during 1943 in a prison camp in Formosa.

Early in March 1942, Col. Arthur F. Fischer, USAR, while convalescing from malaria in Bataan, called the attention of Maj. Gen. Jonathan M. Wainwright's headquarters to 100,000 kilograms of high-grade quinine bark available in Mindanao, from which totaquine could be extracted.[16] Dr. Fischer had pioneered the introduction of cinchona into the Philippines and had worked with that program for 18 years. He was flown to Mindanao for the purpose of beginning large-scale extraction of the quinine bark. Penetration of the area by Japanese Forces prevented completion of the project, and Dr. Fischer was flown to Australia carrying seeds for the establishment of cinchona plantations in South America.

The catastrophic impact of disease and semistarvation on the combat effectiveness of the Filipino-American Force in Bataan was recognized to be of the utmost gravity by all levels of staff and command. On 10 March 1942, the commanding officer of General Hospital Number 2, directed a letter regarding malaria control to the Surgeon, Philippine Department, a portion of which is quoted.

> I would like to point out a grave problem pertaining to the Medical Department and the USAFFE. Malaria is rapidly increasing; some 350 cases were under treatment in this hospital as of March 8th. The admission rate is alarming, some 200 patients

[16] Personal communication, Col. Arthur F. Fischer, USAR, to Maj. Gen. James O. Gillespie, 24 July 1946.

> arriving March 9th. Most of these are medical and a large proportion have malaria * * *. Quinine prophylaxis having stopped we anticipate additional hundreds or even thousands of cases * * *. We are urgently in need of a tremendous stock of quinine for treatment and prophylaxis. The General Staff should understand the extreme gravity of the malaria problem and give priority to quinine above that of any other critical item. If the malaria situation is not brought under control the efficiency of the whole Army will be greatly impaired: in fact it will be unable to perform its combat functions. It is my candid and conservative opinion that if we do not secure a sufficient supply of quinine for our troops from front to rear that all other supplies we may get, with the exception of rations, will be of little or no value.

The USAFFE Surgeon, Corregidor, in a memorandum to the Assistant Chief of Staff, G–4 (logistics), USAFFE, on 22 March 1942, stated that there were 3,000 cases of malaria in Bataan and that the numbers were increasing at an alarming rate. He referred to the extremely high noneffective rate in combat units and recommended that 3 million quinine tablets be sent from Australia by air at once with a like quantity thereafter each month.

To deal with the overwhelming flood of patients in the forward units and to relieve pressure on the general hospitals, the Surgeon, Luzon Force, early in March, directed that battalion aid stations and clearing and collecting companies assume the responsibility for the treatment of all patients except those whose condition was of the utmost gravity.[17] The aid stations were expanded to 200 to 300 beds (bamboo construction) while the clearing and collecting companies handled from 600 to 900 patients each.

The Surgeon, Luzon Force, reported on 23 March 1942, in a letter to the commanding general, that the daily admission rate for malaria had reached 500 to 700 cases and that the available supply of quinine at the medical depot in Bataan was sufficient, using a short course of treatment, only for approximately 10,000 cases of malaria. He anticipated exhaustion of the stock in 3 or 4 weeks and predicted a mortality rate of 7 to 10 percent in untreated cases. Extreme concern was expressed regarding the sharply rising noneffective rate in relation to combat potentialities of the Force. Writing to the Chief of Staff, USFIP (U.S. Forces in the Philippines), on 31 March, the Chief of Staff, Luzon Force, referred to a malaria admission rate reaching 1,000 cases daily and to the imminent loss of combat effectiveness.

By the end of March, some 7,000 patients were hospitalized in the forward medical units, a mere mile or so behind the main line of resistance. These represented only those who were severely incapacitated. Actually, at least 80 percent of the troops had become unfit for duty. One regimental surgeon described the situation as follows:[18]

> To give an accurate word-picture of conditions as they actually existed at the time immediately preceding the surrender of our forces on Bataan would tax the descriptive powers of a rhetorical genius, but in simple language, almost every man in Bataan was suffering, not only from the effects of prolonged starvation, but also from one or both of the acute infections that plagued us throughout the campaign, viz, dysentery and malaria. I

[17] See footnote 8, p. 500.

[18] See footnote 8, p. 500.

have seen men brought into the battalion aid stations and die of an overwhelming infection of dysentery or cerebral malaria before they could be tagged and classified for evacuation. Of the supposedly well men in the field, all were thin and weak from starvation. Many were swollen with nutritional edema; a large percentage were pale and anemic from repeated attacks of malaria or dysentery.

As early as January 1942, General MacArthur had made urgent requests to the Chief of Staff, U.S. Army, for food and medical supplies to be sent through the Japanese blockade by any possible means. General Wainwright in March reiterated the extreme urgency of his requirements for both items and, in response, Gen. (later General of the Army) George C. Marshall, Chief of Staff, requested that maximum amounts of quinine be sent from Australia by air. This could not be accomplished, but 1 million tablets of quinine sulfate were brought by air from the medical depot at Cebu to Bataan. This supplement proved to be sufficient to provide at least a short type of therapy, and no hospitalized patients were denied quinine before surrender. The death rate from malaria before capitulation therefore was extremely low.

When the final Japanese attack began on 3 April 1942, it became imperative to move all patients from forward medical units to the rear hospitals. Approximately five thousand patients were absorbed at General Hospital Number 2 between 5 April and 8 April; other thousands were directed to a convalescent camp in its vicinity.[19] On 9 April 1942, all surviving members of the Filipino-American defense force, including patients and medical personnel, were categorized as captives and thereafter were required to submit to the orders of the Imperial Japanese Army.

IMPACT ON CIVILIAN REFUGEES

The situation of the several thousand civilian refugees behind the Filipino-American lines became increasingly desperate during the period 7 January to 9 April 1942. Most of these refugees were located in the Limay-Mariveles-Cabcaben areas which previously had been established as regions of severe malarial infection. There they lived in refugee camps and were issued the same meager rations as the Army received. Medical attention was provided by refugee Philipino physicians in crudely improvised hospitals. These people were without protection from malarial mosquitoes, and they suffered severely from malaria having no antimalarial drugs for treatment. These unfortunates were often threatened by bombing raids on nearby villages and military installations. Many were wounded and killed.

A mass evacuation from Bataan of refugees and Filipino military patients began immediately following capitulation on 9 April 1942. These individuals trudged along the east road leading out of Bataan. Many of them were ill with malaria and dysentery. Among them were old men, women, and children, carrying their total possessions in assorted bundles, bags, and cans. The pro-

[19] See footnote 15, p. 505.

cession continued for days. Often, the seriously ill would fall by the roadside to die, and after a few days several hundred bodies could be counted along the road between Cabcaben and Limay.

The disruptions caused by war resulted in a considerable increase in the incidence of malaria in Bataan and adjacent provinces after the conclusion of the campaign in 1942. This was brought about by the huge increase in the numbers of human carriers who had become infected and for whom proper treatment was not available, and by the complete breakdown of control measures. Studies made on the civilian refugee population evacuated from Bataan in 1942 showed a large increase in the malaria rate, and it was noted that the disease was more difficult to treat with the higher death rate. Over 24,000 cases of malaria were diagnosed in civilian emergency hospitals in Bataan and surrounding provinces during the fall of 1942.[20] The overall mortality rate was 2.2 percent. Before the war in 1941, the fatality rate in the same provinces had been 0.64 percent. An intensive malaria control program was carried on in Bataan from 1942–44 by direction of the Japanese military command.

IMPACT ON THE JAPANESE FORCES

The impact of malaria on the Japanese Forces can only be partially documented. The Japanese Army had planned for a quick operation in Bataan, expecting to overcome the Filipino-American troops in a week or 10 days. When they met with firm resistance which continued during January and February, their troops began to suffer from some of the same deprivations and diseases which harassed the Filipino-American Forces. The Japanese ration for their troops on Bataan was meager, although it did not reach the low point of the Filipino-American ration. The Japanese were exposed to the same hazards from malaria, diarrhea, and dysentery. By mid-February, the Japanese *14th Army* was definitely depleted, chiefly from malaria.[21] An interpreter who served with the Japanese *14th Army* in Bataan stated to the senior Japanese-held U.S. medical officer in July 1942, that the Cabanatuan prison camp situation, where over 3,000 seriously ill Americans were incarcerated, reminded him of the illness suffered by the Japanese troops in Bataan. He asserted that in some units of the Japanese Army the noneffective rate from malaria and dysentery reached 90 percent and that the death rate from malaria was very high. He stated that the former U.S. military hospital, Sternberg General Hospital, was packed to capacity with Japanese soldiers who had become ill in Bataan.

On 10 April 1942, a Japanese guard of 20 men was assigned to General Hospital Number 2. Approximately 60 percent of these soldiers were acutely

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[20] Urbino, Cornelio M.: Epidemiology of Malaria in Bataan Before the War and During the Japanese Occupation, and Malaria Control From 1942 to 1944. Philippine Islands Health Service Monthly Bulletin 22: 297–344, 1947.

[21] See footnote 7, p. 490.

ill with malaria within 3 weeks. No medication was provided for them by the Japanese Army. They were treated however, by U.S. medical officers at the direction of the Japanese Army. It was estimated by Horiguchi, surgeon of the Japanese *14th Army*, that 10,000 to 12,000 Japanese soldiers were ill with malaria, dysentery, and beriberi in February 1942 and that less than 3,000 effective men remained. The Japanese *14th Army* had begun their campaign with only 1 month's supply of quinine, and in January its use for prophylaxis was discontinued except for frontline troops; after 10 March, quinine was available to them only for therapy. Thus, it seems clear that the firm resistance of the Filipino-American Forces in Bataan, combined with extensive infestation of the Japanese troops with malaria, resulted in an upsetting of the Japanese timetable for the prosecution of the war in the Philippines. This was a significant matter as Japanese troops had to withdraw from Singapore to complete the campaign in Bataan.

IMPACT ON THE FILIPINO-AMERICAN PRISONERS OF WAR

The tragic story of the appalling loss of life in the Filipino-American Forces after the surrender is directly related to malnutrition and disease experienced in Bataan. Malaria contributed significantly to the impressive mortality. Other significant factors included prolonged marches to the prison camps in tropical heat, inadequate food, lack of potable water, lack of medical supplies, deplorable sanitary conditions, extreme overcrowding, and overwork. Twenty-nine thousand five hundred eighty-nine deaths occurred in 1942 at Camp O'Donnell in Japanese-held prisoners of war from Bataan. Six thousand one hundred twenty-nine (20.7 percent) clinically were attributed to malaria.[22] Four hundred ninety-eight deaths occurred in U.S. prisoners at Cabanatuan Prisoner-of-War Camp Number 1 during June 1942. One hundred twenty-eight were diagnosed as caused by malaria. During July 1942 in the same camp 789 U.S. prisoners died. Beginning approximately 1 August 1942, sufficient quinine was provided by the Japanese to treat 1,600 cases of active malaria, using 14 gm. of quinine sulfate per patient.[23] Deaths decreased to 240 during the month of August. On 31 August 1942, the senior Japanese-held U.S. medical prisoner of war requested in a letter to the Japanese camp commander, Cabanatuan Prisoner-of-War Camp Number 1, that 750,000 3-grain tablets of quinine sulfate be furnished to treat an estimated 3,119 cases of malaria. The quantity desired was not obtained, and needless deaths continued. Two thousand four hundred deaths occurred in Japanese-held U.S. prisoners of war at Cabanatuan Prisoner-of-War Camp Number 1 from 1 June to 1 December 1942. Approximately 25 percent of these deaths clinically were attributed to malaria.

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[22] See footnote 20, p. 509.

[23] Diary, Col. James O. Gillespie, MC, U.S. Army, Prisoner of War Camp No. 1, Cabanatuan, P.I., 31 May–31 Aug. 1942.

Japanese-held prisoners of war in the Philippines were subjected to an extreme degree of stress during the first 6 months of captivity. Semistarvation, begun in Bataan, continued for many months after capture. Nutritional edema (wet beriberi), multiple avitaminosis, burning feet syndrome, and pellagra affected 95 percent of prisoners to a greater or less degree. Diarrheal conditions, including specific dysenteries, were commonplace. Two hundred twenty-three prisoners contracted diphtheria between 10 June and 8 August 1942 at Cabanatuan Prisoner-of-War Camp Number 1. Ninety-one of these died. Men depleted by such a variety of conditions did not respond to antimalarial drugs in the manner observed in healthy individuals. The failure to respond may have been due to poor absorption of quinine from the gastrointestinal tract. When intravenous quinine was given, response was satisfactory. Unfortunately, almost none was available.

The protean manifestations of malaria in the prison camps caused much confusion in the presence of dysentery and malnutrition with avitaminosis. Gastrointestinal symptoms such as nausea, vomiting, and severe diarrhea were frequent in proved cases of malaria. Others showed symptoms of acute appendicitis or other acute abdominal crises. These were soon recognized as manifestations of malaria requiring search of a blood film for plasmodia as the most important laboratory procedure. Response to antimalaria therapy often was dramatic in these cases.

Throughout more than 3 years of captivity, malaria recurrences were very frequent in prisoners in the Philippines, Formosa, Japan, and Manchuria. A few individuals had as many as 20 relapses. As a cause of death, malaria became less important during 1943–44 not only because of the better conditions of diet and improved therapy but also because of the tremendous death rate which had eliminated the most severely ill. As late as 1945, an appreciable number of prisoners of war were suffering from malaria relapses.

COMMENT

The defeat of the Filipino-American Forces in the Philippines undoubtedly was hastened by the conditions resulting from a semistarvation ration with the additional deleterious effects from common diarrheas, dysentery, and malaria. The Surgeon, Luzon Force, expressed his opinion as follows:

> The capitulation of Luzon Force represents in many respects a defeat due to disease and starvation rather than to military conditions. Malnutrition, malaria, and intestinal infections had reduced the combat efficiency of our forces more than 75 percent. The Bataan campaign can best be described as a campaign of attrition, a campaign in which consumption without replenishment was the rule. The physical fitness of our troops was so seriously impaired by 1 March that it became a determining factor in tactical operations. From that date onward the physical deterioration of our forces was so rapid that by 2 April a successful defensive stand was no longer possible.[30]

[30] See footnote 8, p. 509.

CHAPTER X

The Southwest Pacific Area

Thomas A. Hart, Ph. D., and Col. William H. Hardenbergh, MSC, USAR (Ret.)

Malaria was one of the chief medical and military problems for U.S. Army troops in SWPA (Southwest Pacific Area) during World War II. Until the middle of 1943, malaria incidence was so great that it seriously handicapped military operations. During the 6 months from October 1942 to April 1943, there were approximately 10 times as many hospital admissions for malaria as for battle casualties, and a majority of the Allied divisions in the theater were incapable of effective military use.[1] The malaria incidence reached its peak in February 1943;[2] after February of that year, there was a steady decline due, primarily, to the creation and the operation of an effective antimalaria organization. Despite the fact that military operations continued throughout the war in areas where the disease was highly endemic, malaria did not thereafter handicap military operations. The organization created in 1943 functioned effectively in malaria control throughout the remainder of the war in the Southwest Pacific.

A most important aspect of the problem of malaria control in SWPA was that any measures taken had to be applicable to an Allied force, not merely to the U.S. Army. Particularly in the first 2 years of this theater's experience, most bases in malarious areas contained U.S. Army, Australian Army, Australian Air Force, and often Navy detachments of both countries. Uniformity of area antimosquito measures and uniformity of malaria discipline of troops were found to be essential.

At the outset of World War II, knowledge regarding the prevention of such endemic diseases as malaria was available and the U.S. Army had had experience in the malarious areas of the Philippines and in Panama, but the mechanics and procedures for the protection of large bodies of troops in highly endemic areas had not been developed. Combat commanders were very slow to recognize the scope of the problems and to heed medical advice for carrying out protective procedures. Blame for the high noneffective rate was often placed on the unit surgeons. Many or most of these had never seen a case of malaria, even in medical school, and in addition, they did not have the authority to enforce adequate antimalaria measures, even in their own units.

[1] War Department Circular No. 223, 21 Sept. 1943.

[2] Monthly Progress Report, Army Service Forces, War Department, 31 July 1944, Section 7: Health, p. 10.

Another early handicap was the policy of the combat commanders that orders should not be explained to the troops. Since, under the conditions existing in this theater, troop education and cooperation were essential, no adequate program of malaria control could at first be enforced. In addition, unit commanders in the early days of the war often flagrantly disregarded such malaria control orders as those requiring the wearing of shirts and leggings during certain hours, thereby making enforcement of such orders practically impossible.

After the evacuation of the Philippines, the Australian mainland was organized as a base for the campaign northward. In 1942, the military organization of SWPA provided for seven base sections and one advanced base section. The seven base sections were all in Australia, with headquarters as follows: Base Section 1, Darwin; 2, Townsville; 3, Brisbane; 4, Melbourne; 5, Adelaide; 6, Perth; and 7, Sydney. The advance base section included New Guinea and adjacent territory. The first sizable complement of U.S. troops arrived in four transports in December 1942.

Many of these troops had been serving in malarious areas, and there were numbers of cases of malaria among them. Though malaria was not a problem of much magnitude in Australia, the entire Queensland littoral was infested with anophelines. In many localities, a local endemic was readily possible if the reservoir of infection were sufficently great. Actually, the problem was treated by the Australian Government as a major one, and involved all troop and individual assignments to the Northern Territory especially, throughout the first 2 years of the war. The protection of Australia against malaria was one facet of a broader problem; that is, the logical insistence of the Australian Government on the protection of Australia against introduced tropical diseases, as well as smallpox. Regulations governing the introduction of malaria-infected troops into potentially malarious areas were enforced, and extensive measures were taken in Townsville and south of Townsville to control mosquitoes in the environs of American hospitals. By cooperation with Australian health authorities and through medication, the threat imposed by the arrival of these infected troops was controlled.

Because malaria was not common in Australia, few cases were reported among troops stationed on the mainland—probably not more than 12 cases during 1942, all north of Townsville. There were a good many cases reported in base sections, but practically all were among troops or patients transferred from New Guinea.

Meanwhile, malaria incidence was increasing among troops in New Guinea. The rate rose in close correspondence with the movement of troops to New Guinea. The malaria rate for New Guinea in October 1942 was less than 200 per 1,000 men per annum, and, for this theater as a whole, it was about 40. In

December 1942, the rate for New Guinea increased to nearly 600 and for the entire theater to approximately 250.[3]

Thus, during the closing days of 1942 and the early part of 1943, malaria had shown itself to be a very serious threat to the success of our military operations in the Southwest Pacific. It was realized also that the problem would be intensified as more troops moved northward into more highly malarious areas. The U.S. Army in this theater lacked the three necessities to conquer the problem: (1) A full appreciation by the various commanders of the nature and scope of the problem and of the part that they must play in controlling it; (2) an organization, adequate in skill and in authority, to control malaria; and (3) adequate antimalaria supplies in the forward areas, due to failure of the theater at first to assign necessary priorities of shipment from the United States and locally.

AREA CHARACTERISTICS

New Guinea

Physiography.—The island of New Guinea is roughly 1,500 miles long and 400 miles wide. A massive mountain backbone runs centrally along its length. Although the western tip of the island lies on the Equator, many peaks are snowcapped throughout the year.

South of the central mountain range is a vast low flatland, honeycombed with rivers, swamps, and high rain forest jungle. The southern coast for the most part is lined with impenetrable mangrove swamps, backed up inland by broad nipa palm swamps. Other inland swamps are covered with grass several feet high (kunai grass) and, when viewed from the air, appear to be grassy plains (fig. 56).

North of the central range are parallel mountain groups lying along the coast. The fertile inland valleys are drained by large rivers, such as the Fly, Mamberamo, Sepik, Ramu, and Markham. Swamps are found along the upper reaches of these rivers, and at their mouths.

The mountains are covered with dense tropical rain forest. Secondary growth of tall grasses and scrub replace forests which have been burned off in the valleys and plains to provide land for temporary cultivation. Although some areas have been planted with rubber and coconut trees, less than 1 percent of New Guinea is under cultivation.

Along the coast, there is little variation in temperature and humidity. The temperature averages 80° F., with local means ranging from 77° to 83° F. The humidity averages 85 percent, with local means ranging from 70 to 95 percent. Above 2,000 feet, temperate climates are encountered.

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[3] Monthly Progress Report, Army Service Forces, War Department, 31 July 1943, Section 7: Health, p. 6.

FIGURE 58.—Open stream with grassy margins, in slight shade, a typical breeding place for *Anopheles farauti*. 17th Malaria Survey Unit, New Guinea.

The annual precipitation ranges from about 40 inches per year at Port Moresby to over 300 inches in the mountains. The season of maximal rainfall also varies from place to place. This seasonal variation is due to the two monsoons (northwest monsoon—November to May; southeast monsoon—May to October) and to the particular exposure or lack of exposure of various areas to these monsoons. Generally speaking, the heaviest rainfall occurs on the windward side of the mountain where the rain clouds are trapped.

Malaria is hyperendemic in coastal areas and at altitudes up to 2,000 to 3,000 feet.

Since there are daily rains in many areas even during the "dry" season, mosquito breeding and malaria transmission may continue throughout the year, but there is an increased incidence at the beginning and end of the rainy season. Where the soil is sufficiently porous, breeding places may exist only during the season of heaviest rains.

