THE U. S. NAVY'S ROLE IN MOSQUITO ABATEMENT[1, 2]

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ABSTRACT. The U. S. Navy's overall mosquito abatement program is presented for the information of other federal and civil agencies. Mosquito surveillance and control procedures utilized by personnel at the field level are discussed in detail. The research, training and certification, and technical assistance programs developed to support these field personnel are reviewed.

INTRODUCTION

The U. S. Navy has maintained for many years an active mosquito abatement program at its installations throughout the world. Aspects of this program have been discussed in part by DeCoursey (1949), Hirst (1951) and Morrill and Stains (1964). The purpose of this paper is to update these articles and to review the Navy's field, training and research activities in more depth in anticipation that such operational information may be of interest to other agencies.

Commanding officers at naval shore installations are responsible for the maintenance and operation of adequate pest control programs including mosquito surveillance and control. These responsibilities are normally delegated to the medical and public works departments. The medical department is assigned responsibility for conducting a mosquito surveillance program and for making recommendations concerning sanitation practices affecting the presence of mosquitoes. In addition, the department insures that pesticides are used safely and that control operations are planned and supervised by properly trained and certified personnel. The Public Works Department conducts all operational phases of the mosquito control program. The Naval Facilities Engineering Command (NAVFACENGCOM) and the Bureau of Medicine and Surgery (BUMED) support these operations by providing appropriate technical supervision and consultation, training and certification, and research.

SURVEILLANCE PROGRAM

Surveillance programs are used by the Navy in the planning, operation and evaluation of its mosquito control activities. By providing day-to-day guidelines for control operations, surveillance data are useful in reducing control costs and limiting the quantity of pesticides applied to the environment. Such data are also valuable for determining the existence of a potential hazard from mosquito-borne diseases such as malaria and encephalitis. Mosquito surveillance is accomplished in most areas from May through September by larval dipping and adult sampling measures such as the use of light traps, resting site surveys, daytime landing rates and man-bite counts.

PERSONNEL. Mosquito surveillance duties within the medical department are usually assigned to enlisted hospital corpsmen who have completed a 6-month course at the Preventive Medicine Technician School in Oakland, California. Attendees of this unique Navy school receive a broad spectrum of training in epidemiology, statistics, parasitology, military sanitation, bac-

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teriology, medical entomology and vector control. Graduates are classified as Navy Preventive Medicine Technicians and are well qualified to establish surveillance programs and assist public works personnel in developing safe and effective control programs.

LARVAL SURVEYS. Regular larval dipping stations are established and visited as necessary to determine precisely the areas where mosquitoes breed. Chemical treatment is then limited to those areas where significant mosquito populations are found. Larval sampling, before and after larviciding operations, is performed to determine control effectiveness.

ADULT SURVEYS. Adult surveys are conducted to determine the need for control programs including when and where control measures should be applied and by what method. Such surveys are also used to evaluate the effectiveness of adult control measures. The tool most often employed for sampling adult populations is the New Jersey light trap.

Light traps are usually operated on four consecutive nights such as Monday, Tuesday, Wednesday and Thursday of each week. One or more traps may be located between known breeding sources and the installation's populated areas. Others may be located near critical areas such as living quarters and recreation sites. The number of traps used is in accordance with the size of the installation, degree of accuracy required and the manpower available. Dichlorvos (DDVP) resin strips are used as the killing agent in lieu of cyanide jars, and photoelectric switches are recommended instead of electric timers.

While light traps are considered the most useful means for determining population trends, landing rate counts, man-bite counts and resting site collections are the preferred methods of survey for more immediate data. This is particularly true when special or serious problems are encountered or when post-control data are required.

UTILIZATION OF SURVEY DATA. Close cooperation and coordination between the Medical and Public Works departments is required for effective operation of the program. It is recommended, therefore, that contour maps of the installation be maintained by each department to show larval and adult sampling stations and known or suspected breeding sites. Data from larval surveys will thus enable Public Works to apply larvicides to the right place at the right time. Over a period of time, records of such data may also serve to justify permanent control measures such as filling and draining. Adult sampling indices and species determinations are transmitted to Public Works as frequently as possible so that appropriate adulticiding measures may be instituted. Weekly light trap indices are plotted on graphs to show mosquito population changes resulting from control measures or annual variations.