Wherever surface water drainage is poor because of high subsoil water level or nonporous soil, mosquito breeding is most prolific. This is especially true in river valley lowlands and in coastal swampy areas. The habits of the two important malaria vectors are such that the mosquitoes take quick advantage of manmade breeding places. This explains the occurrence of "manmade malaria" in this area.

Falciparum malaria prevails on New Guinea, although there is considerable variation from place to place. *Vivax* malaria is also common. Quartan malaria is seen infrequently, but a small focus existed at one time between Morobe and Buna on the Mambare River.

The clearing of vegetation for camp and airfield construction is likely to be attended by a sudden increase of malarial vectors, which are sunlight breeders, unless special care is taken to minimize the occurrence of artificial depressions in which they may collect (map 30).[4]

Range of malaria.—In New Guinea, malaria is endemic to hyperendemic throughout the coastal district and the smaller islands. In areas with well-marked dry seasons, such as Port Moresby, which are exposed to the full force of the southeast trade winds, on the south coast of New Guinea, malaria shows a marked seasonal incidence, with transmission being at its maximum shortly after the end of the wet season and minimal or absent during the later part of the dry season. In more sheltered situations, transmission is perennial, though it may fall off when the breeding grounds are flushed out by heavy storms during the summer. Malaria appears to be absent from the higher inland country at an altitude of 3,000 to 4,000 feet or more, but in high altitudes, fatigue and rigors of travel are particularly liable to provoke relapses of infection contracted on the coast. In limited areas, that is, Port Moresby, Samarai, and Rabaul, a considerable degree of control had been formerly established, but it had lapsed with the Japanese invasion. Even in the Port Moresby area, though there had been much work done for malaria control, the Australian troops stationed in that area from January to June 1942 suffered an infection rate of approximately 50 percent.[5]

Vivax, *falciparum*, and quartan malaria are all present in New Guinea, the proportions varying in different areas and in different seasons, but *falciparum* infections predominate. The effect of malaria is greatest among newly arrived Europeans, and high mortality and morbidity rates are encountered among them. The arrival of Europeans in a given area is usually followed by an increase in the virulence of the disease, and in turn this increased virulence adversely affects the nonimmune native population. In 1940, between 14 and 19 percent of all European hospital admissions were for malaria and blackwater fever. The spleen rate among the natives was between 25 and 30 percent, but in some regions, almost 100 percent of the natives had malaria. The peaks of the malaria season usually occur in January and February, and in May and June. The spleen indices in the various districts of the New Guinea mainland (1936–37) were as follows: Sepik District: 43.1; Madang District, 33.4; and Morobe District, 25.3. Occasional cases of blackwater fever are observed, particularly among the Europeans.

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[4] Health and Disease in New Guinea. Arctic, Desert and Tropic Information Center: Regional Medical Studies. April 1944.

[5] Report. Maj. I. M. Mackerras, Medical Entomologist, Australian Army, Notes on Mosquito-Borne Diseases in Australasia. 1942.

MAP 30.—New Guinea.

Malaria is also widely distributed throughout Papua and the adjacent group of islands. Along the greater part of the coastal region of Papua, as well as in most of the islands, malaria is hyperendemic. The incidence of the disease is also high in the central highlands of the mainland. In the mountainous country above 2,000 feet, it falls to a minimum. The malaria problem in Papua is essentially the same as in the Territory of New Guinea, with the notable exception of Port Moresby. At Port Moresby, there is a well-marked dry season from May to January, with only about 30 inches of rain per year, and though the incidence of malaria is high in this region, there is a notable drop during the latter half of the dry season. Malaria is hyperendemic in the island groups of D'Entrecasteaux and Amphlett. It is highly endemic in the Trobriand Islands, the Louisiade Archipelago, and the Woodlark Islands.

The mainland of New Guinea, and its outlying islands, will be considered in more detail under the following divisions:

1. The Mandated Territory of New Guinea and its associated islands.
2. Papua and its adjacent islands.
3. Netherlands New Guinea.

The Mandated Territory of New Guinea

The territory includes, in addition to a large area on the New Guinea mainland, the islands of New Britain and New Ireland, the Admiralty Islands (Manus), Bougainville and Buka in the Solomon Islands, and numerous smaller islands.

Malaria is prevalent throughout the Territory—in many parts, especially in the coastal regions, it is highly endemic or hyperendemic.

It is reported that at Kokopo near Rabaul (New Britain) 62 percent of the European morbidity was caused by malaria, with many cases of blackwater fever.

A large part of the infant mortality is, directly or indirectly, due to malaria, and it appears to be one of the main factors in the depopulation of certain parts of Malanesia.

Except in limited areas, as at Rabaul and the larger settlements where the control of vectors has been effective, new arrivals are usually quickly infected.

Splenic indices.—Patrol reports in 1934, covering the examination of 22,000 natives, showed the average spleen rate in children to be 30 percent for the Territory generally.

The following splenic indices are for the greatest part examinations made in 1936–37, though a few are from earlier reports:

	Splenic indices
New Guinea mainland:	
Sepik district	48.1
Madang district	23.4
Morobe district	25.3

	Splenic indices
New Britain:	
Gazelle Peninsula	23.1
Talasea district	40
Walonga district	52
New Ireland:	
Kavieng district	34.3
Namatanai district	32.1
Solomon Islands:	
Kieta	63.2
Buka Passage	24.7
Duke of York Group	50
Admiralty Islands:	
Manus	53

Relative frequency of parasites.—*Falciparum*, *vivax*, and quartan parasites are found, the proportions varying in different areas and at different seasons. Since many reports of relative parasite frequency are gathered from examination of hospital patients, it would appear that, in these patients, the reported frequency of *falciparum* may be higher than that prevailing among the general population, as this type more frequently requires hospital treatment.

Examinations at the Rabaul Laboratory (1935) showed the following relative frequencies for whites and natives:

	Relative frequency
Whites:	
Plasmodium falciparum	76
Plasmodium vivax	24
Quartan	0
Mixed	0
Natives:	
Plasmodium falciparum	68
Plasmodium vivax	21
Quartan	4
Mixed	7

The variation in the relative frequency of parasites in different areas can be seen in the results of surveys conducted in the North Coast and the Duke of York Group.

	Relative frequency	Parasite rate
North Coast:		13
Plasmodium falciparum	75	--
Plasmodium vivax	25	--
Quartan	--	--
Mixed	--	--
Duke of York Group:		58
Plasmodium falciparum	40	--
Plasmodium vivax	21	--
Quartan	21	--
Mixed	18	--

In New Ireland, quartan malaria has not been found. *Falciparum* malaria is more common than *vivax*, and mixed infections are not rare.

Blackwater fever.—A number of cases of blackwater fever are reported each year. Administration records for 1936–37 show 12 cases with 3 deaths. The incidence is less than in the early days of the Morobe goldfields, when a poorly nourished European population suffering from neglected malaria was engaged in very hard physical labor. Any alteration in circumstances which tended to produce such a combination of conditions resulted in a fatal outbreak of blackwater.

Seasonal prevalence of malarial attacks.—Heydon, at Rabaul, found that in white residents the maximum of malarial attacks occurred in January and February and in May and June, with the minimum in September and October. He considered that the height of the May–June rise might be due to the cooler weather disposing to relapses.

Positive blood examinations in Rabaul also showed a minimum toward the end of the dry season and a maximum about May. The latter rise was due to *falciparum* infections.

Brennan, in 1935, considered that there was a variation in virulence of *falciparum* strains endemic in various parts of the Territory. Cases of *falciparum* malaria contracted in some parts were much more severe than those in others. This severity was quite independent of the number of parasites present in films.

Australian Papua

Papua and its adjacent islands.—The Australian Territory of Papua comprises the large area in the southeastern part of the New Guinea mainland, and the great island archipelagoes scattered to the east—the Louisiades, the D'Entrecasteaux group, and the Trobriand Islands.

Malaria is hyperendemic in a great part of the coastal region of the mainland, as well as in a large number of the associated islands. The incidence is lower in the central highlands of the mainland and falls to a minimum in the mountainous country above 2,000 feet.

The Port Moresby area differs sharply from the rest of the island in that it lies within a small "rainshadow" zone, with only about 30 inches of rain per annum, with a well-marked dry season from May to January, and with climate and vegetation resembling those of northern Australia rather than the rest of the island. Nevertheless, there has been a high rate of malarial infection both in the natives formerly present and, more recently, in the troops stationed there. The climate peculiarities of this area are, however, of considerable practical importance, for it is likely that transmission of malaria does not occur during the latter half of the dry season.

In the mountainous D'Entrecasteaux group, every island is subject to hyperendemic malaria. The population (about 25,000 natives) practically all live on the narrow, low-lying coastal fringe of the large islands where anopheline vectors breed freely. All newcomers are infected, and blackwater fever and malignant cerebral forms have been common among the few white residents. Habitation ceases at about 2,000 feet, for the mountain slopes above that level are infertile, but high spleen rates are encountered to that limit.

The Amphlett Group, a cluster of small steep-sided and rocky islands to the northeast of Fergusson Island (D'Entrecasteaux), also shows hyperendemic malaria in the scattered villages which nestle at the base of the cliffs. Here, anophelines breed freely in pools and soakages.

In the Trobriand Islands (Kiriwina, Kitava, Kaileuna, and Vakuta), malaria is endemic throughout, but does not reach the rates of the neighboring D'Entrecasteaux group. The spleen rates in children are in the vicinity of 10 percent in most villages, rising to a maximum of 30 percent in a few places.

The small island of Samarai, the administrative station for the eastern division of the Territory of Papua, has, by assiduous control measures, been entirely freed from malaria. The close-lying heavily wooded islands, the Rogeia, Sariba, and Basilaki, outside the sphere of this control, however, are malarious (splenic indices—Rogeia 48, in 1938). The neighboring part of the mainland, the Milne Bay area, is also hyperendemic and was regarded by oldtimers of Papua as one of the worst malarial areas in the eastern division. Splenic indices of 71, 80, and 98, respectively, were found in three villages on the swampy southern shoreline of Milne Bay and of 56, in a village near East Cape. At Buna on the northeastern coast, the disease is also hyperendemic, a splenic index of 68 being reported. In both the coastal area of this eastern extremity of the New Guinea mainland and the neighboring islands, blackwater fever and cerebral malaria have taken a heavy toll of the scanty white population.

In the scattered islands of the Louisiade Archipelago, malaria is endemic throughout. At Misima, the main island of the group, for many years there has been a large concentration of native laborers employed in the mining industry. These laborers have been brought from various parts of the Territory, with the consequent introduction of new strains to an island which already shared the high malarial incidence of the new group.

At Woodlark Island (Murua), malaria is also present. The island is heavily wooded, the lower parts with thick mangrove. The rainfall is heavy, but the higher ground is well drained, and malaria is said to be consequently rarer on the higher parts, though prevalent at Bonagai, the post on Kwaiapan Bay.

Netherlands New Guinea

Netherlands New Guinea comprises a few small scattered settlements along the coast, and large tracts of unexplored territory in the interior of the island, inhabited only by uneducated savages. There has never been any well-integrated health organization, and information concerning disease is scanty. Before Japanese occupation, there were six government-paid physicians on the island located at Meranke, Fakfak, Manokwari, Hollandia, Sorong, and Wissel-meren. In addition to practicing curative medicine, these doctors cooperated with local civil authorities to enforce elementary sanitary measures in their areas. These physicians were responsible to the health officer in Amboina, who, in turn was responsible to a regional officer in Makasar. This officer was responsible to the head of the Public Health Service of the Netherlands East Indies in Djakarta.

The prevalence of malaria in the coastal regions can be ascertained to some extent from surveys in which the splenic indices of natives in many small villages were obtained (table 73).

TABLE 73.—*Splenic indices in natives of Netherlands New Guinea*

Location	Year	Adults		Children	
		Number observed	Percentage spleen index	Number observed	Percentage spleen index
Bonggo-gebergte	1932	100	77	57	79
Demta	1932	83	60	50	74
Genjem	1932	76	65	116	91
Ifaar	1931	72	72	49	75
	1931	46	70	49	84
Imahoei	1937	62	47	42	74
Kobolombo	1937	74	36	51	56
Njao	1931	53	60	30	67
Sabron	1931	47	77	42	100
Sarmi	1931	129	62	44	65
Poelau Waaf	1937	63	30	55	51
Geelvink-baai					
Demba	1931	83	65	51	86
Mamboei	1931	54	52	40	42
Miei	1932	77	82	90	90
Moeoni	1932	56	86		
Nabire	1932	[1] 43	100		
Nappan	1932	91	86	62	84
Niaei	1931	80	61	70	54
Napoeni	1931	73	82	60	53
Paradoi	1931	70	84	90	82
Sajati	1931	85	72	94	77
Sanggei	1931	80	70	30	67
Wainoei	1931	40	77	20	70
Wasior	1932	71	75	66	94
Waren	1931	100	59	69	68
Weinami	1932	61	86	43	93
Windehsi	1932	94	83	87	84
Wiringgi	1932	60	66	56	91
Wonti	1931	100	55	75	57

See footnote at end of table.

TABLE 73.—*Splenic indices in natives of Netherlands New Guinea*—Continued

Location	Year	Adults		Children	
		Number observed	Percentage spleen index	Number observed	Percentage spleen index
North Coast of Vogelkop					
Andai	1931	58	78	28	96
Tandjoeng Fanindi	1931	50	52	50	84
Makebon	1934	26	81	23	96
Manooi	1931	-------	-------	39	72
Samferwori	1931	92	89	60	98
Wasajoni	1931	91	76	62	90
Seget	1934	20	80	20	100
South Coast of Vogelkop					
Inanwatan	1934	-------	-------	62	74
Jahadiang	1933	-------	-------	123	78
Kampoeng Baroe	1933	-------	-------	117	88
Konda	1933	-------	-------	72	61
Mogetemin	1931	-------	-------	35	71
Moegem	1934	-------	-------	111	70
Saga	1934	-------	-------	83	93
Teminaboean	1933	-------	-------	24	75
Wersar	1933	-------	-------	56	68
Teloek Beraoe					
Arandai	1932	-------	-------	24	50
Idore	1934	-------	-------	61	75
Jakati	1932	-------	-------	80	37
Kokas	1931	-------	-------	54	44
Argoeni-baai					
Mediwa	1932	-------	-------	34	50
Sawatawera	1932	-------	-------	57	47
Wanoma	1932	-------	-------	67	67
South Coast to Atoeka-Rivier					
Atoeka I	1932	-------	-------	60	3
Atoeka II	1936	-------	-------	29	58
Kaimana	1932	-------	-------	25	68
Keakwa	1936	-------	-------	55	36
Kokenau Mimika	1932	-------	-------	75	21
Lobo	1934	-------	-------	34	79
Aoeta	1936	-------	-------	33	70
Tetawei	1934	-------	-------	53	85
Timoeka	1936	-------	-------	115	57
Waupoeka	1932	-------	-------	50	4

[1] Laborers.

Source: War Department Technical Bulletin (TB MED) 18, 10 Mar. 1944

The entire northern coast and the southern coast of Vogelkop are highly endemic areas. The vectors most frequently found are *A. punctulatus* and *Anopheles farauti*. *Anopheles bancrofti* Giles is not found on the northern coast. On some parts of the southern coast (between Kaimana and Atoeka), owing to the great height of tides, there are no suitable breeding places for mosquitoes, and some villages are nearly free of malaria. In the Merauke area, perhaps owing to the existence of a definite dry season between June and December, the incidence of malaria is low, although *A. farauti* breeds there in large numbers during the rainy season. In the Mamberamo Rivier valley, malaria is highly endemic. Tanahmerah, in the southern part of the island, was formerly a highly endemic area, but in recent years, the Dutch authorities had reduced the incidence of the disease. Mountainous areas are not necessarily free from malaria since *A. farauti* has been reported at heights of 3,500 feet. However, there is very little malaria in the Zwart-vallei (3,500 feet high). An exploration party in the southwestern part of the central mountains of New Guinea remained for months completely free from malaria.

All three forms of malaria are found, but *vivax* malaria is by far the most common, representing probably from 75 to 80 percent of malarial infections among natives at Manokwari, Seroei, and Babo.[6]

The Philippines

The more than 7,000 islands of the Philippines may be grouped into four main divisions. Eleven of the largest islands constitute more than 94 percent of the total area; only 2,441 of the islands have names. The islands extend 1,152 miles north and south and 688 miles east and west. The combined land area is 115,000 square miles. The climate is distinctly tropical. The average rainfall is 93 inches.

The climate of the Philippines is hot and moist. Average temperatures are in the neighborhood of 80° F., and the words "summer" and "winter" have little meaning. The difference between the highest and lowest monthly averages at coastal stations is usually only a few degrees, and is seldom as great as 10 degrees. Inland stations, at a higher elevation, are much cooler than those on the coast, and have a smaller annual range. The seasonal distinctions in the Philippines depend on precipitation rather than on temperatures and separate the year into a dry season and a wet season, with the difference between the two periods decreasing toward the south and east. Seasonal wind shifts or monsoons (northeast in winter and southwest in summer) cause the wet and dry seasons to occur at different times on the east and west coasts. The east coasts have their rainfall maximums in winter (October to January) and a relatively poorly defined dry season in early summer. West coast stations have

[6] War Department Technical Bulletin (TB MED) 18, 10 Mar. 1944.

a pronounced wet period in summer and a dry period in winter. In the extreme south (Davao, Mindanao), there is a double maximum of rainfall, May or June, and October. Typhoons occur most frequently between July and November and often do great damage because of their force and the torrents of rain which may accompany them.

Thirty-two species of anopheline mosquitoes have been recognized in the Philippines as follows:

1. A. *aconitus* Dönitz 1902
2. *aitkenii* James 1903
3. *aitkenii bengalensis* Puri 1930
4. *annularis* Van der Wulp 1884
5. *baezai* Gater 1933
6. *barbirostris* Van der Wulp 1884
7. *cristatus* King and Baisas 1936
8. *filipinae* Manalang 1930
9. *gateri* Baisas 1936
10. *gigas formosus* Ludlow 1909
11. *hyrcanus pseudosinensis* Baisas 1935
12. *insulaeflorum* Swellengrebel and Swellengrebel de Graaf 1919
13. *karwari* James 1903
14. *kochi* Dönitz 1901
15. *kolambuganensis* Baisas 1932
16. *lesteri* Baisas and Hu 1936
17. *leucosphyrus balabacensis* Baisas 1936
18. A. *leucosphyrus leucosphyrus* Dönitz 1901
19. *leucosphyrus riparis* King and Baisas 1936
20. *lindesayi benguetensis* King 1931
21. *litoralis* King 1932
22. *ludlowi* Theobald 1903
23. *maculatus* Theobald 1901
24. *mangyanus* Banks 1906
25. *minimus flavirostris* Ludlow 1913
26. *nigerrimus* Giles 1900
27. *parangensis* Ludlow 1914
28. *philippinensis* Ludlow 1902
29. *pseudobarbirostris* Ludlow 1902
30. *subpictus indefinitus* Ludlow 1904
31. *tessellatus* Theobald 1901
32. *vagus limosus* King 1932

On the basis of accumulated evidence, only four species of *anopheline* mosquitoes have been blamed in the transmission of malaria. The most active transmitter is *Anopheles minimus flavirostris*, a member of the *funestus-minimus* subgroup. The other two members of the subgroup, *Anopheles mangyanus* and *Anopheles filipinae* are of secondary importance. *Anopheles maculatus* is a doubtful vector. *Anopheles flavirostris* is a stream breeder, definitely preferring clean, fresh, flowing and slightly shady water and with the presence of bamboo shoots or roots. Consequently, malaria is a disease of the foothills and is not seen in the lowlands or ricefields and does not appear above elevations of 2,000 feet. It was not until this fact was fully appreciated that any progress was made in malaria control. When there are pronounced wet and dry seasons, malaria will appear in two waves each year at the change of the seasons. Where such seasons are not pronounced, malaria is perennial. It has been suggested that the prevalence of malaria in the foothills has been partly responsible for the maintenance of ethnologic distinctions between the hill people and those from the plains.[7]

[7] War Department Technical Bulletin (TB MED) 65, 13 July 1944.

MEDICALLY IMPORTANT MOSQUITOES OF THE SOUTHWEST PACIFIC

Anopheles

Anopheles amictus Edwards is found in Queensland, northern Australia, and Australian Oceania. Subspecific variants are *Anopheles amictus amictus* Edwards and *Anopheles amictus hilli* Woodhill and Lee. Larvae breed in shady or sunny swamps. *Anopheles amictus hilli* is more often found in brackish water and *A. amictus amictus* in fresh water. Adults take human or animal blood. Sporozoite-infected *A. amictus hilli* has been reported from Queensland.

Anopheles annulipes Walker is found in Australia and Tasmania up to 1,200 meters and in Australian Oceania. Subspecific variants are *Anopheles annulipes annulipes* Walker and *Anopheles annulipes mastersi* Skuse. Larvae are found in shallow ground and rock pools, usually in fresh, sometimes brackish water. Adults feed avidly on man. No natural infections have been reported, but the insect has been suspected in one or two areas.

Anopheles bancrofti Giles is distributed throughout Polynesia, Australian Oceania, northern Australia and Netherlands New Guinea. Subspecific variants are *Anopheles bancrofti bancrofti* Giles and *Anopheles bancrofti pseudobarbirostris Ludlow*. Larvae breed in permanent, still, abundantly vegetated ponds and pools, generally well shaded. *Anopheles bancrofti* ordinarily feeds at night but sometimes feeds avidly on man in the daytime. Oocysts have been found in *A. bancrofti bancrofti*, but no sporozoites have been reported.

Anopheles bancrofti is found in the interior of New Guinea and along the southern coast but not on the northern coast. It is found in large numbers at Tanahmerah, at Kloofbivak on the Lorentz-Rivier, at Merauke, at Etna-Baai, and at Prauwenbivak. An infection rate of 4.3 percent was reported at Tanahmerah.

Anopheles farauti Laveran 1902 is found in the coastal areas of Moluccas east to New Hebrides and south to 20° south latitude. Synonyms are *Anopheles punctulatus farauti* Laveran, *Anopheles punctulatus moluccensis* Swellengrebel and Swellengrebel de Graaf, *Anopheles farauti farauti* Laveran, and *Anopheles farauti moluccensis* Swellengrebel and Swellengrebel de Graaf.

Larvae breed in ground pools of all varieties, including pools in sand, muck, coral, tracks of vehicles and animals; in grassy margins of sluggish streams, mangrove swamps with abundant flotage, and surface wells; and occasionally in brackish water and at times in containers. *Anopheles farauti* has been reported at heights up to 3,500 feet. Adults feed on man or animals, attack warily but persistently at any time between dusk and dawn, and frequent human habitations.

Anopheles farauti is an important vector of malaria throughout its range and is the only one in the New Hebrides. Numerous gut and gland natural infections of *A. farauti* have been reported with sporozoite indices up to 5 or 6 percent. *Anopheles farauti* is also an important vector of filariasis in the Solomons and New Hebrides.

Gut and gland infection rates of 13 percent were reported at Tanahmerah. This species is the most important vector in eastern New Guinea, the Solomons, and New Hebrides.

In the Philippines, *Anopheles maculatus* Theobald is found chiefly in clear running water of mountain streams well exposed to the sun, often on an opposite bank from *A. minimus flavirostris*, the latter along a more shady edge. *Anopheles maculatus* is often found in seepage water, springs, and shallow wells. Adults feed on man and animals and frequent human dwellings.

Anopheles maculatus ranges from Ceylon through India to South China and Formosa, thence south through Malaya and the Philippines to the Sulawesi. *Anopheles maculatus* is an important vector in Malaya but is of only minor importance in the Philippines and elsewhere in the Southwest Pacific.

Anopheles mangyanus Banks is found in the Philippines. Larvae breed usually in clear flowing and shaded water. *Anopheles mangyanus* has been found naturally infected with sporozoites. *Anopheles mangyanus* is associated with *A. minimus flavirostris* in the transmission of malaria in the Philippines.

Anopheles minimus flavirostris Ludlow is found in the Philippines and south to Djawa. Larvae breed along margins of clear flowing water, generally somewhat shaded, usually in the foothills, and not above 2,000 feet altitude, and not on the plains more than a mile or so distant from hills. Adults enter houses at night to feed on man but are often found inside habitations in the daytime. They prefer earthy resting places such as undercut banks of streams. Adults take cattle blood readily. *Anopheles minimus flavirostris* has been found naturally infected in the Philippines where it is the chief vector of malaria.

Anopheles punctulatus Dönitz is distributed throughout Melanesia north to 20° south and west to 170° east, and west to Sulawesi and northern Australia. Larvae are found primarily in ground pools. *Anopheles punctulatus* is dominant where soil is heavy clay while *A. farauti* tends to replace it where the soil is sand or muck. For example, along the sandy coastal strip north of Oro Bay only *A. farauti* was found but around Milne Bay where there are both clay and sandy areas, both species were found. Pools formed in the tracks of vehicles and animals were notable breeding places, especially around army camps. Larvae were also taken in bomb craters, hog wallows, intermittent streams, grassy pools, and ditches; more rarely in mangrove and sago swamps, in tin cans, and rarely, in brackish water. Larvae were not found in tree holes, cocoanut shells, or foul water, as a rule. Adults take human blood avidly and also animal blood. They frequent human habitations and feed mostly after 2100 hours. The bite seldom causes irritation.

Naturally acquired infections in *A. punctulatus* have been reported from New Guinea, New Britain, and Guadalcanal. *Anopheles punctulatus* is also a vector of filariasis.

This species was often found in settlements recently cleared of forests but was rarely taken in the Upper Digoel region. In northern New Guinea, infection rates were 1.5 to 5.0 perce' '

Anopheles subpictus indefinitus Ludlow occurs in Indonesia to the Sulawesi, in Borneo and the Philippines, in Guam (since World War II), and possibly in Formosa. The form taken in New Guinea and parts of Melanesia may be a subspecific variant. Larvae taken in Melanesia have often been found in brackish as well as in fresh water pools, and in marshes and swamps. Adults prefer animal blood but occasionally feed on man. The form taken in Melanesia and New Guinea may be a secondary vector, as suspected in Papua, but natural infections were not reported in the Southwest Pacific.

Aedes

Aedes aegypti Linn ranges perennially in the humid parts of the world wherever larva habitats do not freeze. *Aedes aegypti* is distributed throughout the Southwest Pacific in coastal sections and has sometimes been called the "mosquito of seaports." Larvae are found in peridomestic containers, such as roof gutters, horse tanks, barrels, bottles, cans, and tire casings, sometimes in leaf axils, rarely more than 1,500 feet from habitations. Adult has short flight range, is house-haunting, and feeds avidly on humans, usually in the daytime. *Aedes aegypti* is a vector of dengue in the Southwest Pacific and also carries yellow fever in Africa and South America.

Aedes albopictus Skuse is distributed from Japan south and west to the continent, and eastward through Micronesia to the Hawaiian Islands. *Aedes albopictus* is a vector of dengue in the Philippines and elsewhere in the Southwest Pacific and resembles *Aedes aegypti*.

Aedes kochi Dönitz is found in Pacific Oceania. Larvae were taken in the water of plant axils. Adults feed avidly on man at night. *Aedes kochi* is a suspected vector of filariasis.

Aedes scutellaris Walker has a complex of forms having similar habits and only slight morphological differences. *Aedes scutellaris scutellaris* Walker is distributed throughout the Philippines and south to New Hebrides but not in the Fiji Islands. *Aedes scutellaris pseudoscutellaris* Theobald is found at 175° east to 120° west longitude and 0° to 22° south latitude. *Aedes scutellaris polynesiensis* Marks is found in the Fiji Islands. Larvae occur chiefly in rot holes of trees. In New Guinea and on Biak, however, larvae were found in almost any container not having mud walls, such as in foul water in canoes, coconut shells, military junk heaps, including paper containers, and in cans with lacquer linings. Adults are day feeders, attacking man freely mostly out of doors but also in tents when near breeding places. *Aedes scutellaris* rest out of doors. *Aedes scutellaris pseudoscutellaris* and *A. scutellaris poly-*

nesiensis are vectors of filariasis in the Fiji Islands, and the closely related *A. scutellaris scutellaris* may be a vector in New Guinea.

Aedes vigilax Skuse is distributed in the tropics from Formosa to Thailand and east and south to New Caledonia and Australia. Larvae are found in shallow ground pools of tidal flats and in mangrove swamps. Adults are strong fliers. They feed avidly on man at night and early morning but sometimes all day in the bush, and they may evade houses. *Aedes vigilax* is a suspected vector of filariasis.

Culex

Culex annulirostris Skuse is found in Melanesia, Polynesia, Papua, and Australia. Larvae are found in ground pools, including those of ricefields and swamps, and in all kinds of domestic containers in urban and rural areas. Adults feed at night on man and animals. *Culex annulirostris*, experimentally, is a vector of filariasis but is not found naturally infected in the Southwest Pacific.

The subspecific variant of *Culex pipiens* Linn, *Culex pipiens fatigans* Wiedemann, which is the *Culex quinquefasciatus* Say of some authors, is found throughout the tropical world and was widespread in the Southwest Pacific. Larvae of *C. pipiens fatigans* were taken in collections of foul water in ground pools and in domestic and periodomestic containers, usually shaded. Adults generally are strong fliers and feed on man and animals, at night, as a rule. *Culex pipiens fatigans* is known as an important vector of filariasis in several areas, as in the Philippines, but its role in New Guinea is still doubtful.

Culex vishnui is a group of species quite similar in appearance and is distributed in the Orient and in Pacific Oceania. Larvae of the various species are found usually in small pools, drainage ditches, ponds, and streams. *Culex vishnui* is considered a vector of filariasis in India but not in the Southwest Pacific.

Mosquito Survey Data

Information on the distribution and bionomics of the mosquitoes of New Guinea and the adjacent islands was materially augmented by the various malaria units. This work was done more or less incidentally to field activities and was handicapped by the lack of suitable minor laboratory supplies and equipment. The paucity of information on the distribution and habits of the principal vector of malaria, *A. punctulatus*, and of other species that may play a part in the transmission of dengue, fiilariasis, and other diseases of military importance, was at first a serious handicap to the full utilization of control procedures. In this field, the work of Capt. (later Maj.) William R. Horsfall, SnC, entomologist of the 17th Malaria Survey Unit at Oro Bay, was especially valuable. He and his associates found *A. punctulatus* in the Markham Valley to range between sea level and 3,800 feet, with very few on the level coastal plains with sandy soil. They were most abundant below 2,000 feet and in areas with impervious soils. Breeding took place in open or slightly shaded water such as pond and stream margins, wheel ruts, and borrow pits.

Anopheles farauti, on the other hand, was more at home along the coast and in partially shaded situations, as along sluggish streams, and shaded pool margins. When present in limited numbers, adults were not prone to stay in tents or huts but apparently were widely distributed in secluded damp places under vegetation. They were observed in protected places in stream banks, in holes, and in overhanging grass, but always in the general vicinity of camps or native paths or villages.

Captain Horsfall reported that development from egg to adult of *A. punctulatus* took place in 8 days in warm water (95° F.) in the sun, and from 10 to 14 days in the laboratory. The egg stage ranged from 1 to 6 days in the laboratory and the larva and pupa stages from 7 to 12 days, with an average of 8.5 days. Captain Horsfall also found that adults traveled freely one-fourth mile, a very few to three-fourths miles. One female lived 17 days. Caged females could not be induced to feed a second time and no eggs were laid.

All agree that adults of *A. punctulatus* fed freely in captivity. In nature they were shy, and produced little or no irritation. This caused men to be careless, as they were not annoyed, and they seldom saw the mosquito.

Anopheles punctulatus was readily infected with either *Plasmodium falciparum* or *Plasmodium vivax*. In the experimental work at Cairns, often nearly 100 percent infection of salivary glands was secured, but high natural infection rates were not found. Of 315 females collected near Oro Bay, April and May 1944, Horsfall reported that only 6.4 percent showed gut infection, and of 586 salivary glands examined, only 0.3 contained sporozoites. These were evidently newly fed. Filarial infestations were found in 9 of 607 females dissected.

Breeding places of various culicine mosquitoes including *Aedes scutellaris*, which was evidently the principal carrier of dengue, were very diverse. Stagnant pools, margins of streams, seepage and rainwater in sago and mangrove swamps, leaf axils of trees, coconut shells, and various manmade water containers produced different species in varying numbers. Along the coast, coral pockets were said to serve as prolific breeding places for *A. scutellaris*.[6]

There were twenty species and subspecies of *Anopheles* and seven species of *Bironella*. Only three of these (*Anopheles karwari* James, a subspecies of *Anopheles subpictus*, and *A. bancrofti pseudobarbirostris*) were more or less widely distributed in adjacent regions, and the first two at least were possibly introductions into New Guinea.

[6] Malaria Report No. 234, Report of the Malaria Mission to the Southwest Pacific Area, 30 Aug. 1944, in Board for Coordination of Malarial Studies, a Joint Body Composed of Representatives of the Office of Scientific Research and Development, the Army, the Navy, and U.S. Public Health Service, and the National Research Council, vol. III. [Official record.]

The commonest and most widely distributed species in the Australasian Region were *A. annulipes*, *A. punctulatus*, and the subspecies of *A. bancrofti* and *A. amictus*. Some of the other species were known only from a single locality or had a limited range. The portions of the region from which the different species have been recorded are indicated in table 74.

Anopheles farauti, the form with an all-dark proboscis previously known as *Anopheles moluccensis*, had the widest distribution (map 31). It was found throughout the islands from eastern Sulawesi to New Hebrides and also occurred in northern Australia, being common at Cairns and in the Darwin area. There was a single record as far south as the Brisbane area reported by Lee and Woodhill.[a] The type form, *A. punctulatus moluccensis*, in which the apical half of the proboscis is largely pale-scaled, was collected in Australia or New Hebrides but otherwise had the same general distribution as *A. punctulatus*. *Anopheles clowi* Rozeboom and Knight, a recently described species, was found only at Hollandia.

The most widely distributed species in the region was *A. annulipes*, found throughout Australia, in Tasmania, a few localities in New Guinea, and the adjacent island of Goodenough. At Port Moresby, it was the commonest anopheline encountered and was said to be the dominant species in the greater part of Australia.

The type form of *A. amictus* was widely distributed in the northern part of the continent and occurred along the eastern coast to northern New South Wales. The subspecies *A. amictus hilli* had the same general distribution and was found also at Merauke in southern Netherlands New Guinea.

The type form of *A. bancrofti* was widely distributed and frequently very abundant in northern Australia from just north of Broome to Cairns, and along the east coast to Brisbane. It occurred in Netherlands New Guinea in the Merauke area and along the Digoel-Rivier. There was a single record from northern New Guinea, at Pionierbivak, which may actually have been the subspecies *A. bancrofti pseudobarbirostris*. The latter was the form found in the remainder of the northern and eastern parts of the island, as also on Goodenough Island. Its range extends into the Sulawesi and the Philippines.

The distribution of *Anopheles stigmaticus*, as given by Lee and Woodhill, is the coastal ranges of eastern Australia and two widely separated localities in New Guinea, one at Bulldog in Papua and the other at Anggi-meer in the northwestern part of the island. *Anopheles atratipes* Skuse occurred in small numbers in the Sydney, Brisbane, and Cairns areas on the east coast and at Perth on the west coast. *Anopheles powelli* was recorded only from the northern portion of Northern Territory and the tip of Yorke Peninsula.

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[a] Lee, D. J., and Woodhill, A. R.: The Anopheline Mosquitoes of the Australasian Region. University of Sydney, Department of Zoology, Monograph No. 2, 1944.

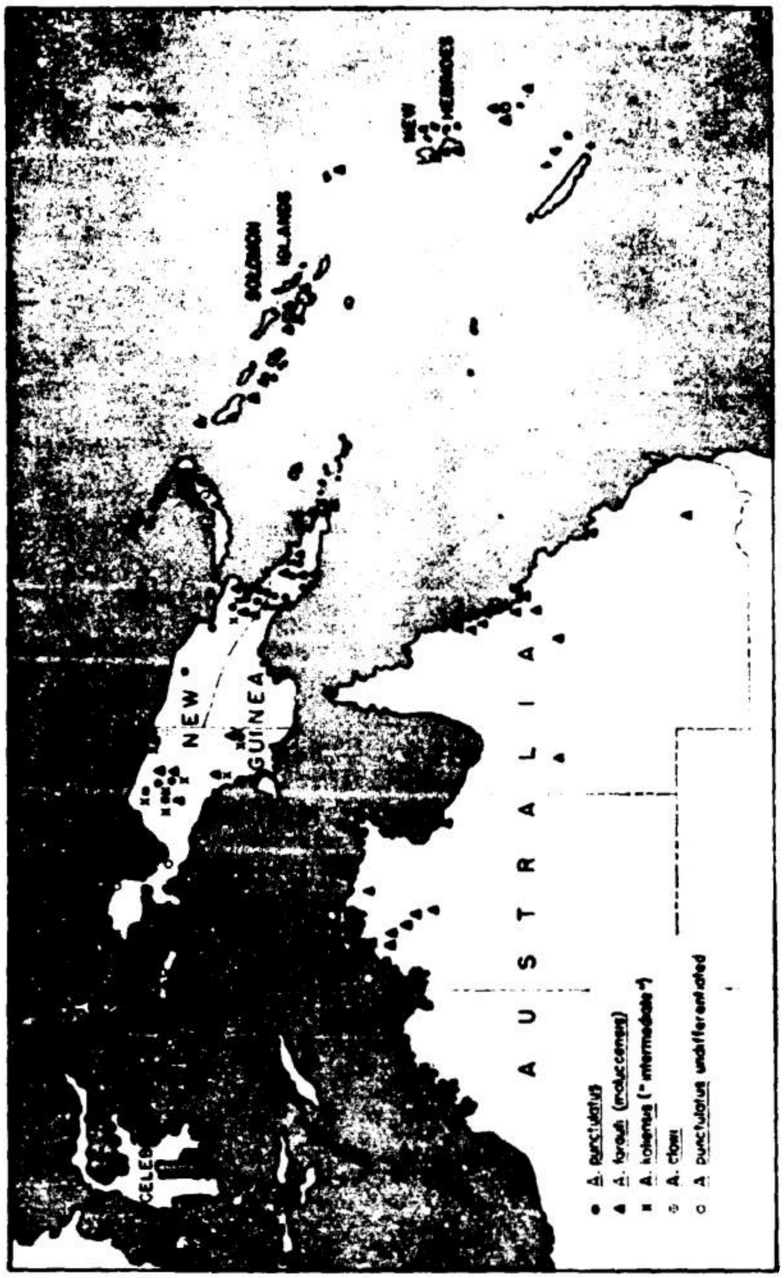
TABLE 74.—*Distribution of anopheline species of the Australasian Region*

Species	Australia				New Guinea		Solomons	Other islands
	N	E	S	W	E	W		
GENUS ***Bironella***								
SUBGENUS ***Bironella***								
1. *derooki* Soesilo and Van Slooten 1931					X			
2. *gracilis* Theobald 1905	X				X	X		Halmahera, Seram, Boeroe.
3. *papuae* Swellengrebel and Swellengrebel de Graaf 1920						X		
4. *brugi* Soesilo and Van Slooten 1931						X		
5. *sesseli* Strickland and Chowdhury 1931						X		
5a. "*sesseli*" sensu Swellengrebel and Rodenwaldt 1932					X	X		Goodenough, New Britain.
SUBGENUS ***Brugella***								
6. *hollandi* Taylor 1934							X	New Ireland.
7. *travestitus* Brug 1928					X	X		Seram, Halmahera.
GENUS ***Anopheles***								
SUBGENUS ***Anopheles***								
8. *atratipes* Skuse 1889	X	X		X				
9. *bancrofti bancrofti* Giles 1902	X	X				X		
9a. *bancrofti pseudobarbirostris* Ludlow 1902					X	X		Goodenough.
10. *powelli* Lee 1944	X							
11. *stigmaticus* Skuse 1889	X	X	X		X	X		

TABLE 74.—*Distribution of anopheline species of the Australasian Region*—Continued

Species	Australia				New Guinea		Solomons	Other islands
	N	E	S	W	E	W		
SUBGENUS *Myzomyia*								
12. *amictus amictus* Edwards 1921	X	X						
12a. *amictus hilli* Woodhill and Lee 1944	X	X				X		
13. *annulipes* Walker 1856	X	X	X	X	X	X		Tasmania. Goodenough.
14. *karwari* James 1903						X		
15. *longirostris* Brug 1928					X	X		Moluccas.
16. *lungae* Belkin and Schlosser 1944						X	X	
17. *meraukensis* Venhuis 1932	X	X				X		
18. *nataliae* Belkin 1945							X	
19. *novaguinensis* Venhuis 1933	X					X		
***punctulatus* series**								
20. *punctulatus* Dönitz 1901					X	X	X	Various to Halmahera.
20a. *clowi* Rozeboom and Knight 1946							X	
20b. *farauti* Laveran 1902 (*moluccensis*) Swellengrebel and Swellengrebel de Graaf 1920					X	X	X	New Hebrides; New Britain to eastern Celebes.
20c. *koliensis* Owen 1945 "intermediate," *auct.*					X	X	X	Probably Moluccas.
21. *solomonis* Belkin, Knight and Rozeboom 1945							X	Moluccas, Timor.
22. *subpictus* (var?) Grassi 1899					X			

Source: King, Willard V.: Anophelines of the Australasian Region. *In* Malariology, edited by Mark F. Boyd. Philadelphia: W. B. Saunders Co., 1949, vol. 1, p. 511.



MAP 31.—Distribution of the *Anopheles punctulatus* series.

Anopheles meraukensis Venhuis and *Anopheles novaguinensis* Venhuis both occurred in Northern Territory, in the Cairns area of northern Queensland, and in the Merauke area of southern New Guinea. The former was found also at Townsville and Brisbane, and the latter on the tip of Yorke Peninsula. *Anopheles longirostris* Brug was recorded from various parts of New Guinea as well as Seram and Halmahera. An unidentified variety of *A. subpictus* was reported in New Guinea only from a few areas along the southern coast of Papua. The same or similar form is widely distributed in the Netherlands Indies. *Anopheles karwari* was found in 1945 at Hollandia and was taken in considerable numbers in one location.[10] It may have been introduced from adjacent parts of the Oriental region where it is widely distributed.