CONTROL PROGRAM

Navy mosquito control operations usually include a combination of methods rather than reliance upon any single measure. Permanent control measures such as filling and draining are the procedures of choice whenever possible as long as they cause a minimum of ecological damage. Temporary measures such as larviciding and adulticiding are accomplished as necessary depending upon the results of the surveillance program. Naturalistic control techniques, such as the use of mosquito-eating fish, are also utilized.

PERSONNEL. Depending on the size and mission of the installation, a number of civilian personnel are employed by the Public Works department for the purpose of accomplishing pest control operations. In addition to preventing and controlling economic pests, these individuals are responsible for all vector control operations. Like military personnel, they have received intensive pest control training. By having a division of responsibility between surveillance and control, an effective check and balance system is maintained in the mosquito abatement program. Having re-

sponsibility for control operations, Public Works personnel use the survey information provided by the Medical Department to determine whether chemical, environmental or naturalistic control will be the most effective, economical and expedient choice.

CHEMICAL CONTROL. In chemical control, an emphasis is placed on larviciding operations using conventional ground equipment such as hydraulic sprayers, mister-dusters and back pack sprayer-dusters. Larvicides in current use include Abate®, malathion, chlorpyrifos, paris green, FLIT MLO® and diesel fuel (with a spreading agent added). Treatment of small, intermittent pools of water using Abate or chlorpyrifos plaster of paris blocks (McDonald and Dickens, 1970) is used extensively at many installations.

Certain Navy installations, particularly those in the southeastern states, are surrounded by mosquito breeding areas, and adulticiding efforts are the primary control methods against migrating mosquitoes. Barrier sprays of malathion or carbaryl are applied to vegetation surrounding the perimeter of the installation, housing area and recreation sites. Using the cold aerosol generator, fogging is relied upon to control adults escaping barrier treatment. The insecticides used include malathion and naled. In keeping with the current trend, it is anticipated that ULV ground dispersal equipment will soon be added to the military system.

Aerial dispersal is occasionally required by certain installations, especially those suffering from heavy influxes of migrating adults originating off-station. The Navy Disease Vector Ecology and Control Center (DVECC) in Jacksonville, Florida, has limited capabilities for aerial dispersal. The Naval Air Stations in Fallon, Nevada and Key West, Florida, have their own ULV aerial spray capabilities. Upon request and certification of immediate need for adult population reduction, the U.S. Air Force Special Aerial Spray Flight Team also flies spray missions for the Navy.

ENVIRONMENTAL AND NATURALISTIC CONTROL. In the area of biological control, the mosquito fish, *Gambusiæ affinis,* is receiving increased attention by many installations as an adjunct to their regular chemical control operations. The successful use of the fish depends, however, on a thorough understanding of their biology, ecological requirements, and husbandry along with close cooperation between the installation's medical, public works, and fish and wildlife personnel.

Permanent control by the elimination or reduction of breeding sites is recommended whenever feasible. Methods of source reduction vary with the particular geographic area. However, attempts are made to follow those methods best suited to a specific locality. These may vary from open ditching, impounding or filling of natural breeding areas to water management, grading and leveling in irrigated areas.

Good sanitation practices, such as removal of artificial receptacles, have been successful in eliminating many serious local mosquito problems. Flyers describing methods to improve premises sanitation are distributed to occupants of naval housing to enlist their aid and to provide them with a better understanding of mosquito biology and of the role that the Medical and Public Works departments play in mosquito control.

COORDINATION WITH OTHER AGENCIES. Mutual benefits are derived by the coordination of military and civilian mosquito abatement programs. In the Navy, this has included the establishment of mosquito coordinating councils, and the utilization of mosquito abatement district services under contract to augment Navy programs at certain installations.