Belkin and coworkers described in addition to *A. punctulatus*, three new species, *Anopheles lungae*,[11] *Anopheles solomonis*,[12] and *Anopheles nataliae*.[13] The last three species are closely interrelated forms distinguishable principally by variations in coloration of the female proboscis and by larval characters.

The following species were reported only from the Moluccas, Seram, or Timor:

A. aitkeni bengalensis	*A. insulaeflorum*
A. albotaeniatus	*A. kochi*
A. annularis	*A. maculatus*
A. barbirostris	*A. minimus*
A. barbumbrosus	*A. sundaicus*
A. hyrcanus	*A. tesselatus*
	A. vagus

It is doubtful if the reports of *A. tesselatus*, *A. barbirostris* and *A. aitkeni* from New Guinea, and *Anopheles ludlowi* from Seram were correct. Specimens from New Guinea, identified as *Anopheles philippinensis*, were thought by Lee and Woodhill to have been *A. meraukensis*.[14]

ESTABLISHING A CONTROL ORGANIZATION

February 1943 was an important date in the malaria control picture in the Southwest Pacific, for it was at this time that the first malariologists and the first malaria survey units arrived. By June, malaria control units were at work in the theater, and thereafter malaria came and remained under firm control.

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[10] King, W. V., and Hoogstraal, H.: Three New Anopheline Records From New Guinea. J. Nat. Mal. Soc. 5: 153, 1946.

[11] Belkin, J. N., and Schlosser, R. J.: A New Species of Anopheles From the Solomon Islands. J. Wash. Acad. Sc. 34: 269, 1944.

[12] Belkin, J. N., Knight, K. L., and Rozeboom, L. E.: Anopheline Mosquitoes of the Solomon Islands and New Hebrides. J. Parasitol. 31: 241–265, 1945.

[13] Belkin, J. N.: *Anopheles nataliae*, a New Species From Guadalcanal. J. Parasitol. 31: 315, 1945.

[14] King, Willard V.: Anophelines of the Australasian Region. *In* Malariology, edited by Mark F. Boyd. Philadelphia: W. B. Saunders Co., 1949, vol. 1, p. 520.

During 1942, the Office of The Surgeon General had been studying the problem of malaria control in those areas where U.S. troops had to operate. As a result of these studies, the Office of The Surgeon General proposed (1) the assignment of trained malariologists as assistants to the surgeons in malarious areas, (2) the formation of special units to determine and control the local factors in malaria incidence, (3) the education of the troops in protective measures, and (4) the utilization of labor personnel for antimalarial work.[15]

The Surgeon General outlined more fully the proposed malaria control organization in a letter to the Commanding General, U.S. Army Forces, Southwest Pacific, dated 24 October 1942. He invited him to submit requests for the additional military and sanitary personnel without delay.

In reply to this letter from The Surgeon General, the theater, on 1 December 1942, requested 1 malariologist, 6 assistant malariologists, 3 survey units, and 12 malaria control units.[16] A cadre of malariologists and an advanced echelon of three malaria survey units, the 4th, 5th, and 6th, were sent by air to the Southwest Pacific in February 1943. Dr. Howard F. Smith of the U.S. Public Health Service, on duty in theater headquarters, was appointed theater malariologist on 27 February 1943 by Staff Memorandum No. 3.

Theater Directives

In compliance with instructions, 1st Indorsement, General Headquarters, SWPA, 5 February 1943, the following basic sanitary and preventive measures for the control of malaria, dengue, and intestinal diseases were established for the information and guidance of all U.S. Army personnel in SWPA:

1. In malarious and potentially malarious areas, the wearing of shirts with long sleeves and full length trousers is necessary to reduce the probability of mosquito bites. Wearing shorts and short sleeved shirts and going without shirts between sunset and sunrise is not authorized.

Mosquito repellent and intact mosquito bars will be provided for all personnel.

Suppressive quinine or Atabrine (quinacrine hydrochloride) will be administered to personnel in hyperendemic malarious areas, in accordance with instructions from the unit surgeon. Supervision is essential to insure that the drug is swallowed.

2. Campsites will be located as far from mosquito-breeding places as the military situation will permit. Except in the combat area, mosquito breeding will be eliminated by oiling, draining, filling, removing empty cans, bottles, coconut shells, and other containers for a distance of 1,000 yards from sleeping quarters and recreation areas. Experience has proved that a small, well-instructed detail, assigned permanently in each unit on sanitary and malaria control work, will procure the best results.

3. When troops receiving suppressive malaria treatment are removed to a nonmalarious area, the base section commander of the new area will be notified immediately. The number of troops removed from suppressive treatment at any time must be commensurate with the hospital beds available.

[15] Letter, Col. John A. Rogers, MC, for The Surgeon General to The Adjutant General, 21 Sept. 1942, subject: Malaria Control.

[16] Coded Message CM–IN–C112, CINCSWPA, to the Surgeon General's Office, 1 Dec. 1942.

4. Medical Field Manual 8–40, "Field Sanitation," describes in detail the most practical methods for use in the field. Special attention to the inspection and handling of foods, the supply and treatment of water, fly control and the disposal of human excreta and garbage is necessary. Prevention of disease, essential for a low noneffective rate, can only be accomplished by the rigid enforcement of sanitary measures.

5. Commanding officers of all grades are responsible for sanitation and for the enforcement of the provisions of sanitary regulations within their organizations and the boundaries of areas occupied by them.

These instructions were reinforced later by a more detailed directive designed to provide a malaria control organization consonant with that recommended by the Office of The Surgeon General (appendix B, p. 585).

Assignment of Duties

Under the organization, as established, a medical inspector special (malariologist) was on the staff of the Chief Surgeon, USAFFE (U.S. Army Forces, Far East). Under the Chief Surgeon, he was authorized to direct and coordinate the operations for malaria control. He also acted as a special adviser to the Chief Surgeon on all matters pertaining to malaria and mosquitoborne diseases, including the avoidance of the introduction of the anopheline mosquito or of malaria into areas then free.

The assistant medical inspectors special (malariologists) were assigned to Headquarters, USAFFE, and attached to the staff of commanders when necessary. These assistants were to advise commanders in the development of malaria discipline in all troops, to instruct personnel in malaria control measures, to assist in planning and supervising survey and control measures, to investigate malaria rates and malaria hazards of proposed campsites, and to furnish commanders with all pertinent information obtained.

Malaria survey units and malaria control units were assigned to USASOS (U.S. Army, Services of Supply) for administration but were under the control of USAFFE for the performance of all duties pertaining to malaria control. These units were normally assigned to areas but under special conditions might be attached to organizations of the Sixth U.S. Army, Fifth Air Force, or USASOS. Regardless of attachment or assignment to duty, these units were under the technical direction of the chief malariologist. They functioned as follows:

The malaria survey units:

1. Determined incidence, distribution, and biology of mosquito adults and larvae in relation to malaria.

2. Surveyed, mapped, and recommended to commanders measures for malaria control in specific areas.

3. Maintained a check on effectiveness of control measures by routine collection of adults and larvae.

4. Performed malaria parasite surveys among civilians and troops to determine incidence and species of parasites.

5. Performed any special studies in regard to malaria or mosquitoborne disease required by the Chief Surgeon.

6. Kept commanders informed on all matters relating to malaria control in their areas.

The malaria control units:

1. Prepared detailed plans for malaria control measures.

2. Demonstrated and advised unit antimalaria details on approved methods of control.

3. Advised the commander on the use of labor, civilian and native, in malaria control work.

4. Initiated plans and advised commanders regarding the maintenance of control measures in areas between units, docks, airfields, and similar areas used by troops of all units.

5. Kept commanders informed on all matters relating to malaria control in their areas.

Personnel and units engaged in malaria control were furnished shelter and meals by organizations to which they were attached, or by organization commanders in whose areas they were assigned to duty. Movements of units within a base were effected by the base commanding officer upon request of the senior malariologist on duty therein. Movements of units from one base to another were directed by USAFFE.

Direct communication on technical matters between malariologists, survey and control units, and the Chief Surgeon, USAFFE, was authorized.[17]

Immediate Results

By late summer of 1943, the program for malaria control in this theater had been operating for approximately 6 months and was beginning to exert its full effect. In that time, the malaria rate in the U.S. Forces in New Guinea had been brought down from 970 per 1,000 men per annum in February 1943, to 200 per 1,000 per annum in August 1943.[18]

IMPORTANT FACTORS IN DEVELOPING THE CONTROL PROGRAM

Australian Medical Military Mission

During 1942, the procurement of adequate antimalaria supplies was very difficult. It was possible to get sufficient quinine, Atabrine, and Plasmochin naphthoate (pamaquine naphthoate) for treatment, but such antimalaria supplies as nets, repellents, insecticides, and sprayers were very inadequate. In fact, the supply situation was so unsatisfactory, from both the United States

[17] Letter, Brig. Gen. L. S. Ostrander, Adjutant General, USAFFE, to Commanding General, USASOS, 12 June 1943, subject: Organization for Malaria Control.

[18] Monthly Progress Report, Army Service Forces, War Department, 31 Oct. 1943, Section 7: Health, p. 12.

and the United Kingdom, that an Australian Medical Military Mission was sent in September 1942 to the United States and the United Kingdom. The objectives of this mission were (1) to bring home to the United States and United Kingdom authorities the grave danger from malaria and other tropical diseases, and (2) to procure an adequate flow of supplies of Atabrine, other malaria drugs, mosquito netting, and repellents. The mission was successful in obtaining approval of a 6-tablet weekly regimen for Atabrine and in obtaining promises for other needed supplies.

Inter-Allied Committee

Among the important factors in the program was the formation of an inter-Allied committee which advised the Commander in Chief of all aspects of the malaria problem. One of the reasons for the lamentable record in malaria control in 1942 and early 1943 was the absence of medical authority at the level of the theater commander's headquarters. The Inter-Allied Committee, under the chairmanship of Brigadier N. Hamilton Fairley, an international authority on malaria, was set up to remedy this deficiency. It was this Committee's recommendations, in the form of proposed directives which were approved and issued by General Headquarters to all commands, that were responsible for a uniform program of malaria control. USAFFE received its regulations from General Headquarters and reissued them to the American elements of the Allied Forces.

Assignment of Responsibility

The program and the management of the available resources for combating malaria were the responsibility of one person, the Chief Surgeon, USAFFE. This made possible the following:

1. The formation of an organization for the control of malaria which carried on the attack on the breeding places of the anophelines in troop areas, assisted and advised the units in such areas in their control work within the unit area, aided in the distribution of available antimalaria supplies, and provided for schools, lectures, films, posters, and other educational devices for the instruction of officers and men in the technique of malaria control.

2. The publication of regulations applying equally to all American Forces governing the use of individual antimalaria measures such as protective clothing, proper use of mosquito nets, repellent, the enforcement of suppressive treatment, and authorized methods of curative treatment.

3. The formulation of systematic programs for the rehabilitation of malarious divisions returning to Australia and the setting up of uniform standards for evacuation of malarious patients to hospitals to Australia from the Advance Base, and from Australia to the United States.

4. The establishment of a card report system which furnished prompt and current information on the malaria rate in different areas and in different

units, so that the malariologist knew where to center his chief efforts and also whether he was or was not being successful.

5. The institution of active research in prevention and treatment by personnel adequately trained and equipped and the restriction of indiscriminate experimentation.

The assignment of the malaria control organization to USAFFE resulted in some difficulties. Malariologists, for instance, could not travel to visit units in the field without securing permission for each separate move from both Sixth U.S. Army and Fifth Air Force, except on a personal basis, in which case no criticism or written report was permissible. All assistant malariologists were assigned to the 8th Medical Laboratory. Separate control organizations, however, for the Sixth U.S. Army, the Fifth Air Force, and USASOS would have been complicated and inefficient. Nevertheless, the system as organized worked well, despite these difficulties.

Survey and Control Units in the Field

Malaria survey units accompanied task forces into new areas and performed the initial mosquito-breeding survey of areas as soon as possible after occupation. It was their function to locate and map all actual and potential breeding places in their initial surveys and to maintain weekly checks on the efficiency of control measures in the area. The survey unit also dealt with the collection and examination of blood smears for the study of malaria parasites in native populations as required, in addition to periodic selected surveys of well troops.

The malaria control units were used in all of the forward areas and normally accompanied the combat troops. With the aid of native labor, the control units were charged with the supervision of all environmental controls throughout any specific area. Major control projects were performed by the control units, with the assistance of Corps of Engineer units or, at times, Seabees (naval construction battalions).

In addition to the special purpose malaria control personnel, each unit commander was required to form an antimalaria detail of one noncommissioned officer and two enlisted men for each company, squadron, or smaller unit. These company details performed routine antimalaria work in each unit area, and in their work they were assisted, advised, and checked by the malaria survey and control units. Projects of any magnitude within unit boundaries were carried out as a special assignment of the malaria control unit.

MALARIA CONTROL ACTIVITIES

After official recognition of the basic problem that malaria was posing in SWPA, malaria control activities were initiated promptly. The methods of control were of two kinds—group and individual. Under the group method were two means of control, that of (1) permanent malaria control measures and (2) temporary malaria control. As a general statement, it could be said that, because of combat conditions and the speed of movement in SWPA, permanent types of malaria methods were not widely applicable. Therefore, under group measures, the temporary methods of control were the general rule; in actual combat conditions, individual methods of control were often the only methods available to the soldier to protect himself against malaria.

Besides these general activities, the malaria control organization also engaged in some special public health work, such as scrub typhus control, general sanitation, and some of the work usually done by the medical inspector's office in military camps and posts in the Zone of Interior.

The program for the performance of group control methods was based on two special organizational units, the malaria survey and the malaria control units. While these units were administrative entities, they had close functional relationships—one survey unit usually serving to define problems and to check on the efficiency of two or three control units.

In general, the commanding officer of a survey unit was a parasitologist or entomologist; of a control unit, a sanitary engineer. The enlisted personnel were composed chiefly of noncommissioned officers to a total of 11 men, many of whom had special training qualifications.

These units arrived in a new situation at various times after D-day usually not before D+15. The survey units proceeded to define the local problem through blood surveys of native population and mosquito and topographic surveys. The information collected was mapped, tracings from topographic maps being largely used for this purpose. This information was then given to the control units. Subsequent activity of the survey units was toward the more precise collection of information on mosquito fauna and its ecology, resurveys of native populations, and checks on the efficiency of control units.

The malaria control units were equipped with appropriate light equipment for oiling and minor drainage. Its enlisted personnel performed some control operations but more often acted as supervisors of native labor or work details from service or combat units. The actual performance of control programs for a half mile around a given organization was done by the personnel from that organization; other areas were handled by the control units.

The control program of a given area consisted, in general, of the following activities:

1. Treatment of breeding places with larvicides.
2. Eradication of breeding places by drainage and filling.
3. Removal of native population groups to locations more than a mile from army units.
4. Strengthening of malaria discipline.

MALARIA CONTROL MEASURES

Throughout SWPA, malaria control was achieved through the use of many different measures, but chief emphasis was on the elimination or control of vector breeding places and the use of suppressive Atabrine therapy.

Personal Protective Measures

An important measure of malaria control was the maintenance of personal protective measures. By means of directives, lectures, and periodic inspections, all officers exercising command, as well as enlisted men, were indoctrinated along these lines. It was impressed on all unit commanders that this was the sole means of malaria control during combat and in new areas, until adequate environmental control could be established.

Nets and clothing.—Few, if any, head nets were worn or were available in the theater, for they were unnecessary and sometimes dangerous because they impaired vision. Bed nets were generally available but were not always used. In several instances, bed nets were not available for days or even weeks after establishment of a beachhead. In most commands, the use of bed nets was strictly ordered and enforced except where combat situations made this impractical. In the best disciplined units, nets were frequently inspected for defects and proper usage. The jungle hammocks were dangerous in advanced positions because the occupants were more susceptible to sneak enemy attacks. These hammocks were generally abandoned after a short trial.

The wearing of protective clothing, which included long trousers and shirt with sleeves rolled down, was required at all times, except when under mosquito nets, when bathing, or when engaged in athletics. Considerable difference of opinion was expressed in the field as to the best discipline in this regard. Some felt that shirts should be worn at all times, except when under a bed net or at bath. It was generally conceded by those responsible for malaria control that shirts should be worn constantly. Details laboring in the open sun, in holds of ships, on docks, or in screened buildings were allowed to remove shirts from 0630 to 1730 hours.

Bathing was restricted to daylight hours except when screened showers were available.

Screening.—Screening, mostly galvanized 16 and 18 mesh, was installed on many of the barracks, hospital wards, messhalls, and recreation rooms, but almost solely at the older and more permanent bases. From a practical standpoint, absolute mosquitoproofing did not seem to be possible because of the nature of the buildings.

Repellents.—In better disciplined bases, mosquito repellent rules were well enforced in connection with attendance at outdoor movies at night. But a relatively small percentage of the total supply of such repellents as dimethyl phthalate was used for the intended purpose. Ample stocks of repellents were generally available, but mosquitoes were so few, except in unusual situations, that the men would not apply the repellents. However, experience indicated that men engaged in a new landing should be amply supplied with repellent for use after landing.

Rather crude tests of dimethyl phthalate indicated that it was not nearly so effective against *Anopheles punctulatus* in SWPA as against *Anopheles* *quadrimaculatus* in the United States; also, that Rutgers 612 gave more lasting protection than the dimethyl phthalate. The protection given by Rutgers 612, however, probably did not exceed 2 or 3 hours.

Aerosols.—Aerosol bombs were generally available in New Guinea but were often improperly used, as against flies, ants, and miscellaneous insects. A few were used to spray tents and bed nets. The tents were practically all without walls, and there was doubt of the efficacy of the Aerosol in these tents, even against mosquitoes.

It was reported that bombs were used for cooling beer or for the construction of improvised small refrigerators.

Aerosol bombs were conscientiously employed in transpacific Air Transport Command planes. The Aerosol was applied freely after each takeoff, and before each landing. Aerosols were not observed in use in Australia or in Army planes in Australia or New Guinea. Aerosol treatment of planes in Australia and parts of New Guinea was probably unnecessary but was employed as the front progressed further north. There was some danger of introducing *A. punctulatus* into northern Australia, but this was not great. There was also the danger of introducing that species into the Philippines or of introducing *Anopheles flavirostris* or other dangerous species into New Guinea.

DDT.—The application of residual DDT sprays to tents and bed nets and the impregnation of these articles with DDT were given consideration. Reports showed that adults of *A. punctulatus* usually rest on tents or other nearby articles for at least a few minutes either before or after feeding. Some impregnated nets did not prevent mosquitoes from biting through them, but caused the death of the mosquitoes as a result of the contact.

Antilarva Measures

Larviciding

For larvicidal purposes, DDT was supplied as commercially pure DDT, and as a 10-percent mixture with talc, known as larvicide DDT, dissolving, and larvicide DDT powder, dusting, respectively. In these forms, DDT was prepared for application as a larvicide, either as an oil solution or as a dust.

A 5-percent oil solution of DDT was an effective larvicide, with certain qualities which made it extremely valuable for use in malaria control. One of these qualities was that a small dose of the solution would effectively treat a large area of water surface. Only enough oil had to be applied to secure coverage. Numerous laboratory and small-scale field trials demonstrated that, where oils spread rapidly, 1 cc. of the 5-percent oil solution will effectively treat 40 square feet of water surface. At this rate, 1 quart of 5-percent DDT oil mixture will treat approximately 1 acre of water surface, as compared with 10 to 14 gallons when ordinary oil is used. A moderate amount of vegetation interferes very little with the spreading ability of the DDT oil solution. The use of DDT oil solution simplified methods of application and, consequently, saved labor and equipment.

Rate of application.—For temporary control, oil solutions of DDT were applied at 0.1 to 0.25 pound of DDT per acre. This amount is contained in the 1 and the 2½ quarts of the 5-percent oil solution, respectively. This rate of application destroyed existing larvae and pupae but did not have residual action. Eggs deposited within a day or two following treatment could be expected to develop into larvae and adults in the normal fashion. The treatment, therefore, was repeated every 6 to 9 days.

The amount of oil solution actually used in treatment was governed to some extent by the type of equipment available and by the character of the area. The distributing apparatus sometimes was such that a much larger quantity of the oil solution was used than the calculated dosage indicated. When vegetation was extremely dense or a scum was present, distribution for adequate coverage often resulted in a larger dose of DDT than necessary for killing the current crop of larvae.

For residual action, single heavy doses of DDT oil solution were applied and curtailed breeding for periods ranging from 3 to 6 weeks in some situations, such as stabilized breeding places containing heavy vegetation which prevented shifting of surface films by wind action or rain. The most effective dose for this kind of treatment was about 5 gallons of 5-percent DDT oil solution per acre. This is equivalent to 2 pounds of DDT. Dosages in excess of this in most cases seemed to show no additive effects.

Methods of application.—Almost any type of container or apparatus available in the field was used to dispense the DDT oil solution. Knapsack or other types of oil sprayers, with the spray nozzle adjusted to produce a fine spray, were generally satisfactory (fig. 57). Owing to the unusual spreading qualities of DDT oil solution, simple pouring from a bottle, bucket, or can was both feasible and effective on some breeding places; or the solution was poured over wet gravel, sand, or earth, which was scattered over the water surface. Successful control of anopheline breeding for periods of 2 to 3 weeks was obtained in ponds on which bags of sawdust soaked with equal parts of 5 percent DDT in crankcase oil and 10 percent DDT in gasoline were placed. A weight was added to the bag to make it submerge. To keep the bag from sinking into the mud at the bottom of the pond, a stoppered empty bottle or some other buoyant object was attached. The DDT oil solution gradually released from the soaked sawdust was observed to control breeding in roadside ponds for 2 to 3 weeks. In the treatment of flowing streams, the oil solution was applied at rather wide intervals, since the moving water assisted in spreading the larvicide. In treating streams, standard mechanical methods of the dripcan type were sometimes used.

For temporary control, DDT dust mixture was applied in the same manner as paris green dust. DDT dust was effective when applied at the rate of 0.1 pound of DDT per acre. This means 10 pounds of a 1-percent dust, or 2 pounds of a 5-percent dust per acre. To insure adequate coverage of breeding

FIGURE 57.—Refilling knapsack sprayers with oil, 8th Malaria Control Unit, New Guinea.

areas, the 1-percent dust was preferred where transportation of materials was not too difficult.

For residual control, a single application of the 10-percent DDT dust concentrate at the rate of 10 pounds per acre was sometimes used to secure a residual killing action for 3 to 5 weeks. Residual action was more likely in water areas covered with thick vegetation where the dust film was protected from wind and wave action.[19]

Oiling with fuel oil in hand spray pumps (knapsacks and especially with CWS (Chemical Warfare Service) decontamination sprayers and some sleeve-type firefighting units) was the most general procedure. Some use was made of buckets and mops, sprinkler pails, and oil-impregnated sawdust, owing to lack of sprayers. Where native labor was available, it was usually employed, and some of it was quite satisfactory. This was more often true in Australian New Guinea than in Netherlands New Guinea. For the use of these laborers, the governments of Australia and Netherlands East Indies were reimbursed at a low rate by the United States (fig. 58).

Sprayers.—Knapsack sprayers were often scarce and the type furnished were short lived. The following suggestion for improvement of this equipment was offered by Capt. John Coffee of one of the control units on Noemfoor: The

[19] War Department Technical Bulletin (TB MED) 14, 3 Mar. 1944.

FIGURE 58.—Malaria control ditching and clearing crews furnished by the Australia New Guinea Administrative Unit to the 12th Malaria Control Unit, New Guinea.

outlet should be reinforced, the bottom securely soldered in, the sponge rubber seal around the top improved, and the top clamp for holding the hose made stronger. Rubber diaphragms of three thicknesses of auto inner tubes were installed in the field, but these, too, were short lived. A spray outfit used by one malaria control unit consisted of two tight drums to serve as pressure tank and oil containers coupled to a small compressor and carried in a light tank.

There was need for good substantial hand sprayers for use in the mess and barracks, as they were not available in advanced areas. The small atomizers (two sizes), developed at the Orlando Laboratory in Florida for hand application of spray concentrates, failed to have any special advantages. They could not be carried into combat by troops and were not as useful in stabilized areas, as were the Aerosol bombs and hand sprayers.

A number of power spray units were improvised in the field and were especially helpful when labor was scarce.

Airplane spraying.—Airplane application of DDT in oil was undertaken on a limited scale. Tests were made in Australia and also in New Guinea. Experimental tests of this method of controlling mosquitoes were carried out in July 1944 at Nadzab with CWS tanks on an A-20 plane and, later, with a special tank (195 gallons) with manual control on a B-25. As a result of this work, it was concluded that DDT was 100 percent effective against flies and 90 percent effective against adult mosquitoes, but was not effective against the mites transmitting scrub typhus.[20]

The second test of the efficiency of airplane distribution of DDT was made on Owi Island, on 20 July 1944. This was primarily to test the value of the spray against mites, but observations were also made of the effects on flies and mosquitoes. The spraying did not appear effective against mites, but flies were not noted after spraying; however, the area of effective coverage appeared to be limited. Biak was sprayed 2 days later, and Sansapor on 4 August, 4 days after the landing was made on that island.

Morotai was sprayed on D-day, 15 September, the first instance where this was done; further sprayings were made on D+1 and D+14. The results were reported by Capt. P. J. Darlington, Jr., SnC, as follows:[21]

> I arrived on shore at 0950 on D-Day, and at 1130 the DDT planes came over. They came over again on D+1 between 1100 and 1115. The weather was clear and dry with only a slight breeze. The planes I saw flew about 100 feet above the ground and followed parallel paths 200 yards or less apart * * *. It seemed to me the planes laid down too little spray. The visible mist trails which they left in the air were very thin and only a few yards wide.
>
> There were very few adult insects here to begin with so far as I could find in the few hours before the first spraying had time to take effect. I saw only one adult mosquito and a very few miscellaneous flies. There are still only a few adult mosquitoes and flies here, except in a few places, but it is a question how much of the credit should go to the DDT. I was not able to find breeding places in time to make a survey of mosquito larvae before the spraying, but on the morning of D+4, 3 days after the second spraying, in an area over which I saw planes pass on both D-day and D+4, in a shallow open swamp, I made about 100 dips and got nearly 1,000 Anopheles and many culicine larvae. The Anopheles were of all instars, including many fourth, but I found no pupae. The absence of Anopheles pupae three days after the second spraying may mean that the DDT killed the large larvae of this species, but certainly the effect on larvae was not great, even in this completely open water, and there was no residual effect.
>
> A single heavy application on D-day would probably be better than two light ones on successive days. In any case, the amount of DDT put down on Morotai was probably insufficient. Although initial spraying of a new beachhead has to be done by the Air Force from a distant base, later sprayings ought to be done from the beachhead itself by properly equipped Cub Planes.

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[20] Memorandum, Col. Maurice C. Pincoffs, MC, to Lt. Col. Gottlieb L. Orth, MC, 11 Aug. 1944, subject: Insect Control (DDT). SWPA.

[21] Letter, Capt. P. J. Darlington, Jr., SnC, Office of the Surgeon XI Corps, to Surgeon, Sixth U.S. Army, 27 Sept. 1944, subject: Airplane Spraying of DDT on Morotai Island.

The 15 September spraying was at the rate of 0.13 pound per acre, the spraying next day was at the rate of 0.46 pound per acre, and on 29 September the rate was 0.30 pound per acre.

Biak was sprayed in October 1944, and Hollandia in November.

The plan of applying DDT in connection with landing operations appears to have been well thought of by both malaria control men and operational officers. The latter did not appear to have been sufficiently impressed, however, with the need for previous preparations of supplies, equipment, flying personnel, and careful application.

Oil solutions of DDT were used, but Mr. Douglas Waterhouse (Council for Industrial and Scientific Research at Canberra) thought emulsion might be applicable. The following formula was his choice after testing many emulsifying agents: From 20 to 25 parts detergent (Bozetol, Tween 60, or Solvadine BL) used with 75 to 80 parts of chlorobenzene, containing 60 percent DDT. The mixture is suitable for preparing emulsions with any type of water and is quite stable in storage.

Extensive work was carried on during November 1944 under the direction of Capt. William C. McDuffie, SnC, to develop standard techniques for applying DDT oil solutions from the air. As a result of this work, improvements were developed which resulted in more effective use. As the combat area moved north, however, the need for airplane application of DDT lessened.

Equipment for airplane application of DDT received attention from the Australian and American authorities. Little testing of the Husmann spray equipment on Cub planes was done. Some tests carried out by the Fifth Air Force in March 1944 showed the equipment to be satisfactory for small-scale work. Most authorities felt that such equipment might be advantageously employed in base or intermediate areas where extensive breeding places must be treated and especially where native labor was scarce. Major emphasis was placed and, in the opinion of these authors, rightfully, on the development of equipment for use on fast planes in combat areas.

The Australian group experimented with the use of wing and belly gas tanks on Beaufort light bombers, which planes were widely available for such use. The wing tanks held about 90 gallons (British) and belly tanks about 135 gallons. They were already fitted with dump valves, about 5 inches in diameter, controlled by air pressure lines from the cockpit. They could be opened and closed readily, thus conserving the solution. The exhausts were fitted for applying insecticide with a tapered spout similar to the spout on the American CWS tanks, and the oil was broken up well with the slipstream. Initial work in New Guinea indicated that airplane spraying with DDT was highly effective against larvae and adults of *Anopheles punctulatus*.

In preliminary tests with a 5- to 8-mile wind, flying at a height of 100 feet at a speed of 170 m.p.h. and the two wing vents open, good coverage was secured over a swath about 300 feet wide and some coverage, for 800 to 900 yards. It was observed that, in some instances, as little as 20 percent of the solution could be accounted for on the ground as indicated by dyes in the solution. The two openings in the belly tank (about 14 inches apart) appeared to give coverage of a somewhat narrower swath. The effects of corrosion of tanks and equipment, and its effects if tanks were subsequently used for gasoline, had to be considered.

In the U.S. Army group, initial work was done with a Piper Cub plane and the Husmann spray unit. Later tests with CWS tanks (M–10) on A–21's with a metal disk in front of the glass disk were made on Owi. The metal disk was provided with a wedge-shaped opening with the curved edge down. Then, the glass was broken by detonation, the disk slowed down the discharge, and permitted complete discharge of the oil. This work indicated the need of manual control. An A–21 with one of these tanks, flying 220 miles per hour at 50 feet, gave effective coverage of an area approximately 2 miles long and 100 yards wide. In these tests, 32 gallons of material was used, and it covered about 72 acres.

A new CWS smoke tank (ELB) of 195-gallon capacity was mounted in the bomb bay of a low-level bomber aircraft B–25–D. This equipment, flown at 200 m.p.h. at an altitude of 100 feet, gave effective covering of an area 200 yards wide and 4.4 miles long. The preliminary work was done at Nadzab, and excellent kills of test insects were secured.

Drainage and filling

With the rapid northward shifting of the war theater, extensive and expensive drainage operations exclusively for mosquito control were not warranted and were not carried out. Furthermore, the rather heavy machinery necessary to carry out this procedure economically was not generally available, since it was required for construction of airstrips and roads. There were some rather large hand-dug ditches near Lae, and such work was expedited by the use of a bulldozer to clear off the surface. Some dynamite was also employed for swamp ditching. Shell craters were used for earth-covered dumps and thus were gradually filled. Roadside drainage was improved in many cases, thereby eliminating important breeding places (figs. 59 and 60).

Destruction or burial of manmade water containers was a first requisite after taking over previously inhabited areas. Experience showed that sago swamps and rain forests should be opened up as little as possible, since elimination of shade induces breeding. Logging operations, however, did that and also left the areas cut up so that water remained on the ground. These areas required special attention and were difficult or impossible to control by conventional larvicide methods.

Naturalistic control

Little or no effort was made to transplant fish into mosquito-breeding pools. So many of these pools were temporary that the fish would soon have been killed. In some more permanent water where breeding occurred, top-feeding

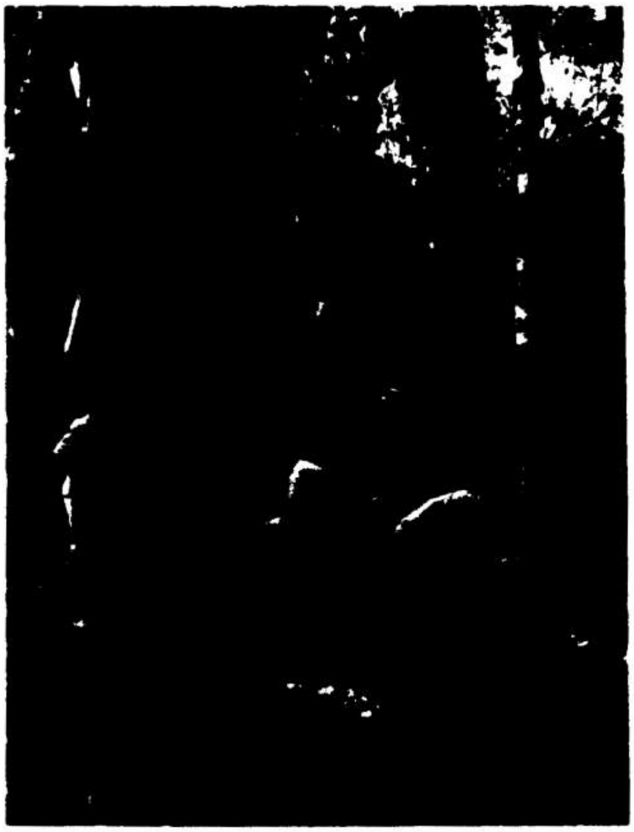

FIGURE 30.—Digging drainage ditch, 8th Malaria Control Unit, New Guinea.

minnows were observed in great numbers and undoubtedly served to hold down mosquito breeding. Manipulation of fish did not appear to have much practical value under New Guinea conditions. Some predaceous mosquito larvae were collected and reared.

Water impoundment and control of water levels seemed to have no place in the control of mosquitoes in connection with the war operations in New Guinea.

Mapping

Some survey units reported shortage of drawing equipment for mapping. Opinions regarding the value of maps differed. In general, they were thought to be useful even though the picture regarding breeding places created by U.S.

FIGURE 60.—Completed drainage ditch, 8th Malaria Control Unit, New Guinea.

operations changed almost from day to day. Aerial photographs were used by some but were not generally regarded as highly useful.

Adult Mosquito Control

Environmental measures that were employed in this theater against adult mosquitoes included killing by means of insecticide sprays and screening. Under ideal climatic conditions, the pyrethrum spray, as dispensed by the Freon Aerosol container, was very effective. However, in the majority of tropical conditions where an attempt was made to maintain the maximum ventilation, it was found that the efficiency of the pyrethrum spray was much less than would be expected in a relatively confined area, owing to the rapid dispersion of the mist by the breeze. Airplanes, when returning from malarious to non-malarious areas, were sprayed, in an attempt to prevent further spread of mosquitoes, and introduction of species.

No use was made of organized adult spraying details, because the principal malaria vector (*A. punctulatus*), when on the wing or attempting to feed, is often not noted by the lay person and in many areas was difficult to capture by experienced observers using standard catching methods. On other occasions, adult spraying was impossible because of inadequate supplies of pyrethrum sprays, although this situation was later corrected. Wire screening, even when available, did not prove practicable in the forward installations of this theater. This was because the majority of the buildings were of native type (thatched) of construction which did not lend itself to screening. Even buildings of better construction were left with many openings through which adult mosquitoes gained admission. Some observers believed that, unless extremely intelligent use of screening was made, the employment of it led to a sense of false security rather than to effective protection.

Theater directives specifically stated that all staging areas and campsites were to be located so as to avoid proximity to native villages and camps and to those areas known to have a heavy population of malaria-carrying mosquitoes. Natives were removed for at least 1 mile from all installations between dusk and dawn.

Suppressive Treatment

Troops under orders to move from the Australian mainland to malarious areas were given two Atabrine tablets (0.2 gm.) daily for the 7 days immediately preceding the expected date of arrival in malarious areas. Troops arriving in malarious areas without having received previous suppressive medication, as frequently happened with new units from the United States, were given four Atabrine tablets (0.40 gm.) daily for the 3 days immediately after arrival, and then continued on with the routine suppressive treatment. Standard Atabrine treatment was directed for all troops in malarious areas; the policy was one tablet (0.1 gm.) per man daily. Suppressive Atabrine was administered by roster in the presence of a commissioned officer in such a manner as to insure that each person actually swallowed the medication. Under certain circumstances, such as in combat areas, where it was found impossible to hold a daily Atabrine formation and the need for maintaining a fully effective trained unit over a period of time was particularly great, an alternative regimen of five tablets (0.5 gm.) twice weekly was used with success and was sufficient to maintain effective blood Atabrine level.

Method of administering Atabrine

The method of administering Atabrine after mess, preferably after the evening meal, was as follows:

1. The soldier proceeded to lyster bag, or other water supply. Water was allowed to run into his canteen cup to the depth of not more than one-half inch, by a private detailed to this duty and to that of regulating the rate at

which the column of men approach the "Atabrine table." This was important. Crowding in the line permitted the improper disposal of the drug.

2. With canteen cup containing water in his left hand, the soldier proceeded to receive his Atabrine with at least a distance of 3 feet between him and the soldier preceding and the one following.

3. The approximate dose of Atabrine was delivered into his outstretched right hand by an enlisted man detailed to this duty. Under no condition was the soldier allowed to "help himself" to the Atabrine. Without closing his hand, the soldier, facing the supervising officer, tossed the Atabrine into his mouth, drank the entire contents of the canteen cup, and inverted the empty cup squarely upon the table. These acts were constantly supervised by the commissioned officer from the beginning to the end of the "muster."

4. The soldier proceeded to a distance of at least 3 feet to "the checker" (noncommissioned officer) to whom he stated his full name and rank and waited until his name was checked on the roster.

5. The soldier then assumed the position of "at ease" in a second formation, new additions to which took their places in front ranks.

The formation was continually supervised by a noncommissioned officer whose duties were to detect any attempt at improper disposal of the Atabrine, to keep the formation *at ease*, and to release small formations after the last man to arrive in the respective formations had been present at least 5 minutes. Stragglers appeared before an officer to take their Atabrine and to be credited for having done so.

The adoption of the simple method of Atabrine administration caused a complete cessation of recurrent attacks of malaria in large bodies of men, all of whom were subjected to acute episodes of this disease.[22] The success rewarding Atabrine suppressive therapy was dependent upon the thoroughness with which the administration of the suppressive agent was supervised.

Suppressive treatment in combat

"The Suppression of Malaria in Combat" is the title of a report forwarded to The Surgeon General from a malaria research unit in the Southwest Pacific and is summarized as follows:[23]

> There is no longer any doubt that Atabrine is highly effective in the suppression of malaria even in combat, but there has been no unity of opinion as to just how much malaria might be expected under suppression. It has been maintained by some that there need be no malaria if everyone took the required amounts of Atabrine. This belief was based on experiments on large but necessarily limited numbers of men under relatively favorable conditions. The few who reported with clinical malaria had been unable to take the drug.

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[22] Letter, Lt. Col. George G. Duncan, MC, Surgeon, 5215th Reconditioning Center (Prov.), to The Surgeon General, 4 Jan. 1944, subject: Medical Department Report, inclosure thereto, pt. III, The Atabrine Muster.

[23] Malaria Report No. 300, The Suppression of Malaria in Combat, 6 Oct. 1944, in Board for the Coordination of Malarial Studies, A Joint Body Composed of Representatives of the Office of Scientific Research and Development, the Army, the Navy, the U.S. Public Health Service, and the National Research Council, Vol. III. [Official record.]

Serious toxic effects—atypical lichen planus, aplastic anemia, and acute psychoses—were infrequent, though an increasing incidence was noted during 1944. Sometimes, they resulted in prolonged disability, evacuation from the theater, and rarely, death. Moreover, knowledge of toxicity had a bad effect on morale. So did the relatively harmless but sometimes alarming yellow-green pigmentation which occurred in the majority of those long under Atabrine suppression. There was also an unfounded but highly prevalent rumor that Atabrine suppression led to impotency and sterility. Such a bad effect did these toxic effects and these rumors have on morale that they sometimes constituted a serious interference with effective Atabrine suppression. All mention of malarial incidence and toxic effects of Atabrine had to be banned by the censorship to avoid quotations in the Australian papers which reached the Allied Forces.

Supplies of Atabrine generally were adequate throughout the theater. In the few instances when the supply ran low, there was always enough available among the men to avoid a break in the routine.

Conclusions of a controlled study of the personnel of the 126th Infantry Regiment, 32d Division, as follows:

1. When 1.0 gm. Atabrine was taken every week, at least 98 percent of the troops were protected against clinical malaria.

2. Difficulties of administration in the field and the inability of a certain portion of the men to retain their 0.5 gm. were at least three times as important as true "breakthroughs" in producing a rate of 140 per 1,000 per year.

3. Even when more than 50 percent of the troops would have developed malaria in 2 months had they not been protected by Atabrine, suppression with this drug was capable of keeping the clinical rate during combat at a negligible rate.

Epidemiological aspects of suppression

A summarized field research report on the epidemiological aspects of Atabrine suppression follows.[24]

As this was the first time that an Atabrinized army had fought in a hyperendemic malarious area, it was important that the part that Atabrine played not only in the suppression of clinical malaria but in the prevention of epidemic malaria be understood. Atabrine had a direct effect on *vivax* gametocytes and prevented the development of *falciparum* gametocytes in adequately suppressed individuals. Thus, it prevented the infection of mosquitoes, which in turn meant fewer infections of other soldiers. This cutting off of the source of further infection made it possible for troops to fight in hyperendemic areas with a high degree of protection from Atabrine and a resultant greatly decreased amount of infection.

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[24] Letter, Malaria Research Unit, 3d Medical Laboratory, to The Surgeon General, 8 Jan. 1945 subject: Report No. 15, The Epidemiological Significance of Atabrine Suppression.

Epidemic *falciparum* malaria in the tropics acquired its explosive nature by the geometric increase in the number of crescent carriers which developed in the nonimmune population. Although the increase of anophelines brought about by the troop operations also played a large part in the genesis of the epidemic, an increase of anophelines alone with minimal number of gametocyte carriers was incapable of producing the epidemics experienced by both the American and Australian Armies in the early campaigns.