Since 1959, the DVECC in Alameda, California, has sponsored a "Mosquito Abatement Council" composed of representatives from military and civilian agencies in the San Francisco area. This Council serves as a joint advisory group to coordinate military and civilian mosquito suppression activities in military areas and their environs. It also provides a common ground for the exchange of operational information of mutual interest.

A similar organization called the "Tidewater Mosquito and Vector Control Council" was established in 1972 for the Tidewater, Virginia area. Membership includes representatives from the State Health Department, Mosquito Control Commissions, U. S. Navy, U. S. Army and the U. S. Air Force.

Some Naval installations have found it advantageous to enter into contracts with local abatement organizations for all or part of their abatement programs. This is particularly true where adequate mosquito control requires equipment and manpower beyond the capabilities of the installation. Since its commissioning, Naval Air Station, Lemoore, California, has contracted with the Kings County MAD for all of its surveillance and mosquito control. Naval Air Station, Key West, Florida, has a contract with the Monroe County Mosquito Control District to provide surveillance and larviciding service on station including some permanent ditching. Aerial ULV applications for adult control are also jointly coordinated. Recently Naval Station, Mayport, Florida, entered into an agreement with the City of Jacksonville Mosquito Control Branch to provide material for occasional larviciding operations on station. In the above examples, where contracts have been in effect for varying periods of time, they have proved to be the most effective and economical means of controlling mosquitoes.

SUPPORTING PROGRAMS

The Department of Defense has established certain standards for the safe and efficient control of disease vectors at all military installations. The Armed Forces Pest Control Board, established in 1956 by the Department of Defense, provides overall coordination in implementing these standards by the three Services. Within the Navy Department, the standards are further promulgated and implemented by the Bureau of Medicine and Surgery and the Naval Facilities Engineering Command. In addition, all mosquito control operations conducted by the Navy are reviewed annually by the Federal Working Group on Pest Management which is responsible to the President's Council on Environmental Quality.

ARMED FORCES PEST CONTROL BOARD. The Armed Forces Pest Control Board serves to maintain contact between the military departments, U. S. Public Health Service, U. S. Department of Agriculture, Environmental Protection Agency, U. S. Department of Interior and other governmental agencies with related interests in pest control. The Board cordinates activity in the field of pest control, serves as an advisory body, provides liaison with other agencies, and coordinates the requirements for research and development of pest control programs. Entomology information services are provided through the Board by the Military Entomology Information Service or MEIS. MEIS is currently headed by a Navy Captain and is a central source where technical entomological or other medical information is collected, evaluated, stored and distributed to military entomologists and other authorized federal agencies. Bibliographic citations on most aspects of mosquito bionomics, surveillance and control are available through this organization.

The U. S. Department of Agriculture's "Insects Affecting Man Research Laboratory" in Gainesville, Florida, provides research information on which the Board may make decisions regarding the materials and techniques used for the control of mosquitoes. The information includes studies on insect repellents, insect resistance, screening of new pesticide compounds and investigations on biological control agents.

NAVAL FACILITIES ENGINEERING COMMAND. The Naval Facilities Engineering Command is charged with technical responsibility of providing measures for maximum protection of grounds, structures, materials and other property from economic pests; supervision of pest control operations (including mosquito control); quarantine matters related to agricultural pests; and training and certification of per-

sonnel for the Naval Shore Establishment. Training and certification is accomplished in cooperation with BUMED personnel. The Biological Sciences Staff of NAVFACENGCOM is responsible for carrying out these tasks and providing broad guidelines for the shore establishment programs. These responsibilities have been further delegated to the Applied Biology Staffs of six strategically located Engineering Field Divisions. There is a total of 20 entomologists currently assigned to Applied Biology Staffs of the field divisions.