Unfortunately, there are no studies available of the gametocyte and mosquito infection rate, from the beginning to the end of an epidemic, but it is possible to compare the rates obtained during endemic and epidemic situations. The outstanding epidemic of malaria in an unprotected and nonimmune population occurred in the Netherlands East Indies colony of Tanahmerah; here, the attack rate reached an average of four yearly attacks per person. It was during this epidemic that the highest infection rate of mosquitoes was obtained—12.7 percent. Heydon[25] at Rabaul found a sporozoite rate of 3.9 percent and an oocyst rate of 3.6 percent in 220 dissections, despite a low parasite rate in the natives. Heydon, however, believed that, since most of the infected anophelines were collected from houses with known gametocyte carriers and since they were kept for some days before dissection, this rate does not reflect the general rate in nature.

Finally, it is of interest that the lowest reported infection rate of mosquitoes (0.06 percent of 1,735 dissections) was obtained during an off season for malaria transmission at the native villages near Lalapipi, and it was here also that the lowest gametocyte rate was obtained in the native surveys. It is true that local conditions contributed to this abnormally low rate in *A. punctulatus*, but it is believed that the data just cited established the fact that in New Guinea and elsewhere there is a direct, although not constant, relationship between the epidemicity of a situation and the infection rate in the anopheline vector.

The combination of (1) an efficient vector in sufficient numbers, (2) a large number of susceptibles, and (3) a few infections to start the chain of transmission make epidemic malaria inescapable. This had been true regardless of the size of the original reservoir. One of the most devastating of military epidemics occurred during the southern campaigns in the Civil War in areas which had only moderate endemicity. Thus, the amount of infection in the natives is of relatively little importance in the outbreaks of epidemic malaria in unprotected troops. If, however, the great majority of soldiers cannot become gametocyte carriers because of adequate Atabrine suppression, the epidemic cannot occur. The amount of infection left behind by enemy troops will have a short-lived effect, while the amount of infection caused by the natives is of much less importance since contact is usually not close.

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[25] Heydon, G. A. M.: Malaria at Rabaul. M. J. Australia 2: 625–634, December 1923.

If the foregoing thesis of the smothering effect of Atabrine suppression on epidemic malaria is correct, it should be possible to demonstrate a direct relationship between the malaria rate under suppression, the gametocyte rate in the troops, and the infection rate of the mosquitoes collected from troop areas (tables 75 and 76). Because Atabrine had a direct effect on the *vivax* gametocytes, but none on the *falciparum* crescents, one expected to find that with good but imperfect suppression only *falciparum* carriers are discoverable.

TABLE 75.—*Comparison of gametocyte rate and malaria rate in selected troops, 1944*

Organization	Malaria rate [1]	Men examined	Gametocyte rate		Expected *Plasmodium falciparum* rate
			Plasmodium falciparum	*Plasmodium vivax*	
		Number	*Percent*	*Percent*	*Percent*
18th Brigade	7,400	90	10	8	12
2/14 Australian Field Company	3,360	88	3.4	9.2	5.7
Selected U.S. Army units [2]	200	2,000	.25		.33

[1] Rate expressed as number of cases per annum per 1,000 average strength.

[2] Under Atabrine suppressive therapy.

Source: Letter, Malaria Research Unit, 3d Medical Laboratory, to The Surgeon General, 8 Jan. 1945, subject: Report No. 15, The Epidemiological Significance of Atabrine Suppression.

TABLE 76.—*Mosquito dissections* (Anopheles punctulatus)

Location	Malaria rate [1]	Mosquitoes examined	Positive		Rate	
			Guts	Glands	Obtained	Expected
		Number			*Percent*	*Percent*
Ramu Valley:						
Dec. 3-17	4,000	154	4	3	4.5	6.6
Jan. 7	2,440	139	1	2	2.2	4.1
Scattered troop areas, 1944	200	677	2	1	.5	.3

[1] The rate (in these troops under suppressive therapy) expressed as number of cases per annum per 1,000 average strength.

Source: Letter, Malaria Research Unit, 3d Medical Laboratory, to The Surgeon General, 8 Jan. 1945, subject: Report No. 15, The Epidemiological Significance of Atabrine Suppression.

The expected *falciparum* gametocyte rate in troops as shown in tables 75 and 76 may be calculated on the following assumptions:

Given a rate of 200 per 1,000 per year, one of every five men was infected each year. If half of these infections are *falciparum* and if one-third of these infections become crescent carriers, then 1 of every 30 men will be a crescent carrier each year. Since the carrier state lasts a little over a month, at any time one might expect 1 in 300 men to have crescents.

If one assumes that the average life of *A. punctulatus* is about 2 weeks, and if at least 50 percent of her blood meals are human, then the average *A. punctulatus* will have had at least two human blood meals. If only 1 per 300 men are crescent carriers and if only one-half of the crescent carriers are infectious for mosquitoes, then only 1 per 300 of the wild caught anophelines may be expected to be infected. These calculations are made for the *falciparum* infections alone. The presence of *vivax* carriers at the same time would change the figures but would not be great enough to change the order of magnitude.

It may be concluded, therefore, that the majority of infections which are acquired by troops under poor or inadequate suppression come from the troops themselves, and as suppression becomes more perfect, a larger percentage of the infections will come from the natives and enemy troops.

Nevertheless, although the troops themselves were the chief source of infection, it was also true that in many areas of the theater there were considerable reservoirs of gametocytes in local populations. The removal of villages to an optimal distance of 2 miles from troop areas and the barring of troop areas to all natives from late afternoon until full morning light were certainly important measures for lessening the transmission of malaria to troops.

Plasmochin naphthoate

Plasmochin naphthoate has often been used in the routine treatment of *falciparum* malaria with the idea of eliminating crescent carriers and thus of cutting down on the spread of the infection among the troops. This would be sound reasoning if most of the persons who are carriers of gametocytes had previously been hospitalized for malaria. With increasingly adequate suppression, however, the gametocyte rate drops. Secondly, only a small proportion of the gametocyte carriers found on routine surveys have been hospitalized for malaria. Of the four crescent carriers who were picked up on routine surveys and whose histories were checked, one denied ever having been sick. Of the others, one had been hospitalized for dengue and two for fever of undetermined origin several weeks previously. Parasites had not been detected in any of them. Thus, none of these cases would have received Plasmochin naphthoate through routine treatment of malaria. The development of a crescent carrier state during indifferent suppression was demonstrated in another person who on routine survey was found to have 100 rings per cubic centimeter of blood but was without symptoms. A repeat smear a month later showed 10 crescents, although he had at no time been sick.

Some specific studies

In the following section, specific data are presented concerning a variety of units under different conditions.

A great deal of emphasis has been placed on the difficulty of malaria control in combat areas with the result that it is often not realized that even during "good mosquito control" in an established base, a large portion of the men became infected. A port company which arrived in one of the bases some months after it was established and which was quartered out of flight range of any native village became, under indifferent suppression, highly infected. Six months after arrival, they had 17.2 percent positive smears and had a rate of 442 per 1,000 per annum. A station hospital which arrived in the base some months after that had 7.1 percent positive smears with a rate of 287 per 1,000 men per annum. Because of poor suppressive and little personal antimosquito protection, these troops served as the source of their own infection and built up a high rate despite the extreme paucity of adult anophelines and the lack of contact with infected natives.

12th Cavalry Regiment.—The 12th Cavalry Regiment of the 1st Cavalry Division is an interesting example of what good Atabrine suppression can do in the way of preventing epidemic malaria in troops. The malaria rates for this regiment from March to July 1944, which are representative of the division, are shown in the following tabulation:

Month	*Rate per 1,000 men per annum*
March	48
April	90
May	48
June	48
July	54

Previously during staging, they had only a few cases in the whole division.

Surveys were conducted on the troops on 24 April and 13 July 1944, 1½ and 4½ months, respectively, after the invasion of the Admiralty Islands. On the first survey, Atabrine levels were very satisfactory, and 2.2 percent of the 184 men showed positive smears. On the second survey, the Atabrine levels had dropped so much that had this group of men been heavily infected one would have expected a high malaria rate. Actually, they did not have a high rate, and only 3 percent of 200 men showed positive smears.

These results were aided by the fact that Los Negros is a predominantly coral island, and thus both adult and larval anophelines were not common. Only 30 adults were taken on repeated collections near the native village. The paucity of anophelines on Los Negros, however, explains the overall low rate which was present in the entire division throughout their period of combat and following, for anopheline larva and adults were very common on the muddy clay soil of Manus Island. One evening's all night catch in an Australia New Guinea Administrative Unit labor camp about a week after combat troops had left the area yielded over 150 adults. The authors suggest then that the campaign on the Admiralty Islands (map 39) is an excellent example of the ability of Atabrine suppression therapy to prevent epidemic malaria and thus a large number of infections, even during combat in a hyperendemic malarious area.

32d Infantry Division.—A different picture was presented by the 32d Infantry Division. Their previous campaigns had left them with a large load of infection to start with, although by the end of 1943 and the beginning of 1944 about one-half of the men were replacements. During the early part of the Saidor Campaign, anopheline breeding was excessive and large numbers of adults could occasionally be collected. The largest catch made by the personnel of the 5th Malaria Survey Unit was 889 in one tent in an all night catch.

MAP 32.—Admiralty Islands.

During this period, the entire division, including the 128th Infantry Regiment which was studied in early May 1944, was taking 0.5 gm. Atabrine twice weekly. This regimen, however, did not produce protective plasma levels. It is natural then that with the swarms of anophelines and with the inadequate suppression which allowed crescent carriers to develop (two were discovered in 400 smears) considerable infection of the troops would take place. Yet suppression was good enough to prevent conditions approaching epidemicity as shown by the low infection rate in the anophelines (table 77).

TABLE 77.—*Malaria attack rates in the 126th and 128th Infantry Regiments, January–July 1944*

[Rate expressed as number of cases per annum per 1,000 average strength]

Month	126th Infantry	128th Infantry
1944		
January	604	45
February	175	88
March	264	175
April	199	184
May	294	90
June	374	222
July	134	150

Source: Letter, Malaria Research Unit, 3d Medical Laboratory, to The Surgeon General, 8 Jan. 1945, subject: Report No. 15, The Epidemiological Significance of Atabrine Suppression.

Special studies were made on the 126th Infantry Regiment during July in the midst of their campaign at Aitape. In many ways, conditions at Aitape were very different from those encountered elsewhere in New Guinea. For weeks, the perimeter was relatively static. Large areas of the jungle were cleared for lines of fire in front of the pillboxes. The continual creation of new breeding places through necessary constructional work in the muddy sunlit areas of the jungle out of reach of ordinary spraying made effective mosquito control very difficult. Collection of adult anophelines at this time from the jungle hammocks scattered throughout the area yielded 122 anophelines. None of these was found to be infected.

At this time, special study was made of the 126th Infantry Regiment which during the previous month had had a high malaria rate. No crescent carriers were found in the 173 men studied, although 10 percent of the replacements were positive on careful search of thick smears. Atabrine determinations taken on the men at random showed excellent levels, as reflected in the drop in the malaria rate during the month.

The story of this division may be reconstructed along the following lines: They renewed their campaign with inadequate suppression which allowed sufficient carriers to develop among the troops so that when they were fighting in areas of high anopheline density a large proportion of the men became infected.

Nevertheless, suppression during both of their campaigns was great enough to smother any tendencies toward an epidemic, as shown by the low rates of infection in the mosquitoes. The story of this division again is an example of the interrelation of mosquito control and Atabrine suppression. These two methods of military malaria control are complementary. If one method is inadequate, then a great load is placed on the other.

41st Infantry Division.—It is often pointed out that, with Atabrine suppression exerting its dampening effect, it is impossible to know just how much transmission is going on in an area. It is suggested that greater attention be paid in the tropics to the ratio of *falciparum* infection to *vivax* malaria as a measure of this transmission. It is now well recognized that *falciparum* infections survive only a few weeks under Atabrine suppression, and thus cases of *falciparum* malaria which occur in suppressed troops must have been acquired recently. In other words, one is able to follow the rise and fall of the transmission by following the percentage of *falciparum* malaria in troops under suppression just as well as during an epidemic in unprotected individuals. The data in table 78 were reported from the 41st Infantry Division during and after their campaign on Biak. This rugged coralline island had very few breeding places, and for this reason, transmission approached zero shortly after the Division landed at the end of May. After this, the incidence of *falciparum* malaria waned.

TABLE 78.—*Number of cases of malaria in the 41st Infantry Division, June–August 1944*

Week ending	*P. vivax*	*P. falciparum*	*P. falciparum*
			Percent
23 June	18	5	21.7
30 June	55	6	9.8
7 July	52	12	18.7
14 July	58	8	12.1
15 July–11 August	226	5	2.2
12 August–25 August	109	0	0

Source: Letter, Malaria Research Unit, 3d Medical Laboratory, to The Surgeon General, 3 Jan. 1945, subject: Report No. 14, The Epidemiological Significance of Atabrine Suppression.

SIXTH U.S. ARMY TRAINING CENTER

The objective in establishing the Sixth U.S. Army Training Center was to receive from combat units personnel infected with malaria and to prepare them physically and mentally for further combat duty. The surgeon was instructed as follows:

> In view of the disappointing results yielded in many cases by methods now in practice in both therapeutic and suppressive treatment of malaria, the Surgeon of the Center will, with the approval of proper authority, make a diligent search to discover and institute other and more promising means of dealing with this problem.

In pursuing this objective, the personnel were divided into companies, and Atabrine was administered according to seven different programs. In all instances, the Atabrine was given after the evening meal, by roster, and supervised by commissioned officers. Parallel studies were conducted in such a manner as to reveal unfavorable as well as favorable results following the respective suppressive treatments. The comparative studies comprised:

1. Average daily attendance at sick call from the respective companies. Conditions and symptoms noted at sick call.
2. Admissions to the hospital for all causes.
3. Admission to the hospital for proved recurrent attacks of malaria.
4. Incidence of tachycardia, splenomegaly, changed hemoglobin values, loss of weight, abdominal pain, diarrhea, vomiting, fever, arterial hypertension, albuminuria, blood smears positive for malaria organisms, and increased "Atabrine Tint" to skin and sclerae.
5. Need for reclassification to permit milder training.
6. Changes in body weight.
7. Blood plasma Atabrine levels.

These Sixth U.S. Army Training Center studies were summarized as follows:

1. Each of several Atabrine suppressive regimens was found to be effective in abruptly and completely interrupting recurring attacks of malaria.
2. Despite intensive military training for 4 weeks, in two of which the exercise periods exceeded 80 hours per week, it was not possible to precipitate an acute attack of malaria in any of the personnel protected by Atabrine.
3. Recurrent attacks reappeared from 2 to 4 weeks after discontinuing suppressive therapy.
4. There was no evidence that Atabrine afforded less protection after prolonged administration.
5. Extensive parallel clinical and laboratory studies conducted over a period of over 4 months failed to reveal any disadvantage in using a larger amount of Atabrine given twice weekly, over a small dose given 6 days per week.
6. Determination of the concentration of Atabrine in the blood plasma revealed that when Atabrine was given in doses of 1.0 gm. per week (0.5 gm. on Mondays and Fridays), or, when given in doses of 0.4 gm. every third day, levels exceeding 30 gamma per liter (the therapeutically effective level) were reached at some period in each 24 hours. It was also found that, for the most part, the plasma Atabrine values remained below 30 gamma per liter when 0.1 gm. of Atabrine was given daily for 6 days each week. Although these low concentrations prevent recurrent attacks of malaria under favorable circumstances, they cannot be expected to afford the same degree of protection offered by higher concentrations under unfavorable circumstances.

7. Intensive military training failed to affect appreciably the concentration of Atabrine in the plasma concentration.

8. Frequent plasma Atabrine determinations made on personnel receiving the greatest amounts of Atabrine failed to reveal any significant changes in the values between the fifth and ninth weeks of the suppressive therapy. Upon withdrawal of the drug, the plasma Atabrine concentrations declined rapidly, reaching levels affording little antimalaria protection on the fourth day.

It was further concluded that Atabrine in doses of 0.5 gm., given every Monday and Friday, offered a high degree of antimalaria protection and was practicable of application. Atabrine in doses of 0.4 gm. every third day was equally effective, but its administration was more complicated. The selection of the therapy of 0.5 gm. of Atabrine, on Mondays and Fridays, recommended for troops in combat was based on:

1. The extremely small incidence (less than 1 percent) of unfavorable reactions.

2. Highly protective plasma Atabrine levels.

3. The especially abrupt cessation of recurrent attacks when this suppressive therapy was instituted.

4. The practicability of administering the drug to troops at the front in contrast to the regimen requiring daily medication.

Only 5 persons out of over 4,000 presented a real problem by having a persistence of gastrointestinal disturbance after the ingestion of Atabrine. Three suffered from a psychoneurosis with a moderately severe anxiety state. Two had preexisting chronic disorders of the digestive tract, and because of their inability to retain the drug, each suffered a recurrent attack of malaria at the Center.

MALARIA RESEARCH GROUP

Mention should also be made of the results obtained by the malaria research group, including, for example, the various studies made by Dr. Frederick B. Bang and others on the relative effectiveness of different forms of therapy; the proof of the efficiency of Atabrine malaria control in a malarious area that was obtained as a result of the "Sooner" expedition to Milne Bay; the evidence obtained there and later confirmed by the experimental work of Fairley that Atabrine suppression, at the rate of one tablet a day, will not prevent infection with *falciparum* malaria but will hold it in a subclinical state and eventually cure it; and the studies made, on the instigation of Col. Earle M. Rice, MC, by the hospitals in Base 3 (Brisbane) on the characteristics of the New Guinea variety of tertian malaria. It was on the proof afforded by these studies, and by the parallel studies in Australian hospitals on Atherton Plateau, that the determination was reached that the relapse rate of this type of malaria was so high that, if troops were to be kept in combat-worthy condition, con-

FIGURE 61.—Cartoon, "Don't Be A Dunce."

tinuous Atabrine suppression of malaria-infected units might be maintained not only in New Guinea but in Australia as well.[38]

PERSONNEL TRAINING

The enforcing of effective personal measures for the prevention of malaria was the greatest problem of the control program in this theater. It was essential that both officers and enlisted men receive frequent reminders of precautions to be observed. To aid unit commanders in this, malariologists were available in a majority of the forward areas. Two antimalaria schools, one in New Guinea and one on the Australian mainland, were established for the instruction of medical officers as well as officers of all other branches. Schools for instruction of company or unit antimalaria details were conducted by malariologists and the officers and men of the malaria survey unit and malaria control unit in the area. Training Films 8-953, "Malaria, Cause and Control," and 9-953 A, Walt Disney's "Winged Scourge," were widely shown in forward areas and in the antimalaria schools. The use of roadside signs with pertinent slogans were of great value in the educational campaign. Several posters were produced in this theater for unit bulletin boards (figs. 61, 62, and 63).

[38] (1) Fairley, N. H.: Chemotherapeutic Suppression and Prophylaxis in Malaria. Tr. Roy. Soc. Trop. Med. & Hyg. 38: 311–365, May 1945. (2) Fairley, N. H.: Atabrine Susceptibility of the Aitape-Wewak Strains of *P. falciparum* and *P. vivax*. Tr. Roy. Soc. Trop. Med. & Hyg. 40: 229–272, December 1946. (3) Fairley, N. H.: Sidelights on Malaria in Man Obtained by Sub-Inoculation Experiments. Tr. Roy. Soc. Trop. Med. & Hyg. 40: 621–676, May 1947.

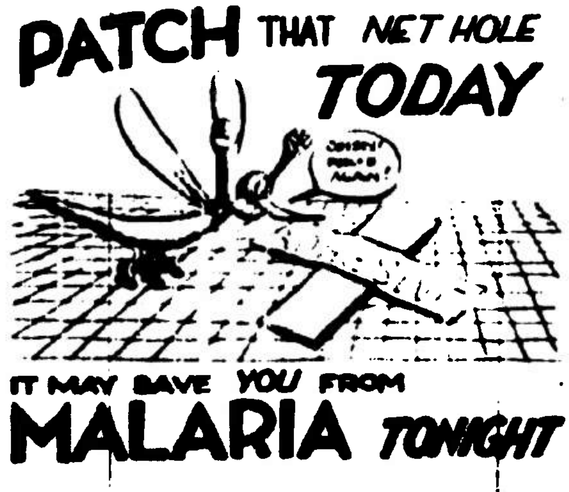


FIGURE 62.—Cartoon, "Patch That Net Hole Today."

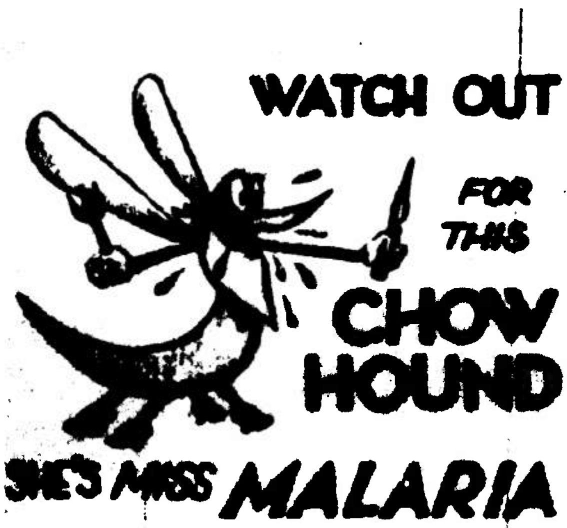


FIGURE 63.—Cartoon, "Watch Out for This Chow Hound."