BUREAU OF MEDICINE AND SURGERY. The Bureau of Medicine and Surgery is assigned technical responsibilities for vector control which includes research, development and field testing of vector control methods; personal protective measures; quarantine matters related to disease vectors, and training and certification of personnel. The Vector Control Branch of BUMED is charged with the task of carrying out these responsibilities and providing guidelines for vector control programs. These responsibilities have been delegated primarily to the two DVECC's (Jacksonville, Florida, and Alameda, California) and the entomologists assigned to the Environmental and Preventive Medicine Units (located in Norfolk, Virginia; San Diego, California; Honolulu, Hawaii; and Naples, Italy) which are also under the management of the Bureau. Eleven military entomologists are assigned to these specialized units and are available on request to provide technical advice, assistance and training to Naval installations within their respective geographical areas of responsibility. Ten additional entomologists are assigned to Naval Medical Research Units, the Naval Medical Field Research Laboratory, Marine Divisions, Armed Forces Pest Control Board, BUMED and graduate training.

TECHNICAL ASSISTANCE. The entomologists at the DVECC's and the Enviromental and Preventive Medicine Units provide technical assistance in the establishment of mosquito surveillance programs, advise on new and approved control procedures, determine the need for permanent or temporary control measures, provide laboratory services for mosquito identifications, conduct resistance studies, develop field guides, training manuals, and other necessary publications, and provide consultation and guidance on certain enviromental pollution matters. Through installation program reviews and special studies, Applied Biology staffs of the NAVFACENGCOM provide technical guidance for establishing and maintaining effective biological control programs and provide direction in the selection of appropriate pesticides, equipment and techniques to obtain the desired control with minimum hazard to the environment.

TRAINING. In accordance with Navy directives, all pest control operations must be performed under the direct supervision of certified personnel using professionally approved pesticides and equipment. Medical department personnel (such as the Preventive Medicine Technicians) are required to complete a 4-week training course in Disease Vector and Pest Control Technology conducted by the DVECC's. This intensive course includes didactic presentations on such subjects as basic medical entomology; biology of mosquitoes and other disease vectors; pest management and control techniques; pesticide safety, formulation and toxicology and enviromental ecology. Field instruction is given in the operation, maintenance and repair of small and large ground dispersal equipment including that used for mosquito larviciding and adulticiding. Military personnel successfully completing the course are certified as "Vector Control Specialists." Public Works civilian personnel may either attend this course or complete a correspondence course in basic pest control technology offered by NAVAC Technical Training Center in Norfolk, Virginia. They then receive on-the-job training before qualifying for certification as pest control technicians. Certification is valid for a period of 2 years, after which recertification is required. Recertification is

normally accomplished by attendance at a regional training conference. These are 3–5 days in duration and are usually coordinated jointly by the field divisions of NAVFACENGCOM and the DVECC's and Environmental and Preventive Medicine Units.

RESEARCH. Research in mosquito control is accomplished by the Naval Medical Research Units in Taiwan and Ethiopia, the Naval Medical Field Research Laboratory in Camp Lejeune, North Carolina, the DVECC's and, to a limited extent, the Environmental and Preventive Medicine Units. Cooperative projects are conducted on occasions with NAVFACENGCOM. The diversified work has included such projects as the development of ULV ground dispersal equipment (Stains *et al.*, 1969), and aerial dispersal equipment (Hayden *et al.*, 1970); development of new survey techniques for *Mansonia* larvae (McDonald, 1970); investigations on the survival rate of malaria vectors in Ethiopia (Krafsur, 1970); studies on the relationship between vector densities and malaria rates in Vietnam (Holway, 1970); utilization of box traps for capturing mosquito fish (Ehrhardt and Sholdt, 1972) and studies on repellent-treated wide-mesh bed nets (Grothaus *et al.*, 1972).

PROFESSIONAL DEVELOPMENT. Navy entomologists are continually encouraged to develop their professional capabilities and competence by attending training courses such as those sponsored by the Center for Diesase Control in Atlanta, Georgia, and by participating in professional societies. Navy representatives regularly attend national meetings of the Entomological Society of America. They are particularly active, however, in the American Mosquito Control Association. Many have served at some time on its committees and, during 1958, Captain J. M. Hirst, MSC, USN, (RET), was president of the Association. The benefits of this professional growth are continually realized as better and more efficient support is provided to those in the field.

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