SWPA Malaria Schools

A malaria control training school was organized at Brisbane, began instruction in September 1943, and continued for almost a year. Two sessions were held each week, one for line officers and one for medical officers. With an average of 15 to 20 officers in each class, a total of 1,500 to 2,000 attended the school. In 1944, the school was transferred to Finschhafen, New Guinea, as troops for the United States were then arriving there instead of Brisbane. A school offering courses for medical and line officers was started at Base A in March 1944, and later a course for nurses was introduced. Some 851 officers and nurses received instruction.

This theater found that visual education was a very important feature in the forward areas. "Sign board" education was highly developed because of the shortage of training films with (1) dock signs wherever troops landed, stressing that this is a highly malarious area and asking cooperation, and (2) road signs of many varieties. Some areas used "Burma Shave" type signs; others used pictures of clothed and practically unclothed female figures. All signs and wording utilized were suggested by the enlisted men. It was realized that paint in assorted colors, and brushes, should be part of the table of basic allowances of every control and survey unit.

As the essence of environmental control was found to be the checking of areas for breeding, one personable enlisted man from each control unit was asigned as liaison man. His sole job was to create good will, inspect the work of unit antimalaria details, furnish equipment and supplies in emergency, and collect essential supplies for his own unit.

All ships were boarded on arrival by assistant malariologists, and commanding officers of units were contacted about Atabrine discipline, clothing, mosquito nets, and all other antimalaria supplies.

A popular measure for promoting oiling work by unit antimalaria details was the practice of running a repair shop for knapsack sprayers by malaria control units.

COMBAT EXPERIENCES AND LESSONS

Malaria control programs varied with local conditions but always included (1) measures directed against the breeding of mosquitoes and (2) the enforcement of individual discipline with reference to the use of Atabrine and to exposure to mosquitoes. As garrison conditions became stabilized, more attention was given to the adjacent native populations which were often heavy reservoirs of infection.

The disastrous effects of malaria on the effectiveness of combat divisions can be illustrated by citing the experiences of several divisions during the campaign to prevent the Japanese from reaching the Australian mainland. It was essential that crucial areas in New Guinea should remain in Allied possession. The strength of the forces available was limited and the loss of combat troops due to malaria could not well be afforded, but no organization existed at that time which could be effective in control under existing conditions.

Four divisions—the 1st and 2d Marine Divisions and the U.S. Army 32d and Americal Divisions—were rendered noneffective by malaria for a period of 4 to 6 months after withdrawal from the combat area. The 41st Division, which had engaged in 76 days of continuous combat around Sanananda Point, Dobodura, and Buna, reported 3,824 persons, or 27.7 percent of the command, as having one or more attacks of malaria. The XIV Corps lost the equivalent of an entire infantry battalion each month from malaria, and between October 1942 and April 1943, 39 percent of all hospital admissions in the South Pacific Area were due to malaria.

During the year 1943, the Southwest Pacific reported 47,663 cases of malaria and 13,230 admissions for fever of undetermined origin. In a group of cases studied, the average hospitalization for a case of malaria was 15.24 days; 10 percent of the cases returned to duty in 7 days; 25 percent, in 10 days; and 50 percent, in 13 days.

In the 10-month period subsequent to its withdrawal from New Guinea, 67 percent of the 32d Division manifested clinical symptoms of malaria. Over 80 percent of the 1st Marine Division was hospitalized for malaria within 9 months of the beginning of the Guadalcanal Campaign.

To illustrate the saving in hospital beds due to effective malaria control, it has been computed that, if the malaria (plus 75 percent of the fevers of undetermined origin) rate had been as great in February 1944 as in February 1943, 10,955 hospital beds would have been required for such cases. Instead, at the later date, only 1,324 beds were actually occupied, representing a saving of 9,631 beds due to effective malaria control measures.

The two primary factors that were responsible for the lowered malaria rates after February 1943 were (1) the assignment of adequate priorities for movement of antimalaria supplies and personnel from the United States and within the theater, and (2) an efficient antimalaria organization which resulted in better malaria discipline, increasingly successful administration of suppressive Atabrine, and more effective antimosquito work of all kinds.

The use of drugs to suppress attacks of clinical malaria was absolutely necessary in operational areas where malaria threatened, but since its action was to prevent clinical symptoms of the disease without preventing the infection, the Army could not know the extent to which malaria was being transmitted in theaters of operations. That transmission continued was certain and that it would greatly increase where antimosquito work was relaxed was even more certain.

Atabrine in daily doses of 0.1 gm. prevented the appearance of clinical symptoms of malaria as long as the drug was continued. No evidence, however, was obtained that Atabrine in suppressive doses even for long periods cured *vivax* malaria. It was found that, after the drug was stopped, relapses usually occurred within 1 or 2 months, but sometimes much later. There was no evidence that the number of relapses expected after a long period of suppression differed materially from the number expected without suppression. Infections of *falciparum* malaria, on the other hand, were usually cured by the suppressive drug when it was continued for 4 weeks beyond the last exposure. Suppressive Atabrine was the rule in the Southwest Pacific except for Australia.

It was necessary that drug suppression of malaria continue to be used to reduce noneffectiveness in certain military situations, but it was realized by all concerned that infection with *vivax* malaria was not prevented thereby and that there was no substitute for control of actual transmission. This entailed full use of malariologists and malaria control and survey units to determine the risk and to plan and execute programs of prevention. Mosquito control was effective in proportion to the skill and the energy with which it was planned and applied. Improved repellents, insecticides, and suppressive drugs were available in the field. Vigilance in the supervision of the individual protective measures of proper clothing, use of bed nets and sprays, application of repellents, and avoidance of native habitations kept down the attack rate in malarious areas.

In the 31 July 1945 issue of *Health*, page 11, it was stated:

> Malaria remains a constant threat to the effective strength of the Army. While the current low admission rates prove that malaria is no longer out of control, which was the case in 1943, they cannot be used as evidence that the problem has been entirely solved. Low rates will continue only so long as effective atabrine discipline and mosquito control measures are rigidly enforced. The invasion of Luzon has again demonstrated that advance into malarious areas may be expected to increase admission rates considerably. In January 1945, the rate for the Southwest Pacific stood at only 27 per 1,000 men per year, but by April it had reached 75; and for troops in the Philippines the rates were even higher, although but a fifth of those prevailing at the end of the Buna-Gona campaign. However, because of the success which can be achieved with rigorous atabrine discipline even continuously low malaria admission rates do not rule out further malaria transmission on a large scale. Under combat conditions, as on Luzon, any lapse in atabrine suppression may cost heavily in clinical malaria.

A good description of operational lessons that can be learned from a military campaign insofar as disease prevention is concerned was stated in the 30 November 1943 issue of *Health*. In malaria control, it was emphasized, the combat division needs experienced malaria survey and control units to follow it immediately into combat if the incidence of malaria is to be held to a minimum and the fighting man to be kept on his feet. It was further pointed out that malaria incapacitated; it put out of action whole divisions for many months. Contrasted with this picture was the fact that malaria could be prevented and suppressed. The great lesson learned was that the most effective control of malaria was the prevention of infection. Although group methods of environmental sanitation and control were highly effective, under combat conditions it was largely what the individual soldier did for his own protection that counted most heavily in keeping down malaria infection. Unless the soldier knew how to protect himself with the means provided, he could be expected to contract malaria in a short time in a highly malarious area. For these reasons, malaria control was determined to be primarily a command function, necessitating the maintenance of a high state of malaria discipline. If the commanders did not enforce control measures, they jeopardized the success of their military mission.

CASE STUDY OF MALARIA INCIDENCE

The malaria experience on Kiriwina Island is typical for the islands off New Guinea during 1943. A study of causes was made, in which most cases of malaria among U.S. troops were interviewed by an officer in order to determine the reason for their having become ill with malaria. Other enlisted men of their organization were then interviewed to substantiate histories. In a number of instances, defects in malaria discipline, especially Atabrine suppression, may have been the cause. It was found that, in some instances, officers did not supervise the suppressive treatment; it was left to the enlisted man to decide if he should take the Atabrine as he passed through the mess line. It was also found that most malaria cases among the mess personnel probably resulted from lack of supervision and that men on outpost duty were occasionally not well supervised. Repellent often was not used by the men, usually they did not have it readily available. It was believed that much of such failure in malaria discipline could be eliminated if an alphabetical roster were kept in each organization to determine whether each enlisted man had actually swallowed his Atabrine tablet and whether he carried a bottle of repellent with him at evening mess.[37]

CASE REPORTING

As the incidence of malaria reached high proportions in the early part of 1943, consideration was given to securing adequate and timely reporting of its incidence. None of the Medical Department reports then in use gave complete coverage of all the facts considered necessary. The statistical report gave only a crude attack rate, with no differentiation between primary and recurrent attacks, and with no clue as to the prevalent types of infecting parasites. The field medical records (WD MD Forms 52b and 52c), which passed through the Central Medical Records Office, had an average timelag approaching 6 weeks between the dates of an attack and of information reaching the Chief Surgeon. These records did not always include statements on the type of infection or the status of attacks.

A malaria case report card was designed by the theater Chief Medical Inspector in the early part of 1943. This card was approved by the theater

[37] Inspection Report No. 1, Office of the Surgeon, Headquarters, Sixth U.S. Army, dated 11 Oct. 1943, subject: Summary of Malarial Survey of Kiriwina Island for September 1943.

Chief Surgeon and the Combined Advisory Committee on Tropical Diseases, the latter adopting the card as the standard method of reporting malaria for all Allied troops in this theater. The initiating directive together with a supply of the cards was distributed to field units in May and June 1943. The first reports using these cards were received from the field the latter part of June 1943. The units in New Guinea and adjacent islands forwarded the cards to the Central Medical Records Office, Office of the Chief Surgeon, APO 501, through the office of the assistant malariologist, Base B, APO 503. Malaria case report cards from units in Australia were sent direct to the Central Medical Records Office.

Before 15 June 1943, the Central Medical Records Office maintained a locator file for patients of hospitals, based upon the admission and disposition sheets. The field medical records were checked, pertinent information was transcribed from the locator file cards, and placing the cards from "active" to the "inactive" section of the locator file was carried out as necessary. Consequently, there existed in this office a fairly reliable basis for the compilation of malaria statistics, at least with respect to unit incidence rates and the number of attacks suffered by given individuals. The locator file was discontinued in the Central Medical Records Office and a file of extracts in the field medical records was instituted for malaria cases only.

In order to compile the individual records, a malaria case summary card record was designed and adopted as a means of condensing the information. This condensation of records was instituted in November, and soon after, case summary cards were completed on approximately 75 percent of the cases in the file. Summary cards were posted as the malaria case report cards were received. These postings were later checked or revised as necessary when the field medical records were processed.

Comparison of field medical records processed in this office with the malaria case summary files indicated that approximately 30 percent of the diagnosed malaria was not reported by the malaria report card. This was due in some degree to the fact that hospitals and medical detachments arriving in the theater were not familiar with the form, to the problem of distributing cards so that they would be available to all units at all times, and to the reluctance of some medical officers to do additional paperwork.

REDUCTION IN HOSPITALIZATION

It was felt that the reduction in the hospitalization time of malaria cases was particularly significant. An analysis of the factors involved showed that the treatment of malaria in SWPA may be divided into certain definite periods. During the first period, which ran from November 1942, when malaria cases in significant numbers were first admitted to hospitals, until April 1943, the treatment generally followed was that recommended in Circular Letter No. 135, Office of The Surgeon General, 21 October 1942. This course of treatment

(QAP: quinine-Atabrine-Plasmochin) lasted for 15 to 17 days and was not followed by a period of followup or suppressive treatment. The ineffectiveness of this treatment led to a certain number of intercurrent recrudescences of fever usually during the period of Atabrine administration. In these cases, the total time of treatment was lengthened.

More important was the fact that, as a consequence of stopping all drugs after the active course was completed, early relapses occurred within the first month in at least one-half of the cases. Many of these relapses appeared while the patient was still in the hospital and led to a repetition of the initial course of treatment. The patients, during this period, were chiefly from the 32d Division, fighting in the Buna-Gona Campaign, and from the 1st Marine Division brought to Australia after the battles of Guadalcanal. Malnutrition had greatly weakened these men, and their stay in the hospital was often lengthened for the purpose of building up their weight and strength. Furthermore, the proportion of battle casualties among the malarious patients was higher at this period than in the later months of 1943, and longer hospitalization was frequently necessary because of wounds. In certain hospitals, necessary investigations of convalescents after malaria led to retention of patients for observation.

Circular No. 15, USAFFE, 12 April 1943, "Treatment of Malaria," prescribed a change in routine treatment and initiated the second period. The 2-day rest period without drugs which was a feature of the previous QAP treatment was eliminated, thus reducing hospitalization by 2 days. Furthermore, the new regimen included a 6-week period following active treatment in which 0.1 gm. Atabrine was given on 6 days of each week. This followup treatment practically stopped the occurrence of relapses in hospitals and greatly shortened the average hospital stay. In this period, battle casualties were few and the nutrition of troops improved. There was therefore less cause to prolong the hospital stay of malaria cases because of wounds or physical weakness of the patient.

An amendment to Circular No. 15 initiated the third stage.[29] It changed the treatment of the malaria attack to the intensive Atabrine treatment of 6 days' duration, thereby reducing hospital stays for active treatment from an average of 13 to 6 days. Control experience in hospitals, in the Sixth U.S. Army Training Center, and in field units had shown by this time that brief hospitalization after subsidence of fever caused by malaria was all that was required. In fact, weight increase, strength, and morale were aided by early removal from the hospital atmosphere. In particular, the fact that repeated prolonged hospitalization for recurrent malarial attacks tended to induce neurosis in the affected soldier was taken into consideration.

Between January and July 1944, the proportion of malaria cases which were also battle casualties had again increased. This tended to lengthen the hospital stay. In summary, therefore, the chief factors in reducing the length of hospital stay for malaria attacks were as follows: (1) The successive short-

[29] Circular No. 72, Headquarters, USAFFE, 7 Sept. 1943.

ening of prescribed routine treatment, (2) the followup with suppressive Atabrine treatment, and (3) the growing realization that the average malaria attack, properly treated, produces comparatively slight aftereffects on the patient.[29]

JAPANESE MALARIA EXPERIENCE

A Japanese Medical Department report captured at Munda, on New Georgia, makes possible interesting comparisons between Japanese troops in the Eighth U.S. Army area and American troops on New Guinea. The report gives detailed data for February 1943 and a summary for December 1942 and January 1943.[30]

At the time the report was prepared, Japanese troops had been in the Rabaul area for at least 8 months, and their estimated average strength was 51,382 in December and 79,901 in February. The strengths are "estimated" in the sense that the translation mentions the number of "personnel examined." It is assumed that this number is the strength of the force from which the admissions were drawn. The area was served by two base hospitals having, with their annexes, a combined capacity in excess of 4,000 beds. Altogether, including an unspecified number of field hospitals, there were at least 8,800 beds, or about 11 percent of the troop strength, during February. During the 3-month period, the health of the Japanese troops was considerably less favorable than was that of the U.S. forces on New Guinea. For all causes, including battle casualties, the average admission rate for the entire period was 4,086 per 1,000 men per annum for the Japanese troops, approximately twice that experienced by the American units.

Malaria was the greatest single cause of admission and noneffectiveness among Japanese troops during this period, causing 17,112 new admissions and 5,415 readmissions. This number of cases represents 37 percent of the mean strength and 35 percent of all admissions for the 3 months. During the same period, diagnosed malaria accounted for 34 percent of all admissions among U.S. troops on New Guinea. The average admission rate for malaria was 1,440 per 1,000 men per annum for the Japanese and 718 for U.S. troops, if only diagnosed malaria be counted. The average noneffective rate for malaria among the Japanese troops was roughly 40 per 1,000 men per day.

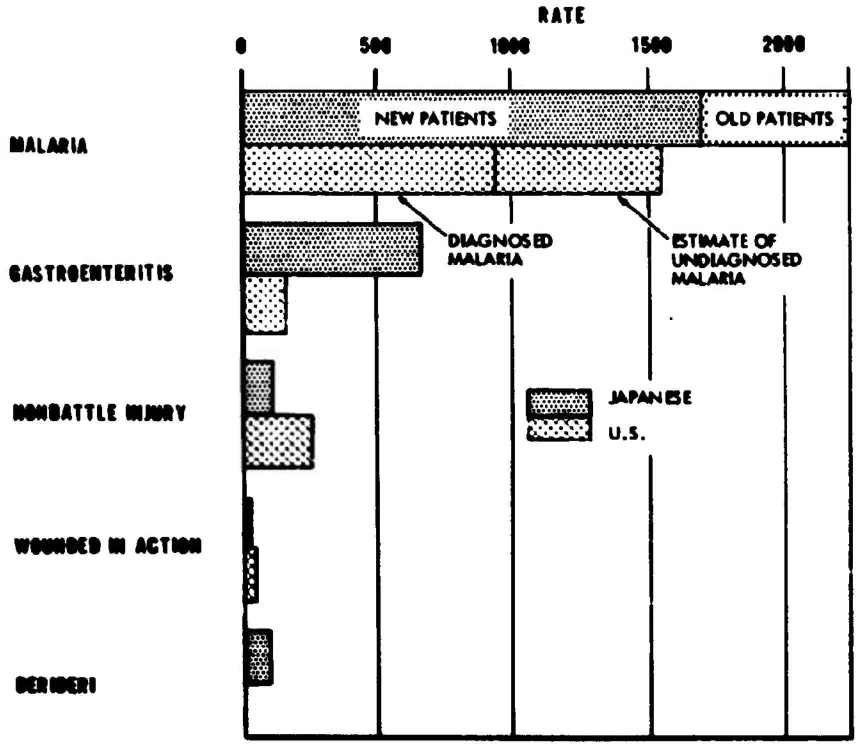
Chart 26 compares Japanese and American admission rates for several diagnoses during February 1943. The Japanese rate for malaria has been separated into two parts, representing new patients and old patients, while the rate for U.S. forces on New Guinea shows the incidence of diagnosed malaria together with an increment representing three-quarters of the admissions for fever of undetermined origin. The comparison of the malaria admission rates depends to some extent upon the completeness of diagnosis. It was customary

[29] Essential Technical Medical Data, Southwest Pacific Area, for July 1944, dated 5 Aug. 1944, pp. 3–5.

[30] Monthly Progress Report, Army Service Forces, War Department, 30 Nov. 1943, Section 7: Health, pp. 12–13.

CHART 26.—*Japanese and U.S. admission rates during February 1943*

[Rate expressed as number of cases per annum per 1,000 average strength]



Source: Monthly Progress Report, Army Service Forces, War Department, 30 Nov. 1943, Section 7: Health.

at U.S. headquarters in SWPA to assume that about three-quarters of the admissions for fever of undetermined origin were probably malaria. The Japanese report made no mention of fever of undetermined origin, and the completeness with which malaria was diagnosed by Japanese medical officers was not known. The Japanese rate, however, must be taken as a minimum if it is to be compared to the estimated total malaria rate for U.S. troops. The moderately high incidence of beriberi among the Japanese was of interest inasmuch as statements of prisoners of war and captured enemy equipment and supplies all indicate that the Japanese were very "vitamin conscious."

During February, 3,776 Japanese troops were treated for enteric diseases, representing a rate of 615 per 1,000 men per year. On 22 March, there were 37 Japanese hospitalized for typhoid fever, 146 for paratyphoid, and 140 for dysentery. The number of cases reported was of interest in view of the fact that Japanese were known to be conducting an immunization program against these three diseases.

At the end of February 1943, there were 72,916 Japanese troops in the Rabaul area, 20 percent of whom were receiving medical care.

OTHER ACTIVITIES OF THE MALARIA CONTROL ORGANIZATION

In addition to combating malaria, the Army Malaria Control Organization was employed on a number of other preventive medicine problems. The sanitary engineering, entomological, medical, and other trained personnel engaged in malaria control had skills which qualified them for many other duties.

Scrub Typhus Control

For instance, malaria units assisted in controlling scrub typhus, which was a serious problem in the early days in New Guinea. It was found that dimethyl phthalate readily killed the mite transmitting this disease. Earlier, various methods had been used to safeguard campsites, such as burning the kunai grass and stripping the sod from the area by bulldozer and other heavy equipment. Experimental work by entomologists indicated that dipping clothing in dimethyl phthalate killed the mites before they could bite. From this work, methods were developed which provided a high degree of protection against this disease.[31]

Filariasis Control

Filariasis was a disease of importance in some areas of SWPA. Existing malaria survey units were used on occasion, in coordination with sanitary engineering personnel, for the control of this disease. Experience indicated the desirability of establishing special units to combat this disease.[32]

Rodent Control

A school for rodent and flea control was proposed as a means of expanding the preventive medicine duties of malaria survey and malaria control units.

With the approval of the Chief Surgeon, USASOS, the first class of the Rodent Control School was started on 12 March 1945. The period of instruction was for 2 weeks. The personnel attending the first class were the officers and enlisted men of the 93d Malaria Control Unit and the 211th Malaria Survey Unit. Subsequent classes were conducted each 2 weeks, beginning on 2 April 1945.

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[31] Philip, Cornelius B.: Scrub Typhus and Scrub Itch. *In* Medical Department, United States Army. Preventive Medicine in World War II. Volume VII. Communicable Diseases: Arthropodborne Diseases Other Than Malaria. [In preparation.]

[32] Swartzwelder, Clyde: Filariasis Bancrofti. *In* Medical Department, United States Army. Preventive Medicine in World War II. Volume VII. Communicable Diseases: Arthropodborne Diseases Other Than Malaria. [In preparation.]

Although written late in 1945 when no longer in SWPA, the report of the 6th Malaria Survey Detachment is interesting because it illustrates the rodent control activities carried on by these units.

Upon arrival in Japan, personnel of the 6th Malaria Survey Detachment were engaged in conducting rodent and flea surveys of Kyōto and vicinity. The primary purpose of such surveys was to determine the following:

1. Density of rat population.
2. Species of rats present.
3. Density of fleas.
4. Species of fleas.
5. Presence of other household pests.

In the initial stages of the survey, many Japanese buildings, such as Japanese Army barracks, were examined thoroughly for evidence of rats, fleas, and other household pests. In many instances, these installations were inspected before being occupied by U.S. Army troops. However, a small number of units had the unfortunate experience of occupying Japanese Army barracks before they were inspected. Because of this, many soldiers suffered considerably from the bites of fleas and bedbugs. On a number of these inspections, the survey party was accompanied by a member of the 10th Malaria Control Detachment, so that a more thorough spraying job was accomplished. Nearly all of the infested installations were sprayed with DDT before occupation by Army troops.

Dengue Fever

Malariologists, malaria survey and malaria control units were concerned with the control of dengue fever as well as scrub typhus and filariasis control. Their primary concern was eradication of breeding areas of the vectors concerned.[33]

Sandfly Fever Control

In its quarterly report, 1 July to 30 September 1944, the 5th Malaria Survey reported that the sandfly *Phlebotomus* was common in New Guinea. Members of the unit visited practically every base in New Guinea, save one, and some of the nearby islands. Sandflies were taken at each base. *Phlebotomus* were collected in tree holes and on the shaded sides of tree trunks and buttresses. The method of collection was to spread a white sheet at the bottom of a tree hole, or on the ground around the tree trunk, or between the buttresses and then spray these areas thoroughly with an Aerosol Freon dispenser. Specimens of these midges were sorted from the collection of all small insects that fell on the sheet.[34]

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[33] (1) Essential Technical Medical Data, Southwest Pacific Area, for May 1944, dated 3 June 1944, p. 8. (2) McCoy, Oliver R., and Sabin, Albert B.: Dengue. *In* Medical Department, United States Army. Preventive Medicine in World War II. Volume VII. Communicable Diseases: Arthropodborne Diseases Other Than Malaria. [In preparation.]

[34] Hertig, Marshall: Sandfly Fever. *In* Medical Department, United States Army. Preventive Medicine in World War II. Volume VII. Communicable Diseases: Arthropodborne Diseases Other Than Malaria. [In preparation.]

Related Activities

The 5th Malaria Survey Unit arrived in the area, Leyte Island, Philippines, on "A" Day, 20 October 1944. Attached to the 24th Infantry Division, the organization was engaged in sanitation work in the town of Palo on 1 November 1944.

No Malaria control work was done during the month. The unit's trucks and drivers were utilized by the 24th Infantry Division to haul supplies and personnel. The quartermaster attached one weapons carrier and driver to the 101st Graves Registration at Carigara from 1 November through 14 November.

While bivouaced on the beach, two of the unit's trucks and drivers were furnished to haul ammunition and supplies to the frontlines. A weapons carrier with driver and 30 shovels was furnished to a division burial detail from 26 October to the close of the month. The unit personnel supervised 14 Filipino laborers in digging latrines and other sanitation work for the civilian population in the overcrowded town of Palo from 27 October to the close of the month. Official war photographers took some movies and stills of this work. The dump truck and driver were furnished to the 36th Evacuation Hospital on 30 and 31 October for hauling gravel. No malaria control work was done.

In the Philippines, the malaria survey and malaria control units expanded their activities into a variety of public health activities, such as the survey control and education on schistosomiasis for Army personnel and civilian populations. They also became involved in restoring and operating municipal water supplies and sewage disposal plants, garbage collection and disposal, latrine building for large segments of the civilian population, sanitary inspection of restaurants, hotels, abattoirs, bakeries, and food processing plants, to mention but a few of the manifold duties. Later on, some of the Sanitary Corps officers who commanded these units were chosen for military government work and continued these important functions in the Philippines, Japan, and Korea after termination of hostilities in World War II.

SURVEY AND CONTROL UNITS

As of 25 September 1944, there were 58 malaria control and 26 malaria survey units assigned to USAFFE. Of these, 21 control and 13 survey units were with the Sixth U.S. Army, from Oro Bay to Biak. There were 10 control and 4 survey units with the Fifth Air Force; 5 control and 3 survey units with the Thirteenth Air Force; and 22 control and 6 survey units with USASOS. In addition, there were 7 control and 6 survey units located in the Southwest Pacific which had been assigned to but had not yet arrived in SWPA. Total in the theater and assigned to it were 65 control and 32 survey units, on 25

September 1944. In comparison, on 25 September 1943, there were 12 control and 5 survey units in SWPA.

Several malaria control units that had difficulty in obtaining the equipment for beginning their work at once emphasized the importance of the units' being shipped and moved with all their equipment. Several units felt that a combination of a control and a survey unit would be desirable, with equipment including trucks, jeeps, spray outfits, electric generator units, tents, and necessary office supplies and equipment. Prompt initiation of control measures after establishment of a beachhead was emphasized many times. It was also suggested that the attachment of enlisted personnel to the combined control survey unit would permit more effective and expeditious work. The attachment of units to commands so that they would be a definite part thereof was generally favored. It was felt that this would result in more adequate facilities for doing necessary work.

FINAL RESULTS

As a result of the control program in the Southwest Pacific, military operations after the middle of 1943 were not seriously handicapped by malaria The campaign in this area was the first one in which so many U.S. Army troops had fought under such highly malarious conditions. The lack of experience in controlling malaria under combat conditions, the absence of any organization suitable for control, and the mental unreadiness of both combat and medical officers represented very serious problems which had to be, and were, overcome.

Numerous examples have been cited throughout this history which show the results obtained in reducing the incidence of malaria. A few examples will be repeated here. In January 1943, U.S. troops in the Milne Bay area had a malaria attack rate of 3,308 per 1,000 men per annum. In January 1944, the rate was 30.7. In February 1943, the malaria attack rate in the command strength of SWPA (including 75 percent of fever of undetermined origin) was 794 per 1,000 men per annum; in February 1944, it was 179. This reduction in malaria rate represented a saving of more than 9,600 hospital beds.

The primary lessons learned were that effective control must be based on (1) utilization of all methods, including larva and adult control, the use of suppressive medication, troop education and discipline, and the employment of a special control organization utilizing engineering, medical, entomological, and other skills; (2) area-based control, not control on a unit or force basis; and (3) unified authority and control, to insure that all necessary phases of the program are carried on in all areas that threaten troops.

The malaria attack rates among U.S. Army personnel, in the Southwest Pacific Area, by type of *Plasmodium* and year of admissions are shown in table 79. Table 80 shows deaths due to malaria by type of *Plasmodium* and year of death.

TABLE 79.—*Number of cases* [1] *and attack rates of malaria among U.S. Army personnel in the Southwest Pacific Area, by type of* Plasmodium *and year, 1942–45*

[Preliminary data based on sample tabulations of individual medical records]
[Rate expressed as number of cases per annum per 1,000 average strength]

Type of *Plasmodium*	1942–45		1942		1943		1944		1945	
	Number of cases	Rate	Number of cases	Rate	Number of cases	Rate	Number of cases	Rate	Number of cases	Rate
Malaria, all forms	124, 109	78. 25	4, 451	62. 49	47, 663	250. 98	33, 475	62. 08	38, 520	49. 03
Vivax malaria	83, 076	52. 38	884	12. 41	27, 902	146. 92	24, 215	44. 91	30, 075	38. 28
Falciparum malaria	13, 624	8. 59	233	3. 27	5, 166	27. 20	3, 945	7. 32	4, 280	5. 45
Malariae malaria	274	. 17	4	. 06	60	. 32	115	. 21	95	. 12
Mixed malarial infections	1, 168	. 74	26	. 37	267	1. 41	315	. 58	560	. 71
Other and unspecified forms of malaria	25, 967	16. 37	3, 304	46. 38	14, 268	75. 13	4, 885	9. 06	3, 510	4. 47

[1] Consists of new admissions and readmissions for malaria as well as cases in which admission was for other causes but in which malaria existed concurrently or developed subsequently.

TABLE 80.—*Deaths due to malaria among U.S. Army personnel admitted in the Southwest Pacific Area, by type of* Plasmodium *and year of death, 1942–45*

[Preliminary data based on tabulations of individual medical records]

[Rate expressed as number of deaths per annum per 100,000 average strength]

Type of *Plasmodium*	1942–45		1942		1943		1944		1945	
	Number of deaths	Rate	Number of deaths	Rate	Number of deaths	Rate	Number of deaths	Rate	Number of deaths	Rate
Malaria, all forms	113	7.12	5	7.02	23	12.11	31	5.75	54	6.87
Vivax malaria	25	1.58	1	1.40	8	4.21	4	0.74	12	1.53
Falciparum malaria	43	2.71	--------	0	5	2.63	11	2.04	27	3.43
Malariae malaria	--------	0	--------	0	--------	0	--------	0	--------	0
Mixed malarial infections	2	.13	--------	0	1	.53	--------	0	1	.13
Other and unspecified forms of malaria	43	2.70	4	5.62	9	4.74	16	2.97	14	1.78

APPENDIX A

Standard Operating Procedure for Control of Malaria and Other Insect-Borne Diseases During a Combat Operation

This Standard Operating Procedure is merely a sample plan adapted to and used during one operation. All such plans should be flexible. One division malaria control group had 4 general plans calling for various degrees of decentralization, the exact plan and details used to be determined by the particular situation.

1. STATEMENT OF PROBLEM

The target for the operation is an area where a flea, louse, and parasite infested native population of several hundred persons per square mile is a seed-bed of disease. Fly-borne and water-borne intestinal diseases are likely to be the most immediate disease hazards. Native food is contaminated by the use of human feces for fertilizer and should not be eaten. Dengue fever, malaria and mite-borne typhus are potential dangers. Schistosomiasis (blood fluke disease) adds to the risk of drinking or bathing in untreated water.

2. MOUNTING PHASE

a. All personnel will again be trained in individual measures to protect against mosquito and mite bites. Water and food discipline will be emphasized. Fly control measures will be reviewed, particularly the use of DDT solutions and of sodium arsenite solutions to spray corpses. Officers will review the importance of campsite selection to avoid proximity to infected natives and to breeding places of disease carrying insects.

b. Bednets of all personnel will be sprayed with a five (5) percent solution of DDT in kerosene.

c. Each man will be provided with 2 uniforms and 1 blanket impregnated with dimethyl phthalate as outlined in TB Med 121, dated December 1944. Measures in b and c will be carried out in as short a time before embarkation as possible.

d. Immunization records will be checked and the necessary booster doses will be given.

e. Suppressive atabrine will be given to all personnel as outlined in TB Med 65, dated 3 July 1944, beginning 3 weeks before D-day.

f. Each individual will be provided with:

Bar, mosquito or hammock, jungle, complete	1
Repellent insect, 2 oz. bottle	2
Atabrine tablets, 0.1 Gm	30
Insecticide, powder, louse, 2 oz. can	1

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[1] Variations of this SOP were published three times—in the South Pacific Area Malaria Training Manual No. 2, revised October 1944; in Preventive Medicine Manual No. 2, HUSAFPOA, March 1945; and in the Journal of Military Medicine in the Pacific, September 1945—of which the last and simplest is reproduced.

g. Each organization will be issued 30 days' supply of the following items which will be conspicuously marked and carried with the organization so as to be readily available:

Insecticide, powder, louse, 2 oz. can	100 per 100 men
Repellent, 2 oz. bottles	300 per 100 men
Sprayer, liquid, insecticide, continuous spray, 2 quart	1 per 100 men
Sprayer, oil knapsack type	1 per 100 men
Diesel oil, No. 2, 55 gallon drum with 5% DDT added	1 per sprayer oil knapsack type
Atabrine tablets, 0.1 Gm	4000 per 100 men
Insecticide, freon-aerosol, 1 lb. dispenser	30 per 100 men

3. COMBAT PHASE

a. The malariologist, with the entomologist and parasitologist will provide the surgeon with an insect survey and an estimate of the malaria and insect-borne disease hazard as rapidly as feasible after D-day, with subsequent estimates as determined by current conditions and needs.

b. Fly control will be done by hand spraying of dead bodies, with 5 per cent DDT solution or with 1 per cent sodium arsenite solution, and by proper care of human waste and garbage.

c. Anti-mosquito measures will be carried out by temporary spray teams as outlined in par. 4. The application of DDT residual effect solution to native dwellings will be emphasized.

d. Airplane spraying of DDT will be available about D plus 10. Requests for airplane spraying will be forwarded to the surgeon and will describe the area to be sprayed with an accompanying contour map or grid map. The nature of the insect problem with exact entomological data should be given and an estimate of the need for repeat spraying.

4. TEMPORARY SPRAY TEAMS FOR EACH REGIMENT

a. Each regimental commander will immediately form a temporary spray team comprising 20 men, one man drawn from the insect and rodent control detail of each company. These spray teams will be assisted by 2 technicians, who will be temporarily attached from the Malaria Survey and Control Detachment assigned to Army, Corps or Division. Each regimental spray team will be quartered with its regimental company for the combat period. The work of these spray teams will be supervised by the Divisional Medical Inspector and by personnel from Malaria and Insect-Borne Disease Control Groups.

b. Duties of These Spray Teams:

In amphibious operations these spray teams will go ashore with the headquarters to which they are attached and begin fly and mosquito control work. Each team will carry out the following measures in the rear of combat lines.

(1) Fly Control. Dead bodies will be sprayed with 5 percent DDT solution or 1 percent sodium arsenite solution. Straddle trenches and pit latrines will be sprayed with 5 per cent DDT at the rate of 1 pint per hole twice a week.

(2) Spraying of dwellings and other temporary mosquito control measures in areas of headquarters, medical facilities, supply stations and along communication lines.

c. Equipment of These Spray Teams.

Every man will be equipped with a sprayer for DDT solution. Technicians from Division malaria and insect control groups will carry a dipper for sampling larva populations and preliminary spot maps. Each spray team will carry one weeks' supply of DDT solution prepared in advance and 3 weeks' supply of DDT powder, dissolving. Each spray team should be equipped with a power sprayer.

d. The Temporary Spray Teams are formed for the period of active operation only. As soon as conditions become stabilized and when designed by the division surgeon, this personnel will return to routine control measures of the company insect and rodent control details.

e. No duties that interfere with their malaria and insect control functions will be assigned to the above personnel.

Individual protective measures against mosquito-borne diseases, mite-borne typhus, and schistosomiasis will be carried out by all division personnel as directed.

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APPENDIX B

Directive on Malaria Control

HEADQUARTERS

UNITED STATES ARMY FORCES IN THE FAR EAST

FEMC: 710 A.P.O. 501

18 April 1943

SUBJECT: Sanitary and Prevention Measures for the Control of Malaria
TO: Commanding General, Sixth Army, APO 442.
Commanding General, Fifth Air Force, APO 925.
Commanding General, U.S.A. S.O.S., APO 501.

1. The following anti-malaria measures are published for the information and guidance of all United States Army troops now serving in or destined for malarious areas:

a. *Prior to movement of a command to a malarious area* the following anti-malaria measures will be made effective:

(1) All available information bearing on health in the area will be collected and evaluated in order to determine the probable effect of these factors on the sickness rate of the troops. Special note will be made of the prevalence of malaria and other insect and water-borne diseases.

(2) Where the military situation permits, especially trained medical personnel will be dispatched in advance of the troops to make a health survey of the area. Results of this survey will form a basis for estimating the relative health hazards of different locations under consideration for occupation or proposed tactical operations.

(3) There will be attached to the staff of the commander, a malariologist or a medical officer especially qualified in tropical diseases, to advise the commander concerning the relative malaria hazards of various proposed camp and bivouac sites, and to inspect and supervise the anti-malaria work and discipline throughout the command.

(4) When the nature of the tactical operation permits, the organization will have attached to it malaria survey and control units.

(5) All commanding officers will take measures to form anti-malaria details in each company, squadron or smaller unit and will provide for the training of these details in anti-malaria work. Details will be made up on the basis of one (1) N.C.O. and two (2) enlisted men per infantry company, and a suitable proportionate number for each smaller unit or detachment. The routine anti-malaria work in each unit area will be done by these details, augmented, if necessary, by additional personnel. The unit commander will be responsible for the anti-malaria work as advised by the attached medical officer.

(6) All military personnel will be thoroughly trained prior to departure in carrying out the anti-malaria measures.

(7) Each individual will have in his possession the following items of anti-malaria supplies and equipment:

Bar, mosquito, or hammock, jungle complete
Headnet, mosquito
Gloves, Mosquito
Repellent, mosquito—2 oz. bottle
Atabrine, tablets, 0.1 gm. (1½ grains)—30

(8) Each organization will be issued the following one month's maintenance stocks:

Bars, mosquito	25 per 100 men
Headnets, mosquito	10 per 100 men
Gloves, mosquito	10 prs per 100 men
Repellent, mosquito	400 2-oz. bottles per 100 men
Atabrine, tablets	0.1 gm.—(1½ grains) 3,000 tablets per 100 men for suppressive treatment

Equipment:

Sprayer, hand, insecticide	10 per each 100 men
Sprayer, knapsack type	1 per each 200 or less men
Malariol (or Diesel Oil No. 2)	1 drum 50 gallon U.S. per sprayer, knapsack
Insecticide, for use in hand sprayers	5 gallons U.S. per 100 men

These unit anti-malaria supplies will be conspicuously marked and must be carried in a readily accessible place on the ship, to be available immediately upon arrival.

(9) Suppressive Treatment (see b.(3)).

b. *Anti-Malaria Measures for Military Personnel in Malarious Areas.*

(1) Unit commanders will be held responsible for the enforcement of anti-malaria measures in their command. They will direct the attached medical officers to give regular and frequent instructions to the personnel of the command on malaria control measures as well as other phases of hygiene and sanitation. The dates, number of hours, and subjects covered in all instructions will be reported in the monthly sanitary reports.

(2) In those units in which anti-malaria details have not been organized, steps will be taken promptly to designate and train such details in accordance with the provisions of paragraph a. (5).

(3) Suppressive treatment will be taken commencing one week prior to arrival in a malarious area and will continue under careful supervision while in the area and for four weeks after return to a non-malarious area. Treatment in *highly malarious* areas will consist of one tablet of atabrine 0.1 gm. once daily, six days a week, taken at mealtime with a drink of water. For troops stationed in areas specifically designated by the Chief Malariologist as *mildly malarious*, the suppressive dose of atabrine will be one tablet 0.1 gm. (1½ grains) twice daily on two days a week, allowing a two or three day interval between days of medication. Suppressive treatment will be supervised by a commissioned officer to insure that each soldier actually swallows the medication.

(4) The *selection of camp and bivouac sites* will be made so as to avoid if possible:

(a.) Proximity to native villages or camps.

(b.) Areas known to have a heavy population of malaria-carrying mosquitoes.

(5) *Individual protective measures will be carried out as follows:*

a.) The wearing of shorts, and shirts without sleeves is prohibited. Work details may during daylight hours work without shirts when so authorized by the officer in charge of the detail. All troops will wear their shirt sleeves rolled down from sunset to sunrise. Leggings will be worn to protect ankles and legs from mosquito bites and from injuries leading to tropical sores.

b.) All personnel will be required to sleep under mosquito nets. Unit commanders or their representatives will instruct the troops in the proper use of sleeping nets; and by frequent inspections at night will see that the nets are efficiently used.

c.) Mosquito headnets and gloves will be worn while on guard duty or other night work whenever this is possible. Officers and men who, because of their work are unable to wear gloves and headnets, will cover all exposed skin surfaces with repellent. The repellent must be re-applied every few hours to be effective.

(6) *Anti-mosquito measures as follows,* will be initiated upon arrival in malarious areas:

(a) Hand killing of engorged mosquitoes will be done daily in each tent and hut within the area.

(b) Each tent, hut, or sleeping place will be sprayed *daily* with insecticide to kill the infected mosquitoes.

(c) Breeding places for mosquito larvae within half a mile radius of the camp site will be drained, filled or oiled by the unit anti-malaria detail. Especial attention will be directed to standing water in man-made excavations, wheel ruts, coconut shells, cans, and other containers. It is the responsibility of the commanding officer to see that the program for the destruction of breeding places is efficienlly carried out.

2. Existing instructions issued by the U.S. Army commands will be revised to conform in detail to the above.

By command of General MACARTHUR.

s/ L. S. OSTRANDER
t/ L. S. OSTRANDER
Adjutant General.

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